TEMPORAL ASPECTS OF SPEECH PRODUCTION IN BILINGUAL SPEAKERS WITH NEUROGENIC SPEECH DISORDERS

by

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"For the Lord gives wisdom, and from his mouth come knowledge and understanding." Proverbs 2:6

Dedicated to the persons with communication disorders with whom I have had the privilege to work…You have enriched my life beyond words!

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"The primary intellectual aim of the humanities and social inquiry, quite generally, is to help us to realize what is of value to us in our personal and social lives. What ultimately matters is personal and social progress towards enlightenment and wisdom: all academic progress is but a means to this end." (Maxwell, 1984:73)

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SUMMARY

TITLE	Temporal aspects of speech production in bilingual speakers with neurogenic speech disorders
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The present study is the first to examine the effect of first versus second language (L1 versus L2) speech production on specific temporal parameters of speech in bilingual speakers with neurogenic speech disorders. Three persons with apraxia of speech (AOS), three with phonemic paraphasia (PP) and five normal speaking participants were included as subjects in the study. Subjects were required to read phonemically similar L1 and L2 target utterances in a carrier phrase, five times each, at a normal and fast speaking rate, respectively. This rendered four speaking contexts that included speech production in L1 at either a normal (L1NR) or fast speaking rate (L1FR) and speech production in L2 at either a normal (L2NR) or fast speaking rate (L2FR). Acoustic analysis of on-target productions involved measurement of utterance onset duration, vowel duration, utterance duration and voice onset time.

Results revealed that in normal speakers, speech production in L2 results in greater token-to-token variability than in L1. However, token-to-token variability in the experimental subjects did not tend to increase whilst speaking in L2, most probably because these subjects generally decreased their speaking rate in this context, resulting in more consistent production. The subjects with AOS and PP seemed to be influenced by the increased processing demands of speaking in L2 to a greater extent than the normal speakers, in that they more frequently experienced difficulty with durational adjustments (decreasing duration in the fast speaking rate) in L2 than in L1. Furthermore, the subjects with AOS or PP also exhibited a greater extent of durational adjustment in L1 than in L2. The durations of most of the subjects with either AOS or PP tended to differ from those of the normal group to a greater extent in L2FR that was hypothesized to be the most demanding speaking context for these subjects.

The longer than normal durations and greater than normal token-to-token variability in the subjects with either AOS or PP imply the presence of a motor control deficit. The extent of the motor control deficit appears to be more severe in AOS than in PP as is evident from the finding that the subjects with AOS generally exhibited longer durations and greater token-to-token variability than the subjects with PP. The pattern of breakdown in respect of different parameters and utterance groups also differed between subjects with AOS and PP. The nature of the disorder in AOS and PP thus appears to be both quantitatively and qualitatively different. Regarding measurement of the different temporal parameters, voice onset time appears to be less subject to the influence of L2 than the other measured temporal parameters.

The results of this study imply that bilingual AOS is as much a reality as bilingual aphasia. Furthermore, the results underscore the importance of taking contextual factors, specifically L1 versus L2, into account when compiling assessment and treatment procedures for persons with either AOS or PP, since speech production in L2 appears to be motorically more difficult than in L1 for persons with neurogenic involvement. The significance of the results is discussed with reference to the influence of speech production in L2 on temporal control and the underlying nature of AOS and PP with regard to theories of speech sensorimotor control.

Key words: speech motor control, speech production, speech and language processing, motor planning, linguistic-symbolic planning, processing demands, apraxia of speech, phonemic paraphasia, temporal parameters, temporal control, token-to-token variability, acoustic analysis, vowel duration, utterance duration, utterance onset duration, voice onset time, contextual factors

OPSOMMING

TITEL	Temporale aspekte van spraakproduksie in tweetalige sprekers met neurogene spraakafwykings
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Hierdie studie is die eerste om die effek van eerste- teenoor tweede taal spraakproduksie op spesifieke temporale parameters van spraak in tweetalige sprekers met neurogene spraakafwykings te ondersoek. Drie persone met verbale apraksie, drie met fonemiese parafasie en vyf normaalsprekendes het as proefpersone aan die studie deelgeneem. Persone moes uitings wat fonemies dieselfde is in hul eerste en tweede taal vyf keer elk lees, teen beide ŉ normale en ŉ vinnige spraakspoed. Hierdie prosedure het vier kontekste vir spraakproduksie tot gevolg gehad, naamlik eerste taal in ŉ vinnige en normale spoed konteks en tweede taal in ŉ vinnige en normale spoed konteks. Akoestiese analise van akkurate produksies het meting van uitingaanvangsduur, vokaalduur, uitingduur en stemaanvangstyd behels.

Resultate het daarop gedui dat tweede taal spaakproduksie in normale sprekers aanleiding gee tot groter temporale veranderlikheid t.o.v. die duurmetings. Uit die resultate het dit geblyk dat persone met verbale apraksie of fonemiese parafasie tot ŉ groter mate beïnvloed is deur die verhoogde prosesseringseise wat deur spraakproduksie in hul tweede taal gestel is, deurdat hulle meer dikwels probleme ervaar het met duuraanpassings (vermindering van duur in die vinnige spoed konteks) in hul tweede taal as in hul eerste taal. Verder het die persone met verbale apraksie of fonemiese parafasie ook ŉ groter mate van duuraanpassing gemaak in hul eerste taal as in hul tweede taal. Die duur van meeste van die persone met verbale apraksie of fonemiese parafasie het verder die meeste van dié van die normale sprekers verskil tydens produksie teen ŉ vinnige spoed in die tweede taal wat voorspel is om die

moeilikste konteks vir produksie te wees vir persone met ŉ spraak- en/of taalafwyking.

Langer as normale duur en meer as normale temporale veranderlikheid in die persone met verbale apraksie of fonemiese parafasie impliseer dat ŉ motoriese komponent moontlik bydra to die spraakprobleme van hierdie sprekers. Die graad van die motoriese afwyking blyk meer uitgesproke te wees in persone met verbale apraksie as in die met fonemiese parafasie, aangesien die persone met verbale apraksie meestal langer duur en meer veranderlikheid van duurmetings getoon het in vergelyking met die persone met fonemiese parafasie. Die patroon van afbraak in terme van die verskillende parameters en uitings waarmee probleme ondervind is tydens produksie het ook verskil tussen die persone met verbale apraksie en fonemiese parafasie. Die aard van die afwyking in verbale apraksie en fonemiese parafasie blyk dus kwantitatief en kwalitatief te verskil. Met betrekking tot aantasting van die verskillende parameters, het die resultate daarop gedui dat stemaanvangstyd tot ŉ mindere mate aangetas is deur spraakproduksie in die tweede taal.

Die resultate van hierdie studie beklemtoon die belang daarvan om kontekstuele faktore, spesifiek eerste teenoor tweede taal spraakproduksie, in ag te neem tydens die evaluering en behandeling van tweetalige persone met verbale apraksie of fonemiese parafasie. Spraakproduksie in die tweede taal van 'n spreker blyk motories meer kompleks te wees as spraakproduksie in die eerste taal vir persone met neurogene spraak- en/of taalafwykings. Die belang van hierdie resultate word bespreek met verwysing na die invloed van tweede taal spraakproduksie op temporale kontrole van spraak en die onderliggende aard van verbale apraksie en fonemiese parafasie soos verklaar deur teorieë oor spraakproduksie.

Sleutelwoorde: motoriese kontrole van spraak, spraakproduksie, spraak- en taalprosessering, motoriese beplanning, linguisties-simboliese beplanning, presesserings eise, verbale apraksie, fonemiese parafasie, temporale parameters, temporale kontrole, temporale veranderlikheid, akoestiese analise, vokaalduur, uitingduur, uitingaanvangsduur, stemaanvangstyd, kontekstuele faktore

LIST OF ABBREVIATIONS

AOS	Apraxia of speech
CA	Conduction aphasia
CSL	Computerized Speech Laboratory
CV	Consonant-vowel
FR	Fast speaking rate
GMP	Generalized motor program
GMPs	Generalized motor programs
IAS	Interarticulatory synchronization
L1	First language
L2	Second language
ms	Milliseconds
N	Normal speaking subject
NGR	Normal group
NR	Normal speaking rate
PP/(s)	Phonemic paraphasia/(s)
SD/(s)	Standard deviation/(s)
UD	Utterance duration
UOD/(s)	Utterance onset duration/(s)
VD	Vowel duration
VOT/(s)	Voice onset time/(s)
WAB	Western Aphasia Battery

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CHAPTER ONE

PROBLEM STATEMENT AND RATIONALE FOR THE STUDY

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1.1 INTRODUCTION AND PROBLEM STATEMENT

The study of neurogenic speech disorders "compliments the study of normal speech to reach an understanding of the normal regulation of spoken language" (Kent, 1990:365). Clarification of the nature of neurogenic speech disorders is thus vitally important, not only for the diagnosis and treatment of these disorders, but also for providing significant information about normal and pathological speech motor control (Itoh & Sasanuma, 1984).

Apraxia of speech (AOS) is one neurogenic speech disorder which, since its initial description in the late 1960s, has been surrounded by controversy regarding its underlying nature (Seddoh, Robin, Hageman, Sim, Moon & Folkins, 1996a). Even though it is now generally accepted that the underlying deficit in AOS is phonetic-motoric in nature (Ballard, Granier & Robin, 2000; McNeil, Robin & Schmidt, 1997), it frequently co-occurs with aphasia where the impairment is linguistic, specifically phonological in nature. In this regard, it was most recently stated that "After more than 30 years of research and hundreds of studies, however, the most incisive reviews are still asking for clarification of the nature of the disorder and for more reliable criteria for differentiating AOS from the dysarthrias and aphasic phonological errors" (Croot, 2002:267).

A factor which further complicates the understanding of normal and pathological speech production, and consequently the nature of AOS, in a country such as South Africa, is the fact that bilingualism, or even multilingualism, is extremely common. Consequently, in addition to the complexity of understanding speech motor control and its possible impairments, there is the poorly understood organization and control of two or more languages in the brain. It is against this backdrop that the study of speech production in bilingual speakers with either AOS or phonemic paraphasia (PP) is undertaken.

The aim of Chapter 1 is to motivate the relevance of the study of temporal parameters of speech production in bilingual speakers with AOS and persons with PP, by presenting the rationale for the study. Furthermore, the relevant terms used in the thesis are defined and an overview of the division and content of the chapters contained in the thesis is provided.

1.2 ORIENTATION TO AND RATIONALE FOR THE STUDY

In order to accurately characterize and describe the salient characteristics of AOS, various studies using different methods of analysis have been conducted. In this regard studies using acoustic (Freeman, Sands & Harris, 1978; Itoh, Sasanuma, Tatsumi, Murakami, Fukusako & Suzuki, 1982; Kent & McNeil, 1987; Kent & Rosenbek, 1983; McNeil, Liss, Tseng & Kent, 1990a; Tuller & Story, 1987; Ziegler & von Cramon, 1985, 1986), kinematic (Fromm, 1981; Hardcastle, Morgan Barry & Clark, 1985; Itoh, Sasanuma, Hirose, Yoshioka & Ushijima, 1980; McNeil & Adams, 1991; McNeil, Caliguiri & Rosenbek, 1989; Robin, Bean & Folkins, 1989; Tseng, McNeil, Adams & Weismer, 1990) and physiologic (electromyographic) (Forrest, Adams, McNeil & Southwood, 1991; Fromm, 1981; Fromm, Abbs, McNeil & Rosenbek, 1982; Shankweiler, Harris & Taylor, 1968) methods of analysis have been performed.

A common conclusion from the results of these studies has been that persons with AOS display a deficit regarding *temporal control*. The deficit regarding temporal control has been supported by findings of longer than normal vowel durations (Collins, Rosenbek & Wertz, 1983; Freeman *et al.*, 1978), overlapping ranges of voice onset time (VOT) for voiced and voiceless stop consonants (Freeman *et al.*, 1978; Itoh, Sasanuma, Tatsumi & Kobayashi, 1979a), longer than normal consonant durations (Kent & Rosenbek, 1983), longer than normal and more variable stop gap durations (Seddoh, Robin, Sim, Hageman, Moon & Folkins, 1996b), longer than normal between-word segment durations (Strand & McNeil, 1996) and greater than normal variability regarding most durational measures (Kent & McNeil, 1987; Seddoh *et al.*, 1996a, b; Strand & McNeil, 1996).

Complicating the characterization of AOS is the fact that considerable overlap of characteristics with persons exhibiting PP has been demonstrated (Kent & McNeil, 1987; McNeil *et al.*, 1997). This overlap of characteristics exists despite the fact that phonemic paraphasic errors are believed to be the result of a deficit at a distinct level of the speech production process compared to apraxic errors. Apraxic speech errors are generally described as phonetic-motoric in nature, whereas phonemic paraphasic errors, which are predominant in persons with conduction aphasia (CA), are generally described as phonological (Kent & McNeil, 1987). McNeil *et al.* (1997:312) state that in order to differentiate motor speech disorders (AOS and the dysarthrias), from phonological-level disorders (literal or PP in aphasia), it is “essential to contrast the phenomenology and the assumptions underlying the labels of these clinical neighbors”. These authors emphasize the importance of “contrasting assumed mechanisms, signs and symptoms between AOS and phonemic paraphasia” in order “to eventually work out the significant characteristics of the groups and find constant differences between them”.

The need to differentiate between AOS and PP is emphasized by the statement by Ballard *et al.* (2000:975), which highlights the fact that even though theoretical characterizations of AOS quite clearly identify specific behavioral manifestations of the disorder, “clinical descriptions have lacked diagnostic power”, with resultant failure to differentiate clearly between AOS and some aphasic syndromes. The focus of the present study is on speech production of persons with AOS, although inclusion of subjects with PP renders the possibility of comparison and/or contrasting of findings in these two groups for better elucidation of the characteristics of AOS. For these reasons, both groups of speakers will be included in the present study.

In order to assist with differentiation of different speech and language disorders and explanation of the level of breakdown in the speech production process related to these disorders, various models and theories of speech production have been compiled. In this regard, Van der Merwe (1997:1) states that “the almost overwhelming corpus of ever increasing data on the intricate detail of the speech production process and the neurophysiology of motor control and also unresolved issues concerning the nature of neurogenic speech disorders underscore the necessity of a comprehensive explanatory framework”. Van der Merwe (1997) proposed a four-level framework of speech sensorimotor control which has appeal for understanding the level of breakdown in the speech production process following a neurologic insult, as well as for understanding normal speech motor control. It has been noted that this framework is perhaps the most detailed and comprehensive attempt to explain deficits in the speech production process in the extent literature, since many of its hypotheses are testable (Ballard *et al.*, 2000). In Van der Merwe's (1997) framework, the speech production process is depicted as consisting of four stages, namely linguistic-symbolic planning, motor planning, motor programming and execution. According to this framework, the deficits in AOS are ascribed to the level of the motor planning of speech, whereas phonemic paraphasic errors are ascribed to the level of linguistic-symbolic planning (Van der Merwe, 1997).

One of the testable hypotheses in Van der Merwe's (1997) framework relates to the depiction of speech production as being context-sensitive. The context-sensitivity of speech production is an important aspect to be recognized in the study of AOS since contextual factors have been found to cause variation in the symptoms of AOS (Kent & Rosenbek, 1983; Van der Merwe & Grimbeek, 1990; Van der Merwe, Uys, Loots & Grimbeek, 1987, 1988; Van der Merwe, Uys, Loots, Grimbeek & Jansen, 1989). Van der Merwe (1997:6) proposes that "contextual factors affect the dynamics of motor control by exerting an influence on the mode of coalition of neural structures involved during a particular phase and on the skill required for the planning, programming and execution mechanisms". It is hypothesized within this framework that certain variants of a specific contextual factor might necessitate more complex control strategies than others. From a motor learning and information processing perspective, this would imply that certain contextual factors might increase the speech and language processing demands causing speech production to be more complex in certain contexts. In these more demanding contexts, the demand for attentional resources also presumably increases (Magill, 2001; McNeil, Odell & Tseng, 1991a). Van der Merwe (1997) emphasizes the need for the determination of the role of the various contextual factors in the different phases of the speech act, since the influence of variation in contextual factors is important for both research and treatment.

On the basis of a review of the relevant literature, Van der Merwe (1986, 1997) identified various contextual factors that presumably influence the process of speech sensorimotor control. According to Van der Merwe (1997), these factors include voluntary or involuntary (automatic) speech (Kelso & Tuller, 1981), phonological structure (MacNeilage, 1983), motor complexity of the utterance (Ladefoged, 1980), utterance length (Strand & McNeil, 1996), familiarity versus novelty of utterances (Sharkey & Folkins, 1985) and speech rate (Kelso, Tuller & Harris, 1983; MacNeilage, 1980). The influence of various contextual factors on different aspects of speech production in AOS and to a lesser degree PP has been investigated. These include studies investigating the influence of linguistic factors (Deal & Darley, 1972; Dunlop & Marquardt, 1977; Martin & Rigrodsky, 1974a, b; Martin, Wasserman, Gilden, Gerstman & West, 1975; Strand & McNeil, 1996), speech rate (Kent & McNeil, 1987; McNeil *et al.*, 1990a), word frequency (Varley, Whiteside & Luff, 1999), sound structure and articulatory characteristics (Van der Merwe, 1986) on speech production. The increased processing demands imposed by various contextual factors might cause persons with deficits regarding one or more of the stages of speech production to be more susceptible to breakdown. For accurate characterization of neurogenic speech and language disorders, it is important to determine which contextual factors lead to breakdown in persons with deficits at different levels of the speech production process. This has the potential to inform about the underlying nature of the disordered processes and will have important implications for the compilation of assessment and treatment procedures.

An aspect that has the potential to influence speech and language processing, and which has been greatly ignored in the study of AOS, is speech production in the first versus the second language (L1 versus L2) in bilingual speakers with AOS. Although bilingual aspects of aphasic speech have been studied quite extensively (Paradis, 1995a), bilingual speech production in persons with AOS has not been systematically investigated. Considering the large number of bilingual speakers that are encountered in the clinical setting (Wiener, Obler & Taylor Sarno, 1995), it is surprising that the effect of the language of production of a bilingual speaker, that is, L1 versus L2 in AOS, has not been investigated. Paradis (1995b:219) states that "Bilingualism is not just a rare, occasional occurrence in the language/speech pathology clinic…but a phenomenon every clinic must be prepared to cope with".

The relevance of studying L1 versus L2 speech production in AOS was first underscored by Van der Merwe and Tesner (2000), who postulated that speech production in L2 will probably differ from that in L1 in the late bilingual speaker, since L2 is not as familiar to the speaker. These researchers conducted the first perceptual study in bilingual AOS by examining the nature and severity of perceptual errors in L1 and L2 in a bilingual speaker with AOS. Van der Merwe and Tesner (2000) found that a greater number of perceptual errors and incorrect words were produced in L2 compared to L1 by the bilingual subject with AOS and proposed that the subject experienced speech production in L2 as motorically more complex, compared to L1. From the results of their study, these researchers concluded that speech production in L2 presumably requires more conscious control, which consequently also affects the motor dynamics of speech production. Furthermore, L2 has not become as automatized and consequently the speaker might experience speech production in L2 as more difficult. These researchers suggested that speech production in L2 requires the speaker to more consciously process on both the linguistic and the motor levels and that this impacts even further on the processing demands.

Regarding the more complex nature of speech production in L2 compared to L1, Klein, Zatorre, Milner, Meyer and Evans (1995) also concluded that L2 might be motorically more difficult to produce. These researchers studied the neural substrates of bilingual language processing using positron emission tomography and found that the left putamen was activated during L2 repetition tasks, but not during repetition tasks in L1. Klein *et al.* (1995) hypothesized from this finding that "activation of the left putamen is a function of the increased articulatory demands imposed by speaking a language learned later in life" (Klein *et al.*, 1995:31). In this regard, the possibility of differential processing patterns during speech production of L1 and L2 has also been proposed (Van der Merwe & Tesner, 2000).

If L2 is motorically more difficult to produce, it would presumably increase the processing demands imposed on the speech production system. The normal speech production mechanism might be able to adjust to these additional demands, but the increased processing demands might impact on the temporal parameters of speech production in persons with AOS who exhibit deficits regarding temporal control

(Kelso & Tuller, 1981; Kent & Rosenbek, 1983). The influence of the increased processing demands might also be evident in persons with PP, due to the proposed sharing of resources amongst language and motor processes (Strand & McNeil, 1996). The fact that language and speech motor processes presumably share processing resources has the implication that resources might be more easily exceeded in the presence of increased processing demands when certain processes involved in speech and language processing already require more than normal resources due to impairment at one or more of the levels of the speech production process.

From the above discussion, the importance of studying speech production in L1 and L2 in bilingual persons with neurogenic speech and language disorders becomes evident. The present study is the first to attempt a systematic investigation of the influence of speech production in L1 versus L2 on specific temporal parameters of speech production in persons with AOS and persons with PP. Speech rate alterations will also be employed to further increase the processing demands posed to the speech production mechanism, since this "additional" contextual factor might assist in demonstrating the effect of speech production in L2 on temporal control more clearly. Studying the influence of L1 and L2 in bilingual speakers with neurogenic speech disorders, renders novel opportunities to infer more about the nature of these speech disorders and the interaction of speech and language processes in the presence of neurologic lesion (Van der Merwe & Tesner, 2000). These data will contribute to further description and definition of temporal aspects of speech production in persons with AOS or PP, which in turn will shed light on normal and pathologic speech motor control. This is of special importance in a society "where bilingualism or even multilingualism is almost the rule" (Van der Merwe & Tesner, 2000:79). The reader is referred to Figure 1.1 for a schematic presentation of the purpose of the study.

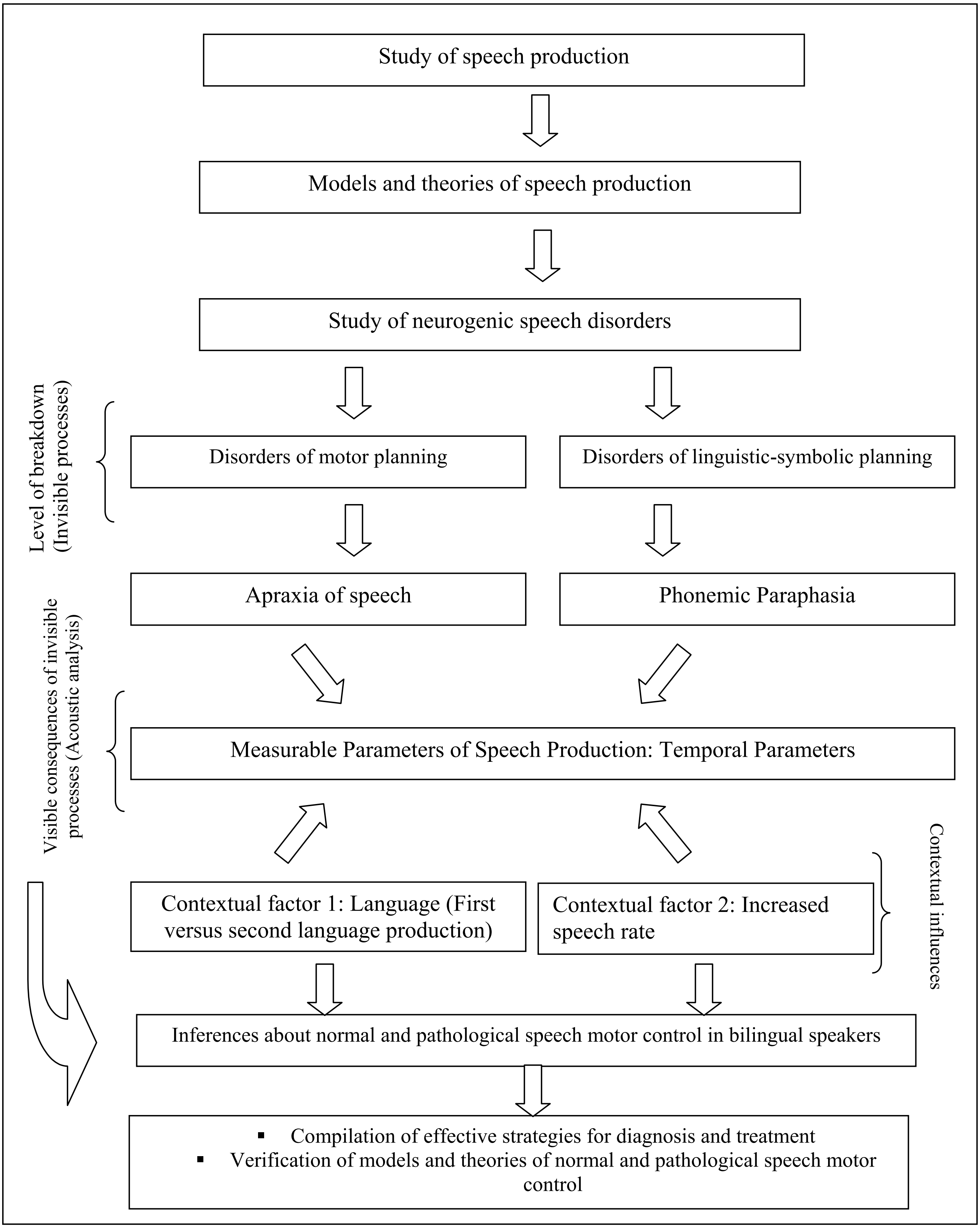

Figure 1.1 Schematic presentation of the purpose of the study of temporal parameters of speech production in bilingual speakers with neurogenic speech disorders

1.3 TERMINOLOGY

In order to obviate confusion, misinterpretation and misunderstanding of the terms used in this study, it is necessary to define and discuss these terms.

1.3.1 Temporal parameters

Articulation refers to the "movements of the vocal tract to produce speech sounds" (Borden & Harris, 1984:279). Van Riper and Emerick (1984:68) provide an even clearer definition by saying articulation involves "the production of speech sounds by incredibly swiftly impeding or valving the airstream and vocal tone by the tongue, lips and jaws". These movements of the articulators need to be *spatially* and *temporally* ordered. Articulation has an acoustic result. The acoustic output of the vocal tract can be depicted as a bridge between speech production and perception. By studying the acoustic output of the vocal tract more can be learned about the mechanism problems related to disordered speech, as well as the effect these problems have on speech intelligibility (Forrest & Weismer, 1997).

Forrest and Weismer (1997:63) state that “the acoustic output of the vocal tract contains the product of the entire speech system’s effort, rather than an isolated component of that effort”. From the acoustic signal information regarding a wide range of speech parameters can be obtained, including, “speaking rate, articulatory configuration for vowels and consonants, rates of change in the overall configuration of the vocal tract, flexibility of the articulatory behavior and aspects of phonatory behavior” (Forrest & Weismer, 1997:63). Temporal aspects of speech production “reflect the duration of selected events” (Forrest & Weismer, 1997:64). One temporal characteristic which has often been studied is segment durations since it is believed to reflect principles of speech timing (Forrest & Weismer, 1997).

The temporal parameters of the acoustic signal which will be investigated in the present study are vowel duration (VD), utterance duration (UD), utterance onset duration (UOD) and VOT.

1.3.2 Bilingual speakers

Paradis (1987:3) describes bilingual speakers as follows:

> Bilinguals have two languages at their command. They can speak one or the other and understand either at any time. They can switch between them, and they can mix them at any level of linguistic structure (phonetic, phonological, morphological, syntactic, lexical, semantic).

In the present study the level of bilingualism of the different subjects had to be the same. In other words, the age at which L2 was introduced, as well as the frequency with which it was used during their nursery, primary and high school years had to be similar. The person thus had to have been educated in Afrikaans, their home language or mother tongue, while English had been introduced as a second language at school. In the present study L1 refers to Afrikaans, while L2 refers to English.

In bilingual aphasic patients, some of their linguistic abilities are lost selectively. The two languages of a bilingual aphasic patient can be affected selectively (Paradis, 1995a). Little is known about the language status of the two languages in bilingual persons with AOS.

1.3.3 Speech

Borden and Harris (1984) state that speech is audible and can be described in terms of its loudness, pitch and duration. Speech "is meaningful sound strung out in time" (Borden & Harris, 1984:2), although speech is only one way in which to use language. Netsell (1982:247) describes "Speech is the motor-acoustic expression of language".

In this thesis "speech" refers to the realization of language through movements of the articulators. The movements involved in speech production are the result of muscle contractions due to nerve impulses, all of which are controlled in the nervous system (Borden & Harris, 1984). Speech results in an acoustic signal. The temporal parameters of speech production can be measured in the acoustic speech signal. In this thesis, speech is thus viewed as separate from language.

1.3.4 Language

Language is a "rule-governed communication system composed of meaningful elements, which can be combined in many ways to produce sentences" (Borden and Harris, 1984:2). Borden and Harris (1984:5) state that language "enables us to express ideas about people, places, or things which are not present".

Language refers to the language systems, also referred to as "the grammar, namely, phonology, morphology, syntax and the lexicon-in other words, what has come to be known as *implicit linguistic competence*" (Paradis, 1998:72).

1.3.5 Neurogenic speech disorders

It is important to define when speech can be classified as being disordered, in other words, when one can state that a person exhibits a speech disorder. It is thus necessary to compile a definition of deviancy. Van Riper and Emerick (1984:34) state "Speech is abnormal when it deviates so far from the speech of other people that it calls attention to itself, interferes with communication, or causes the speaker or his listeners to be distressed".

Neurogenic speech disorders are speech disorders caused by neuropathology and can be divided into two main groups namely, developmental disorders and acquired disorders (Thompson, 1989). Common neuropathologies include cerebrovascular accidents (CVA), head trauma and progressive, degenerative neuropathologies, for example, multiple sclerosis. Developmental neurogenic speech disorders are the result of an insult or lesion to the brain which occurs prior to or during the course of speech development. Acquired neurogenic speech disorders are the result of a lesion to the adult brain after speech development has been completed.

The present study is concerned with acquired neurogenic speech disorders, specifically persons with AOS and subsequently persons with aphasia exhibiting predominant PP. These two disorders will be defined briefly.

Apraxia of speech is defined by McNeil *et al.* (1997:329) as “a phonetic-motoric disorder of speech production caused by inefficiencies in the translation of a well-formed and filled phonological frame to previously learned kinematic parameters assembled for carrying our the intended movement…”.

According to McNeil and Kent (1990:350) "Aphasia is, in the simplest sense, an impairment of the cognitive apparatus that performs language" as a result of "focal brain damage or disease".

Goodglass and Kaplan (1983:90) state "Literal (or phonemic) paraphasia refers to a paraphasia in which, in spite of "easy" articulation of individual sounds, the patient produces syllables in the wrong word order or embellishes his words with unintended sounds". McNeil *et al.* (1997:312) state that phonemic paraphasias “cross aphasic classifications”, but frequently occur in persons with CA.

1.3.6 Context

Van der Merwe (1997, 2002) depicts speech production as being context-sensitive. This “implies that the context in which speech is produced will have an effect on the complexity of the motor task” in that it exerts an influence on the coalition of neural structures (Van der Merwe, 2002:5). More complex utterances might require more complex control strategies (Van der Merwe, 1997). Contexts identified by Van der Merwe (1997, 2002) include voluntary versus automatic production, motor complexity of the utterance, sound/syllable structure, utterance length, familiarity versus unfamiliarity of the utterance and rate of production.

In the present study, *context* refers to factors which influence the complexity of production at any level of the speech production process. The four specific contexts which will be investigated in the present study include speech production in L1 at a normal speaking rate (L1NR), speech production in L1 at a fast speaking rate (L1FR), speech production in L2 at a normal speaking rate (L2NR) and speech production in L2 at a fast speaking rate (L2FR).

1.3.7 Speech rate and speech rate alterations

Smith, Sugarman and Long (1983:748) refer to speech rate as "the timing of phrases and sentences". It can also be viewed as the number of syllables which are produced per second. Speech rate is a temporal variable of speech which can bring about great changes in the speech production process (Gay, 1981; Kelso *et al.*, 1983). Both temporal and spatial aspects of speech are influenced by changes in speaking rate.

Adams (1990:1) states that “Speaking rate is a dimension of speech production that can be controlled voluntarily over a relatively wide range and therefore its manipulation and subsequent investigation has offered the prospect of gaining insight into some of the mechanisms underlying speech motor control”.

Speech rate alterations refer to an increase or decrease of rate of speech production. An increase in speaking rate can be achieved by various means, for example, reducing pauses between phrases, by increasing the rate of words within a phrase and by reducing word or syllable durations (Ludlow, Conner & Bassich, 1987). A decrease in speaking rate can be accomplished by the opposite means used to increase speech rate.

Requesting an alteration in speaking rate is one means of assessing a speaker's motor facility (Kent & McNeil, 1987; McNeil *et al.*, 1990a). A characteristic of motoric competence is the ability to make rate alterations when required. The normal speech production mechanism handles rate adjustments with ease, whereas the impaired motor system may be limited in its ability to vary rate of performance. Another reason for the employment of rate alterations in the study of speech and language disorders is because the linguistic properties of an utterance can be held constant, while the effect of higher demands, with an increase in rate, can be assessed (Kent & McNeil, 1987).

1.3.8 Speech and language processing

One of the many approaches which can be taken to study motor learning and control is an information processing approach. In this view, humans are regarded as active processors of information rather than passive recipients (Shea, Shebilke & Worchel, 1993). The basic assumption is that a number of cognitive processes are required for correct execution of movement by an individual (Shea *et al.*, 1993; Stelmach, 1982).

Levelt (1989:1) views the speaker as a "highly complex information processor which can, in some still rather mysterious way, transform intentions, thoughts, feelings into fluently articulated speech". He further says that "A theory of speaking will involve various such processing components".

When referring to processing or speech and language processing in the present study, the operations or processing occurring during the various stages of the speech production process are implied. Various models of speech production have been proposed to depict the stages involved in speech and language processing. The stages depicted by Van der Merwe (1997) include linguistic-symbolic planning, motor planning, motor programming and execution. The term processing in the present study, includes both speech and language processing and implies the operations involved in the four stages of speech production proposed by Van der Merwe (1997). This also includes the cognitive processes involved in these stages, for example, attention and memory, necessary to drive these processing operations.

1.3.9 Automatic versus controlled processing

Most of the stages involved in speech and language processing are proposed to be automatic, implying that they do not require capacity in working memory (Kent, 1990; Levelt, 1989). In this regard, Kent (1990:374) states "Automatic, or capacity-free, processing contrasts with controlled, or capacity-demanding, processing". Kent (1990:374) further postulates that "speakers are flexible in the deployment of automatic and controlled processing. Under difficult situations, a speaker may rely more on controlled processing. It is likely that speakers with a neurological impairment of speech may be more reliant on controlled processing than are normal speakers".

Levelt (1989) proposes that the processing components which underlie speech work in a "highly automatic, reflex-like way" allowing them to work in parallel which is a prerequisite for uninterrupted fluent speech. Levelt (1989) further proposes that processes involved in speech production can run in parallel and that each processor can work on different bits and pieces of an intended utterance. The fact that the latter can occur is based on the concept of automaticity, since only automatic processors can work without sharing access to attentional resources (Levelt, 1989).

In other words, automatic processing refers to processes which occur without conscious attention exerted by the speaker, whilst controlled processing occurs when demands which increase the processing load are placed on the speech production mechanism (Kent, 1990; McNeil *et al.* 1991a). It can consequently be deduced that the increased processing load presumably causes the speaker to concentrate more "consciously" on speech and language production.

1.3.10 Processing demands

McNeil *et al.* (1991a:35) state that "*Processing load* refers to the idea that the more complex or difficulty the task, the greater is the processing load and the outlay of effort. Tasks that require effort and attention are said to be under *controlled processing.* Conversely, when the task is more automatic, the processing load is smaller and fewer resources, less attention and less effort are required for its successful completion".

In the present study processing demands are synonym to processing load and refer to the influence exerted by a specific context to increase the complexity of production and consequently the cognitive effort involved in speech production.

1.3.11 Attentional resources

Shea *et al.* (1993:312) define attention as "The direction of mental energy or the allocation of resources to important stimuli and ignoring irrelevant ones; the process by which we notice important, meaningful, or relevant information and ignore unimportant stimuli".

Magill (2001:117) describes attention as follows: "in human performance the conscious or nonconscious engagement in perceptual, cognitive and/or motor activities before, during or after performing skills".

McNeil *et al.* (1991a:31) state that "Attention plays a role equivalent to the power supply in man-made mechanical devices. Attention can be conceived as effort per unit of time…It is both indispensable and non-specific for the completion of mental activity". The function of attention or resources "is to energize the machinery responsible for a particular task at hand" (McNeil *et al.*, 1991a:31).

Attention is also referred to as resources, capacity or effort (McNeil *et al.*, 1991a).

Limitations exist regarding the number of activities which can be attended to at one time (Kahneman, 1973; Magill, 2001; Stelmach, 1982). A person is able to perform several tasks simultaneously as long as the resource capacity limits of the system are not exceeded. If these limits are exceeded, performance of one or more of these tasks will deteriorate (Just & Carpenter, 1992; Magill, 2001; Stelmach, 1982).

In the present study, attention or attentional resources refers to available mental "drive" for the performance of speech and language processing operations. Attentional resources are used as synonym to resource capacity.

1.3.12 Resource allocation

Stelmach (1982:79) states that "attentional capacity is not restricted to any one stage of processing, nor is it modality specific, but rather that it can be flexibly allocated depending on the nature of the task".

McNeil *et al.* (1991a:33) state "Several factors, such as the nature of the task or the motivation of the performer, may also influence how attention is actually distributed".

In the present study, resource allocation, refers to the process which is performed either consciously or subconsciously of assigning resources or attention to performance of a specific processing operation.

1.4 DIVISION OF CHAPTERS

Chapter one is the introductory chapter that serves as an orientation to the field of study and presents the rationale and motivation for the study. The importance of accurately defining neurogenic speech disorders is emphasized as well as the study of such disorders within a framework of normal and pathologic speech motor control. The necessity of differentiating between AOS and PP is highlighted, since these two disorders exhibit overlapping speech characteristics despite deficits at distinct level of the speech production process. The importance of the study of the influence of various contextual factors on speech production in persons with AOS or PP is emphasized, since speech characteristics can vary depending on the context of production. The study of the influence of speech production in L1 versus L2 in AOS and PP is imperative because of its potential to inform about bilingual speech production in these speakers and the influence of increased processing demands thereon. A discussion of relevant terms and concepts is provided, as well as a brief review of the chapters of the study.

In *chapter two* prominent models and theories of speech production are reviewed in an attempt to delineate the processes and stages involved in the speech production process. Factors which influence information processing are reviewed with reference to specific contexts which might influence speech and language processing. From this discussion, L1 versus L2 speech production in bilingual speakers is proposed as a context for speech production and concepts relevant to bilingualism are discussed. The manifestation of language processing in the temporal and spatial parameters of speech production is discussed with reference to specific temporal parameters which can be measured acoustically. From this discussion, the relevance of studying the influence of L1 versus L2 production as a context for speech production on specific temporal parameters of speech in persons with neurogenic speech disorders is motivated.

In *chapter three*, AOS is defined and theories attempting to explain its underlying nature are discussed. The importance of the study of the speech of persons with predominant PP is emphasized and PP is contrasted with AOS. The importance of studying the speech of persons with AOS or PP in various contexts, specifically L2 and increased speaking rate is motivated. Studies investigating specific temporal parameters of speech in AOS and CA are reviewed and results are interpreted with reference to Van der Merwe's four-level framework for the sensorimotor control of speech (Van der Merwe, 1997). The need for the study of the effect of specific speech contexts on the temporal parameters of speech production in AOS and PP, in order to determine qualitative differences between these two disorders and to learn more about normal and pathological speech motor control under circumstances of increased processing demand, is highlighted.

In *chapter four* the experimental methodology of the empirical research is described in terms of the research aims, subject selection criteria and procedures, research design, measurement instruments, speech material, data collection procedure and finally the data analysis and processing procedures employed in this study.

In *chapter five* the results of the study are presented according to the various sub-aims. Intra- and intersubject comparisons are made using descriptive statistics. This chapter serves as an introduction to Chapter 6 where the results are interpreted and discussed.

In *chapter six* the results presented in Chapter five are discussed with reference to each sub-aim. Where relevant, the results of the current study are compared to the results of other studies and discussed with reference to the underlying nature of AOS and PP and the influence of speech production in L2 on the speech of these persons. A general discussion is then undertaken for highlighting of the main theoretical issues which emerged from the results of the study.

In *chapter seven* general conclusions are provided as well as an evaluation of the research methodology. The theoretical and clinical implications of the study are discussed and recommendations for future research are made.

1.5 SUMMARY OF CHAPTER ONE

In this chapter the rationale and motivation for the study were presented. The importance of the study of the influence of L1 versus L2 on specific temporal parameters of speech production in AOS and PP was motivated in order to learn more about speech motor control in bilingual speakers with neurogenic speech and language disorders under circumstances of increased processing demands. Finally, the terminology was explained and the content of the chapters in the study were briefly outlined.

CHAPTER TWO

SPEECH AND LANGUAGE PROCESSING: MODELS, THEORIES AND THE INFLUENCE OF CONTEXTUAL FACTORS

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2.1 INTRODUCTION

"The sound generated by a speaker is the product of coordinated multilevel motor processes…" (Smith, 1992a:233). Considering that three to five syllables are produced per second (Ramig, 1983), "it is evident that the nervous system has the complex task of simultaneously controlling and coordinating the movements of the articulators to produce rapidly alternating vocal tract configurations" (Smith, 1992a:233). The search for principles of neural organization which underlie this uniquely human behavior has been vast, leading to the development of various theories and models attempting to explain the processes involved in the motor control of speech and their neural substrates.

Speech is the conversion of language into sound and therefore cannot be completely separated from language. Kent, Adams and Turner (1996:33) underscore this fact by saying that "although one could become completely occupied in the study of speech as a motor behavior or a conversion of articulation into a sound pattern, speech is, after all, of greatest interest because of its primacy as a language modality" and that "one of the most exciting facets of a speech production model is what it can tell us about language". However, investigations attempting to bridge the gap between speech and language processes have been few (Maner, Smith & Grayson, 2000). Similarly few scientists have addressed the question of how speech production relates to a more general model of language formulation (Kent *et al.*, 1996).

Another challenge facing models of speech production is the explanation of the context-sensitivity of speech. The latter refers to the fact that the production of speech sounds varies with the context in which they are produced. The phonemes that make up a word are not merely realized acoustically by the assignment of a set of preset muscle commands for each phoneme and execution of these commands in serial order (Kent *et al.*, 1996). On the contrary, the temporal and spatial parameters of speech production need to be adjusted according to the phonetic context in which the sounds are produced (Van der Merwe, 1997). Apart from the phonetic context which exerts an influence on the parameters of speech production, the other identified contexts (Van der Merwe, 1986, 1997) also influence speech production and contribute to its complexity, as mentioned in chapter one. Van der Merwe (1997) emphasizes the importance of the study of the influence of these various contexts when studying the speech of persons with neurogenic speech and language disorders, since the context of speech production might influence the process of speech sensorimotor control (Van der Merwe, 1997). Van der Merwe (1997) states that variation of certain factors, such as sound structure, have already been found to cause variation in the symptoms of AOS (Kent & Rosenbek, 1983; Van der Merwe & Grimbeek, 1990; Van der Merwe *et al.*, 1987, 1988, 1989). The variation caused in apraxic symptoms by different contextual factors, will need to be taken into account when compiling assessment and treatment procedures for persons with neurogenic speech and language disorders.

Persons with neurogenic communication disorders can exhibit deficits related to language and/or motor processes of speech production. However, linguistic and motoric aspects cannot be completely separated in the study of speech production (Robin, Solomon, Moon & Folkins, 1997). Considering that speech is a modality for language, the languages of a bilingual speaker (L1 versus L2) could serve as two different contexts for speech production. Studying the effect of speech production in L1 versus L2 in bilingual speakers, on specific parameters of speech production, has the potential to shed light on the control and interaction of speech and language processing in the brain. Studying the influence of speech production in L1 versus L2 on temporal parameters in bilingual speakers with neurogenic speech and language disorders who exhibit deficits at distinct levels of the speech production process, will provide insight into the nature of the processing mechanisms involved in bilingual speech and language processing in the presence of a neurologic lesion. Insight into the nature of the processing mechanisms involved in bilingual speech and language processing, in turn, will inform about the nature of these disorders and how different disorders react to different contextual influences.

When studying speech and language processes in the bilingual speaker with neurogenic speech and language disorders, it is necessary to employ information and concepts from several fields of research to form a backdrop against which experimental questions can be investigated and results interpreted. These include concepts related to motor control and motor learning, since speech production is in essence a motor skill. Furthermore, speech is the acoustic realization of language processing in the brain and consequently, theories and models of speech and language production need to be perused. These models and theories provide the platform from where aspects such as bilingualism in neurogenic speech and language disorders can be investigated and results interpreted. Models of speech and language production also serve to explain the underlying mechanisms involved in normal and pathological speech and language processing. Neurophysiological, as well as behavioral accounts of speech and language processing need to be incorporated into these models in order to provide a comprehensive explanation for results obtained. Finally, concepts related to bilingualism need to be reviewed in order to understand the processes involved in bilingual language processing.

In this chapter, models of speech production which have been proposed to explain normal and pathological speech and language processing, will be reviewed. Specific factors or “contexts” (Van der Merwe, 1997) which exert an influence on speech and language processing will then be discussed with reference to an information processing perspective on speech production. These factors can be either inherent to the individual or related to the task or context. From this discussion, the importance of the study of speech and language processing in bilingual speakers will become evident and concepts related to bilingualism will be reviewed. Against this backdrop, the study of the influence of speech production in L1 versus L2 in bilingual speakers, as a context for speech production, will be proposed. Since speech is a motor skill, it will become evident that the control of the temporal and spatial parameters of speech is important for obtaining perceptually accurate speech. The parameters of speech production which are studied in an attempt to gain insight into the motor control strategies of the brain in normal persons and persons with neurogenic speech and language disorders will be reviewed. Specific temporal parameters of speech production which are studied to inform about speech and language processing in general, will finally be discussed. This discussion will provide a rationale for the investigation of specific temporal parameters of speech and the influence of L1 versus L2 speech production on these parameters in speakers with neurogenic speech and/or language disorders.

2.2 THEORIES AND MODELS OF SPEECH PRODUCTION

The fact that speech is an extremely complex phenomenon has led to speech production being modeled in various ways. Neural models, articulatory models, vocal tract models, functional models and models of motor control have been proposed to account for various and diverse aspects of the speech production process (Kent *et al.*, 1996). In the next section, some of the most prominent models which have been related to normal and pathological speech production will be discussed.

The discussion will include, *inter alia*, two theories of motor control which have been related to speech production. Theories of motor control can be divided into two main groups depending on the emphasis placed on either the movement commands issued by the central components of the motor control system, or on the environment (Magill, 2001; Kent *et al.*, 1996). The two models of motor control which will be discussed are schema theory proposed by Schmidt (1975, 1988) and a dynamic system model proposed by Kelso and Tuller (1981). *Motor program theory* gives prominence to commands issued by the central nervous system, while *dynamic pattern theory* "gives more influence to movement commands specified by the environment and to the dynamic interaction of this information with the body, limbs and nervous system" (Magill, 2001:47).

A third model of speech production proposed by Levelt (1989) will then be discussed as a functional model of speech production, incorporating the concept of information processing which attempts to explain the ways various types of information regulate speaking. Finally, a model of speech sensorimotor control proposed by Van der Merwe (1997) will be reviewed, since this model is specifically aimed at describing the processes involved in normal speech production and speech production of persons with neurogenic speech and language disorders due to breakdown at different levels of the speech production process. Van der Merwe's (1997) model incorporates the concept of motor plans and programs, as well as the influence of contextual factors on speech production.

2.2.1 Motor program-based theory

The *motor program* forms the central part of theories that support central control of movement (Magill, 2001). Kent *et al.* (1996:14) define a motor program as "a plan or prescription of movement". A motor program for movement implies that speech movements are available for execution in a pre-assembled form which directs the muscular and articulatory regulation during speech production. The concept of motor programming for speech has been criticized because of its "excessive rigidity, failure to account for corrections in the ongoing movement, and inability to assess the status of the periphery and take proper advantage of these initial conditions" (Kent *et al.*, 1996:15). According to these researchers, motor program theory would not be able to account for the adaptation of movement to the context.

Kent *et al.* (1996) propose that an approach that may avoid some of the objections to the concept of motor programs is a generalized motor program (GMP) or schema theory as proposed by Schmidt (1975, 1982, 1988). Schmidt (1988) proposes two control components which are involved in the learning and control of skills, namely, the *GMP* and the *motor response schema*. The *GMP* is responsible for controlling the general characteristics of classes of actions, such as, kicking, walking and running, whereas the *motor response schema* provides the specific rules governing an action in a given situation, thus providing parameters to the GMP. According to Schmidt's theory (1975, 1982, 1988), motor programs are composed of *schemata*, which refer to "learned relationships among movement outcomes, control signals and boundary conditions" (Kent *et al.*, 1996:16). The schemata are based on four kinds of information which is stored, namely, the initial conditions, the outcome, the sensory consequences and the parameters used during execution of the movement. After each response, this information is stored and the relationships among them abstracted (Schmidt, 1982). These schemata are strengthened by experience with the consequence that practice in situations with different motoric requirements will enhance a particular schema (Kent *et al.*, 1996; Schmidt, 1982, 1988).

According to Schmidt (1988) the GMP controls a class of actions rather than a specific movement or sequence. A class of actions refers to a range of different actions that have a common but unique set of features. These invariant features form the basis of what is stored in memory. When a person wants to perform a specific action in a specific situation, the appropriate motor program (GMP) needs to be retrieved and movement-specific parameters then need to be added in order to meet the specific demands of the situation or context. Invariant features include the *relative time* of the components of the skill, the *relative force* used in performing the skill and the *order or sequence* of the components.

Although the GMP has invariant features which are invariable from one performance of a skill to another, the *parameters* which are applied can be varied. The parameters include overall force, overall duration and the muscles that must be used in execution of the skill. These aspects are adapted according to the requirements of the *situation or context* (Schmidt, 1988; Shea *et al.*, 1993). Schmidt's theory accounts for the performance of novel actions. A person can thus use rules from the motor response schema and add appropriate parameter characteristics to the GMP to perform a novel action (Magill, 2001). In Schmidt's theory, the importance of adapting the movements to the context is evident, although the context is not the primary determinant of the movements which occur in this view of motor control.

- Schmidt's schema theory related to speech motor control

Schmidt's schema theory can also be applied to speech production. In this regard, Kent *et al.* (1996:17) state that "The *motor response schema* generates a motor program based on the desired outcome and the initial conditions", where the desired outcome refers to the desired goal of movement and the initial conditions to the initial position of the articulators in space. The desired outcome, for example, a spatial target for a phonetic unit and the initial conditions (the current state of the speech system, including the positions of the articulators) serve as the inputs to the speech production mechanism and are needed for response recognition as a motor response schema. Feedback signals in the form of efference copy, proprioceptive feedback and auditory feedback are generated. These are thus the expected sensory consequences based on previous experience and outcomes. Actual feedback signals are compared with expected feedback once the movement is in progress and discrepancies between these two are used to adjust the motor response schema. The motor response schema can thus be adapted to deal with novel responses (Kent *et al.*, 1996).

2.2.2 Dynamic Systems Models

Dynamic systems theory, also known as task dynamics and action theory (Kent *et al.*, 1996) proposes that the motor control system can constrain the degrees of freedom by acting as a single unit (Bernstein, 1967; Tuller, Fitch & Turvey, 1982). In this theory "motor behavior is viewed in terms of the interactions between biomechanical and environmental variables" (Kent *et al.*, 1996:19). Dynamic systems theory describes and explains the control of coordinated movement by emphasizing the role of information in the environment and the dynamic properties of the body and limbs (Magill, 2001; Tuller *et al.*, 1982).

In essence, this theory proposes that the degrees of freedom of a motor system can be constrained by groups of muscles functioning as functional units, termed coordinative structures (Tuller *et al.*, 1982). Muscles are thus not controlled individually, but independent muscles are constrained to work as a functional unit or coordinative structure (Shea *et al.*, 1993). The main idea that proponents of this view wish to convey is that actions cannot be considered independent of their context (Kelso & Tuller, 1981). These researchers state that "While a coalitional style of control embodies the advantageous characteristics of heterarchies, namely free dominance, reciprocity and distributed function, it possesses the additional control advantage of effectively reducing the degrees of freedom of the system" (Kelso & Tuller, 1981:232). In their view, control of the degrees of freedom is "accomplished by the contextual framework that operates as a constraint on possible movement".

Proponents of dynamic systems theory, postulate that the contextual constraints specify the parameters of the motor system. The movement itself thus represents the context in which the action takes place and movement originates from the functional coalition of various structures. Depending on the movement to be executed, a coalition between the neural and anatomic structures, such as the muscles, is established. Movement is the result of the selection of synergies (coordinative structures) for a particular action. The coalitional style of organization is in direct opposition with the hierarchical models of control (Kelso & Tuller, 1981; Kelso *et al.*, 1983).

Magill (2001) states that both the GMP and dynamic pattern theory include the concept of relative time invariance as a characteristic. The source of the invariance differs, however, in that in the GMP relative time is an invariant feature of the GMP and is included in the movement commands that are sent to the muscles. Relative time invariance in this case is indicative of a class of movements that are controlled by the same GMP. The dynamic pattern view on the other hand prefers the term "temporal pattern". In this view the invariable temporal pattern is the result of the interaction between the person and the characteristics of the task and/or environment or due to the mechanical dynamics involved in the body and limb movements themselves (Magill, 2001).

- Dynamic systems theory related to speech motor control

Kent *et al.* (1996) apply the dynamic systems theory to speech production in the following way. Dynamic systems theory proposes that a complex system, such as the speech production system, can be simplified when the individual components of the system are functionally linked. The degrees of freedom are reduced by these functional groupings or synergies among the muscles which comprise the system. The effective control of the system is accomplished by appropriate combinations of the synergies. These synergies are "task specific, context sensitive, and adaptive" (Kent *et al.*, 1996:19). They possess both essential and nonessential parameters. Essential parameters are qualitative aspects of a movement's structure, for example, lip closure for the bilabial stop consonant /b/, whereas nonessential parameters are quantitative, for example, differing displacements of the lower lip in the bilabial closure movement when variations are introduced in phonetic context, stress or speaking rate (Kent *et al.*, 1996).

According to Kent *et al.*, (1996:19) when this is applied to the speech production process, essential parameters can account for phonetically distinctive characteristics of movements, while nonessential parameters can account for the effects of stress, rate and other "scalar variables that operate within the phonetic requirements of the movements". When producing a word, a general form of the intended action is contained in the phonological prescription. The coordinate grouping, among the many possible elements, determines the details of the motor events. Equations of constraint specify how the group members/muscles interact within the limits of the particular action and its context. Coordination in this view is described as "a blending of the dynamics of the participating synergies" (Kent *et al.*, 1996:20). In motor program theory, coordination is preassigned by a motor program, where as in dynamic systems, coordination results from the system dynamics. Dynamic system theory interprets invariant phase relations between task-coupled articulators during speech production as indicative of the operation of these functional synergies (Kent *et al.*, 1996).

Kent *et al.* (1996) ascribe the following disadvantages to dynamic system models. These models do not clearly link responses with phonological input to speech production. Furthermore, some predictions about phase relations have not been confirmed experimentally. Acoustic and language-specific timing factors are also neglected in this theory. According to these researchers advantages include, minimizing of the degrees of freedom and recognition of biomechanical properties of the system in relation to tasks.

Neither dynamic systems theory nor motor program models specify how speech production progresses from an intention to communicate to the achievement of perceptually accurate speech. In other words, these models do not explain how the linguistically formulated message is transformed into an acoustic signal. Apart from the motor processes involved in speech production, it is necessary to recognize the importance of the cognitive and language processes which occur in the brain. The model of speech production proposed by Levelt (1989) emphasizes the cognitive and language processes involved in speech production and will be reviewed in the following section.

2.2.3 An information-processing model: Levelt's theory

Since speech is one way to express language, it is evident that speech production cannot be viewed exclusively from a motor control perspective. A number of interactions and conversions take place in the process of going from thought to speech. Speech conversions involve neuromotor, myomotor and articulatory rules, whereas language conversions involve linguistic rules (Netsell, 1982). Consequently all of these aspects need to be incorporated in a model of speech production. Smith (1992a:263) posed an important question related to this issue by asking, "Can a general motor theory account for speech production, or must the linguistic elements of speech ultimately be intimately intertwined with motor processes at every level of the production process?". According to Smith (1992a:263) this debate is unlikely to be resolved soon and provides "a special vigor to the study of speech movement control".

One of the many approaches that could be taken in the study of motor learning and control and in the explanation of speech as the externalization of language processing which occurs in the brain, is an information processing approach. In this view, humans are regarded as active processors of information rather than passive recipients (Shea *et al.*, 1993). The basic assumption of this approach is that a number of cognitive processes are required for correct execution of movement by an individual. Furthermore, the fact that responses can vary in different situations, underscores the influence of contextual factors on speech and language processing. Current circumstances and past experiences that are stored in memory are considered when planning and executing a response in a specific situation (Shea *et al.*, 1993; Stelmach, 1982). Abbs (1988:168) states "the neurophysiologic mechanisms of speech control cannot be separated functionally from the less well-understood neural processes involving motivation, attention, conceptualization and sensory awareness, all of which have been implicated increasingly as influential factors in motor execution processes".

An information processing approach to the study of movement, examines the mental operations which occur after a stimulus has been received and a response has been initiated (Stelmach, 1982). This approach could be especially informative when compiling models of speech and language processing, since language formulation for speech production involves mental processing which is largely inaccessible to man. The speaker can be viewed as "a highly complex information processor who can, in some still rather mysterious way, transform intentions, thoughts, feelings into fluently articulated speech" (Levelt, 1989:1). Levelt (1989:1) proposes that "Developing a theory of any complex cognitive skill requires a reasoned dissection of the system into subsystems, or processing components".

According to Levelt (1989), a theory of speech production will involve various processing components. There are thus various processing systems that underlie speech, in other words, "which translate the speaker's intentions into overt speech" (Levelt, 1989:1). These processing components are specialized and work in a rather autonomous manner. Levelt (1989) underscores this issue by saying that the processing components which underlie speech work in a "highly automatic, reflex-like way" which allows these components to work in parallel. Parallel processing is, according to Levelt (1989), a prerequisite for uninterrupted fluent speech.

Levelt's (1989) theory of speech production incorporates aspects of information processing and is one of the few theories of speech production which have attempted to explain how language is converted to speech. Levelt (1989) proposes the following processing components to be involved in speech and language processing, namely, the Conceptualizer, Formulator, Articulator, Audition processing component and Speech-Comprehension System. The mental activities involved in speaking require the person's conscious attention and include conceiving of an intention, selecting the relevant information to be expressed, ordering this information, monitoring of one's own productions and keeping track of what was said during a conversation. Levelt (1989) refers to these mental activities as conceptualizing and to the subserving processing system as the Conceptualizer. The product of this processing component is termed the preverbal message. This message needs to be encoded by the speaker by making use of both procedural and declarative memory. Paradis (1995a, 1998) proposes that procedural memory underlies implicit linguistic competence, which entails the incidental acquisition and the automatic use of language, while declarative memory subserves metalinguistic knowledge which is acquired consciously and stored explicitly in the brain. The output of the Conceptualizer is the input to the following processing component, namely, the Formulator.

The Formulator translates a conceptual structure into a linguistic structure through grammatical and phonological encoding. The grammatical encoding procedures deposit their interim results in the Syntactic Buffer. Phonological encoding entails retrieving or building a phonetic or articulatory plan for each word and for the utterance as a whole. The output of this processor is a phonetic or articulatory plan, which is the input to the next processing component, namely, the Articulator (Levelt, 1989). The articulatory plan is a "program for articulation" (Levelt, 1989:12). It is not yet overt articulation, but an internal representation of how the utterance should be articulated. Levelt (1989:12) refers to this representation as "internal speech" and to articulating as "the execution of the phonetic plan by the musculature of the respiratory, the laryngeal and the supralaryngeal systems". The phonetic plan is stored in the Articulatory Buffer, since internal speech may be ahead of articulatory execution. During motor execution sets of muscles are used in a coordinated way in order to achieve overt speech. According to Levelt (1989) the articulatory plan is relatively independent of context, but execution adapts to varying circumstances or articulation in order to achieve roughly the same articulatory goal.

According Levelt (1989), the speaker is able to monitor correctness of his production through the Speech-Comprehension System. This system can monitor both internal and overt speech. Trouble in internal speech can be detected before the utterance has been completely articulated. The Speech-Comprehension System's output is parsed speech which entails a representation of the input speech "in terms of its phonological, morphological, syntactic, and semantic composition" (Levelt, 1989:13). The Speech-Comprehension System can detect form errors during production or if speech differs from the intention, in other words, differences between overt speech and the intended speech target.

Although Levelt (1989) proposes different stages to be involved in the progression from an intention to communicate to overt speech or articulation, he does not go into much detail regarding the motor planning and or programming stages of speech production. However, Levelt's (1989) theory of speech production has potential to explain speech and language deficits from an information processing perspective. The framework of speech sensorimotor control proposed by Van der Merwe (1997) describes the various linguistic and motor stages of speech production in detail and will be reviewed in the following section.

2.2.4 Van der Merwe's four-level framework of speech sensorimotor control

Van der Merwe (1997) proposed a framework for the sensorimotor control of speech in which the speech production process is depicted as consisting of four stages. This model is different from traditional models of speech production that propose that the speech production process consists of only three stages, namely linguistic encoding (semantic, syntactic and phonological), articulatory programming and execution (Itoh & Sasanuma, 1984). The most important difference is the distinction which Van der Merwe (1997) makes between motor programming and motor planning of speech. Within Van der Merwe's framework, motor planning and programming are viewed as two separate stages in the speech production process. The addition of another component to the speech production process has important implications for the study of speech motor control, since it implies that temporal specification and control can be exerted on more than one level of the speech production process.

Van der Merwe (1997) ascribes the control of each stage of the speech production process, to a coalition of specific neural structures. The components in the framework proposed by Van der Merwe (1997) will be discussed in detail, since this framework includes the most significant components of various models which have fallen short in explaining normal and pathologic speech motor control. Van der Merwe (1997) relates the various stages involved in speech production to specific neuroanatomic regions.

2.2.4.1 Intention to communicate verbally

The first "event" in the speech production process, yet not one of the formal stages proposed, is the intention of the speaker to communicate verbally. This aspect of speech production is posed to be controlled by the frontal-limbic formations of the forebrain. The limbic system generates the emotional motivation to act. The intention to communicate is, however, distinct from the actual initiation of speech movements.

2.2.4.2 Linguistic-symbolic planning

The first formal stage in the speech production process as postulated by Van der Merwe (1997) consists of the linguistic-symbolic planning of the utterance. During this stage, selection and sequencing of the phonemes take place, governed by the phonotactic rules of the language. This stage entails the syntactic, lexical, morphological and phonological planning of the intended utterance. It is evident from this description that this stage of the speech production process is non-motoric in nature. It further implies that the linguistic and motor planning of speech are performed at two distinct levels of the speech production process. A deficit at the level of linguistic-symbolic planning would thus result in phonologic errors, such as, PPs that occur in certain types of aphasia, for example, CA (Van der Merwe, 1997). The linguistic-symbolic stage proposed by Van der Merwe (1997) appears to be similar to the function performed by the Formulator proposed by Levelt (1989).

2.2.4.3 Motor planning

In order for the phonemes to be actualized at the articulatory level, a transformation of the phonemic representation of the utterance to a code that can be interpreted by the motor system has to take place. During this phase the motor goals for the actualization of the utterance are specified. Van der Merwe (1997) presents a hypothetical description of motor planning and this will be reviewed briefly.

Motor planning commences with the feedforward of the invariant phonological units in sequence to the motor planning system. Van der Merwe (1997) postulates that during the motor planning of the utterance the motor goals for each phoneme are specified in terms of spatial and temporal characteristics. The invariant core motor plan with these spatial (place and manner of articulation) and temporal specifications of movements for each phoneme is recalled from the sensorimotor memory where it is stored. Van der Merwe (1997) emphasizes the fact, however, that although the recalled core motor plan is invariable, adaptations to this core motor plan need to be made during the motor planning of speech, depending on the phonetic context in which it is to be produced. Certain factors thus necessitate adaptations to be made to the temporal and spatial parameters specified in the core motor plan. Van der Merwe (1997) postulates these factors to include aspects, such as, the phonetic or sound context (Borden & Harris, 1984), coarticulation possibilities (Borden & Harris, 1984; Kent & Minifie, 1977), phonetic and linguistic influences on segmental duration and changes in speech rate (Gay, 1981; Kelso *et al.*, 1983).

The core motor plan for each phonological unit is presumably similar to the GMP proposed by Schmidt (1982, 1988). The adaptation which takes place depending on the context in which production takes place is presumably similar to the parameterization which is suggested by Schmidt (1982, 1988). Schmidt (1982, 1988) does not specify, however, how language formulation processes and linguistic planning of the utterance occurs, nor does he specify the influence of specific speech contexts, although he mentions that spatial and temporal parameters are adjusted depending on the context of production.

Van der Merwe's model thus postulates that adaptation of the core motor plan for each phoneme within the context of the planned unit has to be made. This then includes adaptation of spatial specifications to the phonetic (sound) context and rate of production and also adaptation of temporal specifications to segmental duration, speech rate, coarticulation potential and interarticulatory synchronization (IAS). All this is done within the boundaries of equivalence, guided by knowledge of the acoustic effect of movements and a representation of the acoustic configuration to be reached. During adaptation of the core motor plan response feedback is not yet available since the movement has not been actualized at the moment of planning. However, internal feedback and predictive stimulation presumably guides adaptation (Van der Merwe, 1997). The motor system takes the initial conditions into account which is consistent with the dynamic systems view of motor control and also with Schmidt's (1982, 1988) proposal that the initial conditions form part of the information from which the motor response schema is derived.

The different subroutines that constitute the adapted motor plan (such as lip rounding and velar lift) are then specified and temporally organized. Van der Merwe (1997) states that motor goals, such as, lip rounding, jaw depression or glottal closure need to be specified. Interarticulatory synchronization is also planned for a particular phoneme. These temporally arranged structure-specific motor plan subroutines are then systematically fed forward to the motor programming system. This step then concludes the motor planning phase. Van der Merwe (1997) emphasizes the fact that motor planning is articulator-specific and not muscle-specific.

It is evident from the motor planning stage that specification of temporal and spatial parameters of movement is crucial for obtaining on-target acoustic output. Temporal parameters, such as, the duration of movements of the articulators and IAS are specified during the motor planning of speech in order to obtain a desired acoustic output and consequently to achieve an accurate perceptual goal. If the motor planning stage is disrupted, distorted articulation could result, for example, either due to aberrant timing between the movements of the articulators or because of aberrant spatial goal specification or achievement. Examples of other speech characteristics which are the result of difficulty regarding the motor planning of speech include, slow speech or struggling behavior. The aforementioned speech characteristics which result from difficulty regarding the motor planning of speech are characteristic of AOS (Van der Merwe, 1997).

2.2.4.4 Motor Programming

Traditional models of speech production do not distinguish between motor planning and motor programming of speech, but use these two terms as synonyms. This is where the framework proposed by Van der Merwe (1997) differs from most traditional models of speech production. Whereas motor planning of speech refers to the planning of the temporal and spatial goals of the articulators, motor programming refers to the selection and sequencing of motor programs for the movements of the individual muscles of these articulators (including the vocal cords). During motor programming of speech these muscle specific programs are specified "in terms of spatial-temporal and force dimensions such as muscle tone, rate, direction and range of movements" (Van der Merwe, 1997:16). During this phase, sensory feedback is potentially available to update motor programs, while internal feedback controls programming. All the neural structures involved at this stage are supposedly involved in internal feedback. Repeated initiation and feedforward of co-occurring and successive motor programs and integration with respiration for speech concludes the motor programming of speech (Van der Merwe, 1997).

Motor planning is thus a phase prior to motor programming which refers to the planning of motor goals of the articulators (spatial, as well as temporal), while motor programming is more specific and refers to the temporal and spatial specifications for each individual muscle. To achieve accurate temporal and spatial movements of the articulators, the activity of the muscles also needs to be temporally and spatially controlled. DeLong (1971) states that for the accomplishment of synchronized movement the appropriate muscles need to be selected, these muscles then need to be activated/inhibited in the correct temporal relationship and lastly the correct amount of excitation for each muscle needs to be applied. Temporal and spatial specification of muscle movement is thus performed during the motor programming of speech.

2.2.4.5 Execution

Execution refers to the actual realization of speech on the articulatory level. At this stage the temporal and spatial parameters of speech have been specified during motor planning and programming and are realized on the acoustic level. During the execution of movement closed-loop tactile-kinesthetic feedback is supposedly available for control and acoustic feedback is also implemented. Although response feedback is available, it is not necessarily constantly utilized during speech production of the mature speaker (Van der Merwe, 1997).

2.2.5 Conclusion regarding models and theories of speech production

From the above review of prominent models and theories of speech production, it is evident that speech can be viewed from a motor control perspective due to the fact that speech is essentially a learnt motor skill. However, speech production cannot be isolated from the language processes which occur in the brain, since "speech is constrained not only by the task dynamics of its production system and the articulatory-acoustic relations of the vocal tract, but also by its service to language"

(Kent *et al.*, 1996:33). A model or theory of speech production must thus account for the conversion of an abstract language code into movement parameters resulting in overt speech.

No matter from which perspective the speech production process is viewed, it involves complex parallel processing by various components to finally achieve perceptually accurate speech. From the models and theories discussed above, it is evident that speech and language processing is not isolated from external influences, however, and that certain factors exert an influence thereon. Van der Merwe (1997) emphasizes this by saying "contextual factors affect the dynamics of motor control by exerting an influence on the mode of coalition of neural structures involved during a particular phase and on the skill required from the planning, programming, and execution mechanisms". Van der Merwe (1997) identifies specific contextual factors which exert an influence on speech and language processing. The contextual factors proposed by Van der Merwe (1997) will be discussed in more detail further on in this chapter.

2.3 FACTORS INFLUENCING INFORMATION PROCESSING

Before discussing factors or contexts which exert an influence on speech and language processing specifically, it is necessary to peruse factors influencing information processing in general, since they are relevant during execution of any given task. Consequently these factors might also impact on speech and language processing. These factors are important, since they might influence the processing load, which McNeil *et al.* (1991a:35) refer to as "the idea that the more complex or difficult the task, the greater is the processing load and the outlay of effort". Factors influencing information processing and consequently the processing load, will consequently need to be considered when investigating speech production in both normal speakers and speakers with neurogenic speech and language disorders to determine their effect on normal and pathologic speech and language processing. Factors influencing information processing can either be related to the task or context or inherent to the speaker.

2.3.1 Factors influencing information processing related to the task and context

2.3.1.1 Stages of learning

According to Shea *et al.* (1993) performance changes as a movement becomes better learnt. The manner in which the brain processes information, also changes from when the task was first introduced compared to after the task has been practiced several times. Shea *et al.* (1993) mention three stages of learning, namely, the cognitive stage, associative stage and autonomous stage. During the cognitive stage, high demands are placed on sensation and perception processing. The person needs to determine the objective of the skill and take into account the environmental cues that control and regulate the movement. At this stage, demands on response execution are low, since it is too soon to concentrate on refinement of the movement.

During the associative stage the skill is performed and refined and concentration or attention shifts to the task and response execution. The information processing load appears to become reduced and the person becomes better able to attend to other stimuli which are not related to the task. The final stage of learning is referred to as the autonomous stage. This stage results in a nearly automatic kind of performance where the person can attend to other tasks while performing the primary task, for example, driving a car and having a conversation at the same time. Information processing activities thus change as a result of practice (Shea *et al.*, 1993).

2.3.1.2 Automaticity

Speaking is an intentional activity serving the purpose the speaker wants to realize (Levelt, 1989). An intentional activity is believed to be under central control, however (Bock, 1982). Levelt (1989) poses that a speaker invests his attention on matters, such as, his state of motivation, his obligations, what has previously been uttered or what has happened previously, and so forth. The question arises regarding the extent to which the processing components are under central or executive control. If a component is not centrally controlled, its functioning is implied to be automatic in nature. An automatic process is executed without attention or conscious awareness.

It runs on its own resources and does thus not share processing capacity with other processes (Levelt, 1989). Automatic processes are believed to be quick and even “reflex-like” and the structure of such a “process is ‘wired-in’, either genetically or by learning (or both)” (Levelt, 1989:20). Automatic processes can run in parallel without mutual interference, since they do not share resources. Each processor can work on different bits and pieces of the “utterance under construction” (Levelt, 1989:24). This is referred to as incremental processing (Kempen & Hoenkamp, 1987) and is based on the concept of automaticity, since only automatic processors can work without sharing access to attentional resources.

The concept of automaticity is important in the study of speech production, since most of the processing stages involved in normal speech production are generally viewed as occurring in a fairly automatized fashion (Bock, 1982; Kent, 1990; Levelt, 1989). Although the speaker needs to think about what he is going to say, he is mostly unaware of the linguistic and motor processing which occurs in translating thought into overt speech. Levelt (1989:22) states that the processes of the Formulator and Articulator are “probably largely impenetrable to executive control even when one wishes otherwise”. When the speed at which these processes need to take place to achieve fluent speech which is produced at a rate of approximately fifteen phonemes per second (Levelt, 1989) is considered, it becomes evident that conscious processing by these two components (the Formulator and the Articulator) is not feasible.

Borden and Harris (1984) also underscore the fact that although a person is generally conscious of the message he wants to convey, as well as the search for the appropriate words and feelings towards the topic or listener, a person is seldom aware of the processes involved in sound production as such. According to these researchers, sound production only comes to one’s attention when attempting new or unfamiliar words or in unfamiliar circumstances, for example, when speaking with a new dental appliance. Novel responses are thus not yet as automatized as over-learnt responses.

In contrast to automatic processing, controlled processing places demands on attentional resources, with the implication that only a limited number of things can be attended to at a time (Levelt, 1989). Controlled processing requires capacity in working memory (Kent, 1990). The processes which are placed in working memory (to be discussed later on) require a certain level of awareness. In Levelt's (1989) model of speech and language processing, the Conceptualizer requires highly controlled processing, because communicative intentions can vary in infinite ways. According to Levelt (1989) message construction and monitoring are thus subject to controlled processing. In this sense a speaker can attend to his own internal or overt speech and is aware when self-corrections are made. However, only a few concepts or bits of internal speech are available for conscious processing in working memory at a time, however.

Kent (1990) proposes that speakers exhibit flexibility regarding the employment of automatic or controlled processing. Marginal forms of control are hypothesized to be present as evidenced by the fact that a speaker can interrupt his speech when an error is detected in order to correct it. It is proposed that other global aspects of processing, for example, speaking rate, loudness and articulatory precision can also be controlled by the same executive signal. More attention needs to be allocated during the performance or implementation of these parameters according to Levelt (1989). According to Kent (1990), controlled processing is likely to be employed in more challenging situations. Aspects proposed to specifically influence and presumably increase the processing demands during speech production specifically, will be discussed in more depth further on in this chapter.

2.3.1.3 Movement time

The information processing load is increased when the time available to complete a movement is reduced. When executing rapid movements, all information processing must be completed before the movement is begun (Shea *et al.*, 1993). Speech production is the result of "rapidly changing vocal tract configurations" (Smith, 1992a:233). In certain situations a speaker might be required to execute speech at a faster than usual rate due to time constraints, for example. Schmidt (1975) proposes that rapid movements need to be preprogrammed. A motor program implies a set of prestructured commands that are able to control the movement from beginning to end. These programs are presumably stored in memory and once retrieved do not require active information processing related to the construction of an action plan. The existence of these motor programs in memory significantly reduces the information processing load, since active information processing related to action plan construction does not occur (Shea *et al.*, 1993).

As discussed, the concept of motor plans or programs (Schmidt, 1982, 1988; Van der Merwe, 1986, 1997) has also been proposed in various models of speech production. A faster than normal speaking rate will presumably place higher demands on the speech production mechanism and will consequently influence both speech and language processing. Speaking rate as a context for speech production will be discussed in more depth further on in this chapter.

2.3.1.4 Movement complexity

An interval of time in which the motor control system is prepared according to the demands and constraints of the situation/context precedes the intended action. In other words, preparation of the motor control system is required when performing voluntary coordinated movement. Certain actions and circumstances require more preparation than others. The task itself, the situation and personal factors influence the time it takes to prepare the motor control system. The complexity of the action to be performed influences the amount of time the person requires to prepare the motor control system. The number of parts to a movement in turn determines the movement complexity. Furthermore, the more accurate the movement must be the longer the preparation time (Magill, 2001). From the above, it is evident that processing is influenced by movement complexity, since this determines the preparation time the motor control system requires.

2.3.1.5 Environment

Regarding general motor skills, the environments in which movements are executed can be classified on a continuum ranging from closed to open environments (Magill, 2001; Rose, 1997; Shea *et al.*, 1993). Conditions in a closed environment are relatively stable and ample processing time is available is this context. Processing demands are generally placed on sensation-perception and response selection. Open environments exhibit continuously changing conditions and information processing has to occur at a fast rate and anticipation needs to be employed for response selection (Shea *et al.*, 1993).

In the same way that the nature of the environment can influence processing demands involved in motor actions, the conditions under which speech needs to be produced can influence speech and language processing. Although environments for speech production cannot be described as open or closed per se, certain contexts in which speech is produced are also more challenging than others and consequently influence the processing demands. An example of an "environment" in speech production might be related to the phonetic environment in which a phoneme is produced. The presence of a compromised speech motor system due to, for example, a neurologic insult might also be considered as causing changing conditions for speech production. This is a condition inherent to the speaker, however, and not brought about by the environment. All the other contexts proposed for speech production might also be seen as different environments for speech production. The contexts proposed to influence speech and language processing will be discussed further on in this chapter.

2.3.2 Factors influencing information processing inherent to the individual

Certain factors regarding information processing are inherent to the person or speaker. These factors might differ between persons and might be affected in persons with damage to the central nervous system.

2.3.2.1 Attention

Since the earliest days of investigating human behavior, the study of *attention* has been of great interest. It is one of the most significant limitations influencing human learning and performance (Magill, 2001). Attention is also an important concept in the study of speech and language processing. As discussed, the amount of attention which needs to be allocated decreases as the task becomes over-learnt/automatic. This is evident from fluent speech production where the speaker does not need to think about speech production as such. However, certain speaking situations/contexts, as will be discussed, place higher demands on speech and language processing and require allocation of more attentional resources. Therefore, this concept needs to be incorporated and understood in a discussion of speech and language processing.

Shea *et al.* (1993:312) define attention as "The direction of mental energy or the allocation of resources to important stimuli and ignoring irrelevant ones; the process by which we notice important, meaningful, or relevant information and ignore unimportant stimuli". McNeil *et al.* (1991a:30) note that attention is synonymous to "resources, capacity, or effort". Magill (2001) emphasizes the fact that attention can be directed toward perceptual, cognitive and/or motor activities.

Limitations exist regarding the number of activities which can be attended to at one time (Kahneman, 1973; Magill, 2001; Stelmach, 1982). Attention theories propose that attention limits are the result of the limited availability of resources that are needed to carry out information-processing functions. We thus have limited attention resources to do all the activities that we may attempt at one time. One is able to perform several tasks simultaneously as long as the resource capacity limits of the system are not exceeded. If these limits are exceeded, performance of one or more of these tasks will deteriorate (Just & Carpenter, 1992; Magill, 2001; Stelmach, 1982).

Magill (2001) states that theorists have opposing views regarding the nature of resource limitations. The one group poses that there is one central resource pool from where all attentional resources are allocated. The latter is known as central resource capacity theories (Kahneman, 1973). The other group proposes multiple sources for resources and is known as multiple resource theories (Wickens, 1992). These two theories regarding resources will be discussed briefly in the following section.

2.3.2.1.1 Central resource capacity theories

Central resource capacity theories propose that there is a central reserve of resources from which all activities draw when being performed. An example of the central resource theory is proposed by Kahneman (1973). According to Kahneman (1973), the amount of available attention can vary depending on certain conditions related to the individual, the task at hand and the situation. The available attention is viewed as a general pool of effort, which involves the mental resources necessary to carry out activities. Attention can be allocated to several activities at the same time. The allocation of resources is determined by factors such as the characteristics of the activities, as well as the allocation policy of the individual. This in turn is influenced by situations internal and external to the individual. This central pool of available resources is the available capacity and can fluctuate according to the arousal level of the person (Magill, 2001).

Arousal refers to the general state of excitability of a person which involves physiological, emotional and mental systems. A too high or too low arousal level will influence the available attention capacity. To exhibit the maximum attentional resources, the person must be at an optimal arousal level (Magill, 2001). A person with a compromised central nervous system might not always be at an optimal arousal level and this could lead to fluctuations in the ability to effectively allocate attention (McNeil *et al.*, 1991a). It has also been proposed that subjects with aphasia might have difficulty with effective allocation of resources (McNeil *et al.*, 1991a).

2.3.2.1.2 Multiple resource theories

Multiple resource theories propose that we have several attention mechanisms which each have limited resources. Each mechanism is related to a specific information processing activity and is limited as to how much information it can process simultaneously. Here each resource pool is specific to a component of skill performance. Wickens (1980, 1992) proposed the most popular theory regarding the multiple resource theories. According to Wickens (1980, 1992), three different sources are available as resources for processing information. These include the *input and output modalities* (for example, vision, limbs and speech systems), the *stages of information processing* (for example, perception, memory encoding, and response output) and the *codes of processing information* (for example, verbal codes and spatial codes). Depending on whether two tasks demand attention from a common resource or from different resources, they can be performed simultaneously. In other words, when a resource is shared between two simultaneously performed tasks, performance will decrease compared to when the two tasks compete for different resources.

2.3.2.1.3 Attention and context

From the foregoing discussion one can conclude that the allocation of attentional resources is dependent on the context in which actions are executed. The higher the processing demands induced by the context, the more attentional resources will be needed for accurate performance in the specific context (McNeil *et al.*, 1991a). On the other hand, McNeil *et al.* (1991a:35) state "when the task is more automatic, the processing load is smaller and fewer resources, less attention, and less effort are required for its successful completion".

Depending on the context in which speech is produced, demands can be placed on the processing involved in any of the stages in the speech production process. Since speech and language are intertwined, increased processing demands on one level of processing might also affect processing at other levels of the speech production process. Specific "contexts" for speech production (Van der Merwe, 1986, 1997) which are believed to increase processing demands during speech and language processing will be discussed further on in this chapter. The way in which persons with different speech and language disorders react to the increased processing demands has the potential to inform about the underlying nature of the specific disorder.

2.3.2.2 Memory

Memory plays an important role in virtually any activity we perform. Consequently memory storage and retrieval influences learning and performance (Magill, 2001). We are continually confronted by situations which require the use of memory to produce a response. Magill (2001:143) describes memory as "(a) our capacity to remember or be influenced by past experiences; (b) a component of the information processing system in which information is stored and processed". Shea *et al.* (1993:52) refer to memory as the "system that enables us to retain information over time". In the speech production process, memory is important regarding both speech and language processing. Regarding language processing, rules regarding language content, form and use are learnt and stored as implicit linguistic knowledge (Paradis, 1998). These rules are then applied during message formulation and comprehension. Regarding speech production, the motor plans/programs are also presumably stored in and retrieved from memory when the speaker wants to convey his message orally (Van der Merwe, 1997).

Baddeley (1986, 1992) proposed that memory comprises two functional components namely, *working memory,* also known as *short-term memory* and *long-term memory*.

2.3.2.2.1 Working memory or short-term memory

Working memory is active in all situations which require the temporary use and storage of information and the execution of memory and response production processes. Information is stored for a short time in working memory. Critical information processing occurs in this part of memory and it is important in decision-making, problem solving, movement production and evaluation, as well as in long-term memory functions (Magill, 2001). It provides essential processing activity needed for the transfer of information into the long-term memory. Working memory also serves as an interactive workspace where information retrieved from long-term memory is integrated with information in working memory (Baddeley, 1992; Just & Carpenter, 1992; Magill, 2001; Rose, 1997). Working memory contains all the information we attend to and are conscious of at a specific point in time (Levelt, 1989; Rose, 1997). According to Levelt (1989) working memory is active during the processes involved in conceptualizing and monitoring of speech.

Working memory is important in the study of speech and language processing, since aspects of speech and language processing which need to be attended to are placed in working memory. When speech and language processing demands increase, certain aspects might require more attentional resources and presumably occupy space in working memory. According to Levelt (1989) parsed internal speech is also represented in working memory. A person thus has access to his internal and overt speech. In her information processing model of verbal formulation and speech production, Bock (1982) proposes that in normal fluent adult speech, syntactic, semantic and phonological processing do not require capacity in working memory, since these are proposed to be automatic processes (Kent, 1990; Kent & McNeil, 1987). As was mentioned, however, a normal speaker is flexible in his deployment of controlled processing (Kent, 1990; Levelt, 1989). In other words, controlled or conscious processing might be needed and implemented under circumstances of increased processing demand and consequently require space in working memory.

2.3.2.2.2 Long-term memory

Magill (2001:147) describes long-term memory as "a component of the structure of memory that serves as a relatively permanent storage repository for information". Three systems in long-term memory have been proposed, namely, procedural, episodic and semantic memories. In more recent years, researchers have tended to describe only two types of memory, however, namely declarative and procedural memory (Anderson, 1987). Procedural memory relates specifically to storing information about motor skills. It provides knowledge about how to perform a skill. The person might be able to perform the skill, but not be able to describe verbally how he performed it.

Regarding memory for speech production, Paradis (1998) states that implicit linguistic knowledge is subserved by procedural memory and is acquired "automatically". The person is thus not aware of the processes involved in acquiring implicit linguistic knowledge, which refers to the phonology, morphology, syntax and lexicon of a language. According to Paradis (1998), acquisition of L1 occurs in this manner. Whilst speaking, a person is generally not aware of the grammatical aspects of language, for example, sentence construction. He merely utters a grammatically correct sentence due to his implicit linguistic competence (Paradis, 1998). According to Paradis (1995a), damage to this language system results in aphasia proper.

Semantic knowledge refers to general knowledge and includes factual and conceptual knowledge which develops from experiences (Shea *et al.*, 1993). Schmidt (1975) refers to semantic memory as memory for abstract generalization of a movement and labels this "schemas". Shea *et al.* (1993:63) refer to semantic memory as a "person's general background memory about words, symbols, concepts and rules". Episodic memory refers to knowledge about personally experienced events and information about the time they were experienced, for example, when recalling the first time you drove a car, information from episodic memory would be retrieved. Semantic and episodic knowledge can be verbalized. It entails knowing "what to do". These two memory components are referred to as declarative knowledge and can be verbalized. It is important to distinguish between knowing "what to do" and "how to do" it when relating the three memory systems of long term memory with processes underlying motor control. In a specific situation a person might know "what to do", but might not be able to perform the action successfully. This means that problems exist in attaching the appropriate parameter values to the selected motor program (Magill, 2001).

Paradis (1995a, 1998) states that acquisition of L2 occurs using more conscious strategies and this is known as explicit linguistic knowledge. According to Paradis (1995a), explicit linguistic knowledge is subserved by declarative memory. Paradis (1995a:6) states that explicit linguistic knowledge is "learned consciously (possibly but not necessarily with effort), is available for conscious recall, and is applied to the production (and comprehension) of language in a controlled manner".

2.3.3 Conclusion regarding factors influencing information processing

From the above discussion it is evident that specific aspects related to the task and environment/context in which a task is executed, exert an influence on information processing. These aspects include the stage of learning, automaticity, movement time and task complexity. Furthermore, specific aspects inherent to the individual are involved in information processing, namely, attention and memory. In the next section, contexts proposed to influence speech and language processing in particular will be discussed.

2.4 CONTEXTS FOR SPEECH PRODUCTION

Context-sensitivity is an integral part of speech production (Van der Merwe, 1997:6). In Van der Merwe's (1997) framework of speech sensorimotor control, it is hypothesized that "contextual factors affect the dynamics of motor control by exerting an influence on the mode of coalition of neural structures involved during a particular phase and on the skill required for the planning, programming and execution mechanisms". Van der Merwe (1997) states that certain variations of a specific contextual factor might necessitate more complex control strategies than others. The context of speech production thus influences the processing demands, which in turn necessitate the allocation of more attentional resources and consequently more conscious control. Different motor tasks, for example, exhibit different levels of activity of certain neural structures, as has been observed by neurophysiologists (Schultz & Romo, 1992). It has also been found that unfamiliar and precise fine movements require more sensory input and thus greater involvement of the sensory areas, than well-learned or ballistic movements (Brooks, 1986). Van der Merwe (1997) concludes that context therefore influences the control system.

As discussed in chapter one, Van der Merwe (1997) acknowledges a variety of contexts in her framework of speech sensorimotor control. These include voluntary versus involuntary (automatic) speech, sound or phonological structure, motor complexity of the utterance, length of the utterance, familiar versus unfamiliar utterances and speech rate. Van der Merwe (1997) states that the role of the various contextual factors will have to be determined by research and goes on to say that both treatment and research results will be influenced by variation in contextual factors. The contexts for speech production identified by Van der Merwe (1986, 1997) will be discussed in the following section.

2.4.1 Speaking rate

One temporal characteristic of speech production is speech rate. This is a temporal variant which causes drastic changes in the speech production process (Gay, 1981; Kelso *et al.*, 1983) and also has perceptual consequences. Speech physiologists state that an increase in speech rate demands substantial modifications of system control compared to normal speech rates (Abbs, 1973; Gay & Hirose, 1973; Gay, Ushijima, Hirose & Cooper, 1974). An increase in speech rate can be accomplished by reducing pauses between phrases, by increasing the rate of words within a phrase or by reducing word or syllable durations (Ludlow *et al.*, 1987).

Movement duration of the articulators also changes with an adjustment in speaking rate. This implies that during the motor planning of speech, the core motor plan needs to be adapted according to speaking rate. Consequently, Van der Merwe (1997) views speaking rate as a context of speech production. When speech rate changes, the context thus changes which necessitates adaptation of the core motor plan to the context of increased speaking rate (Van der Merwe, 1997). The core motor plan is adjusted in terms of the temporal and spatial characteristics needed for the acoustic realization of the specific phoneme/(s) in context.

When studying the speech of persons with neuropathology, an alteration of speaking rate is often employed as a means of assessing motor facility. The ability to accomplish rate changes with ease is a characteristic of the normal speech production mechanism, whereas an impaired motor speech system will be limited regarding this ability (Kent & McNeil, 1987). Furthermore, studying the effect of changes in speaking rate can tell us more about the disorders in persons with neurogenic speech and/or language disorders, since an increase in speech rate places higher demands on the speech production system and consequently on motor control (Kent & McNeil, 1987; McNeil *et al.*, 1990a). However, linguistic aspects of speech production are also presumably influenced by an increase in speaking rate (Fossett, McNeil & Pratt, 2001).

It could be argued that speech production at a faster than normal rate requires greater motor skill and consequently more attentional resources, and controlled processing needs to be exerted. Resources might, however, be more easily exceeded when rate has to be increased in persons with difficulty regarding speech and/or language processing, causing deficits to become more evident under circumstances of increased processing demands. By studying the effect of speech rate alterations on specific parameters of speech production, more can thus be learnt about the motor control of speech in different subject groups under circumstances of increased processing demand, than by investigating these aspects at the usual self-selected rate alone.

2.4.2 Level of voluntary initiation of actions

Kelso and Tuller (1981:229) mention voluntary versus automatic speech as a contextual factor in speech production. These researchers distinguish between "planned" and "voluntary" acts as opposed to "habitual" or "automatic" acts. Kelso and Tuller (1981) refer to the phenomenon that persons with AOS can perform certain "habitual" actions adequately in certain contexts, whilst other times, they are unable to do so in response to a clinician's request. Buckingham (1979) states that spontaneous conversation is a less voluntary action than when a person is requested to speak. In this sense the level of voluntary initiation can be viewed as a context for speech production (Van der Merwe, 1986).

From an information processing perspective, one could argue that more attentional resources are needed for voluntary initiation of actions than when they are performed "automatically" or in response to a specific stimulus. Capacity in working memory is thus presumably required for the voluntary initiation of the action. Persons with AOS are known to have difficulty with the voluntary initiation of utterances (Wertz, LaPointe & Rosenbek, 1984), indicating that voluntary initiation is more difficult for persons with difficulty regarding the motor planning of speech.

2.4.3 Familiarity: Novel versus automatic production

The more familiar a person is with a skill, the less feedback is utilized for its control and the more fluent the skill becomes (Ashton, 1976). Execution of an unfamiliar movement is slower, probably because it cannot be completely planned in advance (Allen and Tsukahara, 1974). The more familiar a person is with a specific movement pattern, for example, production of a specific word, the better the person can anticipate upcoming events in the movement sequence or utterance. Variability also decreases as the movement becomes more skilled with practice, implying that the planning and execution of the movement are more precise and easier to accomplish than when producing a novel sequence or word (Sharkey & Folkins, 1985).

Novel actions require conscious attention and consequently demand more attentional resources due to the need for controlled processing. Production of a foreign word for the first time, for example, requires conscious attention and consequently greater attentional resources. As actions, or in this case speech, are practised, the movements become "automatized" and attentional resources are not required for their execution (Levelt, 1989; Magill, 2001). Although certain aspects of speech production might still require conscious processing, as proposed by Levelt (1989), the greater part of speech production occurs in a fairly automatic fashion under normal circumstances in normal speakers.

2.4.4 Sound structure

Sound structure can be viewed as a contextual factor for speech production (Van der Merwe, 1986). Speech production is a learnt skill and it appears as if certain speech sounds and combinations thereof require greater skill and are more difficult to produce than others (Calvert, 1980; Oller & MacNeilage, 1983). The fact that certain speech sounds are acquired earlier in childhood (Ingram, 1976) and that the first syllable to be produced consists of a consonant and a vowel or reduplication thereof, might indicate that this structure is easier to produce than other sounds and structures (Van der Merwe, 1986). Rosenbek, Kent and LaPointe (1984) view the consonant-vowel-consonant structure as the easiest to produce. On the other hand, Seddoh *et al.* (1996b) proposed that words with closed syllables might be more difficult to produce than those with open syllables for persons with AOS. Utterances with consonant clusters, for example, CVCCC combinations (for example, “desks”) are also known to be extremely difficult to produce (Calvert, 1980).

2.4.5 Motor complexity

Van der Merwe (1986) states that certain factors, which are not related to the sound structure of an utterance, can also increase motor complexity. These include coarticulation possibilities and greater variation of articulatory characteristics, for example, sequential stretching and rounding of the lips. It is important to determine which contexts influence speech production in persons with neurogenic speech disorders, since persons with AOS have been noted to experience difficulty with the production of certain sounds or combinations thereof (Wertz *et al.*, 1984). The motor complexity of an utterance can most probably not be ascribed to a single factor. A certain combination of sounds might pose higher demands to the linguistic-symbolic planning of an utterance, for example, require more conscious processing and might also be motorically more difficult to produce (Van der Merwe, 1986).

Kent and Rosenbek (1983) state that most dimensions of apraxic disturbances are influenced by increased syllabic or phonetic complexity and that this aspect of apraxic behavior is important for theoretical understanding of AOS. The observation that certain sounds are more difficult to produce than others in persons with AOS underscore the fact that sound structure exerts an influence on motor performance and can consequently be seen as a context for speech production. A motorically complex utterance will presumably increase the demands regarding both motor and linguistic processing. From an information processing perspective, increased movement complexity will presumably require more controlled processing for correct production.

2.4.6 Length of the utterance

The length of the utterance is partially determined by the sound structure, but in this case length also refers to single words versus more words or even sentences. Longer utterances, just as longer movement sequences (Magill, 2001), would presumably take longer to plan. This has been found experimentally by Klapp, Anderson and Berrian (1973). In children it has been demonstrated that during imitation tasks, utterance length contributes to the number of incorrect responses produced (Miller, 1973; Montgomery, Montgomery & Stephens, 1978; Smith & Van Kleeck, 1986).

Strand and McNeil (1996) investigated the effect of length and linguistic complexity on temporal acoustic parameters of speech in persons with AOS. They found that persons with AOS had consistently longer vowel and between-word segment durations than normal speakers in all conditions. The persons with AOS also produced longer vowel and between-word segment durations in sentence contexts than in word contexts. Strand and McNeil (1996) concluded that the differences in duration in sentence production versus word or word-string production implied different mechanisms for executing motor programs for varying linguistic stimuli.

As mentioned previously, an interval of time in which the motor control system is prepared according to the demands and constraints of the situation/context precedes the intended action. The number of parts of the movement increases the movement complexity (Magill, 2001). In the same sense the number of sounds to be articulated might increase speech and language processing demands and consequently complexity of production.

2.4.7 Linguistic complexity

The influence of linguistic aspects on speech production has also been proposed. In a recent study by Maner *et al.* (2000), the influence of sentence length and complexity on speech motor performance was investigated. Specifically these researchers investigated the effect of increased linguistic demands on articulatory movement stability in both children and adults. This was done by analyzing lower lip movement stability, which rendered a spatiotemporal index reflecting the stability of lip movement over ten productions of a specific phrase. The index reflected contributions of spatial variations (for example, variation in amplitude of movement) and temporal variations (for example, change in timing of peak displacements). A higher index reflected greater variability in the normalized movement waveforms. The phrase these researchers used for analysis was spoken in isolation and then embedded in sentences of varying complexity.

Maner *et al.* (2000) found that the spatiotemporal index was increased significantly for the phrase when it was spoken in the complex sentences compared to being spoken in isolation (baseline condition). Furthermore, the spatiotemporal index values of the children were consistently higher than those of the adults across conditions. The adults thus had more stable production systems and were not as easily influenced by the increased processing demands. These researchers concluded that their findings rendered "novel evidence that speech motor planning, execution, or both are affected by processes often considered to be relatively remote from the motor output stage" (Maner *et al.*, 2000:560).

Studies of phonological and syntactic processing in typically developing and disordered children, as well as work on the effect of linguistic variables on speech fluency in stutterers and non-stutterers have also been conducted in an attempt to shed light on the interaction between language processes and speech motor performance (Maner *et al.*, 2000). Kamhi, Catts and Davis (1984) found that increases in language complexity had effects on the accuracy of target sound production in normally developing children aged 22-34 months. Furthermore, these researchers concluded that phonological performance was influenced by changes in language complexity more often in younger children than in older children.

In another study by Masterson and Kamhi (1992) imitated and spontaneous speech tasks were examined in three groups of children, namely, language-learning disabled, reading disabled and normal language-learning. These researchers sought to determine if processing demands in one component would lead to a decrease in performance of another component. Specifically they wanted to establish if increased syntactic complexity would lead to a decrease in semantic/phonological complexity and/or accuracy and vice versa. From the results of their study, Masterson and Kamhi (1992) concluded that for later acquired speech and language skills, increasing processing demands at one level influenced performance at another level. Specifically these researchers found that elementary sentences were produced with higher phonemic accuracy than complex sentences. Gordon and Luper (1989) investigated differences in the number of dysfluencies of three-, five- and seven-year-old non-stuttering children as syntactic complexity was varied using three different syntactic constructions. All three age groups produced a significant complexity effect for the passive sentence construction form. These findings render evidence that linguistic variables affect speech production.

Research in the area of stuttering has also focused on the relationship between syntactic complexity and fluency. If fluency is influenced by syntactic complexity, it would imply that motor speech processes are negatively affected by a linguistic variable, namely increased syntactic processing demands. Gordon, Luper and Peterson (1986) examined the effects of increased syntactic complexity on fluency in five-year-olds with normal fluency during a sentence imitation and sentence-modeling task. A significant effect of syntactic complexity on fluency was only found during the sentence-modeling task. In a later study on normally developing children and children who stutter, effects of syntactic complexity on fluency were also found during imitation tasks (Bernstein Ratner & Sih, 1987).

Silverman and Bernstein Ratner (1997) also reported that normal dysfluencies and errors in repetition accuracy increased in stuttering and non-stuttering adolescents when the syntactic complexity increased. However, stuttering frequency was not affected by changes in syntactic complexity. The researchers concluded that although syntactic effects were strong for young children, they were minimal for older speakers. It was still evident, however, that linguistic factors impacted on motor performance in the subjects in their study.

The above mentioned studies render support for the assumption that interactions occur between linguistic complexity and motor speech performance. When linguistic or syntactic complexity increases, the processing demands are presumably increased regarding both linguistic and motor processing. This presumably requires allocation of more attentional resources, more controlled processing and consequently can impact on the execution level of speech production if resources are exceeded.

2.4.8 First versus second language in bilingual speakers as a context for speech production

The study of bilingualism has attracted attention from several disciplines. These include, amongst others, psychologists who investigate the effect of bilingualism on mental processes, sociologists who treats bilingualism as an element in cultural conflict, educationists who are concerned with bilingualism as it relates to public policy, sociolinguists interested in the ways in which language is used in society, and linguists who are interested in bilingualism as an explanation for certain changes in a language (Romaine, 1995).

Speech production in bilinguals has also been of interest to researchers in the field of speech-language pathology, because of the potential it has to shed light on the underlying mechanisms involved in bilingual speech and language processing (Paradis, 1990, 1992, 1995b). Determination of the localization of two or more languages in the brain and the neural substrate subserving these languages is another aspect which is attempted by such investigations (Albert & Obler, 1978; Ojemann, 1983; Ojemann & Whitaker, 1978; Paradis, 1977, 1989, 1993; Whitaker, 1989). Aphasia in bilingual speakers is also often investigated in an attempt to learn more about the recovery and disruption of language in bilinguals or polyglots in the presence of neurologic lesion (Paradis, 1977).

Speech production in bilingual speakers can be viewed as a context for speech production from a number of perspectives. Speech production in L2 might pose higher demands to both linguistic and motor processing, causing speech production in this language to be more difficult or effortful. The reason for this is that L2 can be viewed as a fairly novel speaking context which is also less automatized compared to L1, since the speaker does not use this language as often as L1. Furthermore, in the case of where L2 was acquired after L1 had been established (coordinate bilingualism), L2 was probably acquired using more conscious metalinguistic strategies, rather than being acquired via more automatic processes (Paradis, 1995a). Language processing in L2 will thus presumably require greater resources and controlled processing, due to the "novelty" and less "automatized" nature of L2. Processes other than conceptualization and monitoring as proposed by Levelt (1989), will thus also require more controlled processing. The speaker will, for example, need to think consciously about word selection for sentence production resulting in increased demands regarding linguistic-symbolic planning of the utterance.

Speech production in L2 might also increase processing demands regarding the motor planning of an utterance. Regarding motor planning or processing of an utterance in L2, sounds in L2 which are not a part of the sound repertoire of L1 will also be novel, less automatized and consequently require more controlled processing for their production. Even if the sounds in L1 and L2 are similar, the increased attention required for formulating and producing utterances in a less automatized language, might also impose demands on the motor planning of the utterance. For these reasons, speaking in L2 is proposed as a context exerting an influence on speech and language processing. The influence of these increased processing demands might impact on the execution level of speech production, since resources between language and motor domains are presumably shared (Strand & McNeil, 1996).

Speech production in L1 versus L2 in bilingual speakers as a context for speech production is particularly important to study in persons with breakdown at various levels of the speech production process. The resource capacity of persons with neurologic lesions might be more easily exceeded when the processing demands are increased with speech production in L2, since more than normal resources already need to be allocated to the levels of the speech production process where difficulty exists. The consequence of increased processing demands might be visible in the temporal parameters of the acoustic speech signal.

Temporal control is inherent to speech motor control and the temporal parameters of speech production are measurable in the acoustic speech signal. Temporal parameters of speech production are often studied in an attempt to infer about the motor processes underlying speech production (Keller, 1990). Studying the effect of these increased processing demands imposed by speaking in L2 thus has the potential to inform about the nature of speech and language disorders in persons with breakdown at various levels of the speech production process. Furthermore, information can be obtained as to how these persons perform in the presence of increased processing demands imposed by a language context (L1 versus L2). The latter in turn will influence the planning of assessment and treatment procedures for these persons. The study of speech production in persons with neurogenic speech and language disorders will be discussed in more depth in chapter three.

To delineate the study of specific temporal parameters of speech production in L1 versus L2 in bilingual speakers, it is necessary to examine some of the concepts and theoretical issues related to bilingualism. After this, speech as a motor skill and the parameters of speech production which are studied in an attempt to learn more about the higher level processes which occur in the brain during speech and language processing will be discussed.

2.5 BILINGUAL SPEECH AND LANGUAGE PROCESSING

2.5.1 Defining bilingualism

Several definitions of bilingualism have been proposed. Considering that the degree to which a person is proficient in L2 can differ regarding comprehension, or expression, or both, it becomes clear that bilingual speakers can function at various ends of a continuum of proficiency (Romaine, 1995). Mackey (in Romaine, 1995:12) consequently "considers bilingualism as simply the alternate use of two or more languages".

2.5.2 Types of bilingualism

Weinreich (1968) distinguishes three types of bilingualism, namely, coordinate, compound and sub-coordinate bilingualism. In coordinate bilingualism the person learns his two languages in separate environments, resulting in the words of the two languages being kept separate with each word having its own specific meaning (Junqué, Vendrell & Vendrell, 1995; Paradis, 1995a; Romaine, 1995). An example of this would be a person whose home language is Afrikaans, but who learned English later in his life, as a second language, at school.

Compound bilingualism entails that the two languages were learnt in the same context and were thus used concurrently whilst being learnt. This results in a fused representation of language in the brain causing two words to be tied to the same mental representation. A single concept with two different verbal labels, one in each language, thus exists. The two languages are consequently interdependent. An example of this would be a person who grew up in a bilingual home (Junqué *et al.*, 1995; Paradis, 1995a; Romaine, 1995).

A third type of bilingualism is a subtype of coordinate bilingualism and is known as sub-coordinate bilingualism. Sub-coordinate bilingualism implies that the bilingual speakers interpret words of their weaker language through words of their stronger language. If English were the weaker language, the English word "book" would, for example, evoke the Afrikaans word "boek" in an Afrikaans/English bilingual speaker. This type of bilingual speaker has a primary set of meanings in L1 with another linguistic system attached to them (Romaine, 1995).

When studying any aspect of bilingualism, it is important that the subjects exhibit the same level/type of bilingualism, since this could influence speech and language processing and consequently the demands imposed by the two languages and the results obtained in a specific study. If one were to study specific parameters of speech production, the level of bilingualism could thus influence speech production in the two languages. In other words, the type of bilingualism could influence the ease with which L2 is produced.

2.5.3 Crosslinguistic influence

The term "crosslinguistic influence" is used to refer to the influence of one language of a bilingual speaker on the other language during speech production (Sharwood-Smith & Kellerman, 1986:1). Foreign accent is an example of crosslinguistic influence at the level of pronunciation. In this instance, a bilingual speaker associates a phoneme of L2 with one in his primary language and subjects it to the phonetic rules of his primary language. This can result in under-differentiation, over-differentiation, re-interpretation or substitution (Romaine, 1995).

Romaine (1995) explains these abovementioned four phenomena as follows. *Under-differentiation* occurs when one language makes a distinction between sounds, which is not made in the other language. English, for example, distinguishes between the vowels of "sit" (/✋/) and "seat" (/♓/), whereas French has only one sound in this area of vowel space, namely, the /♓/ as in "petit". A French/English bilingual speaker might then under-differentiate these two sounds in English and replace both with the French /♓/-sound. *Over-differentiation* results from the "imposition of phonological distinctions made in one language on sounds in the second one", for example, the carryover of vowel system length in one language onto another language where it is not needed (Romaine, 1995:53). *Reinterpretation* occurs when the bilingual speaker is misled by the written form of the word and applies the pronunciation of L1 which is elicited by the specific written form, for example, words with the double consonant in English pronounced by an Italian. The English word "patty" will then be pronounced /patt♓/. *Substitution* occurs when a bilingual speakers replaces a sound of L2 with a sound from L1, because the original sound does not occur in L1. An example of this is English speakers in South Africa who replace the Afrikaans glottal /☒/-sound with a /♑/-sound, because English does not have a glottal /☒/-sound in its phonetic repertoire (Romaine, 1995).

Phonotactic patterns between languages thus differ, with the result that pronunciation of a sound not included in a person's L1 might initially be more difficult to produce on an articulatory level, because the motor pattern for that sound has not been specified in the brain. It is evident that each language has specific characteristics (temporal and spatial parameters) assigned to each phoneme for production of that phoneme. Van der Merwe (1997) refers to the temporal and spatial parameters which are assigned to a phoneme as the core motor plan. If L1 does not have the specifications for production of the specific phoneme in L2, it is thus presumably replaced with a corresponding phoneme in L1 or pronounced with the specifications of the L1 phoneme.

From an information processing perspective, production of sounds not included in a person's L1 can thus be seen as novel and consequently less automatized. This might lead to increased processing demands imposed by speech production in L2. From a motor control perspective, retrieval of core motor plans of L2 speech sounds which do not occur in L1, as well as adaptation of these motor plans to the phonetic context, will contribute to increased motor complexity of L2 utterances. All the operations which occur during the motor planning and programming of speech production as proposed by Van der Merwe (1997) will presumably be more difficult in L2, since L2 speech sounds are novel and less automatized compared to L1 speech sounds.

Cross-linguistic influence can also affect other aspects of speech production, such as, prosody or even the pragmatic level of language (Romaine, 1995). Bilingual speakers can, for example, transfer the stress patterns of L1 to L2, sometimes causing misinterpretation or unintelligibility. Romaine (1995) sites the example of French/English bilinguals who tend to give equal stress to every syllable when speaking English, since it is characteristic of French speech timing.

2.5.4 The study of specific aspects of bilingual speech production

Temporal parameters of speech sounds in L1 compared to L2 have been investigated. This includes, for example, the study of VOT. Caramazza, Yeni-Komshian, Zurif and Carbone (1973) found that bilingual speakers whose two languages have different VOTs may produce VOT values in at least one of the languages which are intermediate in value to those of monolingual speakers. It has also been found that bilingual speakers, whose two languages have different VOTs, perceive VOT differently compared to monolinguals. Watson (as cited in Romaine, 1995) proposed that this compromise reduces the processing load involved in mastering two phonetic repertoires. The bilingual speaker thus stays within the boundaries of acceptable production, but the values do not completely match the values of the monolingual speaker in either of the languages. When a language is acquired later in life, the speaker does not "necessarily establish distinct phonetic categories for the sounds in that language which differ from those of their first language" (Romaine, 1995).

VOT has been found to exhibit inherent language-universal features, as well as learnt, language-specific characteristics (Smith, 1978). For example, the short-lag category of stop consonants in Spanish appears to differ somewhat from the English short-lag category (Lisker & Abramson, 1964) and the Swedish long-lag stop consonants exhibit somewhat greater durational values than English long-lag stops (Fant, 1960). In languages such as Dutch and Afrikaans, aspiration of stops is not as common as in English (Lisker & Abramson, 1964) and different VOT will thus presumably exist for these languages.

Durational aspects of specific speech segments might also be language-specific. It is well-established that the duration of segments varies depending on the phonetic context (Kent *et al.*, 1996; Van der Merwe, 1997). For example, duration of a vowel which precedes a voiced consonant is one and a half times that of the same vowel preceding a voiceless consonant (Kluender, Diehl & Wright, 1988; Peterson & Lehiste, 1960). In this regard, Kent *et al.* (1996:217) state that although the aforementioned finding appears to be present in different languages, it appears "especially pronounced in English, suggesting a learned phenomenon in addition to physiologically based conditioning".

In another study related to speech production in bilinguals, Lubker and Gay (1981) examined the amount of lip rounding for rounded vowels in Swedish and English speakers. They hypothesized that Swedish subjects would have greater anterior-posterior displacements than English speakers, since the Swedish vowel space is more crowded than the American English vowel space, especially regarding rounded vowels. Decreasing the length of the labial segment leads to an upward shift in vowel formants. This would in turn infringe upon the space of another vowel in the Swedish system, thereby creating the chance of perceptual confusion.

From the results of their study, Lupker and Gay (1981) concluded that motor control of the lip rounding gesture in speech production is a language dependant, learnt behavior which is more important to some languages than to others. Swedish speakers move their lips further, initiate onset of movement earlier with greater velocity and precision of goal achievements than speakers of American English. The study by Lubker and Gay (1981) points to the fact that spatial-temporal aspects of speech movements are language-specific and need to be learnt. This underscores the fact that production in L2 might be motorically more complex and consequently exert greater processing demands.

Klein *et al.* (1995) have also proposed that speech production in L2 might be motorically more difficult. Regarding speech production in L2, using positron emission tomography, these researchers found that the articulatory demands of L2 might require additional processing. The latter finding was deduced from activation of the left putamen during articulation in a repetition task in L2. Subcortical activation sites were not evident during speech production in monolinguals. Klein *et al.* (1995) postulated that activation of the left putamen was presumably the result of increased articulatory demands which were imposed by speech production in a language which was learned later in life.

From the above discussion it is evident that production of speech sounds which are not part of one's L1 repertoire would most probably pose higher motor demands to the speech production mechanism, since the motor plans for their production are novel and less familiar. If L2 is not used as often as L1, these motor plans will also not be as automatized as those for sounds in L1. More conscious processing is thus necessary for production of these sounds and consequently allocation of more attentional resources to a process (speech production) which is generally executed automatically. Even if the sounds of L1 and L2 are similar, the less familiar language (L2) might still pose higher linguistic processing demands and these might in turn also place higher demands on motor processing. The influence of these increased processing demands might be manifested in the parameters of speech production as measured in the acoustic speech signal. Speech production in L2 might, for these reasons, hypothetically speaking be more difficult. Difficulty with speaking in L2 might be especially evident in populations with neurogenic speech and/or language disorders, since these subjects display less flexibility to adapt to increased processing demands (Kent & McNeil, 1987).

2.5.5 Language processing and automaticity in bilinguals

Positron emission tomography studies are often employed to study the neuronal processes that underlie linguistic performance in normal unilingual subjects. Activity-related regional cerebral blood flow is measured in order to make inferences about the neural substrates that underlie specific functions of unilingual and also bilingual language processing activities. The rationale for using positron emission tomography activation studies involves the assumption that any task places specific processing demands on the brain (Klein *et al.*, 1995). These demands result in changes in neural activity in various functional areas of the brain causing changes in the local blood flow to these areas (Raichle, 1989). Language is the most studied process in brain-imaging research (Haxby, Grady, Ungerleider & Horwitz, 1991)

Positron emission tomography findings regarding primary sensory processing and motor output have generally been uncontroversial, although localization of higher cognitive functions and their interpretation have been subject to more debate (Demonet, Price, Wise & Frackowiak, 1993; Liotti, Gay & Fox, 1994). These higher cognitive functions include aspects, such as areas which are activated during phonological and semantic tasks. Positron emission tomography studies have rendered support for the hypothesis that some speech tasks are more automatic than others. Klein *et al.* (1995:31), from the results of their study, concluded that "two pathways are distinguished by the degree to which the task at hand is learned or automatic". Word generation requires a non-automatic pathway, while repetition plays an important role in the automatic pathway regarding verbal response selection. Regarding bilingualism and automaticity, Ojemann and Whitaker (1978) suggested that a less extensive cortical area subserves a language which has become more automatized, whereas a language in which one is less fluent (L2) is subserved by a more extensive cortical area. However, according to Paradis (1995b), this study has been questioned regarding methodological considerations.

On a receptive level, different strategies for sentence processing have been suggested in languages which differ typologically, for example, English versus Chinese (Romaine, 1995). Other researchers have also found different strategies used in processing on a receptive level in different languages (MacWhinney, Bates and Kliegl, 1984). From the results of their study, Klein *et al.* (1995) concluded, however, that "the same neural processes subserve second-language performance as subserve first" regarding the particular task which they used in their study. These researchers emphasize, however, that speaking in L1 and L2 might differ regarding the cognitive demands which the two languages place on the speech production mechanism, even though the same brain regions are active in both cases.

2.5.6 Neuroanatomical organization in bilinguals

Another area of research which would support different processing strategies in bilinguals relates to the study of the cerebral localization of languages (Whitaker, 1989). If the two languages of a bilingual speaker are subserved by different neural structures, one could assume that their processing strategies might also differ. The study of the cerebral localization of languages has been undertaken by various means, for example, mapping sites in the brain where electrical stimulation alters naming in bilingual individuals (Ojemann and Whitaker, 1978; Ojemann, 1983). Although it has been proposed that bilinguals have their languages (implicit linguistic competence) less asymmetrically represented in their cerebral hemispheres than unilinguals, research has not supported this proposal (Paradis, 1990, 1995b). Recent positron emission tomography evidence has rendered support for the claim that the two languages of a bilingual speaker are not geographically separated within the brain, but are subserved by the same neurological substrate (Klein *et al.*, 1995). Paradis (1995b) also underscores the fact that all clinical studies indicate that implicit linguistic knowledge is subserved by areas of the left hemisphere in bilinguals to the same degree as in unilinguals.

Increasing evidence has been gathered to indicate increased involvement of the right hemisphere in pragmatic and paralinguistic aspects of language (Paradis, 1995b). Thus, although most researchers currently generally agree that there are not separate loci for different languages in the brain, it has been suggested that the right hemisphere plays a greater role in the acquisition of L2 (Paradis, 1995b). Although not verified, it has been found that bilingual speakers rely to a greater extent on pragmatic aspects to interpret messages in their weaker language (Albert & Obler, 1978). Paradis (1998) explains this by stating that late bilinguals can compensate for gaps in their implicit linguistic knowledge by relying on controlled declarative memory. The latter is based on metalinguistic knowledge, as well as right hemisphere based pragmatic competence. Metalinguistic knowledge is acquired consciously and is stored explicitly. In contrast to this, implicit linguistic competence is acquired incidentally, stored implicitly, without conscious control and used automatically. These two types of memory can be neurofunctionally, although not neuroanatomically different according to Paradis (1995b) and might thus be differentially affected after brain damage. This then might be the reason for findings indicating different localization of different languages in the brain.

2.5.7 Conclusion regarding bilingual speech and language processing

The above discussion indicates that different processing strategies might be employed for different languages during comprehension activities, even though the neural substrate underlying more than one language in the brain appears to be similar across languages. Production in L1 and L2 also appears to be subserved by the same neural substrates, although activation of the left putamen during repetition tasks in L2 indicates that speech production in L2 might impose additional articulatory demands. It thus appears as if speech production in L2 might be motorically more difficult as was proposed by Klein *et al.* (1995). Speech production in L2 might consequently heighten the processing demands and result in greater difficulty regarding the accomplishment of perceptually accurate speech.

One way in which to obtain information regarding the processes which occur in the brain during speech production is to study the manifestation of these processes in the spatial and temporal parameters of the acoustic speech signal. Since speech is a motor skill, it is necessary to discuss some concepts related to the study of speech as a motor skill. However, it is also imperative to bear in mind that speech is the result of both linguistic and motor processing which occur in the brain. The impact of increased processing demands might be visible in the temporal and spatial parameters of speech production as measured in the acoustic speech signal and consequently these parameters of speech production are often studied in an attempt to learn more about the higher level speech and language processing which occurs in the brain.

2.6 SPEECH PRODUCTION AS THE MANIFESTATION OF LANGUAGE

Hodge (1993:128) defines speech as "the acoustic representation of language, that results from highly coordinated movement sequences produced by the actions of the speech mechanism". Mlcoch & Noll (1980:201) define speech production as "a process in which internal thought is progressively externalized into a series of muscular contractions resulting in a particular acoustic output". No matter how the speech production process is defined, it is one of the most complex human behaviors to analyze (Borden & Harris, 1984). In this regard, Gracco (1990:3) states, "Speaking is a complex action involving a number of levels of organization and representative processes" Because these higher level speech and language processing functions are largely inaccessible, researchers must infer the nature of these processes by examining the behavioral manifestations of neural processing (Borden & Harris, 1984). Since temporal and spatial parameters of speech production can be measured on an articulatory level and consequently can be used to make inferences about the language processes which precede the acoustic realization of language, it is necessary to take a closer look at speech as a motor skill.

2.6.1 Speech as a motor skill

Speech is a motor skill with a perceptual goal namely, generating sound patterns to convey a message. Air from the lungs is used to produce different speech sounds. These speech sounds are then further modified depending on the phonetic context in which they are produced (Borden & Harris, 1984). The breath stream is regulated as it passes from the lungs to the atmosphere. To accomplish the perceptual goal, the movements of the respiratory system, larynx and articulators (supralaryngeal) need to be coordinated to reach the desired acoustic output (Smith, 1992a). The movements of these structures are the result of muscle contractions due to nerve impulses, all of which are controlled in the nervous system (Borden & Harris, 1984).

Hirose (1986:61) states "the speech production process can be viewed as a fine motor skill which must be regulated in terms of sequence and duration with great accuracy, speed and rhythmicity". For the accomplishment of coordinated movement, Lashley (as cited in Moll, Zimmermann & Smith, 1977) postulates that there are two major aspects that need to be integrated, namely the temporal and spatial parameters of speech production. Movement is thus the result of signals which are ordered in time and space. An understanding of the spatial aspects of a system is necessary to determine the operation of that system. The "spatial relationships of structures...are important in the development of hypotheses about how movements occur" (Moll *et al.*, 1977:111). However, Moll *et al.* (1977) emphasize the importance of knowledge regarding the temporal characteristics of speech for understanding coordinated motor output.

The spatial and temporal parameters of movement for each articulator and consequently each muscle necessary for movement of the specific structure need to be specified and coordinated with every other muscle/articulator involved in the specific movement. It is thus evident that timing and coordination of speech movements constitute an integral part of speech motor control (Keller, 1990). Abbs (1988) also emphasizes the fact that coordination, including both intra- and interarticulatory coordination or timing, is the essence of speech motor control (Abbs, 1988).

The importance of control of the temporal and spatial parameters of speech production becomes evident when one considers the large number of degrees of freedom of the speech production system and (Kent *et al.*, 1996) the phenomenon of motor equivalence. The presence of these two phenomena thus needs to be considered when studying speech as a motor skill.

2.6.1.1 Degrees of freedom

Considering the number of muscles and movements that need to be coordinated during speech production, the question arises as to how the nervous system controls the many muscles and joints involved in producing a given pattern to generate a specific acoustic signal (Smith, 1992a). This is referred to as the degrees of freedom problem. The degrees of freedom "of any system reflect the number of independent elements or components of the system" and "arises when a complex system needs to be organized to produce a specific result" (Magill, 2001:44).

The degrees of freedom problem is also inherent to speech production. Multiple movements of various articulators need to be temporally and spatially synchronized to accomplish production of a specific sound/(s) with a characteristic acoustic output. According to Gracco (1990), there are more than 70 different muscular degrees of freedom in the production of speech. Kent *et al.* (1996:8) state "The tongue, lips, jaw, velum, larynx and respiratory systems all possess several possible types of movement with respect to range, direction, speed and temporal combinations with one another". This is further complicated by the fact that they can combine their movements in various ways. Kent *et al.* (1996) state that it is important that a theory or model of speech motor control account for the way in which the nervous system solves this control problem. The fact that the movements of so many muscles and structures need to be coordinated during speech production underscores the importance of control of the temporal and spatial parameters involved in these movements.

2.6.1.2 Motor equivalence

Despite the fact that temporal and spatial parameters of movement for each muscle and articulator need to be specified and coordinated, the desired acoustic output can be achieved by varying movements of the muscles and articulators involved. This is known as motor equivalence. A characteristic of general motor skills is the fact that a variety of component movements can produce the same action and therefore obtain the same goal (Abbs, 1981; Folkins, 1981; Hughes & Abbs, 1976; Kelso & Tuller, 1983; Netsell, 1984; Sharkey & Folkins, 1985). Similarly, the same phoneme can be produced with widely varying articulatory movements (Smith, 1992a) depending on the inherent characteristics of the speaker, the speaking rate, amount of stress employed and the nature of the surrounding speech sounds. Thus depending on the phonetic and/or other contexts (for example, speaking rate) in which a phoneme is produced the movements of the articulators will vary (Van der Merwe, 1997), although the specific phoneme will maintain certain acoustic characteristics to be perceived as the intended phoneme.

Motor equivalence is characteristic of all motor skills and point towards the fact that coordination of motor skills is "flexibly accomplished by the nervous system, perhaps to ease what might be impossible, namely, achieving a given functionally significant goal in exactly the same way each time" (Abbs, 1988:160). From this statement it is evident that even in normal speakers, variability regarding the movement parameters is present from one production to the next, even when the context is held constant. Critical boundaries for motor equivalence exist, however, and deviation outside these boundaries will result in sound distortion or even perceived substitution (Van der Merwe, 1986, 1997).

In order to remain within the boundaries of motor equivalence considerable timing adjustments need to occur in the presence of multiple degrees of muscle and movement freedom (Gracco, 1988:4628). In order to shed light on temporal control, the temporal parameters of speech production have consequently been a prominent subject of investigation. One reason for the study of temporal parameters of speech production is because of their perceptual prominence (Kent & Rosenbek, 1983). These temporal parameters are often investigated by means of acoustic analysis, since this allows for objective measurement of temporal aspects of speech production. The study of the temporal parameters of speech production will be discussed in more detail in the following section.

2.6.2 Temporal parameters of speech production

The study of temporal aspects of speech can aid in gaining insight into the motor control strategies used by the central nervous system to accomplish accurate speech production (Keller, 1990). Furthermore, spatiotemporal control is essential for achievement of coordinated movement (Kent & Adams, 1989). Abbs and Connor (1989) pose that a primary role of the motorsensory system for speech and most other motor tasks, is the generation of precisely timed and measured multiple muscle contractions. Information regarding temporal control can thus be helpful when compiling models of normal and pathological speech motor control or in testing hypotheses proposed by such models.

Because time is an integral part of speech motor control, the effect of various factors on timing has been studied in an attempt to gain insight into the motor control of speech by the brain. As has been mentioned, speech production is context-sensitive with the implication that various contexts might influence timing in various ways. Speech production exhibits many temporal parameters, which can be perceived or measured acoustically. These temporal parameters are presumably influenced by the context in which they are produced.

Two temporal parameters of speech production which are often studied due to the fact that they have potential to inform about the nature of motor speech processes includes durational aspects of a segment/segments and the timing amongst movements of different articulators, known as IAS.

2.6.2.1 Segmental duration

Segmental duration is a feature of language that represents the length of a given segment of speech, for example, a phoneme. Segmental duration is typically measured acoustically and is believed to reflect principles of speech timing (Forrest & Weismer, 1997). Importantly, different speech sounds have different intrinsic acoustic durations. Diphthongs and "long" vowels, for instance, are longer than the "short" and unstressed vowels. Similarly, continuous consonants, such as, fricatives are longer than stop consonants (Borden & Harris, 1984; Kent *et al.*, 1996).

Segmental duration is furthermore, dependent on the context in which a phoneme is found (Borden & Harris, 1984; Kent *et al.*, 1996). Vowels, for example, are longer before voiced consonants, than before voiceless consonants, as can be illustrated by comparing the words "leaf" and "leave" (Borden & Harris, 1984; Kluender *et al.*, 1988). Other factors that influence segment durations include speaking rate, the phonetic context, position of the word in an utterance (for example, at the beginning or at the end of the utterance), the type of speech material (for example, isolated words versus connected speech and casual versus formal speech styles) and idiosyncratic speaker characteristics (for example dialect, age, gender and vocal tract length) (Forrest & Weismer, 1997).

It is thus evident that each speech sound has an ideal range of durations which is necessary for accurate perceptual realization thereof. This durational range is dependant on the inherent *characteristics of the phoneme* itself and the phonetic *context* in which it is to be produced. The duration of phonemes needs to be specified during the motor planning of speech (Van der Merwe, 1997; Walsh, 1984) and needs to be within the boundaries or limits of equivalence in order to be perceptually accurate (Van der Merwe, 1997). The ideal duration can thus vary to a certain extent, provided that it stays within the boundaries of equivalence, since too great a change in duration can sometimes result in a change of the meaning of a word in a language, such as, Afrikaans for example. To accomplish this ideal duration of a phoneme or syllable on the acoustic level within the boundaries of equivalence, timing is thus of considerable importance.

2.6.2.2 Interarticulatory synchronization

From the fact that each speech segment has an ideal durational range, it becomes evident that considerable timing control needs to be exerted for the critical acoustic configuration to be reached and consequently for achievement of on-target speech. During the motor planning of speech, the spatial and temporal parameters of movements need to be specified (Van der Merwe, 1997). According to Van der Merwe (1997), these temporal and spatial specifications of movements constitute the motor goals. She emphasizes the fact that motor planning of speech is articulator-specific and that IAS needs to be planned for the production of a particular phoneme. The spatiotemporal features of the core motor plan are thus invariant. Invariant spatiotemporal features of the motor plan are similar to the generalized motor program proposed by Schmidt (1975, 1988).

During the motor planning of speech, the core motor plan is adapted according to the phonetic context and consequently motor goals regarding articulatory synchronization also need to be adjusted depending on the phonetic context. Adaptation of the spatiotemporal parameters of movement is presumably similar to Schmidt's (1975, 1988) proposal of parameters (absolute timing and forces of actions) which need to be scaled according to the context in which a movement is produced. Movements of the various articulators for speech production are thus precisely timed (Kent & Adams, 1989). Apart from the fact that the movement parameters for each articulator need to be temporally controlled (intra-articulatory synchronization), the timing between the movements of the various articulators needs to be accurately controlled. This is referred to as *interarticulatory timing or synchronization*.

Interarticulatory synchronization of various articulators has been studied, for example, synchronization of upper and lower lip movements (Gracco & Abbs, 1986; Tseng *et al.*, 1990) and lingual-laryngeal phasing (Ziegler & von Cramon, 1986). One form of IAS which is often measured in normal and pathologic speakers is VOT. Accurate voicing requires precise timing of a supralaryngeal event (oral articulation) and a laryngeal event (vocal fold vibration for voicing onset), and consequently VOT is viewed as a form of IAS (Tyler and Watterson, 1991; Van der Merwe, 1986).

- **Interarticulatory synchronization of supralaryngeal and laryngeal speech movements: Voice onset time**

Tyler and Watterson (1991:56) state "VOT is a temporal characteristic of stop consonants that reflects the complex timing of glottal articulation relative to supraglottal articulation…VOT is a reliable, relatively easy measurement to make and is thought to reflect a complex aspect of supralyngeal-laryngeal coordination". VOT is defined by Borden and Harris (1984:289) as "the interval of time between the release of a stop-plosive, voiced or unvoiced, and the onset of voicing of the following vowel". The temporal relationship between these two events is usually determined in milliseconds (ms) and specific temporal boundaries of VOT exist for voiced and voiceless sounds respectively, to be perceived as either voiced or voiceless. For voiced sounds, VOT can range from -180 ms, implying that voice onset occurred before the release of air (voicing lead) to 25 ms after this release (voicing lag). In voiceless sounds, voicing needs to be initiated between 40 ms and 120 ms after the release of air (+40ms to +120 ms) (Cooper, 1977; Zlatin, 1974).

It is thus evident that accurate timing plays a crucial role in speech production, since deviant VOT, for example, can also change the linguistic meaning of a word (for example, "pig" and "big"). Timing of articulatory movements relative to each other thus needs to be carefully specified in the motor plan of a specific utterance in order to obtain the desired acoustic output (Van der Merwe, 1997). Itoh and Sasanuma (1984) and Löfquist and Yoshioka (1981) emphasize this by saying that VOT is a temporal aspect of speech production that is less variable than other temporal parameters and needs to be carefully controlled. Furthermore, the fact IAS also needs to be adapted to the context of production underscores the importance of accurate timing of this parameter (Van der Merwe, 1997).

2.7 CONCLUSION

From the above discussion, it is evident that speech is a motor skill enabling measurement of specific speech production parameters. These spatial and temporal parameters need to be specified during the motor planning and programming of speech production as proposed by Van der Merwe (1997) in the four-level framework of speech sensorimotor control. Motor planning, programming and execution need to occur within the boundaries of motor equivalence to prevent distortion of the acoustic speech signal. It is important to bear in mind, however, that the speech production process cannot be considered without reference to the linguistic or language processes which precede the acoustic realization of the intended speech target.

Certain contextual factors might negatively influence both motor and linguistic processing and can impact on the temporal and spatial parameters of speech production. Speech production in certain contexts might thus prove to be more complex or difficult than in others due to increased processing demands. Difficulty in certain contexts might be more readily experienced by persons with neurogenic speech and/or language disorders since they already exhibit difficulty regarding one or more of the levels in the speech production process. The resources in these persons might be more easily exceeded due to the fact that more than normal resources already need to be allocated to the deficient processes.

The study of the influence of speech production in L1 versus L2 as a context for speech has not been undertaken, although the influence of several other contexts has been studied. An investigation of the influence of speech production in L1 versus L2 is important for inferring about the processing demands imposed by speech production in L2 in bilingual speakers. The effect of the increased processing demands is important when studying the speech of persons with neurogenic speech and/or language disorders at distinct levels of the speech production process to gain information about the nature of these disorders and their reaction to increased processing demands. Models and theories of speech production can aid in explanation of normal and pathological speech and language processing in bilingual speakers with neurogenic speech and/or language disorders.

2.8 SUMMARY OF CHAPTER TWO

In this chapter prominent models and theories of speech production were reviewed in an attempt to delineate the processes and stages involved in the speech production process. These models or theories included the dynamic systems model (Kelso & Tuller, 1981), motor schema theory (Schmidt, 1975, 1982, 1988), the information-processing perspective on speech production proposed by Levelt (1989) and the four-level framework of speech sensorimotor control proposed by Van der Merwe (1997). From this discussion, it was evident that contextual factors exert an influence on speech and language processing and consequently on motor control. Contextual factors inherent to the individual and those related to the task, influencing information processing were reviewed. After this, specific contexts which might influence speech and language processing were reviewed. Speech production in L1 versus L2 in bilingual speakers was proposed as a context for speech production, since speech production in L2 might increase processing demands.

Concepts relevant to bilingualism were discussed to gain insight into bilingual speech and language processing. The importance of viewing speech as the manifestation of language processing by the brain was emphasized and manifestation of these processes in the temporal and spatial parameters of speech production was discussed, since speech is in essence also a motor skill. Furthermore, the fact that timing constitutes an integral part of speech motor control led to a review of specific temporal parameters which can be measured acoustically.

From this discussion, the relevance of studying the influence of speech production in L1 versus L2 as a context for speech production on specific temporal parameters of speech in persons with neurogenic speech and language disorders becomes evident. The study of the aforementioned could render important information regarding normal and pathological speech motor control in the presence of increased processing demands.

CHAPTER THREE
SPEECH AND LANGUAGE PROCESSING IN APRAXIA OF SPEECH: DEFINITION, DIFFERENTIATION AND THE INFLUENCE OF CONTEXTUAL FACTORS

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3.1 INTRODUCTION

The framework of speech sensorimotor control, proposed by Van der Merwe (1997), depicts speech production as being context-sensitive with the implication that contextual factors influence the processes involved in speech sensorimotor control. Speech production as a context-sensitive phenomenon consequently requires that adjustments be made regarding the control strategies employed by the brain depending on the context in which speech is produced, in other words, depending on the processing demands imposed by the context (Van der Merwe, 1997). Although a normal speaker can easily adapt to different contextual demands, persons exhibiting difficulty regarding any of the stages involved in speech and language processing, for example, persons with AOS who have difficulty regarding the motor planning of speech, might not be as flexible regarding adaptation to increased contextual demands. Consequently perceptually accurate speech might not be achieved by these speakers when the processing demands are increased. Van der Merwe (1997) emphasizes the importance of determination of the influence of all the identified contextual factors on the different phases of the speech production process, since this will impact on both treatment and research results. Through the study of the influence of contextual factors on speech production in AOS, more can be learnt about the underlying nature of this disorder and pathological speech motor control under circumstances of increased processing demand.

In this chapter, AOS will be defined. Furthermore, the deficit in persons exhibiting a preponderance of literal or PPs will be defined to differentiate between PP and AOS since, unlike those with AOS, persons with PP are believed to exhibit a breakdown at a distinct level of the speech production process (McNeil *et al.*, 1997; Van der Merwe, 1997). In the study of AOS, the inclusion of persons with PP has the potential to assist with differential diagnosis and reveal more about the nature of AOS. Models, theories and frameworks proposed for explanation of AOS will be reviewed in an attempt to explain the underlying deficit in AOS. Where applicable, the emphasis which these models place on the influence of contextual factors on speech production will be highlighted. Aspects of speech timing which are studied in an attempt to learn more about the underlying nature and characteristics of AOS and PP will be discussed, whereafter the effect of different contextual factors on speech production in persons with AOS will be reviewed. From this discussion, the importance of studying the influence of contextual factors, specifically L1 versus L2 production and speech rate alterations, on the temporal parameters of speech production in AOS and PP, will be motivated.

3.2 DEFINING APRAXIA OF SPEECH

Clarification of the nature of neurogenic speech disorders is vitally important, not only for diagnosis and treatment of these disorders, but also for providing significant information concerning normal and pathologic speech motor control (Itoh & Sasanuma, 1984). The first step towards clarifying the nature of a specific speech disorder entails defining that disorder. The compiled definition then forms the foundation from where experimental questions are formulated and methods for answering these questions are derived (Rosenbek & McNeil, 1991). Underscoring this issue, Rosenbek and McNeil (1991:289) stated that names and definitions "if carelessly, idiosyncratically, or prematurely chosen...obscure boundaries, disturb or repudiate concepts, and frustrate experimentation".

AOS is a neurogenic speech disorder which has been subject to continuous controversy regarding its underlying nature since the first mention of "aphemia", characterized by selective impairment of articulatory abilities, by Paul Broca in 1861 (Lebrun, 1989). Since then, some researchers have suggested that AOS is a language disorder and have consequently treated it as a type of aphasia (Goodglass, Quadfasel & Timberlake, 1964; Martin, 1974), while others have postulated that it is a type of dysarthria and have labelled it "phonetic disintegration" (Alajouanine, Ombredane & Durand as cited in Mlcoch & Noll, 1980), "apraxic dysarthria" (Natham as cited in Mlcoch & Noll, 1980) and "cortical dysarthria" (Bay, 1962). However, other researchers proposed that AOS is a motor speech disorder, which can be distinguished from both aphasia and dysarthria (Johns & Darley, 1970). Currently most researchers agree that the nature of AOS is phonetic-motoric (Ballard *et al.*, 2000). However, despite the frequency of AOS, it is still poorly understood and relatively under-researched (Varley & Whiteside, 2001). In the following section the most prominent definitions that have been offered for AOS will be provided and discussed as an introduction, before a perusal of models and theories that attempt to explain the underlying nature and observed characteristics in AOS.

3.2.1 Darley's definition

Darley is recognized as the first researcher who applied the concept of apraxia to speech production (McNeil *et al.*, 1997). Darley in 1969 (as cited in Deal and Darley, 1972:639) defined AOS as follows:

> …an articulatory disorder resulting from impairment, as a result of brain damage, of the capacity to program the positioning of speech musculature and the sequencing of muscle movements for the volitional production of phonemes. The speech musculature does not show significant weakness, slowness, or incoordination when used for reflex and automatic acts. Prosodic alterations may be associated with the articulatory problem, perhaps in compensation for it.

The essence of Darley's definition implies that AOS is a disorder regarding the ability to form vocal tract configurations and to accomplish movement from one vocal tract configuration to the following during the voluntary production of speech (Rosenbek *et al.*, 1984). This inability exists despite the fact that no other motor deficits are evident during the use of these same muscles for other involuntary non-speech movements. In this regard it needs to be mentioned, however, that in recent years, researchers have reported that persons with AOS exhibit motor planning disturbances regarding non-speech movements as well (Clark & Robin, 1998; Hageman, Robin, Moon & Folkins, 1994; McNeil, Weismer, Adams & Mulligan 1990b, Square-Storer, Roy & Hogg, 1990).

Darley's definition is sufficient for diagnostic purposes if it can be specified which behaviors are indicative of a deficit in the ability to form vocal tract configurations and which suggest an inability to accomplish movement from one vocal tract configuration to the next (Rosenbek *et al.*, 1984). Possibly the articulatory search behavior exhibited by persons with AOS during attempted speech production is indicative of these persons' inability to form vocal tract configurations, which in turn could be due to their inability to specify and/or adapt the temporal and spatial motor goals necessary for speech production. In order to form accurate vocal tract configurations the movements of the articulators need to be temporally and spatially controlled. Studying temporal and/or spatial aspects of speech production in AOS, can thus shed light on the motor planning ability of a person with AOS and consequently on the underlying nature of the disorder.

In order to move from one vocal tract position to the next, synchronization of articulatory movements in time and space is needed. Deficits regarding synchronization of articulatory movements could thus possibly result in an inability to accomplish movement from one vocal tract configuration to the next, since temporal overlapping of articulatory movements is needed to accomplish this (Smith, 1992a). It is thus evident that the deficits described by Darley's definition, implicate disruption of temporal and spatial control of movements in persons with AOS. Temporal aspects of speech production can be perceived acoustically and consequently the study of temporal aspects of speech production is potentially important, since it can shed light on the nature of the motor disturbance in AOS. The study of the nature of timing deficits in various neurogenic speech disorders could also assist in differential diagnosis.

3.2.2 Wertz, Rosenbek and LaPointe's definition

Wertz *et al.* (1984:4) slightly modified the definition provided by Darley and defined AOS as follows:

> …a neurogenic phonologic disorder resulting from sensorimotor impairment of the capacity to select, program and/or execute in coordinated and normally timed sequences, the positioning of the speech musculature for the volitional production of speech sounds. The loss or impairment of phonologic rules of the native language is not adequate to explain the observed pattern of deviant speech, nor is the disturbance attributable to weakened or misdirected actions of specific muscle groups. Prosodic alteration, that is changes in stress, intonation, and/or rhythm, may be associated with the articulatory disruption either as a primary part of the condition or in compensation for it.

The definition proposed by Wertz *et al.* (1984) is very similar to the one proposed by Darley (as cited in Deal & Darley, 1972), in that it emphasizes the inability of persons with AOS to position the articulators correctly and timely. This definition also implies disrupted articulatory timing as being a fundamental characteristic of AOS, together with an inability to reach spatial targets. The use of the words "coordinated" and "normally timed sequences" implies the presence of disrupted timing relations among the movements of the articulators, since accurate timing is essential for accomplishment of coordinated movement and normally timed sequences (Keller, 1990). Accurate specification of temporal and spatial parameters, in turn, leads to accomplishment of perceptually accurate speech.

The fact that disrupted timing of articulatory movements is a fundamental characteristic of AOS implies a possible deficit at the level of the motor planning and/or programming of speech, because specification of the temporal parameters for movement of the articulators (planning) and muscles (programming) occurs during these two stages of the speech production process, according to the framework of speech sensorimotor control proposed by Van der Merwe (1997). It is thus not certain why Wertz *et al.* (1984) state that AOS is a *phonologic* disorder, since this implies a deficit at the level of linguistic-symbolic planning (Van der Merwe, 1997). Wertz *et al.* (1984) probably referred to the resulting speech errors or phonological deficits which perceptual judgement of speech errors had revealed. During the time when Wertz *et al.* (1984) compiled their definition, it was generally believed that persons with AOS exhibit predominantly substitutions in their speech. However, phonological errors have since been shown not be the predominant speech characteristic in AOS (McNeil *et al.*, 1997). Furthermore, the term “phonological” in the definition by Wertz *et al.* (1984) was most probably used in the generic sense, with the implication that it included phonetic and phonological aspects of speech production, as well as overt and covert speech (Shriberg & Kwiatkowski as cited in Van der Merwe, 1986). The use of the term phonological in Wertz *et al.*’s definition might cause unnecessary confusion regarding the nature of the disorder in AOS and it might have been more appropriate to say that AOS is a *motor speech* or *phonetic disorder.* There are researchers, however, who still propose AOS to be a phonological disorder, for example, Dogil and Mayer (1998) who give a linguistic account of AOS.

3.2.3 McNeil et al.’s (1997) definition of apraxia of speech

McNeil *et al.* (1997:329) specify the core features of AOS and characterize the mechanisms involved in this disorder by defining it as follows:

> ...a phonetic-motoric disorder of speech production caused by inefficiencies in the translation of a well-formed and filled phonologic frame to previously learned kinematic parameters assembled for carrying out the intended movement, resulting in intra- and inter-articulator temporal and spatial segmental and prosodic distortions. It is characterized by distortions of segments and intersegment transitionalization resulting in extended durations of consonants, vowels, and time between sounds, syllables, and words. These distortions are often perceived as sound substitutions and as the mis-assignment of stress and other phrasal and sentence-level prosodic abnormalities. Errors are relatively consistent in location within the utterance and invariable in type. It is not attributable to deficits of muscle tone or reflexes, nor to deficits in the processing of auditory, tactile, kinesthetic, proprioceptive, or language information. In its extremely infrequently occurring "pure" form, it is not accompanied by the above listed deficits of motor physiology, perception, or language.

From this definition, it is evident that these researchers support the notion that the underlying nature of AOS is phonetic-motoric, whilst the phonological level of the speech production process is believed to be intact. McNeil *et al.* (1997) also make mention of the aberrant temporal and spatial parameters of speech production resulting in distortion and prolonged durations. Prolonged durations are one component of temporal disruption and appear to be an integral part of the symptomatology in AOS.

3.2.4. Conclusion regarding definitions of apraxia of speech

A common theme which emerges from the above three definitions, is the difficulty persons with AOS of speech experience with specification and control of the spatial and temporal parameters of speech production. As discussed in chapter two, temporal parameters of speech are imperative for achievement of perceptually accurate speech. Furthermore, temporal discoordination has been identified as a core characteristic of AOS (Strand & McNeil, 1996). Temporal features of apraxic speech is consequently often investigated and contrasted with linguistic level deficits.

3.3 THE NATURE OF PHONEMIC OR LITERAL PARAPHASIA: DIFFERENTIATION BETWEEN AOS AND PP

Although AOS is now generally recognized as a phonetic-motoric disorder "it frequently co-occurs with aphasia and differentiating between the respective phonetic-motoric and linguistic impairments has proven difficult" (Ballard *et al.*, 2000:969). The linguistic impairments refer to the phonological errors which have been found to overlap between persons with AOS and those with CA exhibiting a preponderance of PPs (Blumstein, 1981; Kent and McNeil, 1987). The underlying nature of the disorders in persons with AOS and persons with PP is, however, proposed to be at two distinct levels of the speech production process (McNeil *et al.*, 1997; Van der Merwe, 1997). In the past, both these groups of speakers were proposed to exhibit sound substitutions and errors of sequencing (Wertz *et al.*, 1984). This led to persons with PP sometimes being mistakenly diagnosed as exhibiting AOS and vice versa. Currently it is known, however, that the perceived sound substitutions in AOS are in fact, in many instances, due to distortions caused by prolonged and/or devoiced phonemes (McNeil *et al.*, 1997).

McNeil *et al.* (1997:326) state "the goal of contrasting assumed mechanisms, signs and symptoms between AOS and PP is also to eventually work out the significant characteristics of the groups and find constant differences between them". For this reason, it is necessary to take a closer look at the speech errors of persons with a preponderance of PPs. Persons with aphasia exhibiting a preponderance of PPs will be referred to as speakers with PP. Since PPs often occur in persons with CA, speakers with this type of aphasia are generally included in studies which attempt to investigate the nature of PP.

The speech of persons with PP is characterized by the presence of sound or syllable sequencing errors, which can include perseverative, anticipatory or metathetic errors, as well as sound substitutions. Furthermore, more errors are generally made on consonants than on vowels and these persons are less consistent than subjects with AOS regarding the location of errors on repeated trials of the same utterance. Persons with PP also exhibit greater variability in the type of errors on repeated trials of the same utterance than persons with AOS. They do not exhibit errors of stress or sound distortions and, like AOS, do not have weakness or abnormal reflexes of the speech musculature when used for non-speech activities (Collins, 1989; Goodglass & Kaplan, 1983; McNeil, 1993; McNeil, Odell, Miller & Hunter, 1995).

Explanations for the underlying deficit in persons with PP include a deficit regarding phonological encoding (Friedrich, Glenn & Marin, 1984), phonemic encoding (Brown, 1975), a stage in motor encoding (Yamadori and Ikumura, 1975), pre-articulatory programming (Kohn, 1984), an impaired ability to generate and maintain abstract phonological codes (Friedrich *et al.*, 1984) and a deficit regarding phonological selection and sequencing as a component of linguistic-symbolic planning (Van der Merwe, 1997). The speech errors of persons exhibiting a preponderance of PPs are thus generally proposed to represent a linguistic or phonological impairment, whereas the speech errors of persons with AOS presumably represent a phonetic-motoric impairment (McNeil *et al.*, 1995). Since the level of disruption in AOS and PP is presumably at two distinct levels of the speech production process, the study of both these disorders in conjunction renders the possibility to contrast the mechanisms involved in error production and to further clarify the nature of AOS.

Studies attempting to differentiate between the speech errors of subjects with AOS and CA exhibiting a preponderance of PPs, have employed examination of factors such as, consistency of error location, variability of error type and successive approximation towards speech targets (McNeil *et al.*, 1995), temporal characteristics of speech production (IAS and durational measures) and the degree of variability regarding temporal measures (Kent and McNeil, 1987; McNeil *et al.*, 1989; Robin *et al.*, 1989; Seddoh *et al.*, 1996a). Although the results of these studies are not all in agreement, the general conclusion has been that AOS is a motor programming disorder as defined in traditional three-level models of speech production (Darley, Aronson & Brown, 1975) or a motor planning disorder, as defined in the four-level framework of speech sensorimotor control by Van der Merwe (1997). AOS is thus viewed as distinct from PP which is ascribed to a deficit regarding phonological planning which is a component of the level of linguistic-symbolic planning as defined in Van der Merwe's (1997) four-level framework.

A complicating factor when attempting differentiation between AOS and PP, is the fact that a motor component has occasionally been proposed to contribute to the pathogenesis in persons with PP, although the nature thereof might be qualitatively different than in AOS (Kent & McNeil, 1987). McNeil, Hashi and Tseng (1991b:1) state that "the traditionally assumed unidimensional phonological-level mechanisms for the speech errors of the conduction aphasic have recently been contested". Features which traditionally have been assigned to AOS, for example, difficulty with initiation of speech and variability of errors, are also shared by persons with PP (McNeil *et al.*, 1997). So, for instance, studies regarding force and position control (McNeil *et al.*, 1990b), absolute and relative timing of speech movements (Kent & McNeil, 1987; McNeil *et al.*, 1990a; Seddoh *et al.*, 1996b), kinematic parameters of movement (McNeil & Adams, 1991), motor control (Clark & Robin, 1998) and token-to-token variability (Kent & McNeil, 1987) have indicated that there might be a motor deficit contributing to the speech deficits in persons with predominant PPs.

The reason for concluding that a motor component is possibly concomitant to the linguistic disorder, stems from the belief that temporal abnormalities "are best interpreted as meaning that motoric planning or execution or both are disrupted" (Kent & McNeil, 1987:213). McNeil *et al.* (1991b:1) state, however, that "an adequate characterization of this phonetic-level deficit has yet to be offered" when referring to the presumed motor deficit in PP.

Regarding the problematic differentiation of the underlying cause of errors in AOS and PP, Blumstein (1981:135) stated:

> In reality, it would not be surprising to find similar patterns of phonological disintegration whether the errors are articulatory or linguistically based, primarily because theoretical linguistic assumptions are derived from the intrinsic nature or organization. Thus, what is articulatorily simple is phonologically or linguistically simple, and what is articulatorily complex is also linguistically complex.

Errors which are measured acoustically could thus presumably be the result of breakdown at either the linguistic or motor planning levels of speech production. In this regard, Rosenbek (2001) proposed that the speech production system might have a limited number of ways to compensate for deficits at any level, with the implication that linguistic-level deficits might be reflected in the temporal parameters of speech production. Rosenbek (2001:269) stated "cognitive, linguistic, and motoric deficits will have a common appearance when motor performance is the outcome measure". In other words, if temporal aspects are measured, the measured parameters might be indicative of a deficit at either the linguistic or motoric level.

Dogil and Mayer (1998) have similarly proposed that temporal deficits evidenced in the acoustic signal might be indicative of higher level phonological impairment and not necessarily of a motor impairment. Kent and McNeil (1987) also speculated about whether phonemic and phonetic-motoric disruptions represent two separate kinds of disruption or rather one common underlying disorder. These researchers proposed that "uncertainties and inefficiencies at a relatively abstract level of speech are reflected in the motor processes that they drive" (Kent & McNeil, 1987:214). In other words, deficits regarding either phonological or phonetic processes will be manifested as aberrant temporal patterns. As an alternative these researchers propose that the phonological and phonetic-motoric levels of organization might be inseparable and that a division between these two levels is invalid.

Regarding performance on non-speech motor control tasks, persons with CA have not consistently been found to exhibit deficits, unlike persons with AOS (Hageman *et al.*, 1994; McNeil *et al.*, 1990b). The aforementioned finding could be indicative of the fact that the nature of the presumed motor deficit in PP is qualitatively different compared to AOS, if indeed a motor deficit is part of the pathogenesis of PP. Clark and Robin (1998), in a study of non-speech movements in AOS and CA, found that one of their subjects with CA exhibited reduced amplitude parameterization accuracy indicating that motor control deficits might be concomitant to the linguistic disorder in some patients with CA. However, these researchers concluded that a motor control deficit does not appear to be a core part of the underlying disorder in CA.

Since persons with either AOS or PP share certain speech characteristics (Blumstein, 1981; McNeil & Kent, 1990; Odell, McNeil, Rosenbek & Hunter, 1991a, b) with different proposed levels of breakdown, it seems sensible to include both these groups of speakers when examining aspects of speech motor control. Studying the effect of different contextual factors on speech production in these two groups of speakers might further elucidate the nature of these disorders. The results obtained from both these groups of speakers will assist in verifying or refuting traditional views of these two disorders and aid in the shaping of models which have been compiled in an attempt to explain normal and pathological speech motor control. These proposed models, theories and frameworks will be discussed in the following section.

3.4 THEORIES REGARDING THE UNDERLYING NATURE OF APRAXIA OF SPEECH

The proposed definitions of AOS attempt to highlight the essence of the disorder and its primary characteristics. In an attempt to elucidate the underlying nature of the disorder, responsible for the perceived characteristics, several theories, models and frameworks for characterization of AOS have been compiled. In this regard, Miller (2002:225) stated "viewing AOS in the context of overall models of motor speech production may lay out a more fruitful and systematic line of enquiry in the quest for understanding how speech is controlled, how it breaks down, and what the underlying nature of this disorder might be". Theories for explanation of the underlying deficit in AOS will be reviewed in the following section. Where applicable, reference will be made to the contribution these theories make in explaining the nature of PP and the role of contextual factors in speech production.

Despite the now general consensus that AOS is a phonetic-motoric disorder, different theories attempting to provide explanations for the source of errors and the underlying nature of the disorder have been proposed (for example, Dogil & Mayer, 1998; Kelso and Tuller, 1981; Mlcoch and Noll, 1980; Rogers and Storkel, 1999; Van der Merwe, 1997; Whiteside and Varley, 1998). According to Ballard *et al.* (2000:970) "the prevailing theoretical approach to AOS claims that the processes that build the phonological representation of a message are intact but the phonetic-motoric level of production is disrupted". Each of the proposed theories for the explanation of the underlying nature of specifically AOS will now be reviewed in more detail.

3.4.1 Van der Merwe's four-level framework for the sensorimotor control of speech

The framework proposed by Van der Merwe (1997) was discussed in depth in chapter two. The fact that Van der Merwe (1997) differentiates between four different phases or levels in the speech production process implies that distinct disorders can arise due to deficits at any one of these four levels. According to Van der Merwe (1997), reconsideration of neurogenic communication disorders within the context of this framework is needed, since traditional models only distinguished three levels in the speech production process (Van der Merwe, 1997). She postulates, however, that due to the fact that some neural structures are involved at several levels of control, a specific disorder might exhibit deviances at more than one level of the proposed framework. This might explain the presumed motor component which is occasionally reported in persons with PP.

Van der Merwe (1997) postulates that a deficit at the level of linguistic-symbolic planning will result in speech and language errors, which are characteristic of persons with aphasia. The latter includes aspects, such as, difficulty with semantic, lexical, morphological and phonological planning. Difficulties with phonological planning will result in problems with the selection and sequencing of phonemes which in turn could lead to substitutions and transpositions. Phonological paraphasias, often predominant in persons with CA, would be characteristic of a deficit at this level of the speech production process.

Within this framework, persons with AOS, who exhibit distortions as a core feature in their speech (Itoh & Sasanuma, 1984), display a deficit regarding the motor planning of speech. Van der Merwe (1997:17) proposes that a deficit regarding the motor planning of speech can involve aspects, such as, difficulty or inability to recall invariant core motor plans for specific phonemes, difficulty identifying different motor goals for specific phonemes, sequencing the movements for each phoneme or sequential movements for a phoneme sequence, adaptation of the spatial and temporal features of the core motor plan to the phonetic context, control of IAS, central monitoring of the efference copy, keeping movement and adaptation within the boundaries of motor equivalence and difficulty relaying the structure-specific motor plan subroutines to the motor programming system. Difficulty with any of these functions would presumably result in slow effortful speech with frequent distortions and even substitutions as is evident in persons with AOS (Van der Merwe, 1997).

As discussed in chapter two, Van der Merwe (1997) depicts speech production as being context-sensitive and emphasizes that fact that some contexts of speech production might require more complex control strategies than others. She mentions the fact that apraxic speech symptoms have been found to vary depending on the context of production and consequently underscores the need to study the influence of various contextual factors on the different levels of the speech production process.

3.4.2 Kelso and Tuller's (1981) coalitional theory of AOS (dynamic pattern theory)

Kelso and Tuller (1981) apply their coalition model to AOS and propose that AOS occurs due to "breakdown in the synergistic relationship between the individual and the environment" (Kelso and Tuller, 1981:233). This breakdown results in failure to meet behavioral goals which, in the case of speech production, entail accomplishment of spatiotemporal goals for intra- and interarticulatory synchronization. According to proponents of this theory the invariant features of movement are represented as attractor states (Ballard, Barlow & Robin, 2001). According to Ballard *et al.* (2000, 2001) attractor states are action patterns which emerge through a combination of factors, including the interaction of the parts of a system with each other and with the external environment, the inherent constraints on the system and the supply of energy which is available. During every performance in varying contexts, the pattern emerges as a new form, although some features remain stable and predictable. When a specific pattern reoccurs consistently, the stability of the emergent pattern increases and develops into an attractor state. The system is able to adapt and reorganize in response to new contexts and conditions (Ballard *et al.*, 2001).

When the motor system is impaired, for example in the case of AOS, the stability of the attractor states is disturbed and the patterns are consequently disrupted or lost. Ballard *et al.* (2001:54) state that this theory "might predict that AOS represents damage to the machinery (i.e. neural substrate) that constructs emergent patterns". The speech of persons with AOS thus represents instability, implying an impaired ability to reach former attractor states (Ballard *et al.*, 2001). Increased token-to-token variability regarding durational parameters, which has been reported for persons with AOS (Kent & McNeil, 1987; Seddoh *et al.*, 1996a, b; Strand & McNeil, 1996), might be indicative of the instability of their speech motor systems. Furthermore, distortions, indicative of temporal and spatial disruptions, might be reflective of the inability of the speech motor systems of persons with AOS to reach these former stable attractor states.

Evidence for the disrupted timing of the tight temporal coupling of the articulators in AOS comes from studies on IAS. From the results of studies investigating, for example, velar movements in an apraxic speaker (Itoh, Sasanuma & Ushijima, 1979b) and articulatory movements of the tongue, lips and velum (Itoh, Sasanuma, Hirose, Yoshioka & Ushijima, 1980), Kelso and Tuller (1981) deduced that the timing patterns between the various articulators might be disrupted in persons with AOS. Studies reporting deficits regarding VOT in AOS (Freeman *et al.*, 1978; Lisker & Abramson, 1964; Sands, Freeman & Harris, 1978) have also been taken as evidence for "disruption of the normally invariant timing relations among articulators" (Kelso & Tuller, 1981:241).

Although Kelso and Tuller (1981) emphasize the importance of the context for motor learning, they do not elaborate on contexts for speech production and postulate that constant relative timing should be preserved regardless of the context of an utterance. Kelso and Tuller's (1981) proposed style of motor organization thus predicts constant timing relations between the articulators despite changes in the external context inducing increased processing demands, for example, when having to increase speaking rate. They postulate that relative timing of neuromuscular events between muscles remains constant even though the absolute timing and spatial parameters of the movements varies. This model does not explain speech errors such as PPs and only emphasizes the control of movement itself. Dynamic systems theory does not explicitly say how language operates within the motor system, nor does it predict how different contextual factors would impact on motor performance, apart from the fact that relative timing would be preserved in such situations.

3.4.3 Theories incorporating concepts of attentional resource allocation or resource capacity limitations

Several theories incorporating the concepts of attention, resource allocation and resource capacity limitations have been proposed to explain the nature of the deficit in AOS (Clark and Robin, 1998; Kent and McNeil, 1987; Rogers and Storkel, 1999; Whiteside and Varley, 1998) and aphasia (Kent & McNeil, 1987; McNeil *et al.*, 1991a; Tseng, McNeil & Milenkovic, 1993). The nature of these theories will be reviewed in the following section.

3.4.3.1 A resource allocation deficit

Kent and McNeil (1987) posed that explanation for the token-to-token variability in the subjects with AOS and CA in their study, needed to incorporate the concept of a resource allocation deficit. According to these researchers, information on syllable structure and phoneme segments is coded separately with the consequence that these two aspects can be differentially affected. Since AOS and CA subjects in their study were prone to deficits at the phonetic-motor planning level, Kent and McNeil (1987) speculated that more attention/resources might be allocated to "the slot-filler specifications of individual syllables and their motoric realization" (Kent & McNeil, 1987:213). According to these researchers, the increased resource allocation to slot-filler specification and motoric realization of individual syllables, as opposed to larger units, might result in the lengthening of both syllables and intersyllabic pauses, causing the secondary characteristic of dysprosody. The latter result was more pronounced for the subjects with AOS in their study.

McNeil *et al.* (1991a) have also proposed a deficit regarding the allocation of attention as explanation for performance variability from one situation to another on the same task in aphasic speakers. These researchers argued that researchers had "failed to provide the necessary and convincing evidence that the linguistic data and the computational linguistic operations are lost", since aphasics can execute certain tasks successfully in certain environments, for example, when counting or naming the days of the week (McNeil *et al.*, 1991a:35). They conclude that the current linguistic models alone can thus not adequately explain aphasia. For this reason, concepts of attention and memory need to be incorporated into the explanation of the underlying pathology in this population (McNeil *et al.*, 1991a). Persons with aphasia thus presumably still have the underlying linguistic competence, but linguistic performance is influenced by difficulty with adequate allocation of resources to the linguistic task at hand (McNeil *et al.*, 1991a). The use of an attention framework for aphasia allows explanation of aspects, such as, variability, stimulability and multidomain deficits in aphasic speech performance. These aspects of aphasic behavior cannot be accounted for by traditional explanations of the underlying disorder (McNeil *et al.*, 1991a; Tseng *et al.*, 1993).

If persons with AOS and CA have difficulty with the allocation of resources, contexts which challenge the speech production mechanism and require allocation of more attention might cause breakdown in the speech production process of these persons, since more resources than normal already need to be allocated to the defective speech and language processes. A person with a normal neuromotor system would presumably be able to adapt successfully to more challenging contexts and successfully allocate additional resources where needed. Contexts which are more challenging would presumably require more conscious processing and consequently allocation of more attentional resources (McNeil *et al.*, 1991a). McNeil *et al.* (1991a) underscore the fact that the processing of a more complex task requires greater resources and controlled processing, whereas automatic tasks impose a small processing load and consequently require fewer resources and less attention for execution.

From the above discussion, it is evident that contextual demands play an integral part in the performance of both persons with AOS and aphasia. The influence of various contextual factors will consequently need to be taken into account when compiling evaluation and treatment methods. Depending on the underlying nature of the disorder, different contexts might affect speech production in a specific population differently. It is thus important to determine the effect of various contextual factors in different disorder groups, not only for incorporation of this knowledge in assessment and treatment, but also for learning more about the underlying nature of these disorders.

3.4.3.2 Whiteside and Varley's (1998) dual-route hypothesis for phonetic encoding

Whiteside and Varley (1998) offer a cognitive-based conceptualization of AOS. These researchers propose that normal speech production occurs by means of access to either a direct or indirect processing route. The direct route accesses stored verbo-motor patterns or whole gestalts (Varley & Whiteside, 2001). These verbo-motor patterns contain the specifications for the relative timing and force for movements of the components of coordinative structures. The movement parameters of frequently used syllables and words are stored and can be accessed via the direct route. Whiteside and Varley (1998:223) state that "In order to reduce computational complexity and therefore the degrees of freedom, the physiological system will link variables to form self-regulating autonomous subsystems" as also proposed by Kelso and Tuller (1981). Speech production is thus simplified through the use of "learned links between muscle commands" (Whiteside and Varley, 1998:223). The result is generation of programs of movement synergies or verbo-motor patterns. Because this route is used for retrieving frequently used utterances, minimal computational resources are required and direct access is offered to a hypothetical mental store of "phonetic"/"mental syllabary" (Levelt, 1989, 1992).

The indirect route, on the other hand, is used to assemble low frequency or novel utterances and these utterances have to be assembled anew each time phone by phone. Consequently this route imposes an increased processing load and individuals with brain damage are known to exhibit difficulty with allocation of attentional resources (Ballard *et al.*, 2001). Whiteside and Varley (1998) propose that persons with AOS exhibit a deficit regarding either the access to and/or the storage of verbo-motor patterns. Consequently the person with AOS has to rely on the indirect encoding route and assemble utterances anew each time, phone by phone. From the speech characteristics of persons with AOS, these researchers concluded that these persons cannot efficiently and adequately compensate through the use of indirect mechanisms though.

Whiteside and Varley (1998) claim that apraxic speech characteristics, such as, reduced coarticulation (McNeil, Hashi & Southwood, 1994; Ziegler & von Cramon, 1985), articulatory groping (Darley *et al.*, 1975), increased segmental and intersegmental duration (Freeman *et al.*, 1978; Kent & Rosenbek, 1983; Mercaitis, 1983; Strand & McNeil, 1996), variable and inconsistent VOT patterns (Freeman *et al.*, 1978; Itoh *et al.*, 1982; Kent & Rosenbek, 1983; Whiteside & Varley, 1996; Ziegler, 1987) and interarticulatory dyscoordination (Freeman *et al.*, 1978; Itoh *et al.*, 1979a, b; Kent & Rosenbek, 1983; Ziegler and von Cramon, 1986) can be accounted for by inefficiency of the indirect route used in isolation. An alternative explanation they provide is that concomitant deficits regarding allocation of processing resources negatively affect the abilities of persons with AOS to make use of the indirect route efficiently, since this route relies heavily on on-line computation and controlled processing. Varley *et al*. (1999:128) contend that the increased processing demands might be "problematic for a speaker with a lesion in the motor control regions of the dominant hemisphere".

The proposal by Whiteside and Varley (1998) has been criticized by researchers on several accounts (Ballard *et al.*, 2001; Miller, 2001; Ziegler, 2001). Ballard *et al.* (2001) criticized the dual-route model on various grounds including, the fact that apraxic speech behavior could be explained by other theories equally well and that support for units smaller than a word has been found in the linguistic literature (Rogers & Spencer, 2001). Ballard *et al.* (2001) further stated that it would be difficult to falsify or even test the model of Whiteside and Varley (1998) and that their model could not account for non-speech findings in AOS, which have been reported by, for example, Clark and Robin (1998). Miller (2001) also criticized the dual-route model by stating that the results of their study do not necessarily imply a "contrast between utilizing prestored versus planned-afresh gestalts" (Miller, 2001:64). According to Miller (2001) durational differences which Varley *et al.* (1999) reported for high and low frequency words, could possibly arise from functionally different performance within a single route. Miller (2001) also criticized Whiteside and Varley (1998) regarding subject selection criteria, implying that the degree of concomitant aphasia and dysarthria in their AOS subjects could have influenced their results.

Regarding Whiteside and Varley 's (1998) dual-route hypothesis, Rogers and Spencer (2001) raised the question as to why automatic speech utterances of speakers with AOS are nearly invariably better than any other types of speech, if direct route encoding is indeed impaired. Ziegler (2001) pointed out the fact that normal speakers only have minor, if any, problems when attempting to produce words which they have never heard before and if speakers with AOS were using the indirect route for compilation of utterances, their speech should be on par with that of normal speakers producing new or unfamiliar utterances. This is not the case, however, since the speech of persons with AOS is characterized by severe sound distortions and substitutions, together with struggle behavior, none of which are evident in normal speakers producing novel words (Ziegler, 2001).

The direct route can be seen as the automatic route of speech production and the patterns which can be accessed via this route are thus highly familiar and overlearned. The indirect route, on the other hand, contains access to novel and unfamiliar responses. Consequently, these two routes can be regarded as two separate contexts for speech production. Familiar utterances utilizing the direct route are more automatic and require fewer attentional resources, whereas the indirect route requires more conscious processing since these words are novel and less automatized. In this sense, novel words present a different and more demanding speech context than high frequency words which are presumably more automatized and overlearned.

As argued by Ballard *et al.* (2001), the proposals by Whiteside and Varley (1998) can be explained by other theories of normal and pathological speech motor control equally well. For example, Van der Merwe's (1997) four-level framework of speech sensorimotor control also predicts that novel utterances might increase the processing load, since the motor plans are not as well established as those of utterances which are more familiar and automatized. Since speech is a motor skill, it improves with practice and becomes more automatized with the result that utterances which are used more frequently will be produced with greater ease and speed if language processes are intact. Varley *et al.* (1999) explain AOS from a cognitive perspective, whereas explanation from a motor control perspective has potential to explain the occurrence of a wider range of speech characteristics in normal and pathological speakers.

3.4.3.3 Rogers and Storkel's reduced buffer capacity hypothesis in AOS

Rogers and Storkel (1999) postulated a reduced capacity of the sublexical processing buffer in AOS. According to these researchers, this capacity problem results in one of the core feature of AOS, namely, syllable segregation. The reason for syllable segregation is presumably that persons with AOS can only plan one syllable at a time (McNeil, Doyle & Wambaugh, 2000).

Initially Rogers and Storkel (1998) conducted a series of five experiments to determine the role of articulatory phonetic features (voicing, place and manner of articulation) and reprogramming operations during the pre-motor stages of speech production. Speech onset latencies were obtained from normal speakers who had to read monosyllabic words presented one at a time as quickly as possible after they appeared on a computer screen. Latencies of words which were preceded by words sharing their phonetic features were contrasted to control conditions in which there were no shared features between consecutively presented words. A *phonologic similarity effect* was found, meaning that consecutively presented words, which shared features regarding the initial sound, rendered significantly longer onset latencies than words of which the initial sounds did not share articulatory phonetic features. The latter finding was taken as evidence for the idea that sublexical units have to be assembled (Rogers & Storkel, 1998) and longer latencies presumably provided evidence of the processing which was required to reprogram the pre-motor processing buffer (Rogers & Spencer, 2001). The researchers ascribed the additional processing time which was required for production of words of which the initial phonemes shared articulatory features, to temporary inactivation of programs which had been used for production of the initial word.

Rogers and Storkel (1999) conducted another experiment involving a parameter re-mapping task where speakers were presented simultaneously with two words sharing articulatory phonetic features, in order to provide them with time to plan/program the utterance before production onset. The need to reprogram the processing buffer between the first and second word was thus alleviated by simultaneous presentation of both words. Rogers and Storkel (1999) predicted that the phonological similarity effect would disappear in normal speakers when both words were presented simultaneously, since these speakers now did not have to reprogram the phonological buffer for the following word, but could plan production of both utterances. Rogers and Storkel (1999) hypothesized that if subjects with AOS exhibited a reduced phonological buffer capacity, the phonological similarity effect would still be present in these persons, despite both words being presented simultaneously, since they would still need to program each word independently.

In the abovementioned experiment by Rogers and Storkel (1999), subjects were thus required to plan production of two words at a time. Slowed production was taken as proof that two words could not be held in the phonological buffer for planning at one time. The initial phonemes of the two words shared one of the following groups of features, namely, voicing and manner of production, place and manner of production, or no similar features. Two measures of inter-word interval duration were obtained. Normal speakers and persons with either aphasia or aphasia with concomitant AOS, served as subjects in this study.

The results of the second study by Rogers and Storkel (1999) revealed that only the AOS subjects exhibited the phonological similarity effect, in other words, exhibited increased latencies for production of words of which the initial phonemes share articulatory features. The latter finding confirmed that the subjects with AOS exhibited a reduced phonological buffer capacity preventing the programming of both words simultaneously. Ballard *et al.* (2000) state that in agreement with the explanation by Rogers and Storkel (1999), other researchers, for example, Rochon, Caplan and Waters (1990) have proposed a reduced short term memory in speakers with AOS resulting from “a reduced ability to perform articulatory rehearsal” (Ballard *et al.*, 2000:974).

From the reduced buffer capacity hypothesis for explanation of articulatory prolongation and syllable segregation in AOS, it can be concluded that the length of an utterance can be seen as a context for speech production. In this regard, longer utterances presumably pose higher demands regarding phonological and motor planning. Persons with AOS are thus more prone to experience difficulty with longer utterances and are more susceptible to breakdown regarding longer utterances (Johns & Darley, 1970; Shankweiler & Harris, 1966; Strand & McNeil, 1996) due to their reduced capacity to plan production of more than one syllable at a time. The theory proposed by Rogers and Storkel (1999) does not allow for explanation of other apraxic speech characteristics, for example, the presence of distortions. Furthermore, the theory by Rogers and Storkel (1999) does not predict the influence of other contextual factors, for example, speaking rate.

The finding that persons with AOS consistently had difficulty planning two utterances when features were shared between the initial sounds of two words which had to be produced consecutively (phonological similarity effect), could also be attributed to the fact that the production of longer utterances are more difficult for persons with AOS, since they are motorically more complex (Van der Merwe, 1997, 2002). Van der Merwe (2002) states that the number of core motor plans which need to be recalled is greater, sequential organization of motor goals is more demanding, the potential for coarticulation increases and IAS also becomes more complex in longer utterances. The phonological similarity effect, reported by Rogers and Storkel (1999) might thus be related to difficulty with the processes occurring during the motor planning of speech and not only to a reduced phonological buffer capacity. Rogers and Storkel (1999) do mention, however, that although their experiment was designed to affect phonological encoding, processing at the subsequent stages, for example, motor programming, might also have been affected. Phonological similarity of utterances can also be regarded as a contextual factor influencing the processing demands.

3.4.4 Selective phonological impairment

Dogil and Mayer (1998) offer a linguistic-based account for AOS. These researchers propose that AOS reflects a purely linguistic or phonological impairment. Dogil and Mayer (1998) performed a cross-linguistic study with German-speaking and Xhosa-speaking persons with AOS and concluded that AOS reflects a "defective implementation of phonological representations at the phonology-phonetics interface" (Dogil & Mayer, 1998:143). Underlying their conclusion is their belief that "speech is encoded in the brain as a sequence of distinctive feature configurations" (Dogil & Mayer, 1998:143). According to these researchers, these configurations are specified with varying degrees of detail depending on their role in the phonological structure of the language. Dogil and Mayer (1998) propose that speech sounds are encoded as a sequence of vocal tract configurations when the transfer from phonological to phonetic representations occurs.

The deficits characteristic of AOS are explained in terms of over-specification of these articulatory configurations, thus over-specification of sounds at the phonetic level, resulting in the inability to coarticulate sounds. In normal speakers a considerable amount of phonological under-specification and phonetic non-specification occurs to accomplish fluently articulated speech. According to these researchers, a speaker with AOS exhibits a "loss of the ability to construct underspecified representations" (Dogil and Mayer, 1998:152) which are subject to coarticulatory effects. These researchers verify this claim by stating that coarticulation in AOS is greatly limited, production of underspecified speech sounds (laryngeal and schwa-like vowels) is difficult and specified speech sounds, like clicks in Xhosa, are produced correctly by persons with AOS, even though these sounds are motorically complex sounds (Dogil & Mayer, 1998). These observations led Dogil and Mayer (1998) to conclude that the underlying problem in AOS is phonologically based as opposed to motor-based. Dogil and Mayer (1998:168) argued that their over-specification hypothesis suggests that gestural complexity does not play a role, but rather "the degree of phonological (under) specification and the ability to preserve it at the phonetic level".

Ballard *et al.* (2000) state that Dogil and Mayer's (1998) account of AOS cannot explain the nonspeech motoric impairments observed by other researchers, for example, Clark and Robin (1998). The fact that the subject studied by Dogil and Mayer (1998) produced click sounds correctly could indicate that more conscious processing was employed during production of this sound, since it is motorically complex and perceptually distinct. Furthermore, this particular sound occurs very frequently used in Xhosa and production thereof could consequently be more automatized than the more neutral sounds, even though it is motorically complex.

The fact that it is generally reported that persons with AOS exhibit greater difficulty with sounds and sound combinations which are motorically more complex (Van der Merwe, 1986) is contradictory to the explanation provided by Dogil and Mayer (1998) for the correct production of the motorically complex click sound. Different contextual factors, for example, level of automaticity (Van der Merwe, 2002), frequency of use of the sound in a particular language (Trost & Canter, 1974) or length of the utterance (Johns & Darley, 1970; Shankweiler & Harris, 1966; Strand & McNeil, 1996) in which the sound occurs, could also contribute to accuracy of production. Difficulty or success with the production of a specific sound can thus not be solely attributed to the distinctive features of which the sound is comprised, but other contextual factors need to be considered as well. The reduced coarticulation in speakers with AOS can be explained equally well by motor-based accounts. The lack of coarticulation could be reflective of an inability to adapt the temporal and spatial parameters of speech production to the phonetic environment during the motor planning stage of speech production (Van der Merwe, 1997). From the latter perspective difficulty regarding the motor planning of speech is present in subjects with AOS.

3.4.5 Schmidt's schema theory

According to Schmidt's schema theory, learned movement patterns are stored as generalized motor programs (GMPs). These GMPs could include articulatory gestures, segments, syllables, words or even high-frequency phrases (Ballard *et al.*, 2001). Depending on the context in which a movement is produced, parameters are adapted regarding the absolute force and duration of the movements. The same utterance will thus differ regarding the absolute temporal and spatial parameters depending on the context of production, as well as during repeated production of the same utterance. The concept of GMPs and parameterization, reduce the storage demands for action representations and account for the relatively invariant features across different productions of an action (Schmidt, 1975). It is not certain what would be regarded as "contexts" for speech production in Schmidt's (1975, 1982) view, but it would most probably entail the phonetic environment or different circumstances under which speech is produced, for example, different speech rates. The context as proposed by Schmidt (1975) could also possibly refer to the same utterance produced at different times or during repeated productions.

Clark and Robin (1998) conducted a study, against the backdrop of Schmidt's theory, in which they examined motor programming in normal speakers, persons with AOS and persons with CA by means of a visual-motor tracking task. The aspects they examined included, GMP accuracy, as well as temporal and spatial parameterization accuracy. Subjects had to produce a movement pattern presented on a monitor with their jaw, after the pattern had been removed from view. The results of the study indicated inter-subject variability in the AOS group in that two of the four subjects demonstrated unimpaired GMP accuracy, but poor parameterization accuracy, while the other two subjects displayed impaired GMP accuracy with normal parameterization.

Clark and Robin (1998) concluded that their results indicated the presence of possible performance trade-offs, since the subjects with AOS in their study had deficits regarding either the GMP or parameterization, but not both. They explained this finding by stating that subjects might have only enough processing resources to correctly program either the GMP or the parameters, but not both. According to these researchers, the inter-subject variability might thus be indicative of different resource allocation strategies used by the different subjects with AOS. Because of their impaired motor system, subjects with AOS might reach the limits of their capacity, forcing them to choose one of these aspects of motor programming to attend to, since their resources are too limited to attend to both (Clark & Robin, 1998). Clark and Robin (1998:710) concluded that AOS involves the entire process of motor programming as opposed to involvement of "only one process (the GMP) within the programming of events". Furthermore, these researchers stated that speakers with AOS are thus required to produce skilled movement "under great resource demand, resulting in an increased susceptibility to breakdown" (Clark & Robin, 1998:710). In terms of Schmidt's schema theory, AOS can thus be thought of as a deficit regarding the ability to activate and/or select a GMP, an inability to correctly parameterize according to a given context, or both (Clark & Robin, 1998).

Clark and Robin (1998) also included subjects with CA in their study. These researchers found that with the exception of one subject, the subjects with CA did not generally exhibit difficulty with implementation of GMPs or parameterization accuracy. From this result, these researchers concluded that some patients with CA might have motor control deficits concomitant to a primary linguistic disorder, but that difficulty regarding motor control is not a core part of the pathogenesis in CA.

As in Van der Merwe's (1997) four-level framework of speech sensorimotor control, Schmidt's theory also proposes that the parameters (spatial and temporal) of movement vary according to the context, although he does not specify specific contexts for speech production. Furthermore, the influence of contextual factors regarding the demands which they place on the speech production mechanism is not commented on. It is assumed, however, that implementation of correct GMPs and/or parameterization accuracy will be influenced by contextual factors which increase the processing demands to the speech production mechanism.

3.4.6 Conclusion regarding theories about the underlying nature of AOS

From the above discussion, it is evident that different explanations exist for the underlying nature of AOS and PP. Each theory presents specific strengths and weaknesses to aid in our understanding of AOS and other neurogenic speech and language disorders. From these theories, it becomes evident that the influence of contextual factors need to be incorporated in models and theories of disordered speech, since speech production is variable due to the influence of contextual demands. Before discussing specific contextual influences on the speech of persons with neurogenic speech and language disorders, temporal aspects of speech production which are studied in an attempt to learn more about the underlying nature of the disorders in these persons will be reviewed. Perceptually on-target speech production will require accurate specification of the spatial and temporal parameters of speech production. The study of these parameters serves as a window through which one can catch a glimpse of the underlying processes involved in speech production.

3.5 THE STUDY OF TEMPORAL PARAMETERS OF SPEECH PRODUCTION IN AOS AND CA: A WAY IN WHICH TO INVESTIGATE THE NATURE OF THE DISORDER

Speech timing has been of considerable interest to researchers concerned with speech disorders due to neurologic etiologies. The main reason for this interest is because deviant articulatory timing resulting in articulatory deficits can be used to characterize the underlying impairment, for example, motor versus phonological impairment, in such disorders and consequently for differentiation of the nature of these disorders

(Ballard *et al.*, 2000). In this regard, Ballard *et al.* (2000) state that the examination of temporal characteristics of speech production is helpful for characterizing deficits in speech and/or language disorders as being either motoric or linguistic in nature.

Studying speech timing in pathological speakers also renders important information that can be used when compiling and verifying aspects of models of normal and pathological speech motor control. Temporal aspects of speech production have been widely studied in AOS, due to the fact that these subjects are believed to exhibit deficits regarding temporal control (Seddoh *et al.*, 1996b; Strand & McNeil, 1996). Inclusion of subjects with CA in such studies is valuable for determination of qualitative differences regarding temporal control and for differential diagnostic purposes, since persons with either AOS or PP are believed to exhibit deficits at two distinct levels of the speech production process.

Various acoustic (Freeman *et al.*, 1978; Itoh *et al.*, 1982; Kent & McNeil, 1987; Kent and Rosenbek, 1983; McNeil *et al.*, 1990a; Seddoh *et al.*, 1996a, b; Strand & McNeil, 1996; Tuller & Story, 1987; Ziegler & von Cramon, 1985, 1986), kinematic (Fromm, 1981; Hardcastle *et al.*, 1985; Itoh *et al.*, 1980; McNeil & Adams, 1991; McNeil *et al.*, 1989; Robin *et al.*, 1989; Tseng *et al.*, 1990) and physiologic (electromyographic) (Forrest *et al.*, 1991; Fromm *et al.*, 1982; Shankweiler *et al.*, 1968) studies have been performed in an attempt to determine the temporal characteristics of neurogenic speech disorders and consequently to shed light on the underlying nature of these disorders. By using these techniques interarticulatory timing between various articulators (Itoh *et al.*, 1980; Robin *et al.*, 1989; Tseng *et al.*, 1990), as well as durational aspects of speech timing (Baum, Blumstein, Naeser & Palumbo, 1990; Code & Ball, 1982; Collins *et al.*, 1983; Colson, Luschei & Jordan, 1986; Cooper, Soares, Nicol, Michelow & Goloskie, 1984; Danly & Shapiro, 1982; DiSimoni & Darley, 1977; Duffy & Gawle, 1984; Gandour & Dardarananda, 1984; Harmes, Daniloff, Hoffman, Lewis, Kramer & Absher, 1984; Kent & McNeil, 1987; Kent & Rosenbek, 1983; McNeil *et al.*, 1990a, Ryalls, 1981, 1982, 1986; Square-Storer & Apeldoorn, 1991; Strand & McNeil, 1987; Sussman, Marquardt, Hutchinson & MacNeilage, 1986; Ziegler & Hoole, 1989; Ziegler & von Cramon, 1985) have been studied.

The following section will provide an overview of studies which have examined temporal aspects of speech production in persons with AOS and those with PP. The emphasis will be on acoustic studies of IAS and the duration of speech segments, since these two aspects are the focus of the present study. It is important to study segment durations due to the fact that "they are thought to reflect principles of speech timing" (Forrest & Weismer, 1997). Furthermore, IAS is an important aspect of speech motor control, since it needs to be planned for each phoneme in an utterance (Van der Merwe, 1997). Interarticulatory synchronization is thus reflective of temporal control amongst various articulators, which in turn is essential for achievement of perceptually accurate speech. Durational aspects have been widely studied in persons with neurogenic speech disorders probably due to the perceptual prominence and their importance for differential diagnosis (Strand & McNeil, 1996).

3.5.1 Interarticulatory timing

An aspect of articulatory timing which is often studied in persons with neurogenic speech disorders is the timing of articulatory movements relative to one another, known as IAS or interarticulatory timing. The movements of the different articulators need to be synchronized in order to obtain the desired acoustic result (Itoh & Sasanuma, 1984; Itoh *et al.*, 1980; Kelso *et al.*, 1983.) Interarticulatory synchronization has been studied by means of both kinematic (Fromm, 1981; Hardcastle *et al.*, 1985; Itoh *et al.*, 1980, 1980; Robin *et al.*, 1989; Tseng *et al.*, 1990) and acoustic (Freeman *et al.*, 1978, Itoh *et al.*, 1982; Kent & Rosenbek, 1983; Tuller & Story, 1987; Ziegler & von Cramon, 1985, 1986) measures. In this way IAS in AOS between various articulatory structures has been examined, for example, IAS of the lip, velum and tongue dorsum (Itoh & Sasanuma, 1984; Itoh *et al.*, 1980) and IAS of velar and tongue movements (Itoh *et al.*, 1979b). As mentioned in chapter two, VOT has often been measured in studies on IAS as an indicator of interarticulatory timing, since it reflects the relative timing between a supralaryngeal (oral articulation) and laryngeal event (vocal fold vibration for voicing onset) (Van der Merwe, 1986). Deficits regarding VOT in AOS and CA have consequently been attributed to difficulty regarding temporal control (Kent & McNeil, 1987).

- **Interarticulatory timing of laryngeal and supralaryngeal events in neurogenic speech disorders: voice onset time**

Deviant VOT in AOS has been reported by several researchers (Blumstein, Cooper, Goodglass, Statlender & Gottlieb, 1980; Blumstein, Cooper, Zurif & Caramazza, 1977; Hoit-Dalgaard, Murry & Kopp, 1983; Itoh *et al.*, 1982; Shewan, Leeper & Booth, 1984; Seddoh *et al.*, 1996b) and this consequently implies deviant interarticulatory timing in this population. Deficits regarding VOT include a restricted range of VOT values in some subjects (Hoit-Dalgaard *et al.*, 1983), longer than normal VOT values (Kent & McNeil, 1987), overlapping VOT values for voiced and voiceless cognates (Blumstein *et al.*, 1977; Itoh *et al.*, 1982) and greater variability regarding VOT (Kent & McNeil, 1987). In AOS it seems possible to attribute errors regarding VOT to the presence of a motor disorder manifested, in amongst other characteristics, the disrupted timing of laryngeal and supra-laryngeal events.

In the framework proposed by Van der Merwe (1997) a deficit regarding VOT is ascribed to the level of the motor planning of speech, since the temporal parameters of speech production are specified at this level of the speech production process. Deviant VOT supports the claim of Kelso and Tuller (1981:241) that "apraxia of speech may be characterized, at least in part, by disruption, of the normally invariant timing relations among articulators". Itoh *et al.* (1982:209) also concluded that "the pathological distributions of VOT values shown by the apraxic subjects studied are indicative of the existence of a difficulty in the temporal programming of the laryngeal and supralaryngeal articulatory adjustments rather than a problem in selecting appropriate phonemes". This statement has to be interpreted with reference to a three-level model of speech production as proposed by Itoh and Sasanuma (1984). The term motor programming as used in the three-level model is synonymous to motor planning as used by Van der Merwe (1997) in her four-level framework of speech sensorimotor control. As mentioned previously, motor planning and motor programming are proposed by Van der Merwe (1997) to be two distinct stages in the speech production process. Some researchers have, however, reported normal VOT values in some persons with AOS (Collins *et al.*, 1983; Kent & Rosenbek, 1983;

Shewan *et al.*, 1984; Van der Merwe, 1986), indicating that this aspect of articulatory timing is not necessarily consistently disrupted in AOS.

Regarding VOT measures in CA mixed results have also been obtained in that some researchers have reported normal VOT values for CA (Blumstein *et al.*, 1980; Itoh *et al.*, 1982; Seddoh *et al.*, 1996b; Shewan *et al.*, 1984;), while others have reported aberrant VOT characteristics in some of these speakers (Kent & McNeil, 1987). Intrasubject differences have also been reported in CA. For example, in an acoustic study performed by Kent & McNeil (1987), one of the subjects with CA had VOT values similar to those of the subjects with AOS, while the other exhibited short VOT values.

3.5.2 Duration of speech segments

Stress and durational patterns have been acoustically analyzed more often than other characteristics of apraxic speech due to their importance for differential diagnosis and their perceptual prominence (Strand & McNeil, 1996). Many studies have confirmed the existence of slower rate and abnormal prosodic patterns for apraxic speakers compared to normal or aphasic speakers (Kent & McNeil, 1987; McNeil *et al.*, 1990a; Odell *et al.*, 1991a, b). The source of the slowed speaking rate in AOS has been ascribed to “motoric limitations, compensation for motoric difficulties, or an attempt to reinstall effective self-monitoring” (Kent & McNeil, 1987:214). Kent and McNeil (1987) proposed that speaking rate can be slowed by either lengthening of intersyllabic pauses or lengthening of the segments produced. The study of durational patterns of speech segments in AOS includes the study of vowel duration, consonant duration and word or intersegment durations. Once again, many of these studies included persons with CA in order to contrast the findings and pathological mechanisms in these two groups of speakers.

3.5.2.1 Vowel duration

It has become increasingly evident that vowel characteristics contribute to speech intelligibility deficits to a great extent and that consonants are not the most "informative bearing" elements of speech (Forrest & Weismer, 1997). Increased vowel durations could thus presumably contribute to the perceived slow rate in AOS, as well as to abnormal prosody (Harris & Umeda, 1974; Umeda, 1974). However, results from various studies regarding vowel duration in AOS and CA have been inconsistent. Some researchers have reported vowel durations within the range of those of normal speakers for both AOS and aphasic speakers for monosyllabic words (Bauman, 1978; Duffy & Gawle, 1984; Gandour & Dardarananda, 1984; Mercaitis, 1983; Ryalls, 1984, 1986). However, other researchers, examining multisyllabic words, have found longer vowel durations in AOS compared to normal speakers and aphasic subjects (Baum *et al.*, 1990; Collins *et al.*, 1983; Kent & Rosenbek, 1983; Mercaitis, 1983; Ryalls, 1981, 1987; Strand, 1987; Strand & McNeil, 1996). A more recent study by Seddoh *et al.* (1996b) examined temporal parameters of speech in subjects with AOS, CA and normal speech by means of acoustic analysis. The results of this study revealed that the apraxic subjects demonstrated longer and more variable stop gap, vowel and consonant-vowel durations than the normal and aphasic subjects, while the subjects with CA exhibited longer vowel and consonant-vowel durations than the normal speakers.

Strand and McNeil (1996) maintain that factors such as the specific vowel measured, method of elicitation of spoken stimuli, rate of presentation of stimuli and the degree to which the apraxic speakers have concomitant disorders might explain the discrepancy in results between various studies. From most acoustic studies it has been concluded, however, that persons with AOS have difficulty in planning durational control of speech segments. The fact that the subjects with AOS in the abovementioned studies exhibited deficits regarding vowel duration for multisyllabic, but not for monosyllabic words, could imply that utterance length and consequently motor complexity of an utterance influences the processing demands and consequently successful production.

Multisyllabic words are presumably motorically and linguistically more difficult to plan due to an increase in the coarticulatory possibilities, the number of core motor plans which need to be recalled, the demands regarding sequential organization of motor goals and IAS (Van der Merwe, 2002). Consequently longer utterances place greater demands on the speech production mechanism, causing persons with difficulty regarding one or more of the stages involved in speech production to be more susceptible to breakdown. Since persons with AOS have difficulty with the motor planning of speech and specifically the sequencing of movement plans (Van der Merwe, 1997), they will presumably be more susceptible to breakdown during production of multisyllabic words than when producing monosyllabic words. Since vowel duration appears to be one of the temporal parameters of speech which is influenced by the context of production, it is a viable variable to study when investigating contextual influences on temporal parameters of speech production in AOS.

3.5.2.2 Other durational measures

Increased consonant duration has also generally been reported for persons with AOS compared to normal speakers (Bauman, 1978; Kent & Rosenbek, 1983), although consonant duration has been studied less often than vowel duration. Longer than normal segment duration, together with increased intersegment (Kent & McNeil, 1987; Mercaitis, 1983) and transition durations (Kent & Rosenbek, 1983) presumably result in the perceived slower than normal speaking rate in AOS (Kent & McNeil, 1987; Kent & Rosenbek, 1983; McNeil *et al.*, 1990a). In the study by Kent and McNeil (1987), the CA subjects also displayed abnormalities regarding segment and intersegment durations, implying the possibility of an underlying motor deficit contributing to the pathogenesis in this group of speakers.

The duration of many other aspects of production have been studied, including the duration of fricatives, syllables, words, pauses and interword intervals (Harmes *et al*, 1984; Kent & McNeil, 1987; McNeil *et al.*, 1990a; Square-Storer & Appeldoorn, 1991). Baum *et al.* (1990), in a study on fricative duration in Broca's, nonfluent and fluent aphasics, found similar results regarding absolute durations across subject groups, although normal speakers exhibited less variability. Code and Ball (1982) found that subjects with Broca's aphasia produced longer than normal durations for both voiced and voiceless fricatives in minimal pairs. Colson *et al*. (1986) found no significant differences between average syllable durations during repetition of nonsense disyllables. Harmes *et al.* (1984) also found no statistically significant differences between normal speakers and persons with Broca's aphasia regarding absolute fricative durations during repetition of all target utterances in their study (single /z/-sound and /z/-words of one to three syllables in length).

Kent and McNeil (1987) on the other hand, found longer average segment durations in both AOS and CA in normal and fast rate conditions compared to normal speakers with the exception of one subject with AOS whose segment durations fell within the average normal duration at the control rate, but not at the fast rate. In the fast rate condition the CA subjects had average segment durations and ranges, which were comparable to those of the apraxic subjects in contrast to their average durations and variability which were more comparable to those of the normal subjects in the control rate. Mean intersegment durations for the AOS subjects in the control rate were longer than those of the normal and aphasic subjects. The aphasic subjects produced intersegment durations within the ranges of the normal subjects in the fast rate condition. Intersegment variability was greater for AOS subjects than for both CA and normal subjects.

Kent and Rosenbek (1983) reported durations of stop consonants and affricates which were comparable to those of normal speakers in monosyllabic words in subjects with AOS with “some” aphasia. However, almost all consonants in multisyllabic words were longer than normal in AOS subjects. The influence of word length on susceptibility regarding difficulty with temporal control is evident from this study. McNeil *et al.* (1990a) reported longer total utterance durations in subjects with AOS compared to normal and aphasic speakers in fast and control rate conditions, but not in the slow rate condition. One of the AOS subjects in the study by McNeil *et al.* (1990a) exhibited shorter than normal durations in the control rate condition. Square-Storer and Apeldoorn (1991) found that the polysyllabic word durations of two of their subjects with AOS were longer than normal, while those of a third subject were not. The subjects in the study by Square-Storer and Apeldoorn (1991) all differed regarding amount of variability with one AOS subject exhibiting little variability.

Mercaitis (1983) investigated the acoustic characteristics of the imitative speech of normals, aphasic and apraxic adults. Vowel duration, VOT, final consonant duration and syllable duration were measured within single syllables and two and three syllable segments. Verbal response time and intersyllable intervals were also analyzed.

Mercaitis (1983) found that apraxic adults exhibited significant differences from non-brain injured adults and aphasics regarding consonant-vowel-consonant syllable duration, final consonant duration and on variability of consonant-vowel-consonant productions. Regarding silent interval measures, the apraxic subjects differed significantly from the normal speakers and aphasics regarding verbal response time, intersyllable intervals and variability regarding these performances. Apraxic adults also differed from non-brain injured and aphasic adults regarding mean segment durations and in the variability of performance on these measures. From the results of her study, Mercaitis (1983) concluded that AOS is a motor programming disorder (as defined in a three-level model of speech production), separate from aphasia, even though the two disorders frequently co-occur.

3.5.3 Variability in temporal parameters

Variability in AOS and CA has been investigated regarding various aspects. These include variability regarding the type of errors produced during consecutive productions of a word (McNeil *et al.*, 1995), variability regarding error location in consecutive productions of a word (McNeil *et al.*, 1995), and variability regarding temporal measures on repeated productions of an utterance (token-to-token variability) (Kent & McNeil, 1987; McNeil *et al.*, 1989; Seddoh *et al.*, 1996a; Van der Merwe, 1986). The degree of variability regarding temporal measures is often used for differentiation of AOS and CA and for indicating motoric deficits (Ballard *et al.*, 2000). Consequently variability of temporal measures is of importance in the present study.

Several researchers have examined token-to-token variability of temporal parameters in speech production of subjects with AOS or CA (Kent & McNeil, 1987; Robin *et al.*, 1989; Seddoh *et al.*, 1996a, b). In a study by Kent and McNeil (1987) subjects with AOS and CA were found to display greater variability than normal speakers regarding VOT (all subjects with AOS and one subject with CA), segment durations and second formant transitions. The AOS subjects exhibited greater variability than the CA subjects regarding intersegment durations, especially in the fast speaking rate.

However, regarding variability of segment durations, the subjects with AOS and CA performed similarly in the fast rate.

In another study, Seddoh *et al.* (1996b) compared the temporal patterns exhibited by subjects with AOS and CA in order to determine similarities and differences and consequently make inferences about the underlying deficits in these two groups. Seddoh *et al.* (1996b) found that durational control was impaired in their apraxic subjects. This resulted in longer than normal mean durations regarding stop gap, vowel, and consonant-vowel productions, as well as increased token-to-token variability regarding these measures. The subjects with CA had longer than normal vowel and consonant-vowel durations, but their productions were not more variable than those of normal speakers. This was taken as evidence for a more stable motor control system in subjects with CA. Consequently Seddoh *et al.* (1996b) concluded that a phonological, rather than a motoric deficit, was present in the subjects with CA in their study.

McNeil *et al.* (1989) examined variability of peak articulatory velocities of the lower lip in subjects with AOS. Although the subjects with AOS exhibited normal velocities, their velocities were more variable than those of normal subjects. Seddoh *et al.* (1996a) studied temporal variability in subjects with AOS and reported greater variability than normal subjects regarding stop gap duration, steady-state vowel duration and total target word duration. Greater variability in subjects with AOS was not reported regarding VOT and second formant transition duration. One of the subjects in the study by Seddoh *et al.* (1996a) exhibited normal variability regarding all temporal parameters.

As is evident from the above discussion, increased variability on repeated trials of the same utterance is believed to reflect a motoric impairment and is often used for differentiation between AOS and CA. Subjects with AOS have generally been found to exhibit greater variability regarding temporal measures than normal speakers and speakers with CA (Kent & Rosenbek, 1983; McNeil *et al.*, 1989; Seddoh *et al.*, 1996b). Furthermore, greater variability is generally associated with instability of the speech motor control system (DiSimoni, 1974a, b; Janssen & Wieneke, 1987; Kent & Forner, 1980; Smith, 1992b, 1994; Smith & Kenney, 1994; Tingley & Allen, 1975;

Wieneke & Janssen, 1987). In this regard, Ballard *et al.* (2000) state that greater variability presumably leads to more frequent off-target productions in subjects with AOS than in normal speakers. It has been argued by Folkins (1985), however, that increased variability might be indicative of compensation when perceptually accurate responses need to be achieved in the presence of an unstable motor control system. In this sense the variability reflects the compensation employed to achieve a perceptually accurate response. Seddoh *et al.* (1996a) suggested that greater than normal variability in the presence of on-target speech might be used as a prognostic indicator in that persons exhibiting large variability and good compensation may recover better than persons who do not compensate well and cannot achieve perceptually accurate speech in the presence of increased variability.

3.5.4 Conclusion regarding the study of temporal aspects of speech production in AOS and CA

From the above discussion regarding the study of temporal aspects of speech production, it is evident that results regarding the duration of various segments, syllables and intersegment durations differ between various studies. The reason for this could be due to different stimuli used (nonsense versus meaningful utterances or mono- versus multisyllabic words), method of elicitation of test stimuli and criteria used for inclusion of subjects (Strand & McNeil, 1996). Furthermore, it is important to mention that although many of the studies investigating temporal aspects of speech production in persons with neurogenic speech disorders generally included individuals with CA, other fluent aphasics were also occasionally included. Furthermore, the subjects with AOS which were included in these studies often had accompanying Broca’s aphasia, the severity of which could have contaminated results and conclusions about the nature of AOS. It is thus very important to clearly specify and control the criteria for inclusion of subjects who are to be representative of a specific speech or language disorder.

What is evident from the studies regarding temporal aspects of speech production in persons with either AOS or CA, however, is their potential to assist with the description of the speech characteristics in these groups of speakers. Furthermore, such studies can aid with differential diagnosis, determination of the underlying nature of the disorders (phonemic versus motoric) and provision of information regarding the nature of normal and pathological speech motor control.

3.6 CONTEXTUAL INFLUENCES ON SPEECH PRODUCTION IN APRAXIA OF SPEECH

As discussed in chapter 2, certain contextual factors have the potential to increase the processing demands to the speech production mechanism necessitating the implementation of more complex control strategies by the brain (Van der Merwe, 1997). A characteristic of the normal motor control system is its extreme flexibility in achieving perceptually accurate productions under circumstances of increased processing demand. However, persons with deficits regarding speech and language processing will be more susceptible to breakdown when contextual factors increase the processing demands, since they might not be able to successfully exert more complex control strategies. The influence of these increased processing demands might consequently impact on the temporal parameters of speech production, especially in persons exhibiting difficulty regarding temporal control even in "normal" speaking situations.

Ballard and Robin (2002), as well as Van der Merwe (1997) underscore the importance of studying the effect of an individual to adapt to various contextual factors. Ballard and Robin (2002) mention phonetic contexts of speech targets (phonemic environment), speech rate and the setting in which the speech task is presented, for example, a quiet versus a noisy environment as potential contextual factors which could exert and influence on speech production. In this regard, these researchers stated that "By systematically examining a variety of conditions, the clinician has the potential to unveil weaknesses in the system that are disguised through compensatory, but perhaps inflexible, motor-based strategies" (Ballard & Robin, 2002:287). It is important to recognize the various contextual influences, since the way in which they are manipulated in therapy can influence the patient's performance and treatment outcome. Some contexts might be more challenging for achievement of correct production and influence persons with different levels of breakdown in the speech production process differently.

In the following section, the study of specific contextual factors on speech production in AOS and CA will be reviewed. A specific contextual factor will presumably influence both speech and language processing, since it is difficult to separate linguistic and motoric aspects during speech production (Robin *et al.*, 1997). The contextual factors which will be discussed in the following section include, sound position in a word, frequency of occurrence of the sound in the specific language, meaningful compared to nonsense utterances, word length, distance of articulatory movement for the upcoming sound, grammatical class, utterance length, linguistic complexity, level of voluntary initiation of utterances and speaking rate. Some of the studies which will be discussed examined more than one of these contextual factors.

3.6.1 Sound position in a word

Some researchers have reported that more errors are made on initial than on final sounds (Shankweiler & Harris, 1966; Trost & Canter, 1974), while others did not find any difference regarding correct production depending on the position of the sound in the word (Dunlop & Marquardt, 1977; Johns & Darley, 1970; LaPointe & Johns, 1975). The finding that persons with AOS exhibit more difficulty regarding initial sounds could be related to the difficulty they have with initiation of speech production.

3.6.2 Frequency of occurrence

Trost and Canter (1974) found that the more frequent a sound occurs in a language, the easier it is to produce. This finding probably relates to the concept of automaticity, in that sounds or utterances that are produced more frequently become automatized and do not require conscious processing or control. Utterances which occur frequently are then also familiar and usually overlearned to a greater extent than infrequently occurring utterances (Van der Merwe, 1997, 2002). On the other hand, sounds or utterances which are used less often require more conscious processing during production. Conscious processing, in turn, utilizes more processing resources (Kent, 1990). Resource capacity might be more easily exceeded in persons with deficits regarding one or more of the stages of speech production, since more than normal resources are already required for allocation to the stages with which difficulty is experienced. The motor plan of speech sounds which are less familiar is also presumably less firmly established, making retrieval of the core motor plan and adaptation thereof to the phonetic environment, as well as the other operations involved in motor planning and/or programming of speech more difficult.

Greater difficulty might be particularly evident in persons with deficits regarding the motor planning and/or programming of speech. For persons with AOS who exhibit a deficit regarding the motor planning of speech (Van der Merwe, 1997), production of speech sounds which occur less frequently in a language will be less automatized and consequently motorically more difficult. Persons with PP might also exhibit deficits regarding production of less frequently occurring speech sounds, since these sounds might pose greater demands regarding phonological processing as well.

3.6.3 Meaningfulness of utterances

Johns and Darley (1970) found that their subjects with AOS produced more errors on repetition of nonsense words than on repetition of real words. Martin and Rigrodsky (1974a, b) and Martin *et al.* (1975) also found that persons with AOS made more errors on meaningless utterances than on utterances which are meaningful.

The meaningfulness of utterances can also be related to the concept of automaticity, as well as to the novelty of the response. Meaningful words are presumably more automatized, since they are used more often than nonsense words which are compiled for experimental purposes. In most cases experimental utterances have not been previously encountered or produced by the subjects in a particular study. Because meaningful words might be overlearned to great extent, they do not require conscious control and consequently do not necessitate more than normal resources. Unfamiliar or nonsense utterances presumably require more conscious processing and allocation of more attentional resources. As mentioned, resource capacity might be more easily exceeded in persons with AOS and those with PP, since more than normal resources are already required regarding the stages of speech production with which difficulty is experienced.

Furthermore, the motor plan for meaningful words is also presumably more firmly established, whereas the motor plan for novel/nonsense utterances has to be constructed anew. During production of nonsense utterances, persons with difficulty regarding motor planning, will thus experience more difficulty with the operations involved in motor planning, for example, adaptation of the core motor plan to the phonetic environment, since the motor plan for such utterances is novel and less automatized. It is suspected that nonsense utterances will also pose greater demands regarding phonological processing and consequently persons with PP would also presumably experience greater difficulty with their production.

3.6.4 Articulatory "distance"

Another factor which has been found to influence the accuracy of articulation is the distance which the articulators have to move from the production of one sound to the next. In this regard, it has been found that the further the distance of the articulation point from one sound to the next, the more likely an error is to occur (Wertz *et al.*, 1984). Since persons with AOS have difficulty with motor planning and consequently with accurate specification of the temporal and spatial parameters, together with difficulty adjusting the individual core motor plans to the phonetic environment (Van der Merwe, 1997), it can be assumed that the further the spatial targets which need to be reached are from each other, the more opportunity there is for breakdown to occur, since there is more "time" and "distance"/"space" in which the movements of the articulators need to be coordinated. Persons with AOS might be less skilled in specifying the spatial and temporal parameters of speech production in such a situation, resulting in inefficient or inaccurate movements, which will presumably result in sound distortion. Furthermore, it might also be more difficult to adapt the core motor plans of each phoneme to the phonetic environment when the place of articulation of the sounds is "further" from each other. Articulatory distance should presumably not negatively influence speech production of persons with linguistic level deficits.

3.6.5 Grammatical class

Many years ago attempts were made to determine the effect of specific linguistic variables on articulatory accuracy in AOS. Researchers attempted to determine if AOS contains intrinsic linguistic components as part of its underlying pathology or if it is influenced by semantic and syntactic factors. Hardison, Marquardt and Peterson (1977) suggested that investigation of linguistic aspects of the disorder would help resolve this issue. If language variables influence motor planning of speech, therapy aimed at improvement of articulatory accuracy need to consider these linguistic variables (Hardison *et al.*, 1977), together with motor learning principles when compiling treatment regimes.

An example of a linguistic factor which was studied is grammatical class. The influence of this variable on frequency of error productions in AOS has rendered inconsistent results. Deal and Darley (1972) reported that grammatical class alone did not exert an influence on errors, but that when it was combined with one or more other factors, namely, the difficulty of the initial phoneme (affricate, fricative or consonant cluster) or the length of the word, the errors increased.

In another study, Dunlop and Marquardt (1977) examined the effect of articulatory and linguistic variables on speech production by analyzing the errors of ten apraxic speakers on a single-word production task. These researchers wanted to determine the effect of grammatical word class (noun, verb or adjective), phoneme position and phoneme difficulty on errors in AOS, as well as the relationship between word abstraction and error production in these speakers. Dunlop and Marquardt (1977) found that the difficulty of the phoneme, but not the position of the phoneme in a word affected the errors of the apraxic speakers significantly. Furthermore, individual subjects were affected differently.

In the second part of their study, Dunlop and Marquardt (1977) attempted to determine the relationship between the abstraction level of a word in noun, verb and adjective grammatical categories and error production of these words in AOS. Nouns were graded as being the least abstract, followed by verbs and adjectives. These researchers found that a low, but significant positive correlation existed between apraxic error scores and single word abstraction ratings, although correlations for the grammatical classes decreased with increases in abstraction. These researchers concluded that language deficits might be associated with AOS and that "impaired motor speech programming may be affected by linguistic and articulatory variables" (Dunlop & Marquardt, 1977:29). The researchers themselves did, however, mention that their subjects might have had concomitant aphasia and that this could have influenced the results of their study. The need for additional studies of the phonemic and non-phonemic aspects of AOS and its relationship to other language processes was noted.

Hardison *et al.* (1977) studied the effect of selected linguistic variables on apraxic speech errors. These variables included word position (nouns in the beginning or end position in a sentence), word abstraction (concrete, abstract or nonsense) and sentence voice (active or passive). From the results of their study, these researchers concluded that the linguistic variables they investigated, significantly affected the ability of the apraxic speakers to program the movements for speech production. They concluded that "articulatory accuracy is at least influenced by semantic and syntactic factors", that AOS probably contains linguistic components as part of its pathogenesis and that speech motor planning is thus "part of an interlocking language system" (Hardison *et al.*, 1977:341).

It must be mentioned, however, that the subject selection criteria for the subjects in the study by Hardison *et al.* (1977), most probably resulted in the inclusion of persons with aphasia. Although subjects had to have had good auditory comprehension abilities, they had to exhibit a predominance of substitution errors and periods of error-free speech during spontaneous utterances. As was established in later years, apraxic speakers exhibit distortion as a predominant speech characteristic and phoneme substitution is primarily characteristic of certain types of aphasia (Odell *et al.*, 1991a, b).

It is quite possible that linguistic factors might impact on motor control processes, since language and motor processes presumably share processing resources (Strand & McNeil, 1996). In AOS, more complex linguistic structures might require more processing resources. The resource capacity of speakers with AOS might be more easily exceeded in the presence of difficulty with the motor processes of speech production, since more than normal resources might already need to be allocated to the deviant processes regarding speech motor control. Consequently erroneous production might result more easily in these speakers.

3.6.6 Length of utterance

It has generally been found that persons with AOS make more errors on multisyllabic words than on monosyllabic words (Johns & Darley, 1970; Shankweiler & Harris, 1966). Furthermore persons with AOS are known to experience more difficulty with the production of longer words (Kent & Rosenbek, 1983; McNeil *et al.*, 1997; Strand & McNeil, 1996). Since persons with AOS have difficulty with the motor planning of speech, it stands to reason that production of longer utterances would be more problematic since these utterances are also motorically more complex (Van der Merwe, 2002). Longer utterances increase the processing demands to the speech production mechanism, since more core motor plans need to be recalled, sequential organization of all the motor goals increases, the potential regarding coarticulation increases and IAS becomes more complex (Van der Merwe, 2002). Longer utterances will also presumably increase the demands regarding linguistic-symbolic planning, since more phonemes need to be selected and sequenced. Consequently persons with PP will also presumably experience greater difficulty regarding production of longer utterances.

3.6.7 Linguistic complexity

Strand and McNeil (1996) investigated the effects of increased utterance complexity and length on temporal parameters by means of acoustic analysis of utterances that vary in type. Vowel duration and two between-word segment durations were measured during production of three response types, namely, words, word-strings and sentences. Eight experimental conditions were employed, which included two length conditions for word-strings, three length conditions for words, and three length conditions for sentences.

The results of the study by Strand and McNeil (1996) indicated that the subjects with AOS consistently produced longer vowel and between-word segment durations in sentence contexts than in word contexts. For the subjects with AOS, intra- and inter-subject variability for between-word segments were also greater for sentences compared to word conditions. These researchers concluded that the differences which were found regarding duration and variability in sentence production versus word and word-string production imply "different mechanisms for executing motor programs for varying linguistic stimuli" (Strand & McNeil, 1996:1018). Furthermore, these researchers speculated that the reasons for linguistic factors influencing motor control could be due to the sharing of resources amongst language formulation and motor control processes. In other words, if difficulty regarding a specific level of the speech production process is present, an increase in processing demands caused by any contextual factor will presumably lead to breakdown regarding speech production in a specific subject, since resource capacity will be more easily exceeded in these circumstances.

3.6.8 Level of voluntary initiation of actions

It has been demonstrated that speakers with AOS are less prone to errors during automatic-reactive speech than during volitional-purposive speech (Darley, 1982). More automatic utterances, for example, reciting the days of the week or inserting comments, for example, "I can't say that" are presumably more automatized and overlearned. Consequently these motor plans can be retrieved and executed with a great degree of automaticity. Volitional-purposive speech requires conscious processing regarding language and/or motor processes and consequently more resources need to be allocated during execution of this task (Kent, 1990). The better performance of persons with AOS on more automatic speech tasks is contradictory to the dual-route theory proposed by Whiteside and Varley (1998) proposing an inability of persons with AOS to access the direct route successfully, since automatic utterances are presumably accessed via the direct route (Ballard *et al.*, 2001).

3.6.9 Speaking rate

The intensity and duration of activity in individual muscles changes with increases in speaking rate, although it is proposed that the relative timing of muscle activity remains constant (Kelso *et al.*, 1983). An increase in speaking rate necessitates that the temporal and spatial parameters of the core motor plan be adjusted and consequently it entails more than just an increase in the speed of firing of consecutive motor impulses. Speech rate can thus be seen as a context for speech production (Van der Merwe, 1986). The reason for employment of an increase in speaking rate in the study of speech motor control in persons with speech and/or language disorders, is the fact that it presumably increases the demands regarding speech and/or language processing. Consequently an increase in speaking rate has the potential to more readily reveal deficits in persons with difficulty regarding speech and/or language processing. Studying the effect of speech rate alterations on articulatory timing can tell us more about the motor disturbance in persons with neurogenic speech disorders, since an increase in speaking rate places higher demands on the speech production mechanism and consequently on speech motor control (Kent & McNeil, 1987; McNeil *et al.*, 1990a).

A few acoustic studies requiring rate adjustments have been performed and will be discussed briefly. Studies in which speech rate was utilized generally concluded that subjects with AOS have difficulty adjusting their speaking rate, especially when speaking rate has to be increased. This has been taken as evidence for a motor component underpinning the nature of the speech disorder in AOS (Kent & McNeil, 1987). CA subjects are generally more successful at increasing syllabic rate and this has led researchers to conclude that these subjects "retain a motoric flexibility that is lost in apraxia of speech" (Kent & McNeil, 1987:215). McNeil *et al.* (1997) recently reported that persons with AOS have difficulty increasing rate without compromising phonemic integrity, while persons with PP exhibit a variable ability to increase rate, but can maintain phonemic integrity.

Kent and McNeil (1987) performed an acoustic study to obtain information about segment and intersegment durations in normal speakers, persons with CA and persons with AOS. In order to cause phonetic-motoric alterations the subjects had to produce speech material at two different speaking rates, namely at a control and fast rate. It is assumed that producing the same material, using different speaking rates "provides a method for manipulating the phonetic level of speech production while theoretically, controlling the phonemic/linguistic level" (McNeil *et al.*, 1990a:136). Kent and McNeil (1987) were motivated by the hypothesis that patients with disorders at the phonetic or motor level of the speech production process would perform differently from normal subjects when rate is manipulated, whereas subjects who have phonological level impairments would maintain relative timing patterns similar to those of the normal subjects, despite changes in speaking rate.

Although it could be argued that an increase in speaking rate, could place higher demands on linguistic processing as well (Fossett *et al.,* 2001), researchers have generally excluded the presence of a phonological level deficit when timing deficits were observed in productions of an on-target response. In the presence of perceptually accurate speech, timing deficits are generally ascribed to a aberrant motor control (Kent & McNeil, 1987; McNeil *et al.*, 1990a). Kent & McNeil (1987) thus used rate manipulation to investigate the nature of the underlying pathology (phonetic versus phonemic level of impairment) in persons with neurogenic speech and language disorders.

Kent and McNeil (1987) reported that both the AOS and aphasic subjects had difficulty with rate manipulation. From this result, these researchers concluded that the difficulty these subjects had experienced with rate alterations seemed to imply a "motoric inflexibility" in these speakers. The subjects with CA were, however, more successful than those with AOS in increasing speaking rate and Kent and McNeil (1987:215) concluded that “in this respect the conduction aphasics seem to retain motoric flexibility that is lost in apraxia of speech”. It must be emphasized, however, that a degree of flexibility is still maintained in subjects with AOS and that inflexibility does not imply a complete inability. Kent and McNeil (1987) concluded that "the nature of the disordered process in both AOS and CA has phonetic and motoric components" and therefore used the term "phonetic-motoric" as a label for the impairment in AOS and CA (Kent & McNeil, 1987:211). This conclusion was also supported by the other motoric abnormalities which were observed in the CA and AOS subjects in their study, namely, abnormal VOT values, variability in formant trajectories and long pauses. These researchers stated, however, that their findings do not imply that AOS and CA are one and the same impairment.

McNeil *et al.* (1990a) performed a study with the main objective being replication of the study by Kent and McNeil (1987) in order to gain insight into "the nature of speech motor control" in persons with AOS and persons with CA. The same subjects as in the Kent and McNeil (1987) study participated in this study, but the two studies differed regarding test utterances and method of analyses. Rate was also manipulated in the study by McNeil *et al.* (1990a) and only on-target utterances were used for analysis. McNeil *et al.* (1990a) made the assumption that when on-target production was achieved and relative timing deviated from that of the normal group, the deviant timing could be attributed to difficulty regarding motor control.

The results of the study by McNeil *et al.* (1990a) indicated that both subjects with AOS and subjects with PP had trouble adjusting their speaking rates, especially when speaking rate had to be increased. The subjects with AOS experienced greater difficulty than the subjects with CA regarding rate adjustments, implying that additional motor control difficulties existed in the subjects with AOS. These results were taken as rendering support for the notion that both AOS and CA speakers exhibit motor control deficits, which possibly account for some of their speech production errors (McNeil *et al.*, 1990a). A study by Robin *et al.* (1989) also found that persons with AOS have difficulty adjusting speech rate for syllable- and sentence-level material, despite exhibiting normal velocity in the lower lip and intact coordination of the movement of the upper and lower lips.

It is important to remember that when speaking rate is increased, higher demands are also presumably placed on phonological planning, since the operations involved in this stage of the speech production process also need to be performed at a greater than normal speed. Kent and McNeil (1987:214) have argued, however, that difficulty regarding phonological planning might have “motoric consequences in the form of abnormal temporal patterns" and that separation of between motor realization and phonological representation might be invalid. This implies that disorders with different underlying impairments might be manifested in much the same way in the temporal parameters of speech production. If a perceptually on-target response is produced, however, one can conclude that the linguistic-symbolic stage of the speech production process was completed successfully, despite the increased demands induced by an increase in speaking rate. Deficits which are identified regarding the temporal parameters of speech production could thus presumably be attributed to difficulty at the level of motor planning and/or programming as defined in the four-level framework of speech sensorimotor control proposed by Van der Merwe (1997), since durational aspects are specified and adapted during these stages of the speech production process.

The studies by Kent and McNeil (1987) and McNeil *et al.* (1990a) demonstrate the use of rate manipulation to assess the proficiency of the speech motor systems of pathological speakers. It is thus evident that speaking rate can be viewed as a context for speech production exerting an influence on processing demands. These increased demands can result in susceptibility to breakdown in persons with difficulty regarding speech and/or language processing. Employment of changes in speaking rate consequently has the potential to reveal deficits regarding motor control in persons with neurogenic speech and/or language disorders.

3.6.10 Speech production in first versus second language in bilingual speakers with neurogenic speech and/or language disorders: A proposed context for speech production

It is not known what the effect of producing speech in L2 is on the motor planning of speech, but it is suspected that, speech production in L2 by a bilingual speaker might be a more demanding speaking context than speech production in L1 (Van der Merwe & Tesner, 2000). This might be especially true in persons who already have difficulty regarding speech and language processing. Speech production in L2 is hypothesized to increase the processing demands for two reasons. Firstly, L2 might contain sounds which are not part of the speaker's L1 repertoire, causing articulation of these sounds to be motorically more difficult. The reason for such sounds being motorically more difficult is the fact that the motor plans for these sounds have not been as firmly established as those of L1 sounds and consequently these plans are less automatized. Even if the sounds of L2 are contained in L1, the words in L2 are novel compared to L1 words and production of L2 words is consequently less automatized. Furthermore, other operations involved in the motor planning of speech, for example, adapting sounds to the phonetic environment will not be as automatized as in L1, since the combination of phonemes (sequencing of phonemes) in L2 words is different than in L1 (Van der Merwe & Tesner, 2000). Secondly, on a linguistic level of processing, message formulation in L2 might require more conscious processing, since the vocabulary and grammatical aspects of L2 are not as familiar to the bilingual speaker as those of L1. More conscious processing is thus required for accurate selection of words and formulation of grammatically correct sentences.

Speech production in L2 is thus presumably not as automated as speech production in L1 in the bilingual speaker, regarding both linguistic and motor processing, necessitating more conscious processing regarding both these processes (Van der Merwe & Tesner, 2000). More conscious processing consequently requires allocation of more attentional resources. From this perspective, speech production in L2 might be more demanding for persons with deficits regarding motor planning and/or programming, as well as for those with deficits regarding linguistic-symbolic planning, since more than normal resources already need to be allocated to these disrupted processes. Resources might consequently be more easily exceeded when the processing demands are increased in persons with neurogenic speech and language disorders. The result of these increased demands regarding motor and linguistic processing might be visible on a motor execution level in the spatial and temporal parameters of speech production. Speech production in L2 might thus have consequences for the motor control of speech (Klein *et al.*, 1995; Van der Merwe & Tesner, 2000).

The source of speech errors in neurogenic speech and language disorders, such as, AOS and PP is either ascribed to the phonologic or motoric level of the speech production process. When speech and language processing demands increase, speakers with speech or language disorders will be more susceptible to breakdown regarding their speech production. In order to learn more about the underlying nature of the disorder in AOS and to contrast this disorder with PP, it is necessary to determine the influence of various contextual factors on speech production in these groups of speakers. If persons with AOS find production of a phonetically similar utterance in L2 more difficult than in L1 compared to normal speakers, it can be concluded that language as a context for speech production exerts an influence on the motor control of speech. The language of the speaker could consequently then be seen as a context influencing motor performance. Due to the frequency of bilingualism in AOS, a systematic study of the effect of L1 versus L2 speech production in persons with AOS is imperative.

Although bilingualism in aphasics has been widely studied, bilingualism in motor speech disorders, such as, AOS, has not received attention, apart from a study by Van der Merwe and Tesner (2000) who examined perceptual characteristics in a bilingual speaker with AOS and the effect of non-language specific treatment on perceptual errors in L1 (Afrikaans) and L2 (English) in this speaker. In this regard Van der Merwe and Tesner (2000:87) stated “Bilingual apraxia of speech seems to be a reality as much as bilingual aphasia. To the disadvantage of clients with AOS, this issue was ignored for much too long”.

3.6.11 Conclusion regarding contextual influences on speech production in neurogenic speech and/or language disorders

As is evident from the above discussion, certain contextual factors can increase the processing demands imposed on the speech production mechanism. In other words, speech production in certain contexts appears to be more challenging to the speech production mechanism than in others. The processing demands are increased by the fact that the contextual factors impact on one or more levels of speech and language processing. This impact, in turn, increases the task complexity, making persons with difficulty regarding one or more of the stages of the speech production process more susceptible to breakdown. The increased processing demand which the various contextual factors impose can mostly be related to the concept of automaticity, the novelty of the response and/or motor complexity of production. These factors, in turn, increase the task complexity and susceptibility to breakdown.

Another explanation for the susceptibility to breakdown occurring in persons with neurogenic speech and language disorders relates to allocation of attentional resources. Ballard *et al.* (2000:983) state it is necessary to "conceptualize AOS as a disorder of motor control that also may have an impact on the availability and allocation of attentional resources for performing and adapting actions". It has been proposed that persons with neurogenic speech and language disorders, specifically AOS and CA, might have difficulty regarding availability and allocation of attentional resources (Clark & Robin, 1998; Kent & McNeil, 1987; Rogers & Storkel, 1999). Consequently difficulty with speech production is experienced when greater demands are placed on the speech production mechanism, since resource capacity is more easily exceeded in these circumstances in persons with difficulty regarding one or more of the stages of the speech production process. The reason for exceeding of resources is the fact that more than normal resources already need to be allocated to the levels of the speech production process where difficulty is experienced.

Normal speakers presumably exhibit greater flexibility regarding adaptation to more demanding speaking contexts. Consequently normal speakers will not experience problems with on-target production when the demands of the speaking context increase with, for example, an increase in speaking rate. The speech production system of a normal speaker can thus probably be "loaded" to a greater extent than that of a person with a compromised speech production mechanism. This is evident from the flexibility these speakers display by the achievement of on-target speech in, for example, mechanical perturbation circumstances (Smith, 1992a), when producing linguistically more difficult utterances (Strand & McNeil, 1996) or when speaking at a faster than normal rate (Ostry & Munhall, 1985).

Different tasks or contextual factors impose different processing loads (McNeil *et al.*, 1991a). It should be interesting to see which contextual factors lead to breakdown in persons with deficits at different levels of the speech production process. Persons with breakdown at different levels of the speech production process might react differently when greater demands are placed on the speech production mechanism by various contexts. Examining the nature of the breakdown and determining which contexts are more difficult to adjust to for persons with specific speech and language disorders, has the potential to shed light on the underlying nature of these disorders.

The present study aims to determine the effect of speech production in L1 versus L2 as a context for speech production on specific temporal parameters of speech in persons with AOS as measured in the acoustic signal using spectrographic analysis. Persons with a preponderance of PP in their speech will also be included in the study, since their level of breakdown is presumed to be regarding linguistic-symbolic planning (Van der Merwe, 1997), which is distinct from the level of breakdown in persons with AOS. Inclusion of persons with PP thus allows for contrasting of results and for clearer delineation of AOS. To further increase the processing demands in both languages, a faster than normal speaking rate will also be employed, since this might reveal difficulty with speech production in L2 more readily.

3.7 CONCLUSION

Various theories, frameworks and models have been proposed to clarify and explain the underlying nature and observed phenomena in AOS. These theories, frameworks and models have led to many research studies attempting to define AOS and describe its salient characteristics. Since persons with AOS are generally described as exhibiting difficulty with temporal control, temporal parameters of speech production are often investigated in an attempt to elucidate the nature of the disorder and to contrast it with other neurogenic speech and language disorders with which it shares common characteristics. Various contextual influences have been identified to exert an influence on the processing demands imposed on the speech production mechanism (Van der Merwe, 1997). These contextual factors impact on the parameters of speech production and need to be studied to learn more about the contextual factors which subject persons with AOS to erroneous production. The effect of L1 versus L2 as a context for speech production has not been investigated in AOS. The need for determination of the influence of L1 versus L2 production becomes evident when one considers the number of bilingual speakers with AOS.

3.8 SUMMARY OF CHAPTER THREE

In this chapter, AOS and the speech disorder in persons with predominant PP were defined. Models, theories and frameworks which have been proposed to explain the underlying nature of AOS were reviewed. From this review it became evident that the context of speech production can influence the achievement of perceptually on-target speech. Studies investigating specific parameters of articulatory timing in AOS and CA, namely interarticulatory timing (VOT) and duration, as well as studies on variability were reviewed. Thereafter the influence of various contextual factors on speech production in AOS and PP was discussed. From the discussion, it became evident that there is a need for the study of the effect of L1 versus L2 on specific temporal parameters of speech production in AOS and PP in order to learn more about the underlying nature of these disorders, for determination of qualitative differences between them and to obtain information about normal and pathological speech motor control.

CHAPTER FOUR
RESEARCH METHODOLOGY

CHAPTER FOUR

RESEARCH METHODOLOGY

4.1 INTRODUCTION

The review of the literature, presented in chapters one, two and three, examined speech as the manifestation of language, the influence of various contextual factors on speech and language processing and the nature of these processes in AOS and PP. From this review it became evident that certain contextual factors increase the processing demands on the speech production mechanism. It was suggested that the influence of these increased processing demands could possibly be manifested in the temporal parameters of speech production in persons with AOS, since these speakers exhibit difficulty regarding temporal control.

A systematic study of the influence of speech production in L1 versus L2, on specific temporal parameters of speech production in bilingual speakers with AOS, has not been undertaken. The study of the influence of speech production in L1 versus L2 on the temporal parameters of speech in bilingual persons with AOS has the potential to reveal more about the underlying nature of this disorder, as well as provide information regarding motor control in L2 compared to L1. These findings will have important implications for the assessment and treatment of bilingual speakers with AOS. Inclusion of persons with PP who are believed to exhibit a deficit at a distinct level of the speech production process compared to AOS, will allow for contrasting of performance and for further clarification of the nature of AOS.

The purpose of chapter four is to present the research methodology of the present study. This chapter entails a description and discussion of the research aims, subject selection criteria and procedures, measurement instruments, speech material, research design, data collection procedure and finally the data analysis and processing procedures used in this study.

4.2 RESEARCH AIMS

4.2.1 Main aim

The main aim of this study was to determine the effect of L1 versus L2 speech production on specific temporal parameters in the speech of bilingual normal speakers and bilingual speakers with neurogenic communication disorders, specifically subjects with either AOS or PP.

4.2.2 Sub-aims

In order to realize the main aim of the study, three sub-aims were formulated. The sub-aims with the rationale for their formulation are displayed in Table 4.1.

4.2.2.1 Sub-aim one

To determine the *extent of durational adjustment* for each temporal parameter (vowel duration, utterance duration, utterance onset duration and VOT) in the fast speaking rate (FR) compared to the normal speaking rate (NR) in L1 and L2 respectively, for each subject individually and for the normal subjects, both individually and as a group (normal group), for each target utterance and for utterances as a group (utterances beginning with a voiceless plosive, utterances beginning with a voiced plosive and utterances beginning with a voiceless fricative).

4.2.2.2 Sub-aim two

To determine in which one of the four contexts, each subject with either AOS or PP differed most from the normal group, regarding the duration of each temporal parameter examined for each target utterance and for each of the three utterance groups. The four contexts were speech production in L1 at a normal speaking rate (L1NR), speech production in L1 at a fast speaking rate (L1FR), speech production in L2 at a normal speaking rate (L2NR) and speech production in L2 at a fast speaking rate (L2FR).

4.2.2.3 Sub-aim three

To determine in which one of the four contexts (L1NR, L1FR, L2NR and L2FR), variability was the greatest for each subject in each subject group and for the normal speakers as a group, for each parameter and target utterance measured.

4.3 SUBJECTS

Normal speakers (N), as well as persons with AOS and persons with aphasia with predominant PPs were included in the study. The normal speakers as a group will be referred to as the normal group, whereas the subjects with either AOS or PP will also be referred to as the experimental subjects.

4.3.1 Criteria for subject selection

The criteria for subject selection in each of the three diagnostic subject categories are as follows:

4.3.1.1 General criteria for all subject groups

All of the subjects in each of the three groups had to comply with the following criteria:

- **Language and level of bilingualism**

All subjects had to be native Afrikaans speakers, who had attended Afrikaans primary and high schools. English had to have been introduced only at school as L2 and not spoken as a home language during any time of their upbringing and school career. All speakers thus had to have the same level of bilingualism regarding Afrikaans and English to ensure that English was indeed their L2. This type of bilingualism, where one language is acquired after the other, is known as coordinative bilingualism (Romaine, 1995).

Table 4.1 Sub-aims and rationales for their inclusion

Sub-aim	Rationale
Sub-aim one: Determination of the extent of durational adjustment in the FR compared to the NR in L1 and L2 respectively, for each temporal parameter of each utterance and utterance group.	When speaking rate is increased, the duration of temporal parameters generally decrease. Durational adjustment refers to the adjustment made to the duration of a specific temporal parameter in the FR compared to the NR. It was predicted that a greater durational adjustment, in other words, a decrease of duration with an increase in rate, would be achieved in the language that was more automatized and produced with greater ease. A smaller durational adjustment in the FR would thus presumably be achieved in the language which is more difficult for the speaker to produce. It was predicted that L1 is more automatized and presumably an easier context for speech production in the presence of increased demands imposed by an increase in speaking rate. It was thus predicted that a smaller durational adjustment would be achieved in L2 compared to L1, if L2 were more difficult to produce.
Sub-aim two: Determination of the context in which each experimental subject differed most from the normal group regarding each temporal parameter of each utterance and utterance group.	It was predicted that the experimental subjects would differ from the normal group regarding mean durations of the measured temporal parameters. Differences between the normal group and experimental subjects might become more apparent in contexts where the processing demands are higher and the experimental subjects are more susceptible to breakdown. The L2FR was predicted to be the most demanding context, since speaking at a faster than normal rate increases the demands on the speech production mechanism. Furthermore, L2 was predicted to be less automatized than L1 and could therefore be more difficult to produce. These two contexts in combination (L2 and FR) might consequently possibly result in the experimental subjects being more susceptible to breakdown.
Sub-aim three: Determination of the context where variability was generally the greatest for each subject regarding each temporal parameter of each individual utterance.	Greater variability is possibly indicative of a more unstable motor system (Seddoh *et al.*, 1996). If a specific context induced greater variability regarding the temporal parameters measured, one could conclude that the speech motor system was not as consistent and precise during production in the particular context. The prediction was that contexts with heightened processing demands would be more challenging, impose a greater processing load and consequently lead to greater instability of the speech production mechanism. It was predicted that normal speakers would possibly not exhibit instability during repeated production of an utterance when processing demands are increased. However, the result of the increased processing demands would possibly become apparent in the speech of persons with neurogenic speech and/or language disorders as measured in the temporal parameters of the acoustic signal, since these persons might be more susceptible to inaccurate speech production under circumstances of increased processing demand.

- **Reading competence**

The subjects' reading competence had to enable them to read the target utterances from cards.

4.3.1.2 Criteria for inclusion in the normal group

- Subjects with normal speech and language abilities comprised the *normal group*, which served as a *comparison group* in the present study.
- Subjects were age and gender matched with the subjects in the AOS and PP groups.
- The subjects had to be without any history of speech, language, cognitive or neurological impairment. As in the study by Strand & McNeil (1996), subjects were excluded if they reported a history of speech or language deficits, neurologic injury or disease and/or previous use of neuroleptic drugs.
- The normal subjects further had to exhibit normal speech and language skills as judged perceptually by two speech-language pathologists, each with over ten years of clinical experience.

4.3.1.3 Criteria for inclusion in the apraxia of speech group

The subjects included in this group had to comply with specific criteria which are used in the diagnosis of AOS. Many of these criteria have also been used in previous studies to identify persons with AOS. The criteria used for inclusion in the AOS group were as follows:

- Subjects had to have a single left-hemisphere lesion as determined by neuroradiologic studies (Clark & Robin, 1998; Seddoh *et al*., 1996b; Strand & McNeil, 1996).
- Subjects had to be diagnosed with AOS by means of perceptual judgement by two speech-language pathologists with over ten years of clinical experience in the assessment and diagnosis of neurogenic speech and language disorders (Seddoh *et al*., 1996b; Strand & McNeil, 1996). Speech characteristics had to include the following:
    - The presence of effortful trial-and-error groping of the articulators (Kent & Rosenbek, 1983; Strand & McNeil, 1996)
    - Dysprosody (Kent & Rosenbek, 1983; McNeil *et al*., 1997; Strand & McNeil,

1996)

- Difficulty with initiation of speech movements (Kent & Rosenbek, 1983; Strand & McNeil, 1996)
- Errors of phoneme distortion (McNeil *et al.*, 1997; Strand & McNeil, 1996), including "distorted perseverative, anticipatory and exchange phoneme or phoneme cluster errors" (McNeil *et al.*, 1997:327)
- Slowed speaking rate (McNeil *et al.*, 1997)

- Subjects had to exhibit minimal accompanying aphasia to ensure pure AOS to the greatest extent possible. In order to ascertain the presence of minimal accompanying aphasia, subjects had to exhibit near normal scores on the Western Aphasia Battery (WAB) (Kertesz, 1982).

Two of the exclusionary criteria used in the study by Strand and McNeil (1996) were included for the subjects with AOS in the present study. These include the following:

- Absence of weakness or incoordination of the speech musculature when used for reflexive or automatic acts, to exclude the presence of dysarthria as the cause of deviant speech production. The absence of the aforementioned was judged by two speech-language pathologists with more than ten years of clinical experience in the assessment and diagnosis of neurogenic speech and language disorders.
- If subjects had a history of any cognitive, language, or motor deficits before the left-hemisphere lesion, they were excluded from the study.

4.3.1.4 Criteria for inclusion in the phonemic paraphasic group

- The subjects included in this group had to be without evidence of AOS or dysarthria as defined in 4.3.1.3 and judged by the two speech-language pathologists.
- The subjects had to exhibit the presence of undistorted sound substitutions, which include "perseverative, anticipatory and phoneme exchange or phone cluster errors" (McNeil *et al.*, 1997:327).
- Subjects had to exhibit near normal speech rate when producing "on-target" phrases

and sentences (McNeil *et al*., 1997).

- A preponderance of phonemic errors often occurs in subjects with CA (Goodglass & Kaplan, 1972), but since persons with other types of aphasia can also exhibit PPs, the selected subjects with PP were not required to display a specific type of aphasia, as long as they complied with the other inclusion criteria for the phonemic paraphasic group. The Western Aphasia Battery (WAB) (Kertesz, 1982) was administered to each subject, however, to determine the type and degree of aphasia.

4.3.2 Procedure for subject selection

Before a subject was selected for the study, a battery of tests was administered to determine if each subject met the inclusion criteria for one of the three groups, namely AOS, PP or normal group. The WAB (Kertesz, 1982) was administered in both English and Afrikaans to determine the classification of aphasia in each language. The reason for this is that different languages might be affected differently after damage to the language areas of the brain (Paradis, 1995a).

4.3.3 Description of selected subjects

Five subjects with normal speech (N1, N2, N3, N4 and N5) who met the inclusion criteria were selected to serve as a normal group in the study. Three persons with AOS (AOS1, AOS2 and AOS3) and three persons with aphasia with a preponderance of PPs (PP1, PP2 and PP3) met the inclusion criteria and served as experimental subjects in this study. A summary of the biographical data of the selected subjects, together with the scores each subject obtained on the WAB (Kertesz, 1982) appear in Table 4.2.

From Table 4.2 it is evident that AOS2 and AOS3 obtained high scores for fluency on the WAB (Kertesz, 1982). Each of these subjects had received intensive therapy for two years after their cerebrovascular accidents. However, despite their fairly fluent speech, these subjects still displayed the required speech characteristics for inclusion in the AOS group, namely, sound distortions, effortful trial-and-error groping, especially on longer words, occasional difficulty with the initiation of utterances and dysprosody. Since the subjects with

Table 4.2 Summary of biographical and descriptive data for the normal, apraxia of speech and phonemic paraphasic subjects

	Subjects	**N1**	**N2**	**N3**	**N4**	**N5**	**AOS1**	**AOS2**	**AOS3**	**PP1**	**PP2**	**PP3**
	Gender	F	F	F	M	M	M	F	F	M	F	M
	Age (years)	43	59	87	63	74	59	68	43	64	85	74
	Time since cerebrovascular accident						8years	2 years	3 years	8 months	2 years	2 years
WAB scores (Afrikaans)	Fluency						5/10	9/10	9/10	6/10	8/10	9/10
	Information						9/10	10/10	10/10	9/10	7/10	10/10
	Auditory comprehension						200/200	200/200	200/200	161/200	181/200	189/200
	Repetition						82/100	88/100	92/100	38/100	91/100	62/100
	Naming						90/100	89/100	88/100	51/100	75/100	93/100
	Aphasia Quotient						82	93	94	64	81	88
	Classification according to the WAB (Kertesz, 1982)						mild anomic aphasia	mild anomic aphasia	mild anomic aphasia	mild conduction aphasia	mild anomic aphasia	mild conduction aphasia
WAB scores (English)	Fluency						4/10	9/10	9/10	not tested	8/10	9/10
	Information						8/10	10/10	10/10	not tested	7/10	10/10
	Auditory comprehension						200/200	197/200	200/200	not tested	178/200	162/200
	Repetition						77/100	74/100	94/100	not tested	91/100	58/100
	Naming						58/100	72/100	87/100	not tested	61/100	73/100
	Aphasia Quotient						71	87	94	not tested	78	80
	Classification according to the WAB (Kertesz, 1982)						mild Broca's aphasia	mild anomic aphasia	mild anomic aphasia	not tested	moderate anomic aphasia	mild conduction aphasia

AOS exhibited speech difficulties, they could not obtain perfect scores on the expressive subtests of the WAB (Kertesz, 1982) and consequently it is inevitable that they would be classified as a specific type of aphasia using a test for aphasia. It is evident from their aphasia quotients, however, that the subjects with AOS exhibited very mild aphasia. The speech errors of these subjects on the expressive subtests of the WAB (Kertesz, 1982) were thus due to their AOS and not a result of aphasic deficits.

From Table 4.2 it is also evident that the WAB (Kertesz, 1982) was only administered in Afrikaans to subject PP1. The reason for this was that this subject fell ill and further testing was not possible.

4.4 ETHICAL ISSUES

Each subject had to give verbal consent to allow participation in the study. A letter was compiled in which the procedure for data recording and assessment was explained. It was furthermore, explained that a subject could withdraw from the study at any time and that their identity would be kept anonymous. Each potential subject also had to give permission that the recorded data could be used for research purposes. The information in the letter was conveyed verbally to each potential subject. The letter of consent is included in Appendix A.

4.5 RESEARCH DESIGN

Leedy (1993:139) states "The nature of the data and the problem for research dictate the research methodology. If the data is verbal the methodology is qualitative, if it is numerical the methodology is quantitative". In the present study, quantitative data were obtained by measuring durational values from the acoustic speech signal.

A quasi-experimental multi-factorial design (Silverman, 1993) with three groups (normal speakers, persons with AOS and persons with PP) and repeated measurements (five repetitions of each utterance) on a number of dependant variables was used. The dependant variables were a series of acoustic measures, namely VOT, vowel duration (VD), utterance duration (UD) and utterance onset duration (UOD). Within each group, two independent variables were manipulated, namely, speech rate (normal and fast speaking rate) and language (Afrikaans, L1 and English, L2). The effect of these two independent variables rendered four experimental factors, Afrikaans normal speaking rate (L1NR), Afrikaans fast speaking rate (L1FR), English normal speaking rate (L2NR) and English fast speaking rate (L2FR).

The effect of these four contexts on the abovementioned acoustic temporal parameters of speech in each group was observed. The reader is referred to Figure 4.1 for a schematic presentation of the methodology.

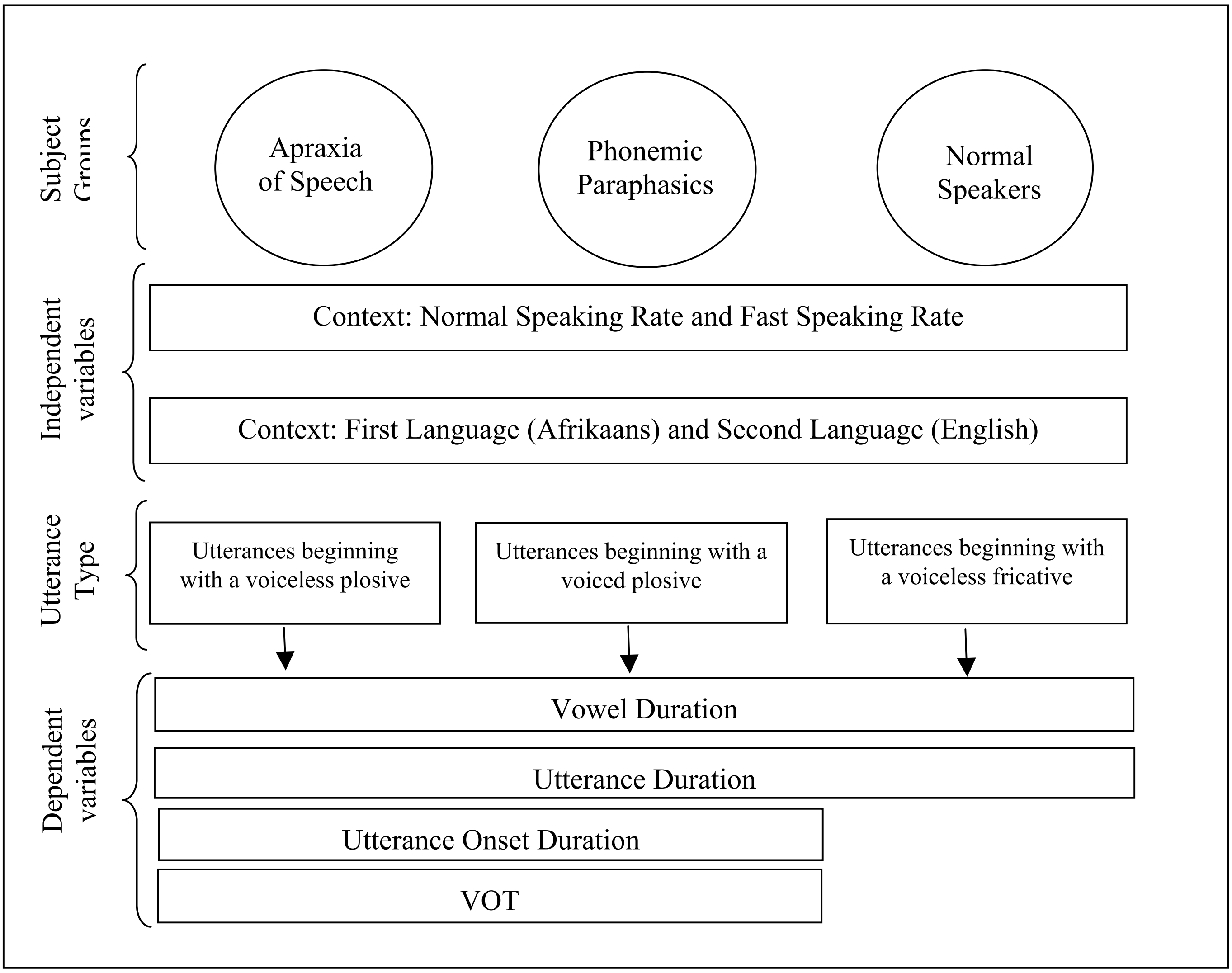

Figure 4.1 Schematic presentation of the methodology of the study

4.6 MEASUREMENT INSTRUMENTS

For data recording a unidirectional FOSTEX M-2 microphone was placed about fifteen centimeters from the subject's mouth and the signal was recorded on a TDK Brilliant B Type I Cassette, using a Marantz Stereo Cassette Recorder CP430. The recorded signal was acoustically analyzed using a software program, Computerized Speech Laboratory 50 (CSL50), Version 5.X (Kay Elemetric Corporation, 1994), in conjunction with the Computerized Speech Laboratory (CSL) 4300B analyzer. The CSL is a digital signal processor, which provides a graphic display of the waveform.

4.7 SPEECH MATERIAL

Utterances that are structurally (consonant-vowel-consonant) and phonetically (as determined by broad phonetic transcription) similar in Afrikaans and English, were used as speech stimuli. Each L1 utterance had a counterpart in L2 which was nearly phonetically identical, as transcribed using broad phonetic transcription. However, the semantic meaning of the sets of utterances differed between languages in some of the utterances. The fact that the meaning of the utterances in L1 and L2 differed should not have influenced the results, since only the *motor/phonetic demand* of the utterances had to be the same. Furthermore, it was more important that the words in each language had to be meaningful, as opposed to meaningless (nonsensical). All the target words were common nouns, ensuring that word class was also the same in each language. The assumption was made that if the utterances were phonetically similar, the *motor demand* posed by production of the utterance, would be the same for L1 and L2 respectively.

English and Afrikaans lend themselves to the current type of study, since these two languages share several words which are phonetically and even semantically, similar. In South Africa, native speakers of Afrikaans who attend schools where the medium of instruction is Afrikaans, are introduced to English as L2 from their first year at elementary school. In

South Africa, a pupil is enrolled in elementary school between the ages of six to seven years. South Africa is a country where both Afrikaans and English, amongst others, are official languages and consequently most persons have a fair command of both these languages. The utterances, which were selected to serve as stimuli in the present study, are presented in Table 4.3.

Table 4.3 Speech stimuli used in the study

	Utterance	Phonetic transcription	Language	Translated meaning
Utterances beginning with a voiceless plosive	Dis ’n pet.	/d↔s↔ pεt/	Afrikaans	It’s a cap.
	It’s a pet.	/ɪts↔ pεt/	English	
	Dis ’n pad.	/d↔s↔ pat/	Afrikaans	It’s a road.
	It’s a putt.	/ɪts↔ p↵t/	English	
	Dis ’n pak.	/d↔s↔ pak/	Afrikaans	It’s a suit/packet.
	It’s a puck.	/ɪts↔ p↵k/	English	
	Dis ’n pap.	/d↔s↔ pap/	Afrikaans	It’s a porridge.
	It’s a pup.	/ɪts↔ p↵p/	English	
	Dis ’n pit.	/d↔s↔ p↔t/	Afrikaans	It’s a pit.
	It’s a pit.	/ɪts↔ pɪt/	English	
Utterances beginning with a voiced plosive	Dis ’n bak.	/d↔s↔ bak/	Afrikaans	It’s a bowl.
	It’s a buck.	/ɪts↔ b↵k/	English	
	Dis ’n bas.	/d↔s↔ bas/	Afrikaans	It’s a bark.
	It’s a bus.	/ɪts↔ b↵s/	English	
	Dis ’n bed.	/d↔s↔ bεt/	Afrikaans	It’s a bed.
	It’s a bet.	/ɪts↔ bεt/	English	
	Dis ’n byt.	/d↔s↔ b↔it/	Afrikaans	It’s a bite.
	It’s a bait.	/ɪts↔ b↔ɪt/	English	
	Dis ’n bek.	/d↔s↔ bæk/	Afrikaans	It’s a mouth.
	It’s a back.	/ɪts↔ bæk/	English	
Utterances beginning with a voiceless fricative	Dis ’n voet.	/d↔s↔ fut/	Afrikaans	It’s a foot.
	It’s a foot.	/ɪts↔ fʏt/	English	
	Dis ’n feit.	/d↔s↔ f↔it/	Afrikaans	It’s a fact.
	It’s a fête.	/ɪts↔ f↔ɪt/	English	
	Dis ’n vas.	/d↔s↔ fas/	Afrikaans	It’s a fast
	It’s a fuss.	/ɪts↔ f↵s/	English	
	Dis ’n set.	/d↔s↔ sεt/	Afrikaans	It’s a set.
	It’s a set.	/ɪts↔ sεt/	English	

Although the target words which were selected for use in the study were phonetically similar in English and Afrikaans, they were not identical owing to, for example, aspiration of English plosives and subtle vowel differences. Sometimes a qualitative difference existed between the vowel of L1 and L2. However, the place of articulation of the two vowels in each language was not significantly different to make production of one more challenging than production of the other. Qualitative differences existed, for example, between the "u"-sounds in English and Afrikaans words. For example, the word "fuss" in English is transcribed as /φ↵σ/, whereas "vas" in Afrikaans is transcribed as /φασ/. The selected vowels were the counterpart of each other in each language. Because of these subtle differences, direct comparison between the absolute durations and measurements obtained for L1 and L2 would not have been reliable. Productions of speakers were thus compared within each language, across the two speaking rates and results of the experimental subjects were compared to those of the normal group for each language and rate condition separately. Furthermore, relative measures of duration were used. This aspect will be discussed in more detail under data processing in 4.11.

Five of the selected target words each began with a voiceless plosive and five with a voiced plosive to enable measurement of VOT. Voice onset time has been shown to be deviant in persons with AOS and occasionally in certain types of aphasia (Blumstein *et al*., 1980; Freeman *et al*., 1978; Gandour & Dardarananda, 1984; Itoh *et al*., 1982; Kent & Rosenbek, 1983). VOT is also viewed as a good indicator of temporal coordination of the larynx and oral articulators (Blumstein *et al*., 1977, 1980; Gandour & Dardarananda, 1984; Itoh *et al*., 1982; Lisker & Abramson, 1964).

Four target words each beginning with a voiceless fricative were also included, since production of fricatives has been shown to be deviant in persons with AOS (Baum *et al*., 1990; Code & Ball, 1982). Furthermore, voiceless fricatives render a clear spectrographic display for easy analysis of the temporal parameters which were included in the present study.

All target words consisted of the structure consonant-vowel-consonant (CVC) and were embedded in a carrier phrase, namely, "It's a ___" (/its↔ ___/) in English and "Dis 'n ____" (/d↔s↔ ___/) in Afrikaans. It was attempted to keep the two carrier phrases phonetically similar, but this was not entirely possible. The meaning of the two carrier phrases was the same, however, in both languages, although there were phonetic differences. To minimize the potential effects of coarticulation, utterances in both languages were preceded by the neutral schwa vowel, /↔/. The two sounds preceding the target word were the same for both languages, namely /s↔/. The preceding sounds should thus not have influenced production of the target word due to coarticulatory effects. The structure of the Afrikaans carrier phrase was consonant-vowel-consonant-vowel and that of the English carrier phrase was vowel-consonant-consonant-vowel.

4.8 DATA COLLECTION PROCEDURES

Before commencing with the recording of the experimental data, each of the target utterances was presented both verbally and in written format by the researcher and repeated by the subject to ensure that, under ideal conditions, correct production of the target utterances was possible. The subjects were allowed to take breaks during the data recording session, as needed.

All recordings were conducted in a soundproof booth to ensure that environmental noise did not interfere with the recorded speech signal. For recording of the speech signal, subjects were comfortably seated in front of a microphone, which was fixed to a microphone stand, approximately fifteen centimetres from the subject's mouth. The researcher was seated facing the subject. The researcher continuously monitored the input volume of the VU-meter of the cassette recorder to ensure that overload of the input signal did not occur.

The subjects were instructed to read each utterance presented by the researcher. The target utterances were printed on cards (17cm x 7 cm) using New Times Roman bold font, size 52. Each of the stimuli was presented five times in random order. The Afrikaans utterances were recorded first using Afrikaans instructions. After this, the English utterances were recorded after instructions had been given to the subjects in English. English instructions were used when recording English utterances in an attempt to prompt the subject to "think in English".

The data collection procedure for each language involved two different tasks, namely, reading utterances at a normal and a fast speaking rate. The utterances produced at a normal speaking rate were recorded first, whereafter those that had to be produced at a fast speaking rate were recorded. During the normal rate condition, the subjects were instructed to read each utterance at a normal, comfortable speaking rate. During the fast rate condition the subjects were instructed to read each utterance as fast as possible without compromising speech intelligibility. Each speaking rate was demonstrated by the researcher before collection of the data for the specific rate condition commenced. The subjects were allowed time to practise repetition of the utterances at a specific rate. During the fast speaking rate, subjects were encouraged throughout the recording to say the utterance as fast as possible.

4.9 DATA ANALYSIS

The recorded signal was acoustically analyzed using a software program, CSL50 (Version 5.X) (Kay Elemetric Corporation, 1994), in conjunction with the Computerized Speech Laboratory (CSL) 4300B analyzer. The analysis program enables the listener to listen repeatedly to parts of the recorded speech signal and to make temporal measurements by means of its digital memory and the use of time cursors. It further provides a simultaneous display of the acoustic waveform and spectrogram of the speech signal, which allows for comparison and consequently more reliable measurement. Acoustic measurements were performed using a dual display of sound wave energy and a wideband spectrogram (bandwidth = 375 Hz, frequency range 0-8000 Hz). From the displayed spectrogram, durational measurements were made for the four dependent variables (VD, UD, UOD and VOT) by placing adjustable time cursors at the beginning and end points of each defined area. The specific measurement procedures which were applied will be discussed in more depth further on in this chapter.

The five trials of each utterance (when five on-target productions were available) were used for data analysis. Only on-target productions were analysed since it would otherwise be difficult to determine if differences between normal and experimental subjects were the result of their specific speech or language impairments or rather related to differences regarding the phonetic nature of an off-target and an on-target response.

4.9.1 Acoustic analysis to determine vowel duration

Vowel duration was measured in the same way for all three utterance groups that is utterances beginning with a voiced plosive, a voiceless plosive or a voiceless fricative. A combination of the waveform and spectrographic display was used for measurement of VD. The first time cursor was placed at the beginning of the vowel. The beginning of the vowel was determined by the beginning of periodicity on the waveform and the spectrographic display and/or the beginning of significant formant energy on the spectrogram, where the first and second formants, as well as voicing, were clearly visible. A second time cursor was placed at the end of the vowel, which was characterized by the end of formants and periodic energy. The time difference in milliseconds between these two cursors was recorded as the VD. In instances where voicing had ceased, even though the second formant was still clearly visible, the end of the vowel was measured at the end of the second formant. The waveform display of the signal was also used as a guide when the end of the vowel was not always clearly visible on the spectrographic display. The end of the vowel was characterized by the cessation of clear periodicity on the waveform. Measurement of VD in an utterance beginning with a voiceless plosive is illustrated in Figure 4.2.

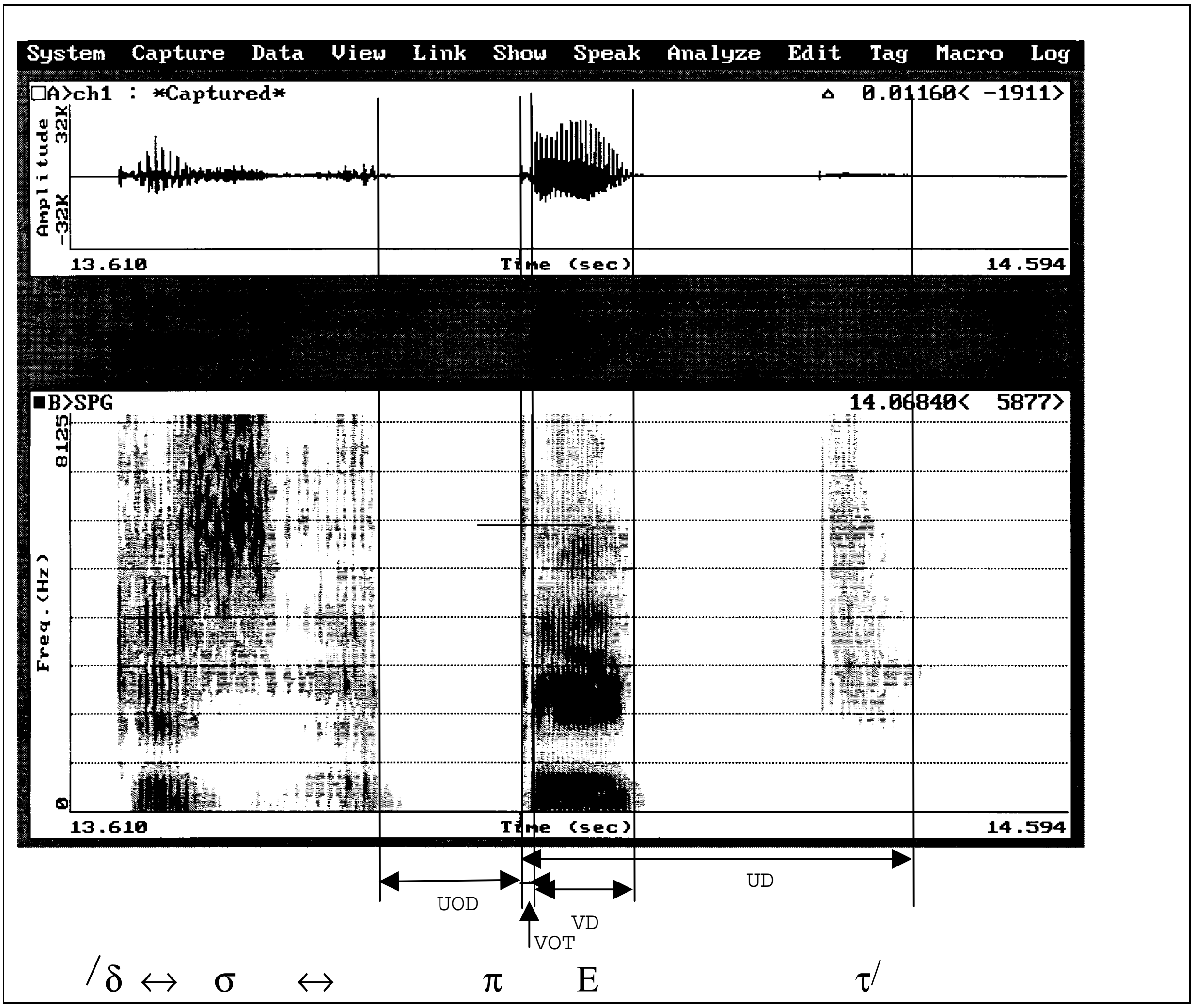

Figure 4.2 **A spectrograph of "Dis 'n pet" (English counterpart: "It's a pet") produced in L1NR by N5, indicating the four temporal parameters measured for utterances beginning with a voiceless plosive, namely utterance onset duration (UOD), voice onset time (VOT), vowel duration (VD) and utterance duration (UD).**

4.9.2 Acoustic analysis to determine utterance duration

Utterance duration was measured for all three utterance groups. These included utterances beginning with a voiced plosive, a voiceless plosive or a voiceless fricative.

4.9.2.1 Measurement of utterance duration in test stimuli beginning with a voiceless plosive

In utterances beginning with a voiceless plosive, UD was measured by placing the first time cursor at the beginning of the energy burst (indicating closure release). Although articulation for the initial plosive commences with lip closure before the release of oral constriction for the plosive (stop release) is visible on the spectrographic display, it was not possible to detect the closure phase (pressure build-up) of the plosive spectrographically. The reason for this is that in normal subjects one could have assumed that the onset of lip closure occurred directly after the end of the carrier phrase, but this was often not the case for the experimental subjects. Some of the experimental subjects occasionally repeatedly attempted production of the target word, before finally producing it correctly. In such instances, these subjects produced the first phoneme or phonemes of the target word several times before finally successfully producing the complete target word.

The energy burst related to production of the complete target word, was consequently taken as the position for placement of the first cursor when measuring UD. A second time cursor was placed at the end of spectral energy of the acoustic signal for the target word. The difference, in milliseconds, between these two cursors was recorded as UD. Measurement of UD in an utterance beginning with a voiceless plosive is illustrated in Figure 4.2 and measurement of UD in an experimental subject who exhibited repeated production attempts before production of the complete target word, is illustrated in Figure 4.3.

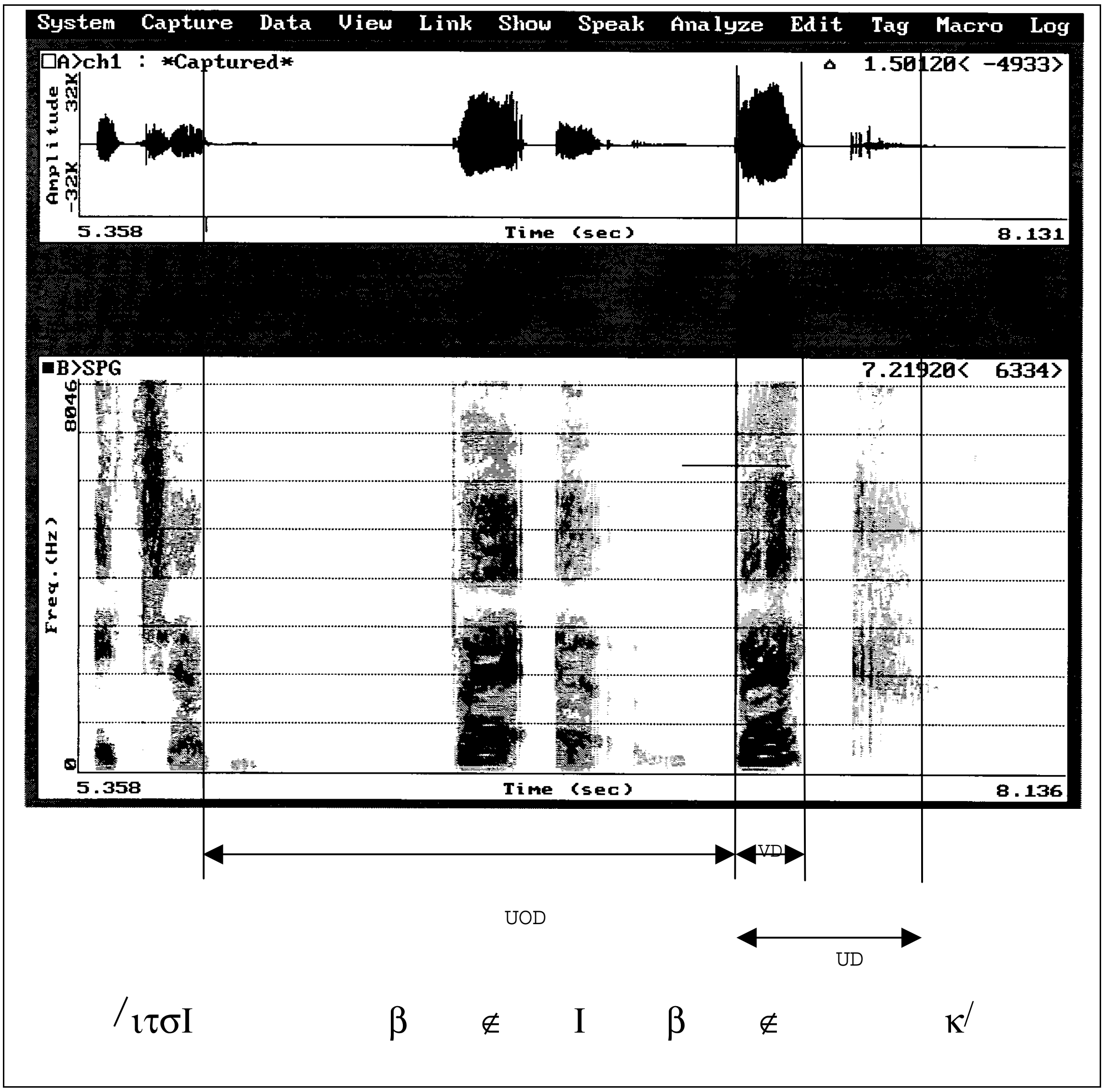

Figure 4.3 **A spectrograph of "It's a back" in L2FR produced by AOS2 as /ιτσΙ β∉ Ι β∉κ/, indicating the four temporal parameters measured for utterances beginning with a voiced plosive, namely utterance onset duration (UOD), vowel duration (VD), utterance duration (UD) and VOT as zero, since the release for the plosive and the spectral energy for the /a/ are the same point in time.**

4.9.2.2 Measurement of utterance duration in test stimuli beginning with a voiced plosive

The same analysis procedure for measurement of UD in utterances beginning with a voiceless plosive was followed for utterances beginning with a voiced plosive. In instances of voicing lead or instances where subjects maintained voicing throughout production of the carrier phrase and the target utterance, the energy burst indicating closure release was still taken as the position for placement of the first time cursor. If the start of voicing were to be taken as the position for placement of the first time cursor, some UD measures would have included the closure phase (stop gap) for the plosive if voicing lead had occurred. This would not have been comparable to other instances where this part of production (stop gap) had not been included for measurement. For example, UD of utterances where voicing lead had occurred or where voicing had been maintained after the end of the carrier phrase, would not have been comparable to UD of utterances with a short voicing lag. Utterances with voicing lead or where voicing had not been ceased before production of the target word would thus have seemed much longer in duration than utterances where a short voicing lag had occurred. For the sake of uniformity and consistent measurement of the same articulatory event, UD was thus consistently measured from the energy burst of the initial plosive to the end of spectral energy of the target word for utterances beginning with either a voiced or voiceless plosive. Measurement of UD for an utterance beginning with a voiced plosive is illustrated in Figure 4.4.

4.9.2.3 Measurement of utterance duration in test stimuli beginning with a voiceless fricative

To determine UD of utterances beginning with a voiceless fricative, the first time cursor was placed at the beginning of the high frequency aperiodic energy (fricative noise) for the start of the target utterance. The second time cursor was then placed at the end of the utterance as determined by the spectrographic display. The UD was recorded as the time interval, in milliseconds, between these two time cursors. In normal speakers the end of the /↔/-sound and the beginning of the fricative was mostly the same point in time. Measurement of UD for an utterance beginning with a voiceless fricative is illustrated in Figure 4.5.

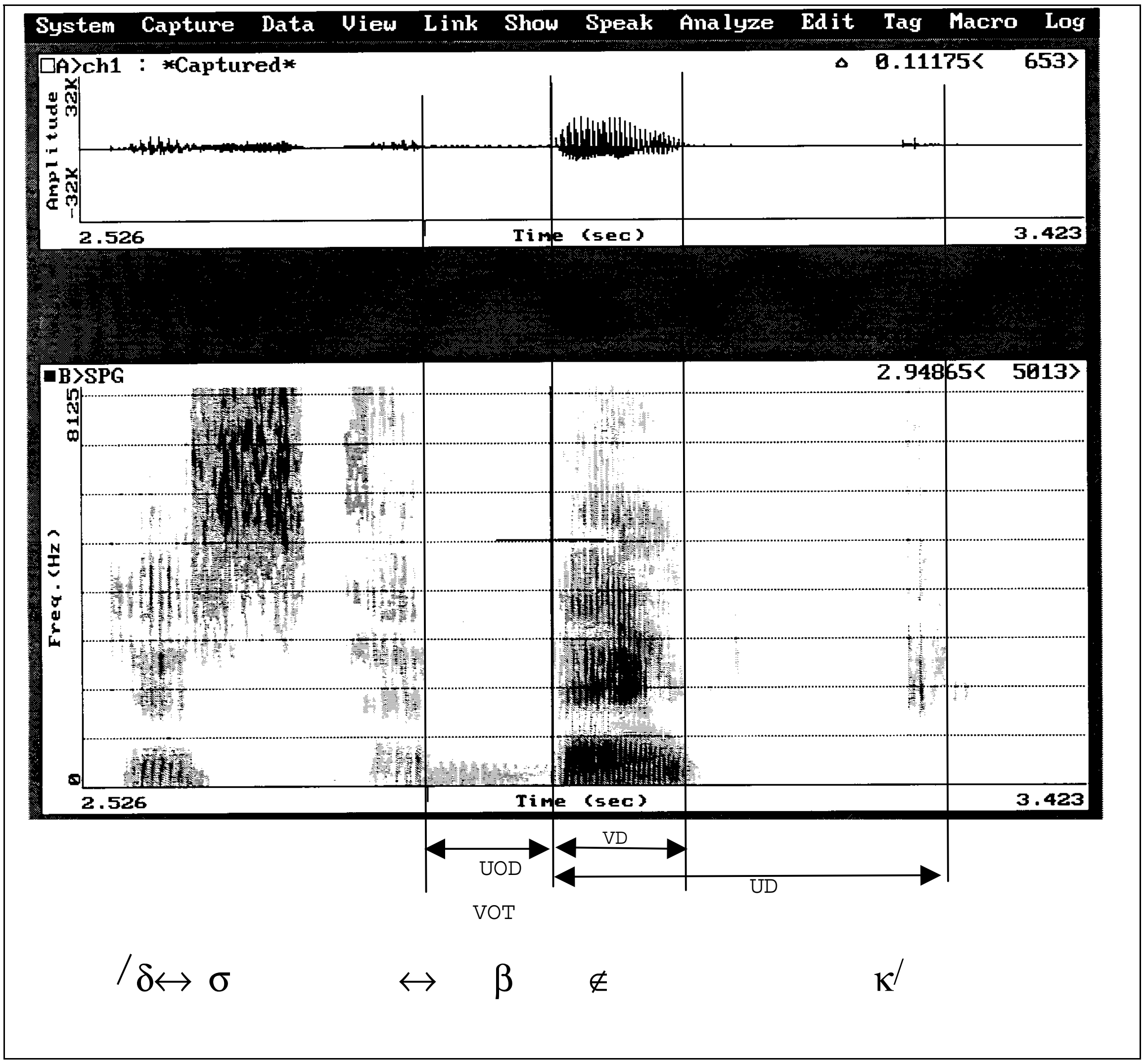

Figure 4.4 **Spectrograph of "Dis 'n bek" (English counterpart: "It's a back") produced in L1NR by one of the normal subjects (N5), indicating the four temporal parameters measured for utterances beginning with a voiced plosive, namely utterance onset duration (UOD), voice onset time (VOT) (in this case negative VOT or voicing lead), vowel duration (VD) and utterance duration (UD).**

4.9.3 Acoustic analysis to determine utterance onset duration

Utterance onset duration was measured as the time period between the end of the last sound in the carrier phrase and the energy burst indicating closure release for the plosive of the target word. Utterance onset duration was a potentially important measure as it enabled the researcher to determine the time which a subject took to initiate the target utterance after the stereotype carrier phrase had been completed.

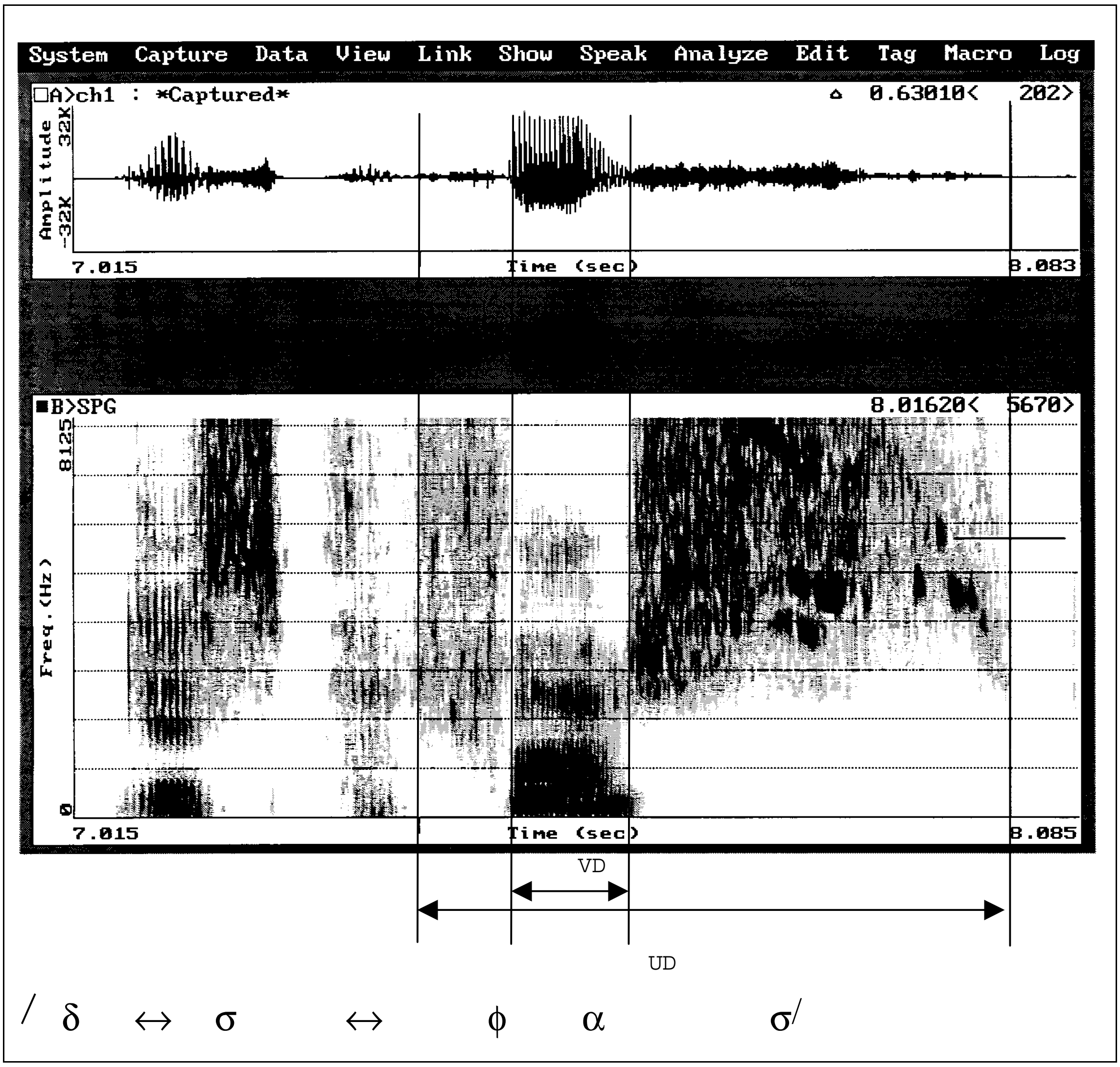

Figure 4.5 **A spectrograph of "Dis 'n vas" (English counterpart: "It's a fuss") produced in L1NR by one of the normal speakers (N5), indicating the two temporal parameters measured for utterances beginning with a voiceless fricative, namely vowel duration (VD) and utterance duration (UD).**

Persons with motor planning problems, specifically AOS are known to display difficulty with the initiation of utterances (Kent & Rosenbek, 1983; Wertz *et al*., 1984).

UOD was only measured for utterances beginning with either a voiced or voiceless plosive, since these sounds require a period of constriction, known as a stop gap (Seddoh *et al*., 1996b). However, it was decided to avoid the use of the term stop gap for the abovementioned measurement, since the experimental subjects often exhibited repeated production attempts after production of the carrier phrase, before complete production of the target word. In these instances, the period of time from the end of the carrier phrase to the stop release for the initial plosive of the complete on-target response was measured as the UOD. In some of the experimental subjects, UOD was thus not the same period of time as the stop gap duration for the target utterance. For this reason preference was given to use of the term UOD, rather than stop gap duration. Figure 4.3 illustrates measurement of UOD in an experimental subject who exhibited repeated production attempts before complete production of the target word.

4.9.3.1 Measurement of utterance onset duration in test stimuli beginning with a voiceless plosive

For measurement of UOD, the first time cursor was placed at the end of the periodic acoustic energy for the last sound of the carrier phrase (/↔/) and the second time cursor was placed at the energy burst indicating closure release for the initial plosive of the target word. The difference, in milliseconds, between the two cursors was then taken as UOD. It was occasionally difficult to determine the end of the /↔/, since subjects sometimes ceased voicing for /its↔/ or /d↔s↔/, although spectral energy for articulation of either the /↔/ extended past the cessation of voicing. In such instances, the cursor was placed where the spectrographic display for /↔/ exhibited at least three vertical traces of energy still touching the cursor vertically when it was placed at this point. Measurement of UOD for an utterance beginning with a voiceless plosive is illustrated in Figure 4.2.

4.9.3.2 Measurement of utterance onset duration in test stimuli beginning with a voiced plosive

The same procedure for determination of UOD for utterances beginning with a voiceless plosive was followed for utterances beginning with a voiced plosive. In instances where voicing occurred before the energy burst of the plosive (voicing lead instances), the start of the *energy burst* (indicating closure release), and not the start of voicing, was still taken as the point for placement of the second time cursor. The reason for this is that in some instances the normal speakers did not cease voicing after production of the carrier phrase, before the stop release. In such instances, the end of the /↔/ in the carrier phrase and the start of voicing would thus have been the same point in time, resulting in an UOD of zero. For the sake of uniformity the point of closure release was always taken as the point of placement for the second cursor for determination of UOD, even though voicing might have occurred before this point. Measurement of UOD for an utterance beginning with a voiced plosive is illustrated in Figure 4.4.

4.9.4 Acoustic analysis to determine voice onset time

Voice onset time was measured in word-initial stop consonants of words beginning with either a voiced or a voiceless stop consonant. A combination of the waveform and spectrogram were used to measure VOT.

4.9.4.1 Measurement of voice onset time in test stimuli beginning with a voiceless plosive

For measurement of VOT in utterances beginning with a voiceless plosive the first time cursor was placed at the start of the energy burst for the initial plosive indicating closure release. A second time cursor was then placed at the start of vocalization determined by the first sign of periodicity. The time interval, in milliseconds, between the two cursors was recorded as VOT. In utterances beginning with a voiceless plosive, voicing always followed the stop release (voicing lag) with all VOTs for voiceless plosives being positive. The measurement of VOT in an utterance beginning with a voiceless plosive is illustrated in Figure 4.2.

4.9.4.2 Measurement of voice onset time in test stimuli beginning with a voiced plosive

For measurement of VOT in utterances beginning with a voiced plosive, the same analysis procedure was followed as for utterances beginning with a voiceless plosive. However, in utterances beginning with a voiced plosive, the start of vocalization could either lead or follow the energy burst for the plosive. Voicing lead (where voicing starts before the energy burst) is indicated with a negative value. A negative VOT was also obtained when voicing was maintained after production of the /↔/ of the carrier phrase through the beginning of the target utterance. Voicing lead can normally occur only in voiced plosives. A spectrogram displaying continuous voicing from the end of the carrier phrase to the stop release (voicing lead) is illustrated in Figure 4.4.

In some subjects (normal and experimental subjects), when voicing was maintained after the end of the /↔/ of the carrier phrase, a short break in voicing sometimes occurred, just before the stop release of the target word. This "break" in continuous voicing could have been caused by the supraglottal pressure which had increased to a similar level as the subglottal pressure whilst voicing occurred and lip closure was maintained. The movement of the vocal folds was then presumably suppressed by similar subglottal and supraglottal pressures. When the release of oral constriction occurred, the vocal folds could presumably continue their vibration again. It was therefore decided to measure the maintained voicing as negative VOT if the cessation of voicing was not more than two periodic pulses before the energy burst for the initial plosive and if the voicing following the stop release exhibited clear periodic pulses indicative of true voicing for the following vowel. In some subjects the voicing ceased more than two pulses before the stop release. In these instances VOT was then measured as being positive, since the voicing could merely have been an extension of the voicing for the /↔/ of the carrier phrase and not indicative of true negative voice onset for the vowel following the plosive.

When voicing lead occurs for voiced consonants, in other words, when voicing for the vowel following the stop consonant is initiated before the stop release, it is generally accepted that the vowel follows immediately after the energy burst indicating closure release (Borden & Harris, 1984). However, this was not always as clearly displayed in the current study. In some cases true periodic energy extending through the first and second formants could only be seen after the stop release even when voicing lead had occurred. The stop release and the start of the vowel were then not taken as the same point in time. The stop release and the start of the vowel were only viewed as the same point in time, when the first and second formants for the vowel were clearly visible together with voicing.

4.10 RELIABILITY

A ten percent sample of the data was reanalysed by the researcher to determine intraobserver reliability. The first ten percent of recorded utterances for each rate condition and language of each subject was used for reanalysis. A second spectrogram of each of these utterances was made and each temporal parameter (VD, UD, UOD and VOT) was measured again by hand. If the difference between the original measure and the reliability measure was not more than 3 milliseconds (Seddoh *et al*., 1996b), or if these two measures did not differ by more than two increments, as determined by moving the cursor either to the left or the right of the original point of measurement, the two measures were accepted as being in agreement. Intraobserver reliability was determined by dividing the total number of reanalysed utterances which were in agreement with the initial measurements by the total number of utterances which were reanalysed (Shriberg & Kent, 1982). Agreement between intraobserver reliability procedures was 89 percent.

Ten percent of the utterances were also analysed by the researcher and another researcher with extensive experience regarding acoustic analysis of speech samples. The latter researcher was also consulted for a second opinion when the present researcher was uncertain about a specific measurement point. This resulted in at least ten percent of the data being analysed by a second researcher. In instances where the second researcher was consulted, the measurement was recorded only after consensus had been reached.

4.11 DATA PROCESSING

Data of the experimental subjects were processed according to individual performance, whereas data for the normal speakers were processed according to both individual and group performance. The reason for not grouping the experimental subjects is the fact that the degree of aphasia or AOS differed between subjects in a specific group. If such a small number of subjects had been grouped, it might have led to one subject's data dominating the group data.

The data processing involved a descriptive approach using a measure of central tendency, namely the mean (Guy, Edgley, Arafat & Allen, 1987; Smit, 1983) and a measure of variability, namely, the standard deviation (SD). Intra- (within subjects across contexts), as well as intersubject comparisons (between the experimental subjects and the normal group) were made using descriptive statistics. Graphic representations of these comparisons were constructed using bar graphs. Tables were also compiled to highlight main trends.

For each temporal parameter, namely, VD, UD, UOD and VOT the mean durations (in milliseconds) and SDs of each target word were calculated for each context (L1NR, L1FR, L2NR, L2FR) using the durational values of each subject's five repetitions of a specific utterance. These values were used for further processing of the data according to each sub-aim. The mean durations and SDs of each individual subject and the normal group for each temporal parameter, utterance and context are displayed in Appendix B.

Data processing will be discussed according to the various sub-aims of the study.

4.11.1 Data processing for sub-aim one: Determination of the extent of durational adjustment in the fast rate compared to the normal rate in first language versus second language speech production

As discussed, the purpose of sub-aim one was to determine the extent in which a subject decreased the duration of a specific temporal parameter in the FR compared to the NR in L1 and L2 respectively. It was predicted that a subject would be able to decrease duration in the FR relative to duration in the NR to a greater extent in the language that is more automatized and consequently produced with greater ease. In the present study, it was predicted that L1 would be produced with greater ease and would consequently display a greater extent of durational adjustment compared to L2.

The extent of durational adjustment was determined for each target utterance, as well as for each utterance group. The three utterance groups included utterances beginning with a voiceless plosive, utterances beginning with a voiced plosive and utterances beginning with a voiceless fricative. The processed data for sub-aim one are included in Appendix C.

4.11.1.1 Data processing for individual utterances in each utterance group for sub-aim one

- **Determination of the extent of durational adjustment**

The extent of durational adjustment in the FR compared to the NR was calculated for L1 and L2 respectively, for each temporal parameter measured, namely, UOD, VD, UD and VOT for each subject and utterance individually. The values of mean duration of each temporal parameter for each utterance, context and subject, contained in Appendix B, were used for calculating the extent of durational adjustment in the FR compared to the NR.

For determination of the *extent of durational adjustment* in the FR compared to the NR, the duration in the FR was expressed as a percentage of the duration in the NR. The *extent of durational adjustment* was calculated for each language (L1 and L2) separately, using the formula 100 x [1 minus (duration in the FR divided by the duration in the NR)]. The obtained percentage values are included in Appendix C. The reason for expressing the duration in the FR as a percentage of the duration in the NR, and not merely using the difference in milliseconds between these two durations, was to allow for comparison of the *extent of durational adjustment* between languages and subjects. A relative measure was thus used, in order to prevent differences in absolute durations between subjects and languages from obscuring the results. Each subject's *extent of durational adjustment* could thus be compared with that of other subjects and between languages, regardless of the absolute durations obtained by a subject in the two different languages.

When a positive percentage value was obtained, using the abovementioned formula, it indicated that the duration of the specific temporal parameter had been decreased in the FR condition, whereas a negative value indicated that the person was not successful in decreasing duration in the FR and that the duration, in fact increased in this rate condition. For example, if AOS1 obtained a value of 20% in L1 using the aforementioned formula, it implied that this subject made a 20% durational adjustment in the FR relative to the duration in the NR. If for L2 the calculated extent of durational adjustment was 10%, it implied that this subject had made a 10% durational adjustment in the FR relative to the duration in the NR in this language. A greater extent of durational adjustment was thus made in L1 by this subject, although a decrease in duration was successfully achieved in the FR in both languages. From these results, it could be seen in which language the *extent of durational adjustment* in the FR compared to NR was the greatest for each target utterance. The aforementioned results were needed to calculate an average extent of durational adjustment in L1 compared to L2 for each utterance group (to be discussed later) and also to determine trends regarding the accomplishment of durational adjustment in L1 and L2 respectively for individual utterances.

- **Accomplishment of durational adjustment in L1 and L2 respectively**

To determine if L2 led to greater difficulty compared to L1, regarding the achievement of durational adjustments, tables were compiled in which specific trends were indicated (see Table 5.2 as an example). For each utterance of each subject and the normal group, the information mentioned below was indicated in these tables.

- Specifically, it was indicated for each utterance whether the extent of durational adjustment was greater in L1 than in L2.
- Furthermore, it was indicated whether durational adjustment was unsuccessful for more L2 utterances than L1 utterances.
- Lastly, it was indicated whether if more than half of the utterances in the specific utterance group exhibited a greater extent of durational adjustment in L1 than in L2.

If a subject was unable to obtain a shorter duration in the FR in both L1 and L2, this utterance was excluded for the purpose of determination if more than half of the utterances in a specific utterance group exhibited a greater extent of durational adjustment in L1 compared to L2. For example, if a specific subject exhibited a greater extent of durational adjustment in L1 for two of the five utterances, but was unable to decrease duration in the FR in either L1 or L2 for each of the other three utterances, it would have been incorrect to say that this subject exhibited a greater extent of durational adjustment in L1 for only two of the five utterances, in other words, for less than half of the utterances in the utterance group. The reason for this is that the above statement would imply that a greater extent of durational adjustment had been achieved in L2 for the other three utterances. For this reason, it would be more correct to state that AOS1 obtained a greater extent of durational adjustment in L1 for two of a possible two (thus for more than half) of the utterances in which a decrease in duration could be obtained in at least one language.

The findings from the tables which were compiled for determination of the abovementioned trends were used for the compilation of summary tables for sub-aim one (see Table 5.7 as an example). In these summary tables it was indicated if more than half of the target utterances that were used for calculation in a specific utterance group, exhibited a greater extent of durational adjustment in L1 compared to L2. The latter was taken to prove a trend regarding a greater extent of durational adjustment generally occurring in L1 than in L2. In the summary tables for sub-aim one (Tables 5.7, 5.14, 5.19 and 5.22), it was also indicated if a subject was unsuccessful regarding the accomplishment of durational adjustment more often in L2 than in L1.

4.11.1.2 Data processing for utterance groups for sub-aim one

- Determination of the extent of durational adjustment

After calculating the percentage of durational adjustment of each temporal parameter for each subject (and the normal group), language and utterance separately, an *average percentage* of the extent of durational adjustment in the FR compared to the NR was calculated for each of the three *utterance groups* for each temporal parameter, subject (and the normal group) and language. The former calculation thus rendered a percentage depicting the *extent of durational adjustment* for each subject (and the normal group), language and temporal parameter for each of the three utterance groups. The five utterances beginning with a voiced plosive, the five utterances beginning with a voiceless plosive and the four utterances beginning with a voiceless fricative were grouped separately in order to obtain an average *extent of durational adjustment* in the FR compared to the NR for each of these three *utterance groups*.

The *extent of durational adjustment* for each *utterance group* was calculated by adding the percentage values of durational adjustment of the utterances in the specific utterance group and dividing this by the number of utterances in the group (five in the voiceless plosive group, five in the voiced plosive group and four in the voiceless fricative group). This calculation rendered a percentage value depicting the extent of durational adjustment for each of the three utterance groups. The latter value was calculated for each temporal parameter, subject and language separately, as well as for the normal group. These values are included in Appendix C. Bar graphs were then constructed to illustrate the extent of durational adjustment in the FR compared to the NR for each temporal parameter for each subject and normal group for each *utterance group*. For an example of a graphic representation of the average *extent of durational adjustment*, the reader is referred to Figure 5.1 which illustrates VD in the FR expressed as a percentage of VD in the NR for L1 and L2 respectively, for the voiceless plosive utterance group. The results for the utterance groups will be reported before the results for each target utterance, when the results for sub-aim one are presented in chapter five.

- **Accomplishment of durational adjustment in L1 and L2 respectively**

In order to determine if L2 led to greater difficulty with the accomplishment of durational adjustments, tables were also compiled (as for the individual target utterances) for each utterance group and temporal parameter in which the information mentioned below was indicated for each individual subject and the normal group (see Table 5.1 as an example).

- It was indicated if the extent of durational adjustment in the NR compared to the FR in L1 was greater than in L2 for utterances as a group. If the aforementioned occurred, this would imply that it was presumably more difficult to accomplish durational adjustments in L2 than in L1.

- It was further indicated if a shorter duration in the FR compared to the NR *could not* be achieved in L1 and L2 respectively, for utterances as a group. It was also indicated if durational adjustment was only unsuccessful in L2, but not in L1. The latter would imply that it was presumably more difficult to accomplish durational adjustments in L2 than in L1.

Using the findings in these tables, it was thus possible to determine specific trends regarding the accomplishment of durational adjustments in L1 and L2 respectively, for each temporal parameter of each subject and the normal group regarding each utterance group. A summary of the data processing procedure for sub-aim one is provided in Figure 4.6

4.11.2 Data processing for sub-aim two: Determination of the context (L1NR, L1FR, L2NR or L2FR) in which each experimental subject differed most from the normal group regarding each temporal parameter

The purpose of sub-aim two was to determine in which context the durations of each experimental subject deviated most from the durations of the normal group regarding each temporal parameter. It was predicted that L2FR would pose the greatest processing demands to the speech production mechanisms of subjects with speech and/or language disorders and that these subjects would consequently deviate most from the normal group in this context.

Data processing for sub-aim two was performed for each temporal parameter, subject and utterance separately, as well as for each utterance group. The mean durations of the five repetitions of each utterance, of each experimental subject for each of the temporal parameters (UOD, VD, UD and VOT) for each context (L1NR, L1FR, L2NR, L2FR) and utterance were used for data processing of sub-aim two. In conjunction to this, the mean durations of the normal speakers as a group (normal group) regarding each temporal parameter, context and utterance were used. As mentioned previously, the mean durations of each subject and the normal group are displayed in Appendix B.

Sub-aim One

Aim: To determine the extent in which each subject decreased their duration of a specific temporal parameter in the FR compared to the NR in L1 and L2 respectively.

Prediction: Experimental subjects should be able to decrease duration in the FR relative to duration in the NR, to a greater extent in the language which is more automatized and consequently produced with greater ease. In the present study, it was predicted that L1 would be produced with greater ease and consequently a greater extent of durational adjustment should presumably occur in L1 than in L2.

DATA PROCESSING: Step 1

Express the duration in the FR as a percentage of the duration in the NR for each subject and the normal group using the mean duration of the five repetitions of each subject for *each utterance*, temporal parameter and context (Appendix C).

Formula used: 100 x [1-(duration in FR/duration in NR)]

Obtained value: Positive value indicates duration was decreased in the FR relative to the NR. Durational adjustment was thus accomplished successfully. Negative value indicates duration in the FR was longer than the duration in the NR. Durational adjustment was thus not accomplished successfully.

↓

Step 2

Compilation of tables indicating the following for *each utterance* (for example, Table 5.2):

- Whether the extent of durational adjustment was greater in L1 than in L2.
- Whether durational adjustment was unsuccessful for more L2 utterances than L1 utterances.
- Whether more than half of the utterances in the specific utterance group, exhibited a greater extent of durational adjustment in L1 compared to L2.

Prediction: If L2 is a more demanding context, more instances will occur in L2 compared to L1 where duration in the FR could not be decreased.

↓

Step 3

Determination of the extent of durational adjustment for each *utterance group* for each language.

How? Add the percentage values for extent of durational adjustment of the utterances in each utterance group for either L1 or L2 and divide this value by the number of utterances in the group to determine the average extent of durational adjustment for each utterance group for each language (for example, Figure 5.1).

↓

Step 4

Compilation of table indicating for each *utterance group* whether the extent of durational adjustment was greater in L1 compared to L2 and if durational adjustment was only unsuccessful in L2 (for example, Table 5.1).

Prediction: If L2 is a more demanding context, an inability to decrease duration would occur in L2 as opposed to L1 and the extent of durational adjustment should be greater in L1 than in L2.

↓

Step 5

Compilation of *summary table* for each temporal parameter to indicate for *individual utterances* whether more than half of the utterances displayed a greater extent of durational adjustment in L1 and whether duration could not be decreased in the FR for more L2 utterances than L1 utterances. For *utterance groups* it is indicated in the summary table if the extent of durational adjustment was greater in L1 than in L2 and if durational adjustment in the FR was unsuccessful, only in L2 (Tables 5.7, 5.14, 5.19 and 5.22).

Figure 4.6 Summary of data processing procedure for sub-aim one

4.11.2.1 Data processing for individual utterances for sub-aim two

For data processing of sub-aim two the duration of each temporal parameter of each experimental subject was expressed as a percentage of the mean duration of the normal group for each target utterance. In order to express the duration of an experimental subject as a percentage of the duration of the normal group, the formula 100 x [(duration of the experimental subject divided by the duration of the normal group) minus 1] was used. A positive percentage value indicated that the duration of the experimental subject was longer than that of the normal group, whereas a negative percentage value indicated that the duration of the experimental subject was shorter than that of the normal group. The use of a relative measure, once again, allowed for comparison between languages and subjects despite differences in absolute durations. From the obtained values, it could be seen in which context of production (L1NR, L1FR, L2NR, or L2FR) each experimental subject differed most from the normal group regarding a specific temporal parameter. The processed data for sub-aim two are included in Appendix D.

4.11.2.2 Data processing for utterance groups for sub-aim two

The data were pooled across utterance groups, namely utterances beginning with a voiceless plosive (5 utterances), a voiced plosive (5 utterances) or a voiceless fricative (4 utterances). This was done by adding the percentage values (duration of each experimental subject expressed as a percentage of the duration of the normal group) of the utterances in a specific utterance group and dividing the obtained value by the number of utterances in the group. Bar graphs were then constructed for each utterance group displaying the duration of each experimental subject as a percentage of the duration of the normal group (Figures 5.10 to 5.18).

The data expressing the duration of each temporal parameter of each experimental subject as a percentage of the duration of the normal group for each of the four contexts for each utterance and utterances as a group are displayed in Appendix D. The data of the individual utterances and utterance groups were then processed further as discussed below.

4.11.2.3 Ranking of the magnitude of difference between each experimental subject and the normal group for utterance groups

Tables for each utterance group were compiled in which a value from one to four was assigned to each context (L1NR, L1FR, L2NR and L2FR) to rank the extent each subject differed from the normal group (Tables 5.23 to 5.31). A value of one indicated that the difference of a subject from the normal group was the greatest and a value of four indicated that that the difference was the least. The greatest difference was taken as the largest positive value, since it was hypothesized that persons with underlying difficulty regarding the motor planning of speech would generally be expected to exhibit longer durations than the normal group. If, for example, a percentage value of 40% was obtained, it implied that the duration of the experimental subject was 40% longer than that of the normal group in the specific context. A percentage value of 60% indicated that the duration of the experimental subject was 60% longer than that of the normal group. Consequently the difference between the normal group and experimental subject was greater in the context where 60% was obtained, as opposed to 40%. In this example, a value of one would be assigned to the context where 60% was obtained and a value of two to the context where 40% was obtained and so forth.

If a negative percentage value was obtained, in other words, if the duration of the experimental subject was shorter than that of the normal group, this would imply that the subject performed "better" than the normal group and a bigger value (from one to four) would be assigned to this context than to a context where a positive value was obtained. If a negative value were obtained for all four contexts (L1NR, L1FR, L2NR, L2FR), then the smallest ranking value (one) would be assigned to the largest negative percentage value and the largest value (four) would be assigned to the smallest negative percentage value. For example, if the values were -3%, -10%, -15% and -20%, a one would be assigned to -3%, a two to -10%, a three to -15% and a four to -20%. The reasoning for this was that the more negative the percentage value, in other words, the smaller the percentage value, the "better" the experimental subject performed compared to the normal group and the subject thus differed less from the normal group in this context.

The assigned values from one to four were tabulated for each subject across the four contexts and it was then indicated in which of the four contexts, the specific subject differed the most from the normal group. These findings were used in a summary table for sub-aim two (Table 5.32), where it was indicated for each subject regarding each utterance group if they had deviated most from the normal group in L2FR, which was predicted to be the most demanding context for speech production.

4.11.2.4 Ranking of the magnitude of difference between each experimental subject and the normal group for individual utterances

After tabulating the data according to utterance groups, the data of individual target utterances were tabulated and values of one to four were assigned in the same manner as described above. A value of one to four was thus assigned to each context for each utterance in a specific utterance group. The percentage of utterances in each context which were assigned a value of one (greatest difference from the normal group) was then calculated and tabulated by dividing the number of utterances with an assigned value of one by the number of utterances in the group. For example, if for "pup" in L1NR, AOS1 had the value "one" assigned to two of the five utterances in the voiceless plosive group, it implied that for 40% of utterances in this context (L1NR), AOS1 differed the most from the normal group. From this calculation, the percentage of utterances in each context where the experimental subject differed the most from the normal group could be determined and the context where each experimental subject exhibited the greatest percentage of utterances which were assigned a value of one was then indicated in these tables. The latter would be the context which presumably posed the greatest demands to the speech production mechanisms of the experimental subjects.

If in a specific context the value of one was assigned to an utterance with a negative percentage value, in other words, where the experimental subject exhibited a shorter duration than the normal group, this instance was marked with an asterisk in the table, since the experimental subject then actually performed "better" than the normal group in this context. It was only possible to assign a value of one to a percentage with a negative value if the percentage values of all four contexts for the specific utterance had negative values. The reason for this is that if even only one context for the specific utterance had a positive percentage value, indicating that the duration of the experimental subject was greater than that of the normal group, the positive percentage value would have been assigned a value of one.

The processed data for sub-aim two for the individual utterances, indicating the assigned values in each context and the percentage of utterances assigned a ranking value of one for each temporal parameter and utterance group for each subject are displayed in Appendix E.

The results obtained from the data processing for sub-aim two for the individual utterances were also used in the summary table for sub-aim two (Table 5.32). It was indicated in Table 5.32 if L2FR was the context exhibiting the largest percentage of utterances assigned a value of one. In other words, it was indicated if a subject tended to deviate most from the normal group most often in the L2FR context. A summary of the data processing procedure for sub-aim two is provided in Figure 4.7.

4.11.3 Data processing for sub-aim three: Determination of the context (L1NR, L1FR, L2NR or L2FR) in which variability of each subject was the greatest

For processing of this sub-aim, the SDs deviations of each subject's set of five repetitions were used. As mentioned previously, the SD was calculated for each utterance and context for each temporal parameter, UOD, VD, UD and VOT, separately. The SD for the normal group was also calculated by adding the SDs of the normal subjects for the specific utterance and context and dividing this value by the number of normal speakers, namely, five. The SDs are displayed in Appendix B.

A table was then compiled for each utterance group, listing each individual utterance and context for each subject and also for the normal group. A value of one to four was then assigned to each context for a specific utterance in order to rank the variability across the four contexts for determination of the extent of variability in each context. These tables are displayed in Appendix F. A value of one indicated the greatest variability, whereas a value of four indicated the least variability for a specific context.

Sub-aim Two

Aim: To determine in which context the durations of each experimental subject deviated most from the durations of the normal group regarding each temporal parameter.

Prediction: L2FR should pose the greatest processing demands to the speech production mechanisms of speakers with speech and/or language disorders and consequently these speakers should presumably deviate most from the normal group in this context.

DATA PROCESSING: Step 1

Express the duration of each temporal parameter of each experimental subject as a percentage of the duration of the normal group (Appendix D).

Formula used: 100 x [(duration of the experimental subject/the duration of the normal group) - 1]

Obtained value: A positive value indicated that duration of experimental subject was longer than that of the normal group. A negative value indicated that duration of experimental subject was shorter than that of the normal group

↓

Step 2

Pool data according to utterance groups: Utterances beginning with a voiceless plosive, a voiced plosive or a voiceless fricative. **How?** Add percentage values of each utterance in a specific utterance group and divide by the number of utterances in the group. **Result:** Average percentage value expressing the duration of each experimental subject as a percentage of the duration of the normal group for each utterance group (Appendix D and Figures 5.10 to 5.18).

↓

Step 3

Compile table for each *utterance group* and assign a value of 1 to 4 to each percentage value in each of the four contexts. 1=largest positive percentage value (subject thus deviated most from normal group in this context) and 4=smallest positive percentage value (subject thus deviated least from normal group in this context) (Tables 5.23 to 5.31).

↓

Step 4

Indicate in table which context is assigned a value of one in order to determine the context in which each subject deviated the most from the normal group regarding each *utterance group*. The latter context presumably posed the greatest processing demands to the speech production mechanisms of the subjects exhibiting this behavior (Tables 5.23 to 5.31).

↓

Step 5

Compile table for each individual utterance and assign a value of 1 to 4 to each percentage value in each of the four contexts (Appendix E).

↓

Step 6

Determine the percentage of utterances in each context assigned a value of one. Indicate which context had the largest percentage of utterances assigned a value of one, in other words, determine the context in which each experimental subject differed the most from the normal group most frequently to determine which context presumably posed the greatest processing demands to the speech production mechanism (Appendix E).

↓

Step 7

Compilation of summary table (Table 5.32) to indicate for each utterance group if the duration of each experimental subject differed most form the duration of the normal group in L2FR. For individual utterances, it was indicated if the duration of each experimental subject differed most from the duration of the normal group in L2FR for most of the utterances in the utterance group.

Figure 4.7 Summary of data processing for sub-aim two

From these tables the percentage of utterances in each *utterance group,* which were assigned a value of one, was then indicated in a separate table in order to determine the context with the most utterances exhibiting the greatest variability. The latter context was then indicated in the table and this context was presumably indicative of the context which generally led to the greatest variability (Tables 5.33 to 5.42).

In addition to the above processing regarding sub-aim three, it was also determined if the SD of each experimental subject was larger or smaller than that of the normal group for each temporal parameter, utterance and context. This was done by expressing the SD of each experimental subject as a percentage of the SD of the normal group *for each target utterance*. The former calculation was performed using the formula 100 x [(SD of the experimental subject divided by the SD of the normal group) - 1]. To obtain a percentage value expressing the SD of each subject as a percentage of the SD of the normal group for each *utterance group,* the obtained percentage values of the target utterances in each utterance group were added and divided by the number of utterances in the group. This was done for each context and utterance group for each subject regarding each temporal parameter separately.

The percentage values expressing the SDs of each experimental subject as a percentage of the SDs of the normal group for each *utterance group* were used for discussion of the results relating to variability of the experimental subjects compared to that of the normal group. A positive percentage value indicated that the SD of a subject was greater than that of the normal group, whereas a negative percentage value indicated the SD of a subject was smaller than that of the normal group. Bar graphs were compiled to visually display the SDs of each experimental subject as a percentage of the SDs of the normal group for each utterance group (Figures 5.19 to 5.28). This was done for each *utterance group* regarding each temporal parameter separately. The data expressing the SDs of each subject as a percentage of the SDs of the normal group for *each utterance* and *utterance group* are displayed in Appendix G.

The results obtained from the above processing were used to indicate specific trends in a summary table which was compiled for sub-aim three (Table 5.43). Specifically, it was indicated in Table 5.43, for each subject and the normal group for each *utterance group*, if the largest percentage of utterances with the greatest SD was in either of the L2 contexts (L2NR or L2FR), since it had been predicted that L2 would possibly cause greater variability due to increased processing demands imposed by speech production in L2. Furthermore, it was indicated in Table 5.43 whether the SDs of each experimental subject were greater than those of the normal group across all four contexts regarding each utterance group. A summary of the data processing procedure for sub-aim three is provided in Figure 4.8.

Sub-aim Three
Aim: Determination of the context (L1NR, L1FR, L2NR or L2FR) in which variability is the greatest for each subject and for the normal group regarding each temporal parameter.
Prediction: L2FR should pose the greatest processing demands to the speech production mechanisms of persons with speech and/or language disorders. These increased processing demands might be reflected in greater variability in the L2FR context.

DATA PROCESSING: Step 1
Calculation of the SD of each subject and the normal group for each set of five repetitions of an utterance, for each temporal parameter, utterance and context (Appendix B).

↓

Step 2
Assignment of ranking values of one to four to the SDs of each context to depict the magnitude of variability for each utterance across the four contexts. This was done for each utterance of each subject and the normal group (Appendix F).

↓

Step 3
Calculation of the percentage of utterances in each utterance group which were assigned a value of one. Compilation of a table to display the percentage of utterances assigned a value of one for each context for each subject and temporal parameter. Indication of the context in which the most utterances were assigned a value of one, in order to determine which context generally led to the greatest variability (Tables 5.33 to 5.42).

↓

Step 4
Expression of the SDs of each experimental subject as a percentage of the SDs of the normal group for each utterance. **Formula used:** 100 x [(SD of the experimental subject/SD of the normal group) - 1].
Obtained value: Positive value indicated SD of experimental subject was larger than that of the normal group
Negative value indicated SD of experimental subject was smaller than that of the normal group (Appendix G)

↓

Step 5
Obtain a percentage value expressing the SD of each subject as a percentage of the SD of the normal group for each *utterance group* in order to determine if the SD of the experimental subject was greater than the SD of the normal group across all four contexts. **How?** Add percentage values obtained for individual utterances (Step 4) and divide by the number of utterances in the group (Appendix G and Figures 5.19 to 5.28).

↓

Step 6
Display findings in summary table for sub-aim three to indicate specific trends. Specifically it is indicated if the largest percentage of utterances with the greatest SD occurred in L2NR or L2FR, since it was predicted that the L2 context would lead to greater variability than the L1 contexts. It is also indicated if the SDs of each experimental subject were greater than those of the normal group across all four contexts of production (L1NR, L1FR, L2NR and L2FR) (Table 5.43).

Figure 4.8 Summary of data processing for sub-aim three

4.12 SUMMARY OF CHAPTER FOUR

In this chapter the research methodology of the study was presented. This entailed a description and discussion of the sub-aims against the theoretical motivation for their inclusion and the underlying hypotheses. This was followed by a description of the subject selection criteria and procedures, measurement instruments utilized, speech material and research design. Finally, the data collection procedure, data analysis and processing procedures for each sub-aim were discussed in detail.

CHAPTER FIVE
RESULTS OF THE STUDY

CHAPTER FIVE

RESULTS OF THE STUDY

5.1 INTRODUCTION

In this chapter, the results of the study are presented in relation to the experimental sub-aims. The results utilize descriptive statistics to explore temporal parameters of speech production in persons with normal speech and persons with either AOS or PP, across four contexts, namely Afrikaans at a normal speaking rate (L1NR), Afrikaans at a fast speaking rate (L1FR), English at a normal speaking rate (L2NR) and English at a fast speaking rate (L2FR). The study of temporal parameters of speech across the four contexts of speech production is undertaken in an attempt to realize the main aim of the study, namely to determine if speech production in L2 influences the temporal parameters of speech in persons with AOS. Persons with normal speech were included to serve as a comparison group, as well as persons with PP, to allow for comparison of the results with those of persons with AOS.

The results for each temporal parameter, namely, UOD, VD, UD and VOT, will be discussed separately according to each formulated sub-aim. For each temporal parameter, the data for each of the three utterance groups, namely, utterances beginning with a voiceless plosive, voiced plosive or voiceless fricative will be discussed first. *Utterance group* results involve the pooled results of all the utterances in a specific utterance group. This will be followed by a discussion of the individual utterances in each utterance group. The latter involves the mean data for the five repetitions of each utterance in a group. *Individual utterances* thus refer to the mean data for each different target utterance. The reason for reporting the results for individual utterances in addition to utterance group results is that the data for utterances as a group sometimes masked findings which were evident for most of the utterances in an utterance group. The results for a particular utterance in a group would thus have dominated the utterance group results, if its results were very different from those of the other utterances in the group. The means and SDs for the five repetitions of each utterance for each person, utterance and context, which were used for data processing for the three sub-aims, are included in Appendix B.

5.2 SUB-AIM ONE: DETERMINATION OF THE EXTENT OF DURATIONAL ADJUSTMENT IN THE FAST RATE COMPARED TO THE NORMAL RATE IN L1 VERSUS L2

For normal speakers, it was hypothesized that the duration of the measured temporal parameter (VD, UD, UOD or VOT) would decrease in the FR compared to the NR due to the fact that the person is producing utterances faster than at a usual self-selected speaking rate. Furthermore, regarding an increase in speaking rate in L1 compared to L2, it was predicted that a speaker would be able to decrease duration, in other words, increase speaking rate, to a greater extent in the language which is more automatized when increased demands are imposed on the speech production mechanism. In the present study, increased demands were imposed by an increase in speaking rate and speaking in L2.

To determine if speaking in L2 affected the temporal parameters of speech production, the following questions were posed to address sub-aim one:

a. Was the extent of durational adjustment in the FR compared to the NR greater in L1 than in L2?

b. Could duration be decreased in the FR compared to the NR in L1 and L2 respectively? From this it could be determined if there were more instances in L2 than L1 where duration could not be decreased in the FR compared to the NR. If this were indeed the case, it could be deduced that durational adjustments in L1 were accomplished to a greater extent under conditions of increased demands on the speech production mechanism. It was predicted that this phenomenon would not necessarily be evident in normal speakers, but rather in persons with compromised speech production mechanisms.

As discussed in chapter four, the duration in the FR was expressed as a percentage of the duration in the NR to determine the extent of durational adjustment in the FR compared to the NR. A positive percentage value, of for example 16%, indicates that the duration in the FR is 16% of the duration in the NR and a durational adjustment of 16% relative to the NR was thus made in the FR condition. A negative percentage value indicates that the duration in the FR was in fact longer than the duration in the NR and that an appropriate durational adjustment (decrease in duration) in the FR could thus not be made. The processed data for sub-aim one, expressing the duration in the FR as a percentage of the duration in the NR for each temporal parameter, utterance and utterance group across the four contexts, for each speaker and the normal group (NGR), are displayed in Appendix C.

5.2.1 Determination of the extent of durational adjustment in L1 versus L2 for *vowel duration*

Vowel duration was measured for utterances beginning with a voiceless plosive, voiced plosive and voiceless fricative.

5.2.1.1 Determination of the extent of durational adjustment in L1 versus L2 for *vowel duration* of utterances beginning with a *voiceless plosive*: Results for *utterances as a group*

In Figure 5.1, the VD in the FR is expressed as a percentage of the VD in the NR for each subject in L1 and L2 respectively.

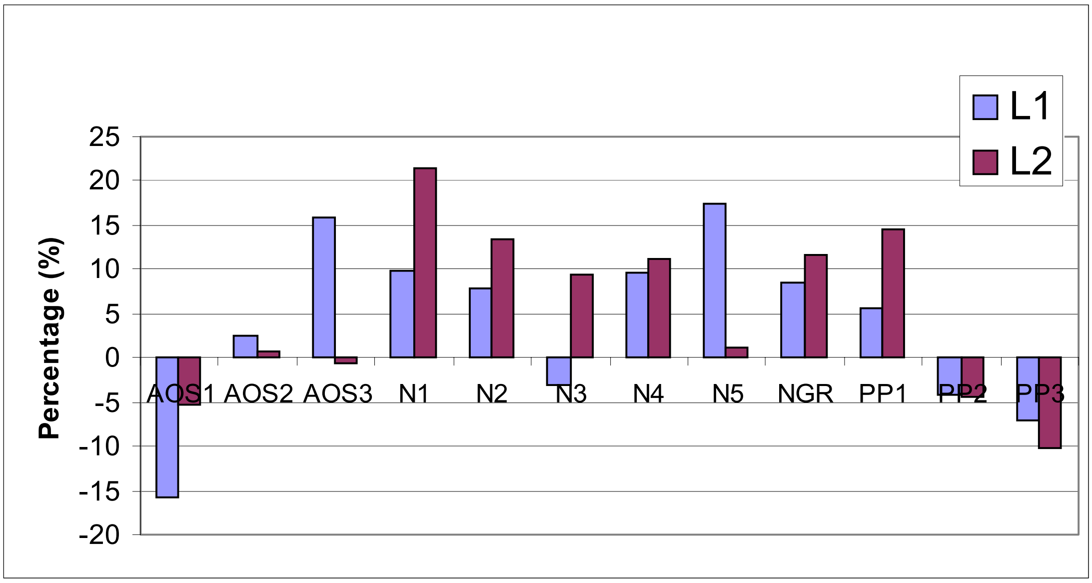

Figure 5.1 VD in FR expressed as a percentage of VD in NR indicating the extent of durational adjustment in the FR compared to the NR in L1 and L2 for utterances beginning with a voiceless plosive as a group

Regarding extent of durational adjustment in L1 compared to L2, the results indicate that all the speakers in the normal group, with the exception of N5, exhibited a greater extent of durational adjustment in the FR compared to the NR in L2. Consequently, as a group, the normal speakers had a greater extent of durational adjustment in the FR compared to the NR in L2 (11.7% in L2 compared to 8.5% in L1). PP1 also exhibited a greater extent of durational adjustment in the FR compared to the NR in L2. In contrast to this result, both AOS2 and AOS3 exhibited a greater extent of durational adjustment in L1. Subjects AOS1, PP2 and PP3 were not able to obtain a shorter duration in the FR compared to the NR in either L1 or L2. Consequently comments regarding the extent of durational adjustment in L1 compared to L2 cannot be made for these subjects. Of the normal group, only N3 did not succeed in obtaining a shorter duration in the FR compared to the NR and this occurred in L1 only.

The findings relevant to answering the questions posed to address sub-aim one are summarized in Table 5.1. In this table it is indicated if durational adjustment (decrease of duration in the FR compared to the NR) was unsuccessful for L1 and L2, respectively. It is also indicated if durational adjustment was unsuccessful in L2 only. Furthermore, it is indicated if the extent of durational adjustment was greater in L1 than in L2. If duration could not be decreased in the FR in either L1 or L1, "not applicable" was indicated, since it is not relevant to comment on the extent of durational adjustment in L1 compared to L2 if this had not been successfully achieved in either language.

Table 5.1 Findings related to the achievement of durational adjustments in L1 and L2 regarding VD of utterances beginning with a voiceless plosive as a group

	Durational adjustment was unsuccessful		Extent of durational adjustment in L1 is greater than in L2	Durational adjustment was only unsuccessful in L2
	L1	L2		
AOS1	X	X	n.a.	
AOS2			X	
AOS3		X	X	X
N1				
N2				
N3	X			
N4				
N5			X	
NGR				
PP1				
PP2	X	X	n.a.	
PP3	X	X	n.a.	

X indicates that the named behavior occurred.

5.2.1.2 Determination of the extent of durational adjustment in L1 versus L2 for *vowel duration* of utterances beginning with a *voiceless plosive*: Results for *individual utterances*

The results for each of the five utterances beginning with a voiceless plosive were viewed separately to determine the number of utterances in which the behaviors relevant to the questions posed for sub-aim one occurred. The findings relevant to these questions for utterances beginning with a voiceless plosive are indicated in Table 5.2. Specifically, it is indicated for each utterance if the extent of durational adjustment was greater in L1 than in L2. Furthermore, it is indicated if durational adjustment was unsuccessful for more L2 utterances compared to L1 utterances. Lastly, it is indicated if more than half of the utterances exhibited a greater extent of durational adjustment in L1 than in L2.

Table 5.2 Findings related to the achievement of durational adjustments in L1 and L2 regarding VD of individual utterances beginning with a voiceless plosive

	puck/"pak"	pet/"pet"	pit/"pit"	putt/"pad"	pup/"pap"	Durational adjustment was unsuccessful for more L2 utterances than L1 utterances	More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2*
	The extent of durational adjustment for the utterance was greater in L1 than L2						
AOS1							
AOS2	X	X				X	
AOS3	X	X	X	X	X	X	X
N1							
N2			X				
N3							
N4					X		
N5	X	X	X	X	X	X	X
NGR							
PP1					X		
PP2				X	X	X	X
PP3			X			X	X

X indicates that the named behavior occurred. *Utterances where the duration could not be decreased in both L1 and L2 were excluded from this calculation. In other words, this column indicates if more than half of the utterances for which *duration could be decreased in at least one of the languages*, exhibited a greater extent of durational adjustment in L1 compared to L2.

From Table 5.2, it is evident that subjects AOS3, N5, PP2 and PP3 exhibited a greater durational adjustment in L1 for more than 50% of the utterances. It can thus be concluded that speech production in L2 only affected the extent of durational adjustment for these four subjects. With the exception of N5, none of the normal speakers obtained a greater extent of durational adjustment in L2 than in L1 for more than one of their utterances. Consequently the results for the *normal group* indicate that for none of the five utterances in the voiceless plosive group, the extent of durational adjustment was greater in L1 than in L2. PP1 fared similar to the normal group and also exhibited a greater extent of durational adjustment in L1 for only one of the five utterances.

For two of the three subjects with AOS (AOS2 and AOS3), two of the three subjects with PP (PP2 and PP3) and for N5, more instances occurred in L2 than L1, in which the duration in the FR could not be decreased compared to the duration in the NR. Even though for some of these subjects the appropriate durational change was also not successfully accomplished in L1 either, it occurred for a greater percentage of utterances in L2 in these speakers.

5.2.1.3 Determination of the extent of durational adjustment in L1 versus L2 for *vowel duration* of utterances beginning with a *voiced plosive*: Results for *utterances as a group*

Figure 5.2 provides a visual presentation of the results regarding the extent of durational adjustment in L1 and L2 respectively, for the voiced plosive utterance group. A summary of the findings related to the answering of the questions posed for sub-aim one is tabulated in Table 5.3.

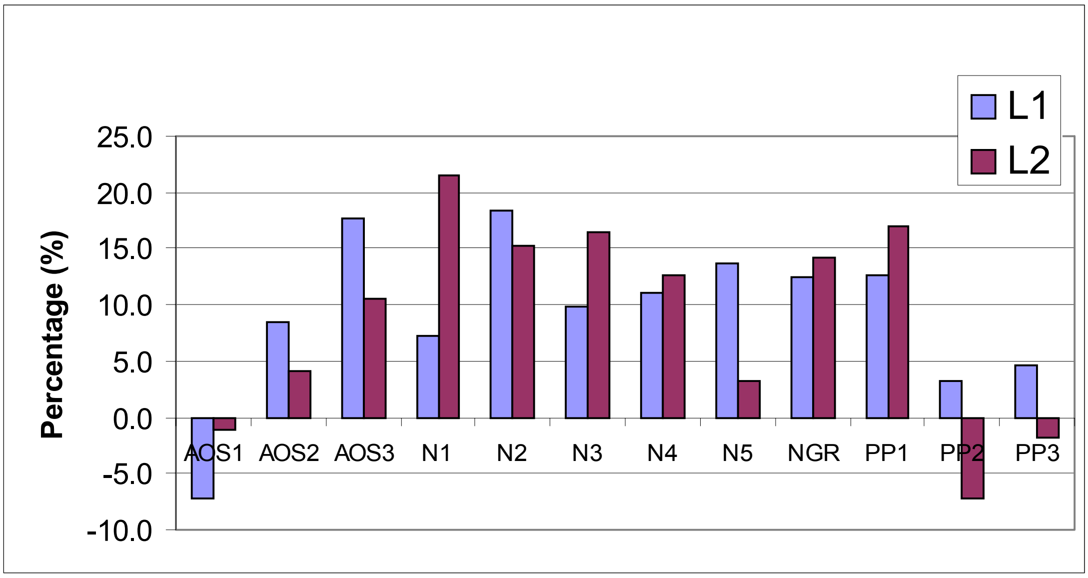

Figure 5.2 VD in the FR expressed as a percentage of VD in the NR indicating the extent of durational adjustment in the FR compared to the NR in L1 and L2 for utterances beginning with a voiced plosive as a group

Table 5.3 Findings related to the achievement of durational adjustments in L1 and L2 regarding VD of utterances beginning with a voiced plosive as a group

	Durational adjustment was unsuccessful		Extent of durational adjustment in L1 is greater than in L2	Durational adjustment was only unsuccessful in L2
	L1	L2		
AOS1	X	X	n.a.	
AOS2			X	
AOS3			X	
N1				
N2			X	
N3				
N4				
N5			X	
NGR				
PP1				
PP2		X	X	X
PP3		X	X	X

X indicates that the named behavior occurred.

Regarding the extent of durational adjustment, it is evident from Figure 5.2 and Table 5.3 that AOS2, AOS3, N2, N5, PP2 and PP3 exhibited a greater extent of durational adjustment in L1 than in L2. It is further evident that AOS1 was unable to make an appropriate durational adjustment in either L1 or L2. Consequently, comments regarding the effect of L2 on the extent of durational adjustment in L1 versus L2 cannot be made for this subject. Subjects PP2 and PP3 were unsuccessful in decreasing duration in the FR, only in L2.

Except for AOS3 and PP1, the experimental subjects generally exhibited durational adjustments in the FR compared to the NR which were smaller than those of the normal group. In L1, the normal group exhibited a mean durational adjustment of 12.4%, whereas the durational adjustments for subjects with AOS1 and AOS2 were -7.2% and 8.4%, respectively. Subjects PP2 and PP3 exhibited durational adjustments of 3.2% and 4.6% respectively in L1. For L2 the normal group exhibited a mean durational adjustment of 14.2%, whereas the durational adjustments for subjects AOS2 and AOS3 were –4.0% and 10.5%, respectively. PP2 and PP3 exhibited durational adjustments of –7.1% and –1.9% respectively.

5.2.1.4 Determination of the extent of durational adjustment in L1 versus L2 for *vowel duration* of utterances beginning with a *voiced plosive:* Results for *individual utterances*

Table 5.4 provides a summary of the relevant findings for sub-aim one regarding individual utterances in the voiced plosive utterance group. Regarding extent of durational adjustment in L1 compared to L2, subjects AOS2, AOS3, N2, N5, PP2 and PP3 exhibited more than half of utterances in L1 with a greater extent of durational adjustment than in L2. Only subjects AOS3, N5, PP2 and PP3 exhibited a greater number of utterances in L2 than in L1 where VD in the FR could not be decreased.

Table 5.4 Findings related to the achievement of durational adjustments in L1 and L2 regarding VD of individual utterances beginning with a voiced plosive

	bait/"byt"	buck"/"bak"	bus/"bas"	back/"bek"	bet/"bed"	Durational adjustment was unsuccessful for more L2 utterances than L1 utterances	More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2*
	The extent of durational adjustment for the utterance is greater in L1 than L2						
AOS1	X				X		
AOS2	X	X	X	X	X		X
AOS3	X	X	X		X	X	X
N1							
N2	X	X	X	X	X		X
N3							
N4			X		X		
N5	X	X	X	X	X	X	X
NGR		X					
PP1							
PP2		X	X	X		X	X
PP3		X		X	X	X	X

X indicates that the named behavior occurred. *Utterances where the duration could not be decreased in both L1 and L2 were excluded from this calculation. In other words, this column indicates if more than half of the utterances for which *duration could be decreased in at least one of the languages*, exhibited a greater extent of durational adjustment in L1 compared to L2.

5.2.1.5 Determination of the extent of durational adjustment in L1 versus L2 for *vowel duration* of utterances beginning with a *voiceless fricative*: Results for *utterances as a group*

Figure 5.3 provides a visual presentation of the results regarding the extent of durational adjustment for utterances beginning with a voiceless fricative.

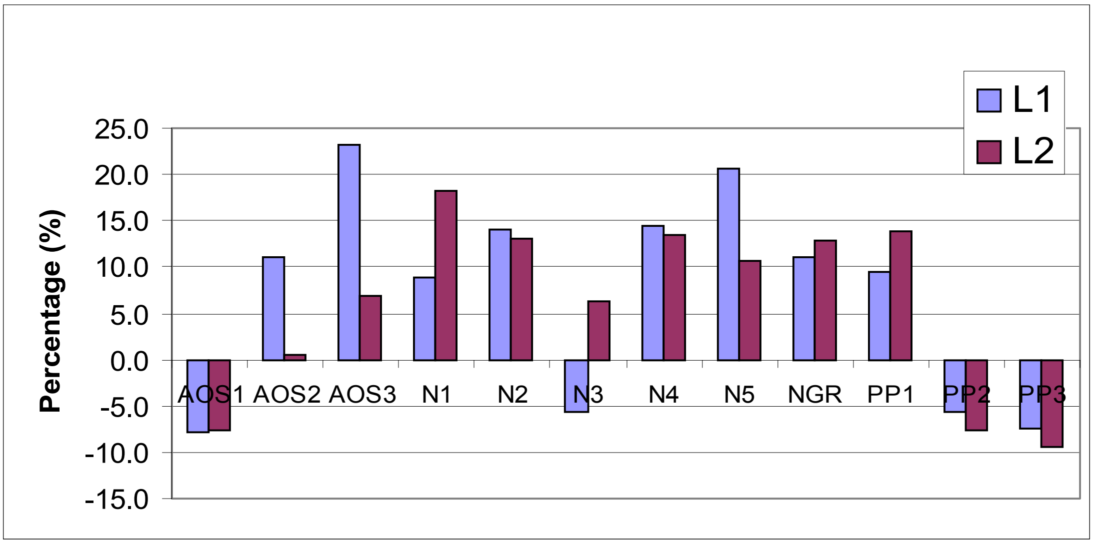

Figure 5.3 VD in FR expressed as a percentage of VD in NR indicating the extent of durational adjustment in the FR compared to the NR in L1 and L2 for utterances beginning with a voiceless fricative as a group

Regarding the extent of durational adjustment in L1 compared to L2, it is evident from Figure 5.3 that AOS2, AOS3, N2, N4 and N5 exhibited a greater extent of durational adjustment in L1 than in L2. From Figure 5.3 it is further evident that AOS1, PP2 and PP3 were unable to achieve a shorter duration in the FR compared to the NR in both L1 and L2. Only one normal speaker, N3 was unable to achieve a shorter duration in the FR and this occurred in L1 only. None of the subjects had more instances in L2 than in L1 where duration in the FR could not be decreased. The normal group exhibited a greater extent of durational adjustment (12.8%) in L2 than all the experimental subjects, with the exception of PP1. The extent of durational adjustment of the experimental subjects, excluding PP1, ranged from -9.4% (for PP3) to 6.9% (for AOS3). The findings relevant to answering the questions posed for sub-aim one are summarized in Table 5.5

Table 5.5 Findings related to the achievement of durational adjustments in L1 and L2 regarding VD of utterances beginning with a voiceless fricative as a group

	Durational adjustment was unsuccessful		Extent of durational adjustment in L1 is greater than in L2	Durational adjustment was only unsuccessful in L2
	L1	L2		
AOS1	X	X	n.a.	
AOS2			X	
AOS3			X	
N1				
N2			X	
N3				
N4			X	
N5			X	
NGR				
PP1				
PP2	X	X	n.a.	
PP3	X	X	n.a.	

X indicates that the named behavior occurred.

5.2.1.6 Determination of the extent of durational adjustment in L1 versus L2 for *vowel duration* of utterances beginning with a *voiceless fricative:* Results for *individual utterances*

The results pertaining to sub-aim one for the individual utterances are summarized in Table 5.6. A greater extent of durational adjustment in L1 than in L2, was made for more than half of the utterances by AOS2, AOS3, N2 and N5. Regarding instances where an appropriate durational adjustment (decrease of duration in the FR) could not be made, it is evident that AOS2, AOS3 and PP2 exhibited this behavior more often for L2 utterances than for L1 utterances.

Table 5.6 Findings related to the achievement of durational adjustments in L1 and L2 regarding VD of individual utterances beginning with a voiceless fricative

	set/"set"	fuss/ "vas"	Fête/"feit"	foot/"voet"	Durational adjustment was unsuccessful for more L2 utterances than L1 utterances	More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2*
	The extent of durational adjustment for the utterance is greater in L1 than L2					
AOS1						
AOS2	X	X	X	X	X	X
AOS3	X	X	X	X	X	X
N1						
N2	X	X	X	X		X
N3						
N4		X		X		
N5	X	X	X	X		X
NGR						
PP1		X		X		
PP2		X			X	
PP3						

X indicates that the named behavior occurred. *Utterances where the duration could not be decreased in both L1 and L2 were excluded from this calculation. In other words, this column indicates if more than half of the utterances for which *duration could be decreased in at least one of the languages*, exhibited a greater extent of durational adjustment in L1 compared to L2.

5.2.1.7 Summary of results regarding the extent of durational adjustment for *vowel duration* in L1 and L2

Table 5.7 provides a summary of the findings regarding the extent of durational adjustment for VD in L1 versus L2 for *utterances as a group* and for *individual utterances* in an utterance group. Table 5.7 aims to highlight trends which emerged regarding the effect of speech production in L2 on durational adjustments by indicating if specific events occurred (A, B, C and D). An X indicates that the stated behavior (A, B, C and D) occurred, whereas an open space implies that the stated behavior was absent.

For *utterances as a group*, it is indicated if durational adjustments were unsuccessful in L2 only (behavior A in Table 5.7) and if a greater extent of durational adjustment occurred in L1 than in L2 (behavior B in Table 5.7). For *individual utterances* in each utterance group, it is indicated if durational adjustment was unsuccessful for more L2 utterances than L1 utterances (behavior C in Table 5.7) and if more than half of the utterances exhibited a greater extent of durational adjustment in L1 than in L2 (behavior D in Table 5.7). For *utterances as a group*, "not applicable" (n.a.) is indicated if comments regarding the extent of durational adjustment in L1 compared to L2 could not be made due to the fact that the duration in the FR could not be decreased in either language.

Table 5.7 Summarized findings related to durational adjustments of VD for utterances as a group and individual utterances in each utterance group

Utterance Type	Finding	AOS1	AOS2	AOS3	PP1	PP2	PP3	N1	N2	N3	N4	N5	NGR
Voiceless Plosives													
Utterances as a group	A			X									
	B	n.a.	X	X		n.a.	n.a.					X	
Individual utterances	C		X	X		X	X					X	
	D			X		X	X					X	
Voiced Plosives													
Utterances as a group	A					X	X						
	B	n.a.	X	X		X	X		X			X	
Individual utterances	C			X		X	X					X	
	D		X	X		X	X		X			X	
Fricatives													
Utterances as a group	A												
	B	n.a.	X	X		n.a.	n.a.		X		X	X	
Individual utterances	C		X	X		X							
	D		X	X					X			X	

Utterances as a group:
A=For utterances as a group, durational adjustments were unsuccessful in L2 only
B=For utterances as a group, the extent of durational adjustment was greater in L1 than in L2
Individual utterances in an utterance group:
C= Durational adjustment was unsuccessful for more L2 utterances compared to L1 utterances
D= More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2

From Table 5.7 it is evident that a particular behavior was sometimes reflected by the findings for the individual utterances in a particular utterance group, but not for utterances as a group and vice versa. If a named behavior (A, B, C and D) was reflected by the *individual* or *utterance group findings*, this behavior was regarded as characteristic of the speech production of the specific subject.

From the results depicted in Table 5.7 it appears as if the L2 context affected the named behaviors (A, B, C and D) for AOS2, AOS3 and PP2 for all utterance groups. PP3 was also affected by the L2 context with the exception of the voiceless fricative utterance group. The normal group does not seem to have been affected by the L2 context regarding the named behaviors. However, when the data of individual normal speakers are viewed, it is evident that N2 exhibited a greater extent of durational adjustment in L1 than in L2 for utterances beginning with a voiced plosive and utterances beginning a voiceless fricative. N4 also exhibited a greater extent of durational adjustment in L1 for utterances beginning with a voiceless fricative, whereas N5 exhibited a greater extent of durational adjustment in L1 than in L2 for all utterance groups. N5 also had a larger number of utterances in L1 than in L2, where duration could not be decreased in the FR.

The fact that AOS1 does not feature any of the named behaviors in Table 5.7 is due to the fact that this subject was very seldom able to decrease duration in the FR condition in either L1 or L2. In summary, it appears as if two of the subjects with AOS (AOS2 and AOS3) and two with PP (PP2 and PP3) were affected by the L2 context resulting in temporal control being exerted more successfully in L1. In other words, the aforementioned subjects were more successful regarding achievement of durational adjustments (decrease in duration) in L1 under circumstances of increased demands imposed by an increase in speaking rate. The fact that some of the normal speakers sometimes did not decrease duration in the FR could be indicative of the fact that individual performance differs when rate has to be increased and might suggest that these subjects occasionally produced only the carrier phrase at a faster rate and not necessarily the target word.

5.2.2 Determination of the extent of durational adjustment in L1 versus L2 for *utterance duration*

Utterance duration was measured for utterances beginning with a voiceless plosive, voiced plosive and fricative. The data for each utterance group will be discussed separately.

5.2.2.1 Determination of the extent of durational adjustment in L1 versus L2 for *utterance duration* of utterances beginning with a *voiceless plosive*: Results for *utterances as a group*

In Figure 5.4 the UD in the FR is expressed as a percentage of the UD in the NR for L1 and L2 respectively in order to indicate the extent of durational adjustment in the FR compared to the NR for utterances beginning with a voiceless plosive.

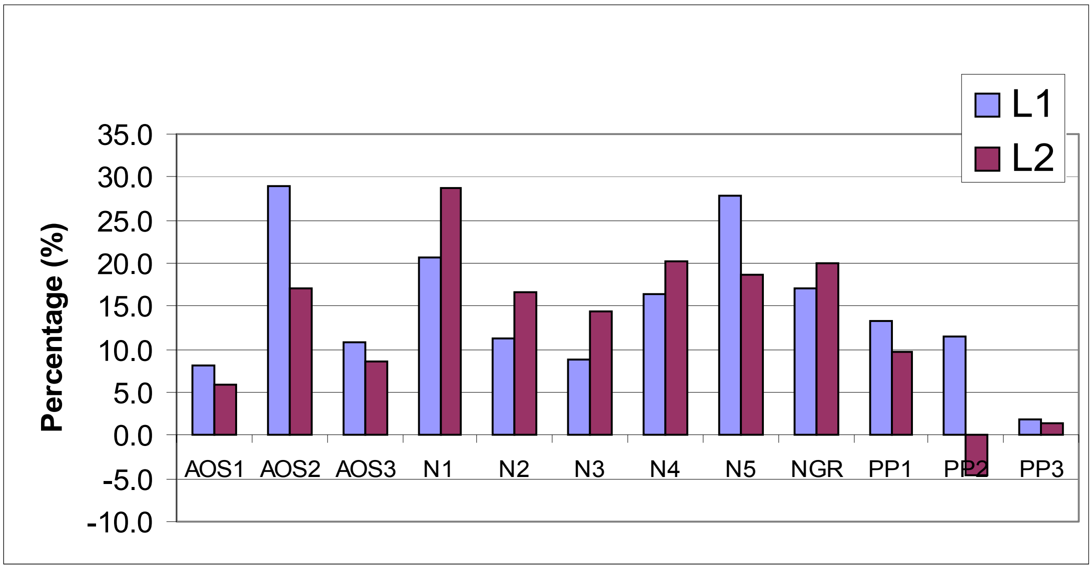

Figure 5.4 UD in FR expressed as a percentage of UD in NR indicating the extent of durational adjustment in the FR compared to the NR in L1 and L2 for utterances beginning with a voiceless plosive as a group

Regarding the extent of durational adjustment it is evident from Figure 5.4 that all three subjects with AOS and PP respectively, as well as N5 exhibited a greater extent of durational adjustment in L1 than in L2. In contrast to the experimental subjects, the normal group exhibited a greater extent of durational adjustment in L2.

This is similar to the finding for the voiceless plosive utterance group regarding durational adjustments for VD. In L2 all the subjects with AOS (5.9%, 17.1% and 8.6% for AOS1, AOS2 and AOS3 respectively) and those with PP (9.8%, -4.5% and 1.4% for PP1, PP2 and PP3 respectively) exhibited a smaller extent of durational adjustment than the normal group (19.9%). From Figure 5.4 it is evident that all the subjects, with the exception of PP2 in L2, were able to decrease duration in the FR in both L1 and L2.

Table 5.8 summarizes the findings pertaining to the questions posed for sub-aim one. As can be seen in Table 5.8, PP2 was thus the only subject who exhibited unsuccessful durational adjustment L2 only.

Table 5.8 Findings related to the achievement of durational adjustments in L1 and L2 regarding UD of utterances beginning with a voiceless plosive as a group

	Durational adjustment was unsuccessful		Extent of durational adjustment in L1 is greater than in L2	Durational adjustment was only unsuccessful in L2
	L1	L2		
AOS1			X	
AOS2			X	
AOS3			X	
N1				
N2				
N3				
N4				
N5			X	
NGR				
PP1			X	
PP2		X	X	X
PP3			X	

X indicates that the named behavior occurred.

5.2.2.2 Determination of the extent of durational adjustment in L1 versus L2 for *utterance duration* of utterances beginning with a *voiceless plosive*: Results for *individual utterances*

Table 5.9 provides a summary of the findings regarding the extent of durational adjustment for individual utterances beginning with a voiceless plosive. Regarding a greater extent of durational adjustment in L1 than in L2, it is evident from Table 5.9 that subjects AOS2, N5 and all three subjects with PP exhibited a greater extent of durational adjustment in L1 for more than half of the utterances beginning with a voiceless plosive. This implies that for these subjects, L1 generally led to achievement of a greater extent of durational adjustment. L2 thus seems to have influenced the extent of durational adjustment negatively in these subjects.

Table 5.9 Findings related to the achievement of durational adjustments in L1 and L2 regarding UD of individual utterances beginning with a voiceless plosive

	puck/"pak"	pet/"pet"	pit/"pit"	putt/"pad"	pup/"pap"	Durational adjustment was unsuccessful for more L2 utterances than L1 utterances	More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2*
	The extent of durational adjustment for the utterance is greater in L1 than L2						
AOS1	X		X				
AOS2	X	X	X	X	X		X
AOS3			X	X		X	
N1				X	X		
N2		X			X		
N3	X						
N4	X						
N5		X	X	X	X		X
NGR					X		
PP1		X	X	X		X	X
PP2	X		X	X	X	X	X
PP3			X		X	X	X

X indicates that the named behavior occurred. *Utterances where the duration could not be decreased in both L1 and L2 were excluded from this calculation. In other words, this column indicates if more than half of the utterances for which *duration could be decreased in at least one of the languages*, exhibited a greater extent of durational adjustment in L1 compared to L2.

Regarding the number of utterances in L1 and L2, in which a shorter duration could not be obtained in the FR, it is evident that AOS3 and all three PP subjects were unsuccessful in decreasing duration in the FR for more L2 utterances than L1 utterances. The normal speakers were always successful in decreasing duration in the FR compared to the NR.

5.2.2.3 Determination of the extent of durational adjustment in L1 versus L2 for *utterance duration* of utterances beginning with a *voiced plosive*: Results for *utterances as a group*

Figure 5.5 entails a visual presentation of UD in the FR as a percentage of UD duration in the NR for L1 and L2 for utterances beginning with a voiced plosive as a group. The findings pertaining to the questions posed for sub-aim one for UD of the voiced plosive utterance group are summarized in Table 5.10.

Regarding the extent of durational adjustment in L1 compared to L2, subjects AOS2, AOS3, N2, N5, PP1 and PP2 exhibited a greater extent of durational adjustment in L1 than in L2. The normal group's extent of durational adjustment in L1 compared to L2 differed by only 0.8%, indicating that as a group the extent of durational adjustment in L1 and L2 was very similar.

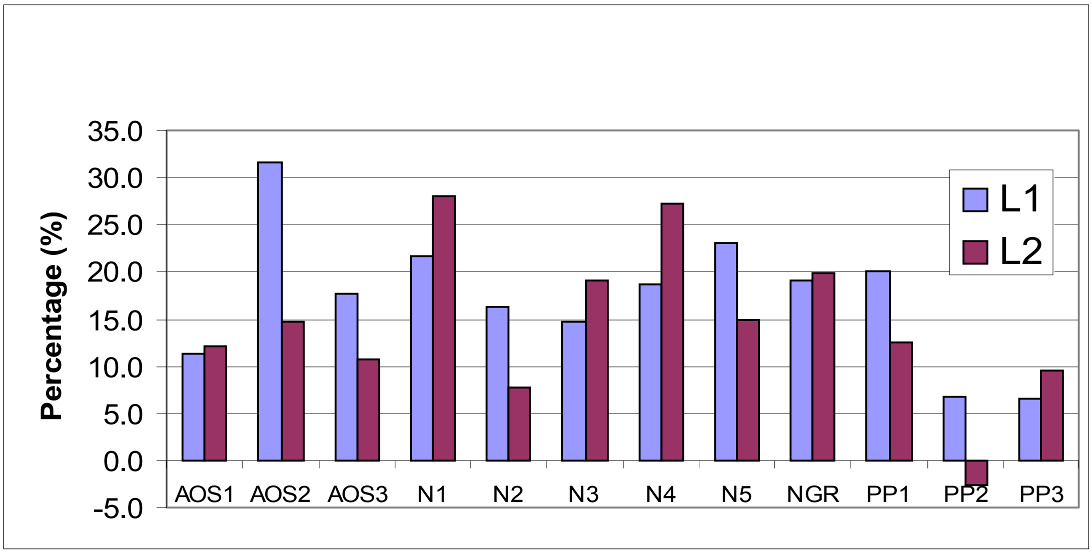

Figure 5.5 UD in FR expressed as a percentage of UD in NR indicating the extent of durational adjustment in the FR compared to the NR in L1 and L2 for utterances beginning with a voiced plosive as a group

Table 5.10 Findings related to the achievement of durational adjustments in L1 and L2 regarding UD of utterances beginning with a voiced plosive as a group

	Durational adjustment was unsuccessful		Extent of durational adjustment in L1 is greater than in L2	Durational adjustment was only unsuccessful in L2
	L1	L2		
AOS1				
AOS2			X	
AOS3			X	
N1				
N2			X	
N3				
N4				
N5			X	
NGR				
PP1			X	
PP2		X	X	X
PP3				

X indicates that the named behavior occurred.

AOS1 had a slightly greater extent of durational adjustment in L2 with the difference between the percentage values of L1 and L2 being only 0.7%. Both AOS2 and AOS3 exhibited quite a big difference between their extent of durational adjustment in L1 and L2. For AOS2 the difference between the durational adjustments in L1 and L2 was 16.9% and for AOS3 it was 7.6%. PP1 exhibited a difference of 7.4%, and PP2 a difference of 9.5%, between the extent of durational adjustment in L1 and L2.

As with the voiceless plosive utterance group, only PP2 was not able to obtain a shorter duration in the FR compared to the NR in L2 only. Achievement of durational adjustments thus appears to have been negatively influenced by L2 in this subject. In L2, all the experimental subjects had a smaller extent of durational adjustment than the normal group, with the extent of durational adjustments ranging from 10.6% to 14.7% for the subjects with AOS and from –2.7% to 12.6% for the subjects with PP. The normal group exhibited an extent of durational adjustment of 19.9% in L2.

5.2.2.4 Determination of the extent of durational adjustment in L1 versus L2 for *utterance duration* of utterances beginning with a *voiced plosive*: Results for *individual utterances*

The findings pertaining to the questions posed for sub-aim one regarding individual utterances beginning with a voiced plosive are summarized in Table 5.11. From the results indicated in Table 5.11 it is evident that only N2, PP1 and PP2 were unsuccessful regarding the achievement of durational adjustments more often for L2 utterances than for L1 utterances. Regarding the extent of durational adjustment in L1 compared to L2, subjects AOS2, AOS3, N2, N5 and all subjects with PP exhibited a greater extent of durational adjustment in L1 than in L2 for more than half of the utterances in the voiced plosive utterance group.

Table 5.11 Findings related to the achievement of durational adjustments in L1 and L2 regarding UD of individual utterances beginning with a voiced plosive

	bait/"byt"	buck"/"bak"	bus/"bas"	back/"bek"	bet/"bed"	Durational adjustment was unsuccessful for more L2 utterances than L1 utterances	More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2*
	The extent of durational adjustment for the utterance is greater in L1 than L2						
AOS1	X	X					
AOS2	X	X	X	X	X		X
AOS3	X	X	X		X		X
N1		X					
N2	X	X	X		X	X	X
N3		X					
N4			X				
N5	X	X		X			X
NGR	X	X					
PP1	X		X	X	X	X	X
PP2	X	X	X		X	X	X
PP3		X	X		X		X

X indicates that the named behavior occurred. *Utterances where the duration could not be decreased in both L1 and L2 were excluded from this calculation. In other words, this column indicates if more than half of the utterances for which *duration could be decreased in at least one of the languages*, exhibited a greater extent of durational adjustment in L1 compared to L2.

5.2.2.5 Determination of the extent of durational adjustment in L1 versus L2 for *utterance duration* of utterances beginning with a *voiceless fricative*: Results for *utterances as a group*

Figure 5.6 displays UD in the FR as a percentage of UD in the NR for utterances beginning with a voiceless fricative as a group, while Table 5.12 provides a summary of the findings pertaining to the questions posed for sub-aim one.

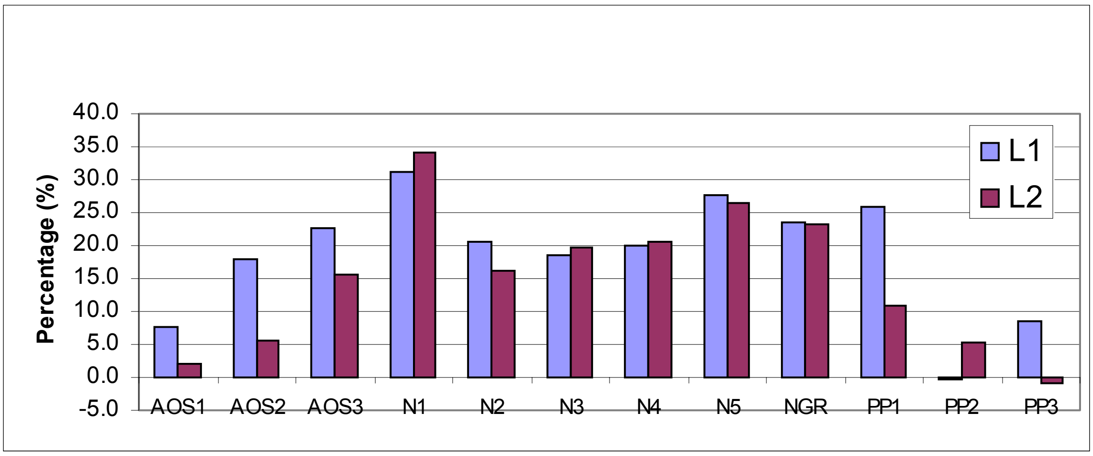

Figure 5.6 UD in FR expressed as a percentage of UD in NR indicating the extent of durational adjustment in the FR compared to the NR in L1 and L2 for utterances beginning with a voiceless fricative as a group

Table 5.12 Findings related to the achievement of durational adjustments in L1 and L2 regarding UD of utterances beginning with a voiceless fricative as a group

	Durational adjustment was unsuccessful		Extent of durational adjustment in L1 is greater than in L2	Durational adjustment was only unsuccessful in L2
	L1	L2		
AOS1			X	
AOS2			X	
AOS3			X	
N1				
N2			X	
N3				
N4				
N5			X	
NGR			X	
PP1			X	
PP2	X			
PP3		X	X	X

X indicates that the named behavior occurred.

From Figure 5.6 and Table 5.12 it is evident that all the experimental and normal subjects, with the exception of N1, N3, N4 and PP2, exhibited a greater extent of durational adjustment in L1 compared to L2. As with the voiced plosive utterance group, the normal group exhibited a very similar extent of durational adjustment in L1 and L2, with the percentage of durational adjustment for L1 and L2 differing by only 0.3%. The difference between the extent of durational adjustment in L1 and L2 was generally quite small for the individual normal speakers who exhibited a greater extent of durational adjustment in L1 (4.4% for N2 and 0.9% for N5). The difference between the percentage of durational adjustment in L1 and L2 was much larger in the subjects with AOS (5.7% for AOS1, 12.4% for AOS2 and 7.0% for AOS3) and the subjects with PP (15% for PP1 and 9.2% for PP3) who achieved a greater extent of durational adjustment in L1.

Regarding an inability to decrease duration in the FR, only PP2 was unable to decrease duration in the FR in L1 and PP3 in L2. Other than this, all the experimental and normal subjects were able to decrease duration in the FR. Consequently, only PP3 was unsuccessful regarding achievement of durational adjustments in L2 only.

All the subjects with AOS, as well as PP2 and PP3 exhibited smaller percentages of durational adjustment than the normal group in both L1 and L2. In L1, the extent of durational adjustment ranged from 7.7% to 22.7% for the subjects with AOS and from –0.3% to 8.4% for the two subjects with PP, while that of the normal group was 23.6%. In L2, the normal group had an extent of durational adjustment of 23.3%, while the extent of durational adjustment ranged from 2.0% to 15.7% for the subjects with AOS and from –0.8% to 11% for PP1 and PP2.

5.2.2.6 Determination of the extent of durational adjustment in L1 versus L2 for *utterance duration* of utterances beginning with a *voiceless fricative*: Results for *individual utterances*

The results pertaining to the questions posed for sub-aim one of individual utterances beginning with a voiceless fricative are summarized in Table 5.13. It is evident from Table 5.13 that subjects AOS1, AOS2, N2, normal speakers as a group, PP1 and PP2 exhibited a greater extent of durational adjustment in L1 for more than half of the utterances in the voiceless fricative utterance group. For these subjects the L2 context thus appears to have influenced the extent of durational adjustment negatively in it led to achievement of a smaller extent of durational adjustment. Subjects AOS3 and PP2 exhibited a greater extent of durational adjustment in L1 for half of the target utterances in the voiceless fricative utterance group and a greater extent of durational adjustment in L2 for the other half.

Table 5.13 Findings related to the achievement of durational adjustments in L1 and L2 regarding UD of individual utterances beginning with a voiceless fricative

	set/"set"	fuss/ "vas"	Fête/"feit"	foot/"voet"	Durational adjustment was unsuccessful for more L2 utterances than L1 utterances	More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2*
	The extent of durational adjustment for the utterance is greater in L1 than L2					
AOS1	X	X	X		X	X
AOS2	X	X	X	X	X	X
AOS3			X	X		
N1			X			
N2	X	X	X	X		X
N3	X	X				
N4			X	X		
N5	X		X			
NGR	X		X	X		X
PP1	X	X	X	X	X	X
PP2	X		X			
PP3	X	X			X	X

X indicates that the named behavior occurred. *Utterances where the duration could not be decreased in both L1 and L2 were excluded from this calculation. In other words, this column indicates if more than half of the utterances for which *duration could be decreased in at least one of the languages*, exhibited a greater extent of durational adjustment in L1 compared to L2.

Regarding an inability to decrease UD in the FR, it is evident from Table 5.13 that AOS1, AOS2, PP1 and PP3 were unsuccessful in decreasing duration in the FR for more L2 utterances than L1 utterances. PP2 had an equal number of utterances in each language where UD in the FR could not be decreased. Although this subject thus has difficulty with the accomplishment of durational adjustment, this was not influenced by the L2 context. None of the normal speakers exhibited instances where the duration in the FR could not be decreased.

5.2.2.7 Summary of results regarding the extent of durational adjustment of utterance duration in L1 and L2

Table 5.14 provides a summary of the findings regarding the extent of durational adjustment for UD in L1 versus L2 for *utterances as a group* and for *individual utterances* in an utterance group. Table 5.14 aims to highlight trends which emerged regarding the effect of speech production in L2 on durational adjustment for UD by indicating the occurrence of specific behaviors (A, B, C and D). The same behaviors (A, B, C and D) are indicated and in the same manner as was done for VD (see 5.2.1.7).

Table 5.14 Summarized findings related to durational adjustments of UD for utterances as a group and individual utterances in each utterance group

Utterance Type	Finding	AOS1	AOS2	AOS3	PP1	PP2	PP3	N1	N2	N3	N4	N5	NGR
Voiceless Plosives													
Utterances as a group	A					X							
	B	X	X	X	X	X	X					X	
Individual utterances	C			X	X	X	X						
	D		X		X	X	X					X	
Voiced Plosives													
Utterances as a group	A					X							
	B		X	X	X	X			X			X	
Individual utterances	C				X	X			X				
	D		X	X	X	X	X		X			X	
Fricatives													
Utterances as a group	A						X						
	B	X	X	X	X		X		X			X	X
Individual utterances	C	X	X		X		X						
	D	X	X		X		X		X				X

Utterances as a group:
A=For utterances as a group, durational adjustments were unsuccessful in L2 only
B=For utterances as a group, the extent of durational adjustment was greater in L1 than in L2
Individual utterances in an utterance group:
C= Durational adjustment was unsuccessful for more L2 utterances compared to L1 utterances
D= More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2

From Table 5.14 it is evident that L2 appears to have influenced temporal control in AOS2, AOS3, PP1, PP3 and N5 regarding extent of durational adjustment in all three utterance groups. The aforementioned subjects all obtained a greater extent of durational adjustment in L1 compared to L2 for all three utterance groups as evidenced by the findings for either the utterances as a group and/or for more than half of the utterances in each utterance group. AOS1 seems to have been influenced by L2 regarding the extent of durational adjustment for the voiceless plosive and voiceless fricative utterance groups, whereas PP2 exhibited a greater extent of durational adjustment in L1 for both the voiceless and voiced plosive utterance groups. Subject N2 also exhibited a greater extent of durational adjustment in L1 for the voiced plosive and voiceless fricative utterance groups. The normal group does not appear to have been consistently influenced by the L2 context regarding the extent of durational adjustment, and only exhibited a greater extent of durational adjustment in L1 for the voiceless fricative utterance group.

From the results in Table 5.14 it is further evident that AOS1 and AOS2 exhibited more L2 utterances than L1 utterances where duration in the FR could not be decreased, but only for the voiceless fricative utterance group. PP2 was unsuccessful in decreasing duration in the FR for more L2 than L1 utterances regarding all three utterance groups, whereas this behavior occurred only in the voiced and voiceless plosive utterance groups for PP2 and in the voiceless plosive and voiceless fricative groups for PP3. It thus appears as if the different utterance groups influenced the various subjects differently.

In summary, it is evident that the L2 context influenced the subjects with either AOS or PP to a greater extent than the normal speakers regarding the achievement of a greater extent of durational adjustment in L1 than in L2. However, two of the normal speakers, N2 and N5, appear to have been influenced by L2 regarding the extent of durational adjustment. With the exception of N2, none of the normal speakers exhibited an inability to decrease duration in the FR more often in L2. All the subjects with either AOS or PP exhibited an inability to decrease duration in the FR more often in L2 than in L1, in at least one of the three utterance groups.

5.2.3 Determination of the extent of durational adjustment in L1 versus L2 for *utterance onset duration*

UOD was only measured for utterances beginning with either a voiceless or voiced plosive, since utterances beginning with a voiceless fricative did not have a period of silence displaying no acoustic energy between the end of the carrier phrase and the beginning of the target utterance, as is the case with utterances beginning with a plosive. The reason for this is that plosive sounds have a period of constriction for their production. The data for each utterance group will be discussed separately.

5.2.3.1 Determination of the extent of durational adjustment in L1 versus L2 for *utterance onset duration* of utterances beginning with a *voiceless plosive*: Results for *utterances as a group*

For description of the results regarding durational adjustment of UOD, the reader is referred to Figure 5.7 and to Table 5.15 for a summary of the results pertaining to the questions which were posed for sub-aim one.

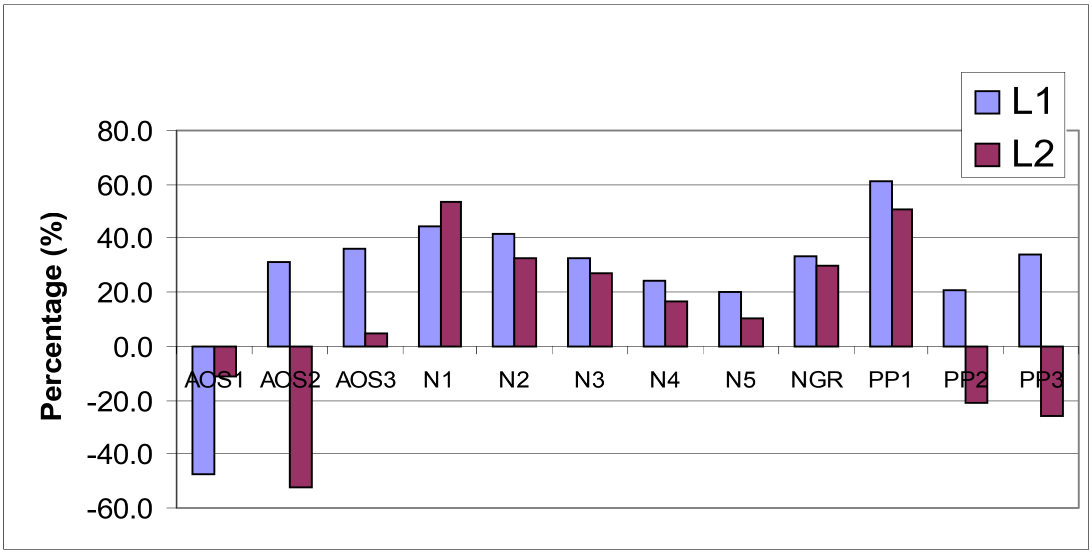

Figure 5.7 UOD in FR expressed as a percentage of UOD in NR indicating the extent of durational adjustment in the FR compared to the NR in L1 and L2 for utterances beginning with a voiceless plosive as a group

Table 5.15 Findings related to the achievement of durational adjustments in L1 and L2 regarding UOD of utterances beginning with a voiceless plosive as a group

	Durational adjustment was unsuccessful		Extent of durational adjustment in L1 is greater than in L2	Durational adjustment was only unsuccessful in L2
	L1	L2		
AOS1	X	X	n.a.	
AOS2		X	X	X
AOS3			X	
N1				
N2			X	
N3			X	
N4			X	
N5			X	
NGR			X	
PP1			X	
PP2		X	X	X
PP3		X	X	X

X indicates that the named behavior occurred.

Regarding the extent of durational adjustment in L1 compared to L2 it is evident from Figure 5.7 and Table 5.15 that all subjects, with the exception of AOS1 and N1, exhibited a greater extent of durational adjustment in the FR in L1 than in L2. For the normal group, the difference between the extent of durational adjustment in L1 and L2 was quite small (3.8%), indicating that durational adjustments were achieved to much the same extent in both languages. In contrast to the aforementioned result, the difference between the extent of durational adjustment in L1 and L2 ranged from 31.5% to 83.1% for AOS2 and AOS3 and from 10.8% to 59.5% for the subjects with PP, which is much larger than the difference for the normal group. This implies that speaking in L2 had a greater effect on accomplishment of durational adjustments in the experimental subjects than in the normal group, since the experimental subjects were able to obtain a much greater extent of durational adjustment in L1 than in L2.

From Figure 5.7 and Table 5.15 it is evident that AOS1 was unable to decrease UOD in the FR in both L1 and L2. This implies that when the speaking rate had to be increased, production resulted in a longer UOD in the FR than during the NR in both languages. Subjects AOS2, PP2 and PP3 failed to achieve a shorter UOD in the FR in L2 only, indicating that this context presumably influenced temporal control negatively in these subjects.

In L1, the extent of durational adjustment of AOS2, AOS3, PP2 and PP3 generally fell within the range of that of the normal subjects. The extent of durational adjustment for the aforementioned experimental subjects ranged from 20.7% (PP2) to 63.2% (AOS3), while the extent of durational adjustment for the normal speakers in L1 ranged from 20.4% (N5) to 44.7% (N1).

5.2.3.2 Determination of the extent of durational adjustment in L1 versus L2 for *utterance onset duration* of utterances beginning with a *voiceless plosive*: Results for *individual utterances*

Table 5.16 provides a summary of the findings regarding the extent of durational adjustment for UOD for individual utterances in the voiceless plosive utterance group. From this table it is evident that AOS2, AOS3, all normal speakers, with the exception of N1 and all subjects with PP, achieved a greater extent of durational adjustment L1 than in L2 for more than half of the utterances in this utterance group. This implies that temporal adjustments were achieved to a greater extent in L1 in these subjects when the demands were increased with an increase in speaking rate.

Table 5.16 Findings related to the achievement of durational adjustments in L1 and L2 regarding UOD of individual utterances beginning with a voiceless plosive

	puck/"pak"	pet/"pet"	pit/"pit"	putt/"pad"	pup/"pap"	Durational adjustment was unsuccessful for more L2 utterances than L1 utterances	More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2*
	The extent of durational adjustment for the utterance is greater in L1 than L2						
AOS1		X					
AOS2	X	X	X	X		X	X
AOS3	X	X	X		X	X	X
N1							
N2	X		X	X	X		X
N3	X	X	X		X		X
N4	X		X	X			X
N5	X	X	X	X	X		X
NGR	X		X	X			X
PP1			X	X	X		X
PP2	X	X	X		X	X	X
PP3	X	X	X	X	X	X	X

X indicates that the named behavior occurred. *Utterances where the duration could not be decreased in both L1 and L2 were excluded from this calculation. In other words, this column indicates if more than half of the utterances for which *duration could be decreased in at least one of the languages*, exhibited a greater extent of durational adjustment in L1 compared to L2.

Subjects AOS2, AOS3, PP2 and PP3 were more often unsuccessful regarding the achievement of durational adjustments when producing L2 utterances than when producing L1 utterances. Subject AOS1 exhibited difficulty with decreasing duration in the FR in both L1 and L2. Subject PP1 and all the normal speakers were successful regarding decreasing duration in the FR for all utterances in both L1 and L2.

5.2.3.3 Determination of the extent of durational adjustment in L1 versus L2 for *utterance onset duration* of utterances beginning with a *voiced plosive*: Results for *utterances as a group*

Figure 5.8 displays the durational adjustment in L1 and L2 respectively for UOD of utterances beginning with a voiced plosive as a group. The findings pertaining to the questions posed for sub-aim one are summarized in Table 5.17.

Regarding the extent of durational adjustment in L1 compared to L2, it is evident that AOS1, AOS3, N2, N3, N5, PP2 and PP3 exhibited a greater extent of durational adjustment in L1 compared to L2. The normal group had a very similar extent of durational adjustment in L1 and L2, with the percentage values for the two languages differing by only 0.1%. The difference between the durational adjustment in L1 and L2 for AOS1 was 5.3% and for PP2, 8.3%. When viewing the data of the individual normal speakers, the differences between L1 and L2 were also quite big, however, ranging from 3.3% (N4) to 18.7% (N5).

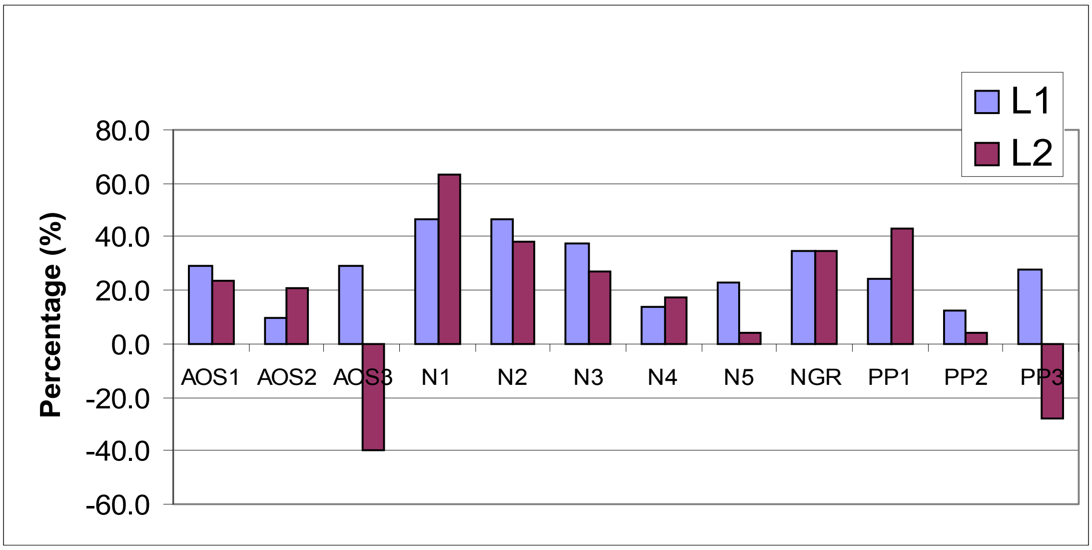

Figure 5.8 UOD in FR expressed as a percentage of UOD in NR indicating the extent of durational adjustment in the FR compared to the NR in L1 and L2 for utterances beginning with a voiced plosive as a group

Table 5.17 Findings related to the achievement of durational adjustments in L1 and L2 regarding UOD of utterances beginning with a voiced plosive as a group

	Durational adjustment was unsuccessful		Extent of durational adjustment in L1 is greater than in L2	Durational adjustment was only unsuccessful in L2
	L1	L2		
AOS1			X	
AOS2				
AOS3		X	X	X
N1				
N2			X	
N3			X	
N4				
N5			X	
NGR				
PP1				
PP2			X	
PP3		X	X	X

X indicates that the named behavior occurred.

From Figure 5.8 and Table 5.17, it is further evident that only AOS3 and PP3 were not successful in decreasing duration in the FR in L2 utterances only. These two subjects thus appear to exhibit greater difficulty with achievement of durational adjustments in L2.

5.2.3.4 Determination of the extent of durational adjustment in L1 versus L2 for *utterance onset duration* of utterances beginning with a *voiced plosive*: Results for *individual utterances*

The results pertaining to the extent of durational adjustment in L1 and L2 of individual utterances beginning with a voiced plosive are summarized in Table 5.18.

Table 5.18 Findings related to the achievement of durational adjustments in L1 and L2 regarding UOD of individual utterances beginning with a voiced plosive

	bait/"byt"	buck"/"bak"	bus/"bas"	back/"bek"	bet/"bed"	Durational adjustment was unsuccessful for more L2 utterances than L1 utterances	More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2*
	The extent of durational adjustment for the utterance is greater in L1 than L2						
AOS1	X			X			
AOS2		X					
AOS3	X	X		X		X	X
N1							
N2	X	X	X	X	X		X
N3	X	X	X	X			X
N4			X	X	X		X
N5	X	X	X	X	X	X	X
NGR	X			X	X		X
PP1		X	X				
PP2		X	X	X		X	X
PP3	X		X	X			X

X indicates that the named behavior occurred. *Utterances where the duration could not be decreased in both L1 and L2 were excluded from this calculation. In other words, this column indicates if more than half of the utterances for which *duration could be decreased in at least one of the languages*, exhibited a greater extent of durational adjustment in L1 compared to L2.

From Table 5.18 it is evident that AOS3, PP2, PP3 and all the normal speakers, with the exception of N1, exhibited a greater extent of durational adjustment in L1 than in L2 for more than half of the utterances in the voiced plosive utterance group. This result implies that durational adjustment generally accomplished to a greater extent in L1 utterances when the demands were increased with an increase in speaking rate. Furthermore, durational adjustment was unsuccessful for more L2 than L1 utterances in AOS3, PP2 and N5. All the normal speakers were able to decrease duration in the FR for all utterances in both L1 and L2, with the exception of N5 who was unable to obtain a shorter duration in the FR for "bait" in L2 (see Appendix C). Subjects AOS1, AOS2 and PP1 also had instances where duration in the FR could not be decreased, although this did not occur more often in L2 than in L1, implying that L2 did not lead to greater difficulty with the accomplishment of durational adjustments in these subjects.

5.2.3.5 Summary of results regarding the extent of durational adjustment of utterance onset duration in L1 and L2

Table 5.19 summarizes the findings regarding the extent of durational adjustment in L1 and L2 for UOD regarding *utterances as a group* and *individual utterances* in each of the three utterance groups. The behaviors (A, B, C and D) indicated in this table are similar to the previous tables regarding VD (Table 5.7) and UD (Table 5.14).

Table 5.19 Summarized findings related to durational adjustments of UOD for utterances as a group and individual utterances in the voiceless plosive and voiced plosive utterance groups

Utterance Type	Finding	AOS1	AOS2	AOS3	PP1	PP2	PP3	N1	N2	N3	N4	N5	NGR
Voiceless Plosives													
Utterances as a group	A		X			X	X						
	B	n.a.	X	X	X	X	X		X	X	X	X	X
Individual utterances	C		X	X		X	X						
	D		X	X	X	X	X		X	X	X	X	X
Voiced Plosives													
Utterances as a group	A			X			X						
	B	X		X		X	X		X	X		X	
Individual utterances	C			X		X						X	
	D			X		X	X		X	X	X	X	X

Utterances as a group:
A=For utterances as a group, durational adjustments were unsuccessful in L2 only
B=For utterances as a group, the extent of durational adjustment was greater in L1 than in L2
Individual utterances in an utterance group:
C= Durational adjustment was unsuccessful for more L2 utterances compared to L1 utterances
D= More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2

From Table 5.19 it is evident that the L2 context appears to have influenced the extent of durational adjustment regarding UOD negatively for both the voiceless and voiced plosive utterance groups in AOS3, PP2, PP3 and all the normal speakers with the exception of N1. The reason for concluding that the L2 context influenced the extent of durational adjustment negatively is the fact that all the aforementioned speakers obtained a greater extent of durational adjustment in L1 compared to L2. AOS1 exhibited a greater extent of durational adjustment in L1 for the voiced plosive utterance group, but was unable to decrease duration in the FR in both L1 and L2 regarding the voiceless plosive utterance group. AOS2 and PP1 exhibited a greater extent of durational adjustment in L1 for only the voiceless plosive utterance group.

AOS3, PP2 and PP3 were unsuccessful regarding decreasing duration in the FR more often in L2 than in L1 for both the voiced and voiceless plosive utterance groups, indicating that difficulty with temporal control under circumstances of increased demand became more apparent whilst speaking in L2 in these subjects. AOS2 was unsuccessful in decreasing duration in the FR more often in L2, only for the voiceless plosive utterance group. The normal speakers did not exhibit difficulty with decreasing duration in the FR with the exception of N5 for one utterance in the voiced plosive group in L2.

5.2.4 Determination of the extent of durational adjustment in L1 versus L2 for v*oice onset time*

Voice onset time was measured for utterances beginning with either a voiced or voiceless plosive, although only the data for the voiceless plosives will be reported for sub-aim one. Because utterances beginning with a voiced plosive often displayed a negative VOT (voicing lead), it was not possible to use the formula which was compiled to determine the extent of durational adjustment of a temporal parameter in the FR compared to the NR. The reason for this was that a negative percentage value would not necessarily have reflected that the VOT was longer in the FR, as was the case with the other temporal parameters, since it might merely have been due to the fact that a negative VOT value had been used for calculation. Because of this, it was decided to use only the data from the voiceless plosive utterance group. It was predicted that VOT would decrease in the FR compared to the NR in normal speakers (Kessinger & Blumstein, 1998).

5.2.4.1 Determination of the extent of durational adjustment in L1 versus L2 for *voice onset time* of utterances beginning with a *voiceless plosive*: Results for *utterances as a group*

Figure 5.9 provides a visual presentation of durational adjustment regarding VOT in L1 and L2 respectively, for the voiceless plosive utterance group. Regarding the extent of durational adjustment in the FR in L1 compared to L2, it is evident that only N4, PP2 and PP3 exhibited a greater extent of durational adjustment in the FR in L1 than in L2. It thus appears as if VOT is not influenced to the same extent by the L2 context as the other measured temporal parameters where the extent of durational adjustment in speakers with AOS and those with PP was generally greater in L1. Furthermore, it is evident from Figure 5.9 that AOS1, N2 and N3 was unsuccessful at decreasing VOT in the FR in L1, whereas PP2 had difficulty decreasing VOT in the FR in L2.

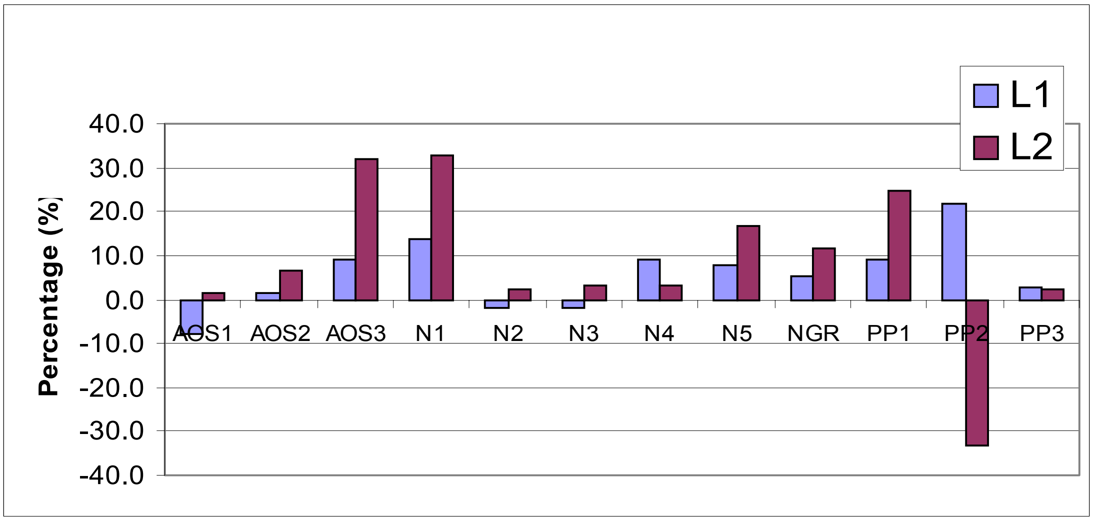

Figure 5.9 VOT in FR expressed as a percentage of VOT in NR indicating the extent of durational adjustment in the FR compared to the NR in L1 and L2 for utterances beginning with a voiceless plosive as a group

The findings pertaining to the questions posed for sub-aim one are summarized in Table 5.20.

Table 5.20 Findings related to the achievement of durational adjustments in L1 and L2 regarding VOT of utterances beginning with a voiceless plosive as a group

	Durational adjustment was unsuccessful		Extent of durational adjustment in L1 is greater than in L2	Durational adjustment was only unsuccessful in L2
	L1	L2		
AOS1	X			
AOS2				
AOS3				
N1				
N2	X			
N3	X			
N4			X	
N5				
NGR				
PP1				
PP2		X	X	X
PP3			X	

X indicates that the named behavior occurred.

From Table 5.20, it can be concluded that L2 does not seem to cause difficulty with the achievement of durational adjustment, nor does it influence the extent of durational adjustment negatively, since most subjects achieved a greater extent of durational adjustment in L2 than in L1. VOT does not seem as susceptible to the influence of L2 under circumstances where additional motor demands are placed on the speech production mechanism with an increase in speaking rate.

5.2.4.2 Determination of the extent of durational adjustment in L1 versus L2 for *voice onset time* of utterances beginning with a *voiceless plosive*: Results for *individual utterances*

The results regarding the questions posed for sub-aim one are summarized in Table 5.21.

Table 5.21 Findings related to the achievement of durational adjustments in L1 and L2 regarding VOT of individual utterances beginning with a voiceless plosive

	puck/"pak"	pet/"pet"	pit/"pit"	putt/"pad"	pup/"pap"	Durational adjustment was unsuccessful for more L2 utterances than L1 utterances	More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2*
	The extent of durational adjustment for the utterance is greater in L1 than L2						
AOS1				X	X	X	
AOS2					X		
AOS3		X					
N1					X		
N2			X	X	X	X	X
N3			X				
N4	X	X		X		X	X
N5			X	X			
NGR				X	X		
PP1	X		X				
PP2	X	X	X	X		X	X
PP3					X		

X indicates that the named behavior occurred. *Utterances where the duration could not be decreased in both L1 and L2 were excluded from this calculation. In other words, this column indicates if more than half of the utterances for which *duration could be decreased in at least one of the languages*, exhibited a greater extent of durational adjustment in L1 compared to L2.

From Table 5.21 it is evident that only N2, N4 and PP2 displayed a greater extent of durational adjustment in L1 than in L2 for more than half of the utterances in the voiceless plosive utterance group. Furthermore, it is evident that only AOS1, N2, N4 and PP2 were unable to decrease duration in the FR, more often in L2 utterances than in L1 utterances. It is interesting to note, however, that all the normal speakers, with the exception of N1, exhibited utterances in either L1 and/or L2 where duration in the FR was not decreased. It thus appears as if decreasing VOT in the FR is not necessarily characteristic of normal speech production. In summary, it thus appears as if the experimental subjects (AOS and PP) performed similarly to the normal group regarding achievement of durational adjustments for VOT.

5.2.4.3 Summary of results regarding the extent of durational adjustment of voice onset time in L1 and L2

The results pertaining to the extent of durational adjustment of VOT in L1 and L2 for the three utterance groups and for individual utterances in each utterance group are summarized in Table 5.22.

Table 5.22 Summarized findings related to durational adjustments of VOT for utterances as a group and individual utterances in the voiceless plosive utterance group

Utterance Type	Finding	AOS1	AOS2	AOS3	PP1	PP2	PP3	N1	N2	N3	N4	N5	NGR
Voiceless Plosives													
Utterances as a group	A					X							
	B					X	X				X		
Individual utterances	C	X				X			X		X		
	D					X			X		X		

Utterances as a group:
A=For utterances as a group, durational adjustments were unsuccessful in L2 only
B=For utterances as a group, the extent of durational adjustment was greater in L1 than in L2
Individual utterances in an utterance group:
C= Durational adjustment was unsuccessful for more L2 utterances compared to L1 utterances
D= More than half of the utterances exhibited a greater extent of durational adjustment in L1 compared to L2

From Table 5.22 it is evident that L2 does not seem to have had a consistent influence on the extent of durational adjustment in L1 compared to L2 or the inability to achieve a shorter duration in the FR in L2. The normal speakers, with the exception of N1, also exhibited instances where VOT in the FR was not decreased and it thus seems as if VOT is not necessarily decreased when increasing speaking rate. The subjects with PP and those with AOS, with the exception of PP2, thus seem to have performed similarly to the normal speakers regarding durational adjustments for VOT.

5.3 RESULTS FOR SUB-AIM TWO: DETERMINATION OF THE CONTEXT (L1NR, L1FR, L2NR OR L2FR) IN WHICH EACH EXPERIMENTAL SUBJECT DIFFERED MOST FROM THE NORMAL GROUP REGARDING EACH TEMPORAL PARAMETER

For this sub-aim it was predicted that if the mean durations of the experimental subjects were to differ from those of the normal group, this difference would be most evident in the context which placed the highest demands on the speech production mechanism, since the experimental subjects should presumably be more susceptible to breakdown when processing demands are increased. The context predicted to pose the highest demands to the speech production mechanism was L2FR. The reason for this is that in addition to the increased demands imposed by increasing speech rate, an additional demand is presumably placed on the speech production mechanism by speech production in L2.

As discussed under data processing, for each temporal parameter and each context, the mean duration of the five repetitions of each utterance of each experimental subject was expressed as a percentage of the mean duration of the normal group. This was also done for utterances as a group. The aforementioned procedure made it possible to determine the context in which each experimental subject differed most from the normal group. The data expressing the duration of each temporal parameter of each experimental subject as a percentage of the duration of the normal group for each utterance and utterance group, are displayed in Appendix D.

The results will be described separately for each temporal parameter according to the percentage values obtained for each *utterance group*. The results for the *individual utterances* in an utterance group will only be mentioned if they differ from those for the utterances as a group.

5.3.1 Determination of the context (L1NR, L1FR, L2NR or L2FR) in which each experimental subject differed most from the normal group regarding *vowel duration* of utterances beginning with a *voiceless plosive*

Figure 5.10 provides a graphic presentation of the duration of each experimental subject's VD as a percentage of the VD of the normal group for the voiceless plosive utterance group. The values of one to four, assigned to each context to indicate the magnitude each experimental subject differed from the normal group for the voiceless plosive utterance group are displayed in Table 5.23.

When viewing Figure 5.10, it is evident that all the subjects with AOS, as well as subject PP3, exhibited longer durations than the normal group across all four contexts as indicated by the positive percentage values which were obtained. Subject AOS1, for example, exhibited a mean VD which was 13.6% longer than that of the normal group in the L1NR context and a mean VD which was 42.8% longer than that of the normal group in the L1FR context. AOS1 differed most from the normal group in

L1FR and least in L1NR. A value of one was thus assigned to the L1FR context and a value of four to the L1NR context of this subject.

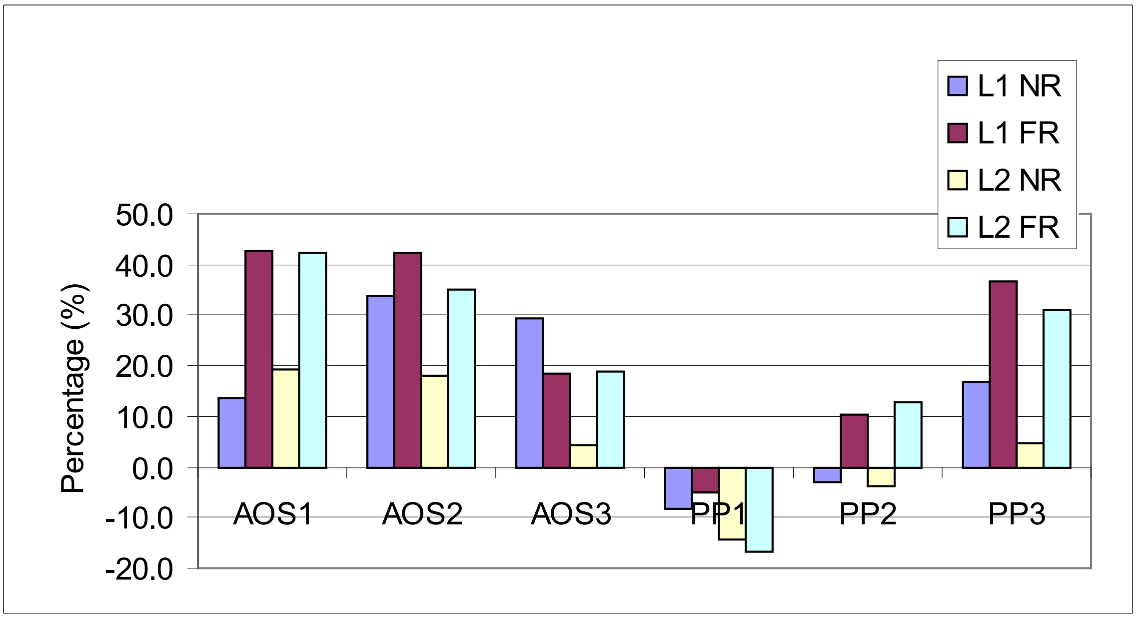

Figure 5.10 Mean vowel duration of each subject expressed as a percentage of the vowel duration of the normal group for each context for the voiceless plosive utterance group

Table 5.23 Assigned values indicating the magnitude of difference between the mean vowel duration of each experimental subject and the normal group for each context for the voiceless plosive utterance group, with a value of one depicting the context where the greatest difference existed and a value of four indicating where the least difference was present

	Value assigned to each context				Context where the subject differed the most from the normal group
	L1NR	L1FR	L2NR	L2FR	
AOS1	4	1	3	2	L1FR
AOS2	3	1	4	2	L1FR
AOS3	1	3	4	2	L1NR
PP1	2*	1*	3*	4*	L1FR
PP2	3*	2	4*	1	L2FR
PP3	3	1	4	2	L1FR

An asterisk (*) indicates that the mean duration of the subject was shorter than the mean duration of the normal group and that a negative percentage value was thus obtained.

From Table 5.23 it can be seen that for the voiceless plosive utterance group, a trend was not evident regarding the greatest difference between the experimental subjects and the normal group occurring in L2FR (with the exception of subject PP2). When viewing the results of the assigned values for the individual utterances (Appendix E), a trend could be observed, however, in that AOS1, PP2 and PP3 exhibited the largest percentage of utterances which were assigned a value of one in L2FR. Furthermore, AOS2 exhibited an equal number of utterances assigned a value of one in L1FR and L2FR, implying that both these two contexts presumably posed an equal demand to the speech mechanism of this subject.

Regarding the utterance group data (Table 5.23), it is evident that in the NR in both L1 and L2, subject PP2 exhibited shorter durations than the normal group, as indicated by the asterisk, whereas PP1 exhibited shorter durations than the normal group across all four contexts. These two subjects thus exhibited shorter VDs than the normal group in these contexts.

In AOS1, AOS2, PP2 and PP3 the FR context in each language always led to a greater difference from the normal group than the NR. This indicates that the NR context presumably places fewer demands on the speech mechanisms of these subjects compared to the FR context.

5.3.2 Determination of the context (L1NR, L1FR, L2NR or L2FR) in which each experimental subject differed most from the normal group regarding *vowel duration* of utterances beginning with a *voiced plosive*

Figure 5.11 provides a visual presentation of the results depicting the difference between the mean VD of each experimental subject and the normal group, expressed as a percentage, for the voiced plosive utterance group. The values assigned to each context indicating the magnitude of difference between each experimental subject and the normal group are displayed in Table 5.24.

From Figure 5.11 it is evident that all subjects with AOS, as well as subject PP3 displayed longer durations than the normal group across all four contexts. This result is similar to the result reported for the voiceless plosive utterance group. The percentage values of the subjects with AOS ranged from 5.8% (AOS1 for L1NR) to 46.9% (AOS3 for L1NR) and for the subjects with PP from –6.9% (PP2 for L2NR) to 25.3% (PP3 for L2FR). From these values it is evident that the subjects with AOS generally differed more from the normal group than the subjects with PP.

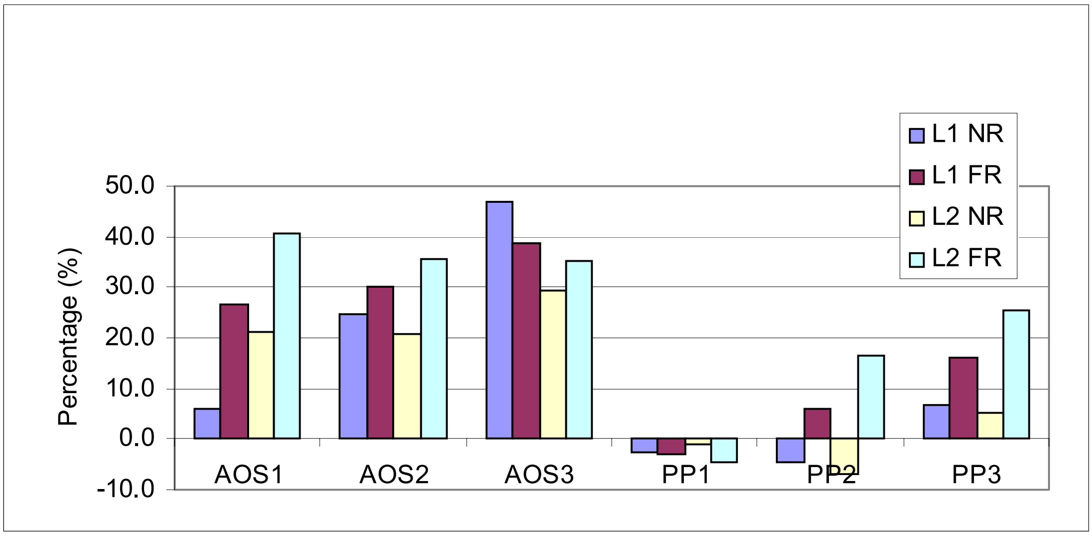

Figure 5.11 Mean vowel duration of each subject expressed as a percentage of the vowel duration of the normal group for each context for the voiced plosive utterance group

Table 5.24 Assigned values indicating the magnitude of difference between the mean vowel duration of each experimental subject and the normal group for each context for the voiced plosive utterance group, with a value of one depicting the context where the greatest difference existed and a value of four indicating where the least difference was present

	Value assigned to each context				Context where the subject differed the most from the normal group
	L1NR	L1FR	L2NR	L2FR	
AOS1	4	2	3	1	L2FR
AOS2	3	2	4	1	L2FR
AOS3	1	2	4	3	L1NR
PP1	2*	3*	1*	4*	L2NR*
PP2	3*	2	4*	1	L2FR
PP3	3	2	4	1	L2FR

An asterisk (*) indicates that the mean duration of the subject was shorter than the mean duration of the normal group and that a negative percentage value was thus obtained.

PP1 exhibited shorter durations than the normal group across all four contexts and PP2 exhibited shorter durations than the normal group in L1NR and L2NR respectively. The fact that PP2 exhibited longer durations than the normal group only in the two FR conditions indicates that the language context alone did not result in longer durations than the normal group. Only when speaking rate had to be increased, did thus subject exhibit longer durations than the normal subjects.

For the voiced plosive group, it is evident that subjects AOS1, AOS2, PP2 and PP3 differed most from the normal group in L2FR. The second greatest difference occurred in L1FR for all these subjects, however, and not in L2NR. This would imply that the L1FR context was presumably more demanding than the L2NR context leading to a greater difference from the normal group occurring in the L1FR context compared to L2NR. It thus appears that speech production in L2 alone (L2NR) for the specific test stimuli, is not sufficient to increase the difference between these subjects (AOS1, AOS2, PP2 and PP3) and the normal group when compared to L1FR. The additional demands, in this case an increase in speaking rate, is thus necessary to lead to greater deviance from the normal group.

There was not a consistent pattern regarding magnitude of difference between the normal group and experimental subjects in L1NR compared to L2NR. It appears that in some subjects L1NR led to greater differences between the normal group and experimental subjects than L2NR and vice versa. This would imply that speaking in L2 at a NR is not necessarily more difficult for these subjects than speaking in L1NR for the test stimuli used in the present study.

For individual utterances in the voiceless plosive utterance group, the percentage of utterances assigned a value of one was in agreement with the findings for utterances as a group in that AOS1, AOS2, PP2 and PP3 exhibited the greatest percentage of utterances assigned a value of one in L2FR. The only difference which was evident when viewing the data of individual utterances (Appendix E) was for AOS3 who had an equal percentage of utterances assigned a value of one in L1NR and L2FR, whereas the utterance group data only indicated L1NR as the context where this subject differed most from the normal group.

5.3.3 Determination of the context (L1NR, L1FR, L2NR or L2FR) in which each experimental subject differed most from the normal group regarding *vowel duration* of utterances beginning with a *voiceless fricative*

The percentage values depicting the difference between the mean VDs of each experimental subject and the normal group for each context for the voiceless fricative utterance group are displayed in Figure 5.12. From Figure 5.12 it is evident that all subjects with AOS, as well as PP2 and PP3 exhibited longer durations than normal group across all four contexts. This result is similar to that found for the voiced and voiceless plosive utterances groups with the exception of PP2 who did not display longer mean durations than the normal group across all four contexts for the voiceless and voiced plosive utterance groups.

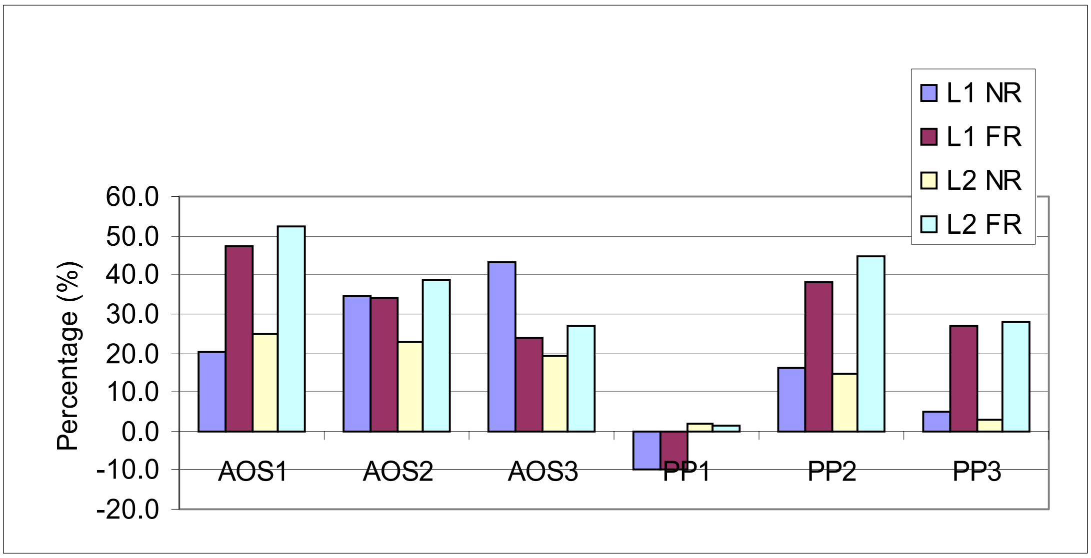

Figure 5.12 Mean vowel duration of each subject expressed as a percentage of the vowel duration of the normal group for each context for the voiceless fricative utterance group

The mean VDs of the subjects with AOS appear to be longer than those of the subjects with PP. The subjects with AOS had durations which were from 19.1% (AOS3 for L2NR) to 52.6% (AOS1 for L2FR) longer than those of the normal group. The subjects with PP had durations which ranged from 9.6% (PP1 for L1NR and L2FR) shorter than those of the normal group to 44.6% (PP2 for L2FR) longer than those of the normal group.

PP1 exhibited shorter durations than the normal group for both L1NR and L1FR, but longer durations for both L2NR and L2FR, implying that L2 led to longer durations than the normal group occurring in this subject. Compared to the subjects with AOS, as well as PP2 and PP3, the durations of PP1 differ much less from those of the normal group.

In Table 5.25 the assigned values, indicating the magnitude each experimental subject's mean durations differed from those of the normal group for each context for the voiceless fricative group, are displayed. In Table 5.25, it can be seen that subjects AOS1, AOS2, PP2 and PP3 exhibited the greatest difference from the normal group in

L2FR. In AOS1, PP2 and PP3, L2FR was followed by L1FR regarding the magnitude of difference from the normal group.

Table 5.25 Assigned values indicating the magnitude of difference between the mean vowel duration of each experimental subject and the normal group for each context for the voiceless fricative utterance group, with a value of one depicting the context where the greatest difference existed and a value of four indicating where the least difference was present

	Value assigned to each context				Context where the subject differed the most from the normal group
	L1NR	L1FR	L2NR	L2FR	
AOS1	4	2	3	1	L2FR
AOS2	2	3	4	1	L2FR
AOS3	1	3	4	2	L1NR
PP1	¾*	3/4*	1	2	L2NR
PP2	3	2	4	1	L2FR
PP3	3	2	4	1	L2FR

An asterisk (*) indicates that the mean duration of the subject was shorter than the mean duration of the normal group and that a negative percentage value was thus obtained.

In subject PP1 the greatest difference from the normal group was in L2NR followed by L2FR, whereas shorter durations than the normal group were obtained in L1NR and L1FR. In this subject, the L2 contexts thus led to a greater difference from the normal group compared to the L1 contexts. AOS3 differed the most from the normal group in L1NR. This result was also found for the voiced and voiceless plosive utterance groups for this subject.

When viewing the results of the individual utterances in the voiceless fricative utterance group, the same pattern of results as discussed for the utterances as a group emerged, with the exception of the results for PP1. For the individual utterances, an equal percentage of utterances were assigned a value of one in each context, implying all contexts presumably posed an equal demand to the speech production mechanism of this subject. Neither the L2 nor the faster speaking rate made this subject deviate further from the normal group.

5.3.4 Determination of the context (L1NR, L1FR, L2NR or L2FR) in which each experimental subject differed most from the normal group regarding *utterance duration* of utterances beginning with a *voiceless plosive*

Figure 5.13 displays the UD of each experimental subject expressed as a percentage of the UD of the normal group in each context for the voiceless plosive utterance group. It can be seen in Figure 5.13 that subjects AOS1, AOS2, PP2 and PP3 exhibited longer durations than the normal group across all four contexts. AOS3 only exhibited a greater duration than the normal group in L2FR, whereas PP1 exhibited a longer duration than the normal group in all contexts with the exception of L2NR where a slightly shorter duration (-0.7%) than the normal group was obtained. The durations of AOS3 were only slightly shorter than those of the normal group (9.7% shorter than the normal group for L2NR, 7.5% for L1NR and 1.6% for L2FR).

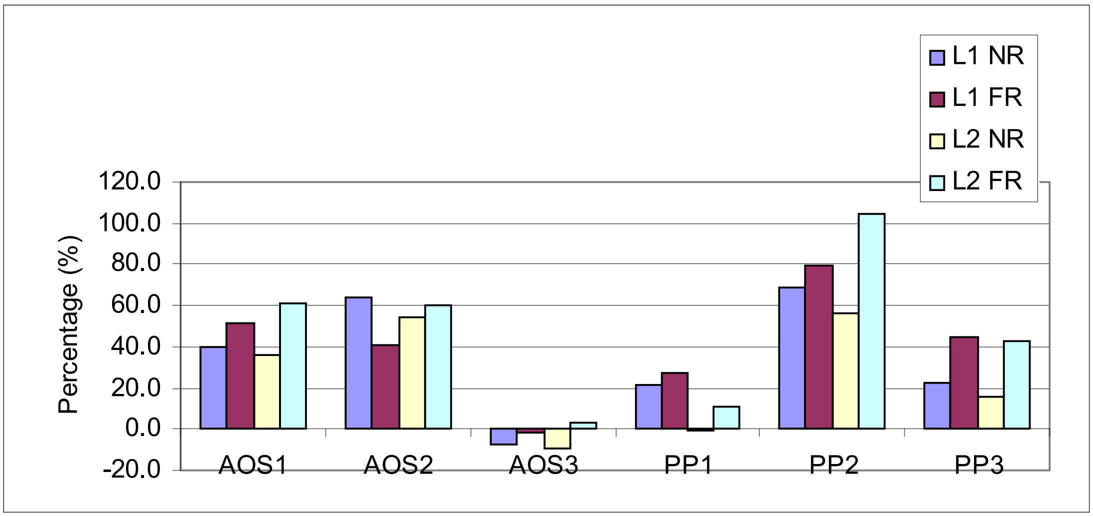

Figure 5.13 Mean utterance duration of each subject expressed as a percentage of the utterance duration of the normal group for the voiceless plosive utterance group

The values which were assigned to indicate the magnitude each subject's mean durations differed from those of the normal group across the four contexts are displayed in Table 5.26.

Table 5.26 Assigned values indicating the magnitude of difference between the mean utterance duration of each subject and the normal group for each context for the voiceless plosive utterance group, with a value of one depicting the context where the greatest difference existed and a value of four indicating where the least difference was present

	Value assigned to each context				Context where the subject differed the most from the normal group
	L1NR	L1FR	L2NR	L2FR	
AOS1	3	2	4	1	L2FR
AOS2	1	4	3	2	L1NR
AOS3	3*	2*	4*	1	L1FR
PP1	2	1	4*	3	L1FR
PP2	3	2	4	1	L2FR
PP3	3	1	4	2	L1FR

An asterisk (*) indicates that the mean duration of the subject was shorter than the mean duration of the normal group and that a negative percentage value was thus obtained.

From Table 5.26 it is evident that AOS1, AOS3 and PP2 exhibited the greatest difference from the normal group in L2FR. For all three these subjects, the greatest difference in L2FR was followed by the L1FR context. The fact that the second greatest difference between the normal group and these three subjects (AOS1, AOS3 and PP2) was in L1FR indicates that the faster rate in L1 is possibly a more demanding context than L2 at a normal speaking rate, since L1FR led to greater deviance from the normal group than L2NR in these subjects.

When the results of the individual utterances are viewed, a different picture emerges for AOS3 and PP3. For AOS3 an equal percentage of utterances in L1NR and L2FR were assigned a value of one, in other words, exhibited the greatest difference from the normal group. Furthermore, for PP3 60% of utterances differed the most from the normal group in L2FR, implying that this context seems to have led to greater deviance from the normal group.

5.3.5 Determination of the context (L1NR, L1FR, L2NR or L2FR) in which each experimental subject differed most from the normal group regarding *utterance duration* of utterances beginning with a *voiced plosive*

The results expressing the mean UD of each experimental subject as a percentage of the mean UD of the normal group for each context for the voiced plosive utterance group are visually displayed in Figure 5.14.

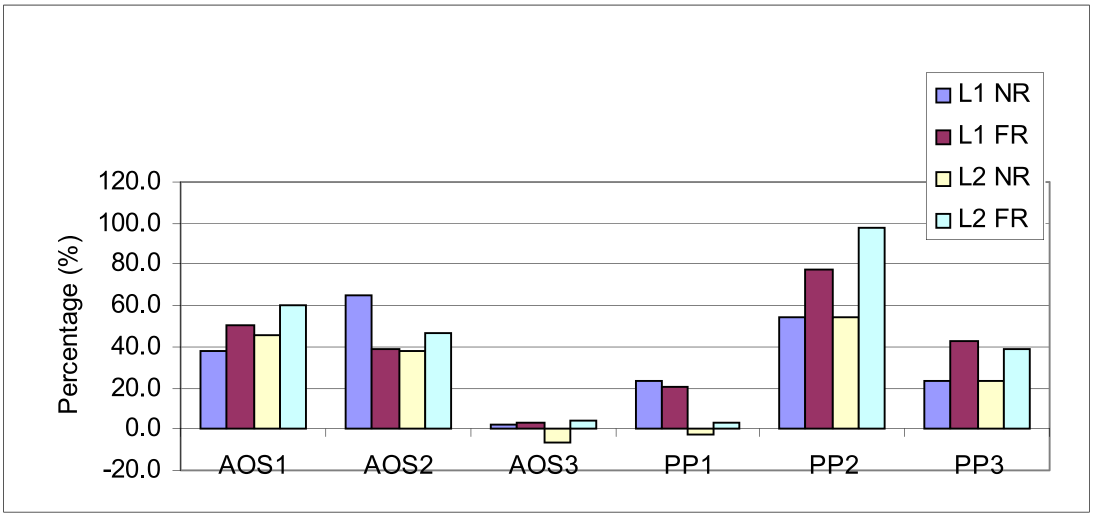

Figure 5.14 Mean utterance duration of each subject expressed as a percentage of the utterance duration of the normal group for the voiced plosive utterance group

From Figure 5.14 it is evident that subjects AOS1, AOS2, PP2 and PP3 displayed longer durations than the normal group across all four contexts. The durations of the experimental subjects ranged from being 2.4% (AOS3 for L1NR) to 98% (PP2 for L2FR) longer than those of the normal group. Both AOS3 and PP1 displayed shorter durations than normal group in L2NR, but longer durations in the other three contexts. In the L2NR context, the duration of AOS3 was 6.7% shorter than that of the normal group and the duration of PP1 was 2.9% shorter than that of the normal group.

In Table 5.27 the values which were assigned to each context to depict the magnitude of difference between the mean duration of each experimental subject and the normal group, are displayed.

Table 5.27 Assigned values indicating the magnitude of difference between the mean utterance duration of each subject and the normal group for each context for the voiced plosive utterance group, with a value of one depicting the context where the greatest difference existed and a value of four indicating where the least difference was present

	Value assigned to each context				Context where the subject differed the most from the normal group
	L1NR	L1FR	L2NR	L2FR	
AOS1	4	2	3	1	L2FR
AOS2	1	3	4	2	L1NR
AOS3	3	2	4*	1	L2FR
PP1	1	2	4*	3	L1NR
PP2	4	2	3	1	L2FR
PP3	3	1	4	2	L1FR

An asterisk (*) indicates that the mean duration of the subject was shorter than the mean duration of the normal group and that a negative percentage value was thus obtained.

From Table 5.27, it is evident that AOS1, AOS3 and PP2 display the greatest difference from the normal group in L2FR, followed by L1FR. There was not a consistent pattern indicating that subjects differed more from the normal group in either L2NR or L1NR.

When viewing the results for the individual utterances, different results from the group data emerged for AOS3 and PP3. For AOS3, instead of L2FR being the context resulting in the greatest difference from the normal group, the individual data indicate that L1NR and L1FR had an equal percentage of utterances assigned a value of one for this subject. For PP3, it was evident that 80% of utterances in the L2FR context were assigned a value of one, indicating that this context appears to have caused the greatest difference from the normal group. The utterance group data of PP3 indicated L1FR as resulting in the greatest difference from the normal group.

5.3.6 Determination of the context (L1NR, L1FR, L2NR or L2FR) in which each experimental subject differed most from the normal group regarding *utterance duration* of utterances beginning with a *voiceless fricative*

The results for the voiceless fricative utterance group are displayed in Figure 5.15.

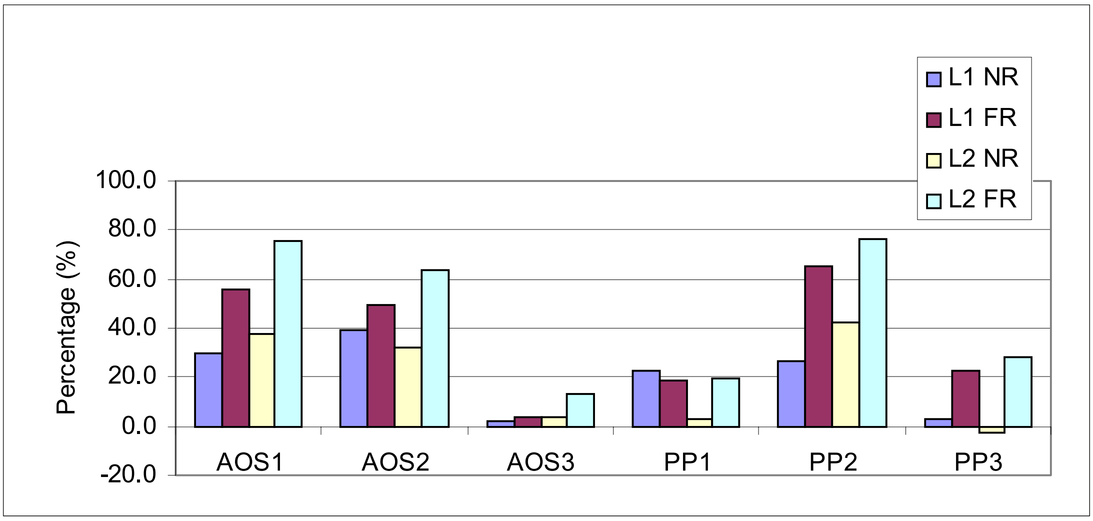

Figure 5.15 Mean utterance duration of each subject expressed as a percentage of the utterance duration of the normal group for the voiceless fricative utterance group

It can be seen in Figure 5.15 that all subjects with the exception of PP3 in L2NR displayed longer mean durations than the normal group across all four contexts.

Subject AOS3 had only slightly longer durations than the normal group compared to the other subjects, however, with durations which were from 2.4% to 13.5% longer than those of the normal group. The other experimental subjects exhibited durations which were from 2.8% (PP3 for L1NR) to 76.4% (PP2 for L2FR) longer than those of the normal group.

In Table 5.28 the assigned values, indicating the magnitude each subject's mean durations differed from the normal group for each context for the voiceless fricative group, are displayed. It is evident from Table 5.28 that all subjects, with the exception of PP1, exhibited the greatest difference from the normal group in L2FR. In all of the subjects exhibiting the greatest difference in L2FR, with the exception of AOS3, the second greatest difference was in L1FR.

Table 5.28 Assigned values indicating the magnitude of difference between the mean utterance duration of each experimental subject and the normal group for each context for the voiceless fricative utterance group, with a value of one depicting the context where the greatest difference existed and a value of four indicating where the least difference was present

	Value assigned to each context				Context where the subject differed the most from the normal group
	L1NR	L1FR	L2NR	L2FR	
AOS1	4	2	3	1	L2FR
AOS2	3	2	4	1	L2FR
AOS3	4	3	2	1	L2FR
PP1	1	3	4	2	L1NR
PP2	4	2	3	1	L2FR
PP3	3	2	4*	1	L2FR

An asterisk (*) indicates that the mean duration of the subject was shorter than the mean duration of the normal group and that a negative percentage value was thus obtained.

When viewing the individual utterances, slightly different results were evident for AOS2 and PP1. For both PP1 and AOS2, an equal percentage of utterances were assigned a value of one for L1NR and L2FR. The results of AOS2 and PP1 indicate that both these contexts (L1NR and L2FR) equally affected durations to deviate from those of the normal group.

5.3.7 Determination of the context (L1NR, L1FR, L2NR or L2FR) in which each experimental subject differed most from the normal group regarding *utterance onset duration* of utterances beginning with a *voiceless plosive*

Figure 5.16 provides a visual display of the results for sub-aim two of each experimental subject and the normal group for each context for the voiceless plosive utterance group.

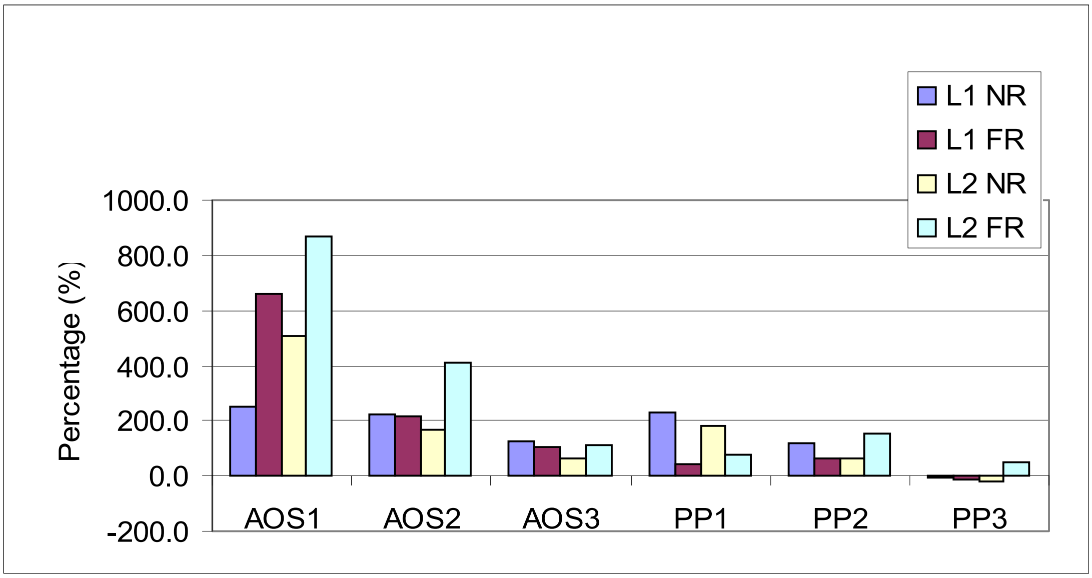

Figure 5.16 Mean utterance onset duration of each subject expressed as a percentage of the of utterance onset duration of the normal group for the voiceless plosive utterance group

From Figure 5.16 it is evident that all subjects, with the exception of PP3, displayed longer durations than the normal group across all four contexts. PP3 only displayed a longer mean duration than the normal group in L2FR and slightly shorter durations than the normal group in the other three contexts. It is evident that the UODs of AOS1 are the longest, with UODs being from 253.6% (in L1NR) to 865.2% (in L2FR) longer than those of the normal group.

Table 5.29 provides a summary of the assigned values indicating the magnitude of difference between the durations of each experimental subject and those of the normal group in each context. From Table 5.29 it is evident that subjects AOS1, AOS2, PP2 and PP3 differed most from the normal group regarding their durations in L2FR. In AOS1, the greatest difference in L2FR was followed by L1FR implying that speaking in L1 in the FR was presumably more difficult than speaking at a NR in L2.

Table 5.29 Assigned values indicating the magnitude of difference between the mean utterance onset duration of each experimental subject and the normal group for each context for the voiceless plosive utterance group, with a value of one depicting the context where the greatest difference existed and a value of four indicating where the least difference was present

	Value assigned to each context				Context where the subject differed the most from the normal group
	L1NR	L1FR	L2NR	L2FR	
AOS1	4	2	3	1	L2FR
AOS2	2	3	4	1	L2FR
AOS3	1	3	4	2	L1NR
PP1	1	4	2	3	L1NR
PP2	2	3	4	1	L2FR
PP3	2*	3*	4*	1	L2FR

An asterisk (*) indicates that the mean duration of the subject was shorter than the mean duration of the normal group and that a negative percentage value was thus obtained.

Both AOS2 and PP2 exhibited the second greatest difference from the normal group in L1NR. This result is difficult to explain, but it could be indicative of the inconsistency in performance in subjects with AOS and that this inconsistency across speech tasks is also exhibited by persons with PP. Both AOS3 and PP1 exhibited the greatest difference from the normal group in L1NR condition.

When viewing individual utterances, the same results as for the utterances as a group emerged for subjects AOS1, AOS2, PP2 and PP3 in that the largest percentage of utterances which were assigned a value of one was also in the L2FR context.

5.3.8 Determination of the context (L1NR, L1FR, L2NR or L2FR) in which each experimental subject differed most from the normal group regarding *utterance onset duration* of utterances beginning with a *voiced plosive*

The reader is referred to Figure 5.17 for a graphic presentation of results displaying the mean UODs of each experimental subject as a percentage of the mean UODs of the normal group for each context for the voiced plosive utterance group. From Figure 5.17 it can be seen that all subjects, with the exception of PP3, exhibited longer durations than the normal group across all four contexts. PP3 only exhibited a longer duration than the normal group in L1NR and L2FR and a slightly shorter duration than the normal group in L1FR (-2.9%) and L2NR (-1.2%). Subject AOS1 had the longest durations which were from 606.4% (L1NR) to 1429.2% (L2FR) longer than the durations of the normal group.

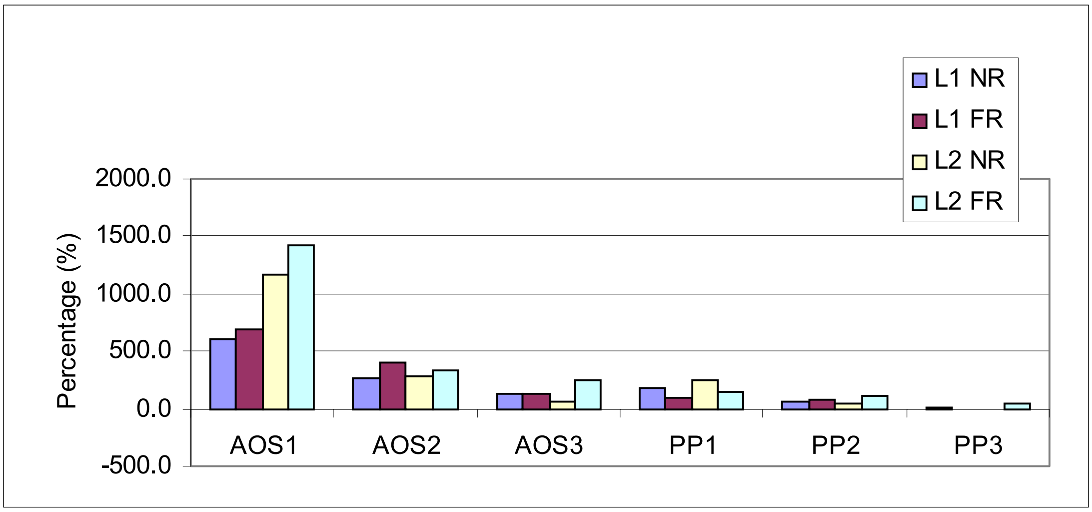

Figure 5.17 Mean utterance onset duration of each subject expressed as a percentage of the utterance onset duration of the normal group for the voiced plosive utterance group

In Table 5.30 a summary of the assigned values indicating the magnitude of difference between the durations of each experimental subject and the normal group in each context is provided.

Table 5.30 Assigned values indicating the magnitude of difference between the mean utterance onset duration of each experimental subject and the normal group for each context for the voiced plosive utterance group, with a value of one depicting the context where the greatest difference existed and a value of four indicating where the least difference was present

	Value assigned to each context				Context where the subject differed the most from the normal group
	L1NR	L1FR	L2NR	L2FR	
AOS1	4	3	2	1	L2FR
AOS2	4	1	3	2	L1FR
AOS3	2	3	4	1	L2FR
PP1	2	4	1	3	L2NR
PP2	3	2	4	1	L2FR
PP3	2	4*	3*	1	L2FR

An asterisk (*) indicates that the mean duration of the subject was shorter than the mean duration of the normal group and that a negative percentage value was thus obtained.

In Table 5.30 it can be seen that AOS1, AOS3, PP2 and PP3 exhibited the greatest difference from the normal group in L2FR. The context where the second greatest difference occurred for these subjects varied with no specific trend emerging.

When viewing the results of the individual utterances in the voiced plosive utterance group, a slightly different result emerged for AOS1 and PP2. For both these subjects the utterance group data indicated that the greatest difference from the normal group was in L2FR. However, for the individual utterances AOS1 had an equal percentage of utterances assigned a value of one for L2NR and L2FR and PP2 exhibited an equal percentage of utterances assigned a value of one for L1FR and L2FR.

5.3.9 Determination of the context (L1NR, L1FR, L2NR or L2FR) in which each experimental subject differed most from the normal group regarding *voice onset time* of utterances beginning with a *voiceless plosive*

Figure 5.18 displays the results regarding the extent each subject's VOTs differed from those of the normal group in each context for the voiceless plosive utterance group.

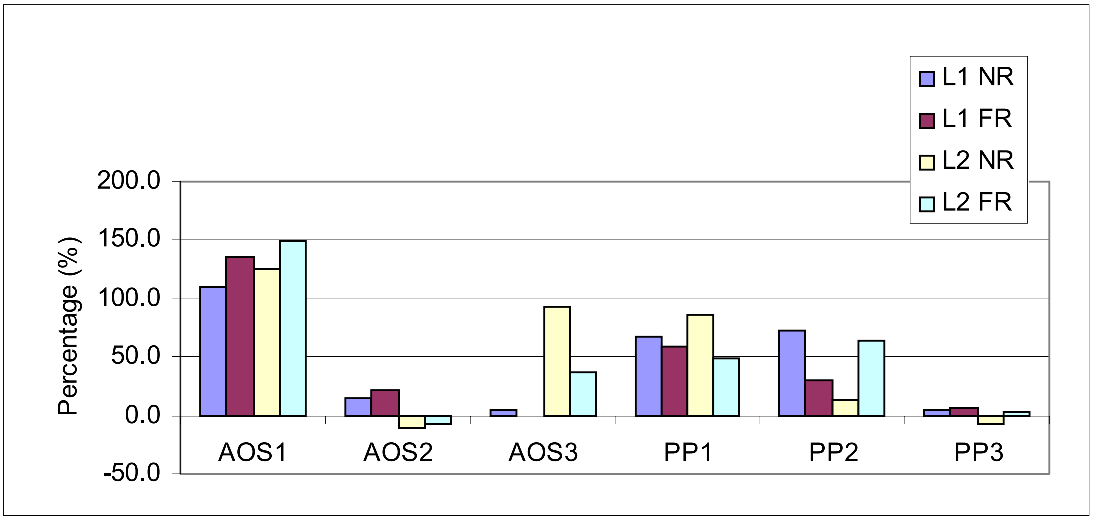

Figure 5.18 Mean voice onset time of each subject expressed as a percentage of the voice onset time of the normal group for the voiceless plosive utterance group

From Figure 5.18 it is evident that AOS1, PP1 and PP2 exhibited longer mean VOT durations than the normal speakers across all four contexts. AOS2 exhibited shorter durations than the normal group in L2NR (–11.3%) and L2FR (-7.5%), whereas AOS3 exhibited a slightly shorter duration (-0.7%) than the normal group in L1FR. PP3 also exhibited a shorter duration than the normal group for L2NR (–6.8%). AOS1, who had the most severe AOS, exhibited durations which were 109.1% (for L1NR) to 149.7% (L2FR) longer than those of the normal group. The durations of the other experimental subjects did not differ from those of the normal group to the same extent as those of AOS1 and were from 3.3% to 92.4% longer than those of the normal group.

Regarding the context in which the greatest difference between the durations of each experimental subject and those of the normal group existed, the reader is referred to Table 5.31.

Table 5.31 Assigned values indicating the magnitude of difference between the mean voice onset time duration of each experimental subject and the normal group for each context for the voiceless plosive utterance group, with a value of one depicting the context where the greatest difference existed and a value of four indicating where the least difference was present

	Value assigned to each context				Context where the subject differed the most from the normal group
	L1NR	L1FR	L2NR	L2FR	
AOS1	4	2	3	1	L2FR
AOS2	2	1	4*	3*	L1FR
AOS3	3	4*	1	2	L2NR
PP1	2	3	1	4	L2NR
PP2	1	3	4	2	L1NR
PP3	2	1	4*	3	L1FR

An asterisk (*) indicates that the mean duration of the subject was shorter than the mean duration of the normal group and that a negative percentage value was thus obtained.

From Table 5.31 it can be seen that only AOS1 differed most from the normal group in L2FR followed by L1FR. AOS3 exhibited the greatest difference from the normal group in L2NR followed by L2FR, indicating that the L2 context contributed to the deviation from the normal group, although the prediction of L2FR resulting in the greatest deviation from the normal group was not verified. PP1 also exhibited the greatest difference from the normal group in L2NR, although the least difference occurred in L2FR.

When the results of the individual utterances are viewed, a different result emerged for PP3, in that both the L1NR and L2FR had an equal number of utterances assigned a value of one, whereas the utterance group data indicated that this subject differed the most from the normal group only in L2FR.

5.3.10 Summary of results for sub-aim two

In order to consolidate and summarize the findings related to sub-aim two, Table 5.32 was compiled. In this table it is indicated whether the hypothesis that the L2FR context would result in subjects deviating most from the normal group, was verified. If a subject differed most from the normal group in L2FR for either the utterance group (behavior A) or the largest number of individual utterances in the utterance group (behavior B), an X is indicated in the table. From Table 5.32, it is possible to determine whether a trend existed for each experimental subject regarding deviating most from the normal group in L2FR. The results regarding the abovementioned prediction are provided for utterances as a group and for individual utterances in an utterance group respectively, for each temporal parameter. It is also indicated in Table 5.32 if a subject exhibited longer durations than the normal group across all four contexts (behavior C).

From Table 5.32 it is evident that regarding VD, UD and UOD, subjects AOS1, PP2 and PP3 appear to exhibit a trend of the greatest deviation from the normal group occurring in L2FR. AOS2 also exhibited this trend for all utterance groups regarding VD. Regarding UD, the durations of AOS2 differed most from the normal group in L2FR only for the fricative utterance group and regarding UOD only for the voiceless plosive group. AOS3 also exhibited the trend of differing most from the normal group in L2FR, but to a lesser degree. Regarding VD, subject AOS3 differed most from the normal group equally in L1NR and L2FR for the voiced plosive utterance group, although this trend was exhibited for all utterance groups regarding UD and for the voiced plosive group regarding UOD. PP1 does not appear to differ most from the normal group in L2FR at all, with the exception of the voiceless fricative utterance group regarding UD, where an equal difference from the normal group occurred in L1NR and L2FR.

Table 5.32 Summarized findings for sub-aim two indicating whether the durations of each experimental subject differed most from those of the normal group in the L2FR context regarding each temporal parameter for utterances as a group and for individual utterances of each utterance group

	Utterance group	Finding	AOS1	AOS2	AOS3	PP1	PP2	PP3
Vowel duration	**Voiceless Plosives**							
	Utterances as a group	A					X	
	Individual utterances	B	X	L1FR & L2FR			X	X
		C	X	X	X			X
	Voiced Plosives							
	Utterances as a group	A	X	X			X	X
	Individual utterances	B	X	X	L1NR & L2FR		X	X
		C	X	X	X			X
	Voiceless Fricatives							
	Utterances as a group	A	X	X			X	X
	Individual utterances	B	X	X		All contexts equal	X	L1FR & L2FR
		C	X	X	X		X	X
Utterance duration	**Voiceless Plosives**							
	Utterances as a group	A	X		X		X	
	Individual utterances	B	X		L1NR & L2FR		X	X
		C	X	X			X	X
	Voiced Plosives							
	Utterances as a group	A	X		X		X	
	Individual utterances	B	X				X	X
		C	X	X			X	X
	Voiceless Fricatives							
	Utterances as a group	A	X	X	X		X	X
	Individual utterances	B	X	L1NR & L2FR	X	L1NR & L2FR	X	X
		C	X	X	X	X	X	
Utterance onset duration	**Voiceless Plosives**							
	Utterances as a group	A	X	X			X	X
	Individual utterances	B	X	X			X	X
		C	X	X	X	X	X	
	Voiced Plosives							
	Utterances as a group	A	X		X		X	X
	Individual utterances	B	L2NR & L2FR		X		L1FR & L2FR	X
		C	X	X	X	X	X	
VOT	**Voiceless Plosives**							
	Utterances as a group	A	X					
	Individual utterances	B	X					L1NR & L2FR
		C	X			X	X	

A=The duration of the experimental subject differed most from the duration of the normal group in L2FR.
B=L2FR had the largest percentage of utterances where the duration of the experimental subject differed most from that of the normal group.
C=The duration of the experimental subject was greater than that of the normal group across all four contexts.
An X is indicated if the finding is present. In instances where more than one context rendered the same result, both these contexts are cited.

5.4 RESULTS FOR SUB-AIM THREE: DETERMINATION OF THE CONTEXT (L1NR, L1FR, L2NR AND L2FR) IN WHICH VARIABILITY OF EACH SUBJECT IS THE GREATEST

The objective of sub-aim three was to determine for each subject, in which of the four contexts variability was generally the greatest regarding each temporal parameter. It was predicted that the greatest variability would occur in L2FR, since this context was hypothesized to pose the greatest demands to the speech production mechanism. It was further hypothesized that greater processing demands would result in greater variability for persons with compromised speech production systems, since their speech mechanisms would presumably be more "unstable" when processing demands were increased.

As discussed in chapter four, variability of duration was determined by calculating the SD of the five repetitions of each utterance for each subject and the normal group for each context. For each target utterance of each subject and the normal group, a number from one to four was then assigned to the SD in each context, in an attempt to rank the SDs from smallest to largest. The tables for each temporal parameter and target utterance of each utterance group displaying the assigned values of one to four to the SDs of the four contexts are displayed in Appendix F.

For each utterance group the percentage of utterances which were assigned a value of one was then calculated for each context. These percentage values were then tabulated and it was indicated in which context the largest percentage of utterances were assigned a value of one (Tables 5.33 to 5.42). From these results it was possible to determine if the largest percentage of utterances where the SD was the greatest, generally occurred in either, L2NR or L2FR. If a trend existed that the largest percentage of utterances assigned a value of one was in either L2NR or L2FR, it could be argued that the speech motor system was more "unstable" or "unreliable" in these contexts, and consequently that these contexts posed higher demands to the speech production mechanism.

In addition to determining the context where the SD was generally the greatest for most utterances in an utterances group, it was determined for each experimental subject within each context, if their SDs were greater than those of the normal group regarding each utterance group of each temporal parameter. The latter was done by expressing each subject's SD as a percentage of the SD of the normal group for each utterance. From these values a mean percentage value was then calculated for each utterance group. The percentage values expressing the SDs of each pathologic subject as a percentage of the SD of the normal group for each temporal parameter and utterance group are displayed in Appendix G. The results for each temporal parameter and utterance group are discussed separately. At the end of the discussion, a table is provided (Table 5.43) with summarized findings for sub-aim three to determine whether a trend existed regarding variability generally being the greatest in the L2NR or L2FR context.

5.4.1 Determination of the context (L1NR, L1FR, L2NR and L2FR) in which *variability* of each subject is the greatest for *vowel duration* of utterances beginning with a *voiceless plosive*

Table 5.33 displays the percentage of utterances in each context for the voiceless plosive utterance group which were assigned a value of one, in other words, that exhibited the greatest SDs.

Table 5.33 The percentage of utterances in each context in the voiceless plosive utterance group which were assigned a value of one indicating the context where variability was the greatest for most utterances regarding VD

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	The context with the largest percentage of utterances displaying the greatest SD
AOS1	0	20	40	40	L2NR and L2FR
AOS2	0	40	20	40	L1FR and L2FR
AOS3	40	20	20	20	L1NR
N1	20	0	40	40	L2NR and L2FR
N2	40	20	40	0	L1NR and L2NR
N3	20	40	0	40	L1FR and L2FR
N4	20	20	40	20	L2NR
N5	80	0	0	20	L1NR
NGR	20	0	40	40	L2NR and L2FR
PP1	20	0	80	0	L2NR
PP2	20	0	40	40	L2FR and L2NR
PP3	0	60	0	40	L1FR

From Table 5.33 it can be seen that for the normal group, both L2NR and L2FR, had 40% of utterances assigned a value of one. This result indicates that speech production in the L2 context (L2NR and L2FR) resulted in more variable production on repeated trials of a specific utterance. When the results of individual speakers in the normal group are viewed, it is evident that the context with the greatest variability differed amongst speakers and it does not appear that the L2NR or L2FR context consistently led to greater variability. For example, N5 exhibited the greatest variability for 80% of the utterances in the voiceless plosive utterance group in L1NR.

The subjects with AOS also did not show a consistent pattern regarding the greatest variability occurring predominantly in a specific context. AOS1 exhibited an equal percentage of utterances where variability was the greatest in L2NR and L2FR (40% of utterances in each context), indicating that the L2 contexts led to greater variability in this subject than the L1 contexts. AOS2, on the other hand, exhibited an equal percentage of utterances where variability was the greatest in L1FR and L2FR (40% of utterances in each context). This indicates that the FR conditions led to greater variability in this subject. AOS3 had the largest percentage of utterances with the greatest variability in L1NR (40% of utterances), whereas the other three contexts each had one utterance (20% of utterances) where the greatest variability occurred. For this subject, L1NR thus appears to have resulted in the greatest variability.

In PP1, 80% of utterances displayed the greatest variability in the L2NR context. The increased rate did not seem to affect variability of production in this subject, possibly implying that this person's speech production is more consistent when speaking at a faster than normal rate. PP2 fared similar to the normal group in that 40% of utterances in both L2NR and L2FR exhibited the greatest variability, indicating that L2 contexts led to greater variability in this subject. In PP3, 60% of utterances exhibited the greatest variability in L1FR and 40% of utterances in L2FR. This result implies that the FR in both languages led to greater variability.

In Figure 5.19 the SDs of each experimental subject are expressed as a percentage of the SDs of the normal group. A positive percentage value indicates that the SD of the experimental subject was larger than that of the normal group, whereas a negative percentage value indicates that the SD of the subject was shorter than that of the normal group.

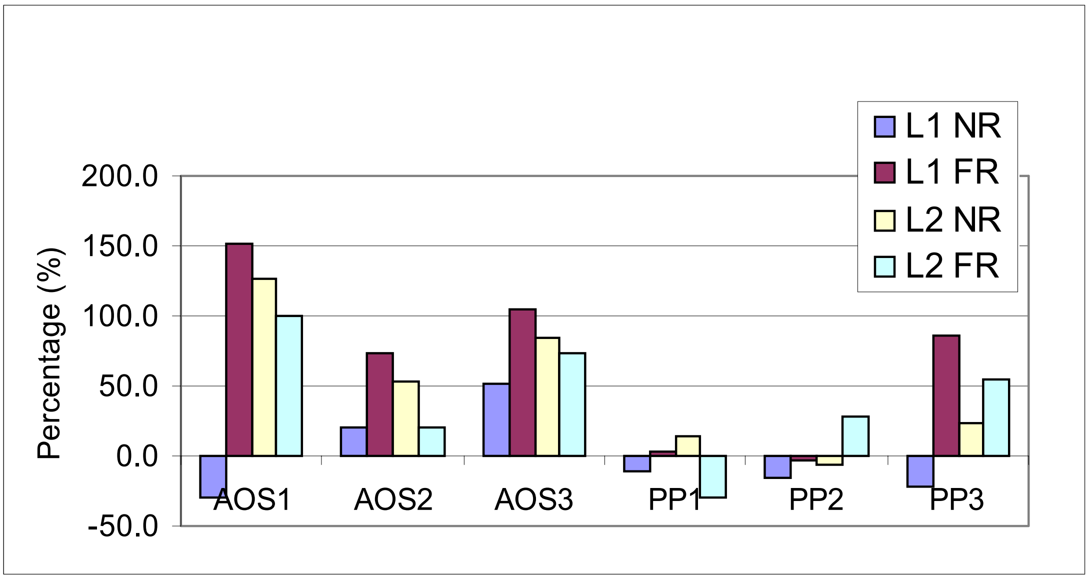

Figure 5.19 The SDs of vowel duration of each subject expressed as a percentage of the SD of the normal group for each context for the voiceless plosive utterance group

From Figure 5.19 it is evident that AOS2 and AOS3 exhibited greater SDs than the normal group across all four contexts, whereas AOS1 had greater SDs than the normal group in all contexts except L1NR. The SDs of the subjects with AOS ranged from being 30% shorter (AOS1 for L1NR) than those of the normal group to being 151.7% longer (AOS1 for L1FR). PP3 also exhibited greater SDs than the normal group in all contexts except the L1NR context where the SD of this subject was 22.5% smaller than that of the normal group. PP1 had greater SDs than the normal group only in L1FR and L2NR, whereas PP2 had a greater SD than the normal group only in L2FR. The subjects with AOS generally had greater SDs than the subjects with PP, especially PP1 and PP2. The SDs of PP1 and PP2 appear to be more comparable to the SDs of the normal group and were often slightly shorter than those of the normal group.

5.4.2 Determination of the context (L1NR, L1FR, L2NR and L2FR) in which *variability* of each subject is the greatest for *vowel duration* of utterances beginning with a *voiced plosive*

The results regarding the percentage of utterances, beginning with a voiced plosive, which exhibited the greatest variability in each context, are displayed in Table 5.34.

Table 5.34 The percentage of utterances in each context in the voiced plosive utterance group which were assigned a value of one indicating the

context where variability was the greatest for most utterances regarding VD

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	The context with the largest percentage of utterances displaying the greatest SD
AOS1	0	20	20	60	L2FR
AOS2	40	40	20	0	L1NR and L1FR
AOS3	20	40	20	20	L1FR
N1	0	0	60	40	L2NR
N2	20	20	40	20	L2NR
N3	20	0	0	80	L2FR
N4	40	20	0	40	L1NR and L2FR
N5	40	0	0	60	L2FR
NGR	20	0	20	60	L2FR
PP1	60	0	20	20	L1NR
PP2	20	0	20	60	L2FR
PP3	60	20	20	0	L1NR

From Table 5.34, it is evident that subjects AOS1, PP2 and the normal group exhibited the largest percentage of utterances (60%) with the greatest variability in L2FR, indicating that this context generally led to greater variability in the speech of these subjects. The L2 context, together with the increased demand of increasing rate, thus resulted in greater token-to-token variability. The individual normal speakers exhibited the largest percentage of utterances with the greatest variability in either L2NR or L2FR. AOS2 had 40% of utterances in both L1NR and L1FR which exhibited the greatest variability. Both PP1 and PP3 exhibited 60% of utterances with the greatest variability in L1NR.

All the experimental subjects exhibited greater SDs than the normal group across all four contexts as is evident from Figure 5.20.

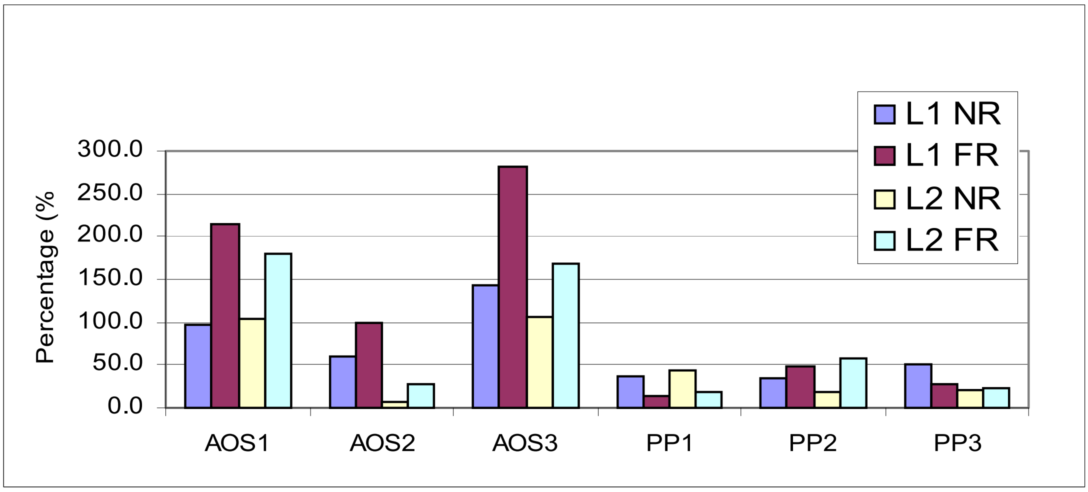

Figure 5.20 The SDs of vowel duration of each subject expressed as a percentage of the SD of the normal group for each context for the voiced plosive utterance group

From Figure 5.20 it is further evident that the subjects with AOS generally had greater SDs than the subjects with PP, with the exception of AOS2 in L2NR. The SDs of the subjects with AOS were between 6.7% (AOS2 for L2NR) and 280.4% (AOS2 for L1FR) greater than those of the normal group. The subjects with PP displayed SDs which were between 13.5% (PP1 for L1FR) and 57.1% (PP2 for L2FR) greater than those of the normal group.

5.4.3 Determination of the context (L1NR, L1FR, L2NR and L2FR) in which *variability* of each subject is the greatest for *vowel duration* of utterances beginning with a *voiceless fricative*

The results regarding the percentage of utterances beginning with a voiceless fricative that exhibited the greatest variability in each context are displayed in Table 5.35. From this table it is evident that subjects AOS1, AOS2, PP2 and the normal group exhibited the largest percentage of utterances with the greatest SD in L2NR.

Table 5.35 The percentage of utterances in each context in the voiceless fricative utterance group which were assigned a value of one indicating the context where variability was the greatest for most utterances regarding VD

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	The context with the largest percentage of utterances displaying the greatest SD
AOS1	25	25	50	0	L2NR
AOS2	0	25	50	25	L2NR
AOS3	25	50	25	0	L1FR
N1	0	25	75	0	L2NR
N2	25	25	50	0	L2NR
N3	0	0	25	75	L2FR
N4	25	0	25	50	L2FR
N5	100	0	0	0	L1NR
NGR	0	0	75	25	L2NR
PP1	75	0	0	25	L1NR
PP2	25	25	50	0	L2NR
PP3	25	50	0	25	L1FR

The individual normal subjects, with the exception of N5, exhibited the largest percentage of utterances with the greatest variability in either L2NR or L2FR indicating that the L2 contexts led to greater variability than the L1 contexts.

AOS3 exhibited 50% of utterances with the greatest variability in the L1FR context and 25% each in the L1NR and L2NR context. Speech production in the FR in L1 thus led to greater variability in this subject than in the L2FR context. The L2 context thus does not seem to have influenced the accuracy of performance on various trials of a specific utterance in this subject. The other two subjects with PP did not exhibit the greatest variability in a L2 context, with PP1 exhibiting 75% of utterances with the greatest variability in L1NR and PP3 exhibiting 50% of utterances with the greatest variability in the L1FR context.

Regarding the SDs of the experimental subjects relative to those of the normal group, it is evident from Figure 5.21 that all the subjects with AOS exhibited greater SDs than the comparison group across all four contexts with SD being between 20.1% (AOS3 for L2FR) and 310.8% (AOS1 for L1FR) greater than those of the normal group. The subjects with AOS generally had greater SDs than PP1 and PP3 who occasionally displayed SDs smaller than those of the normal group.

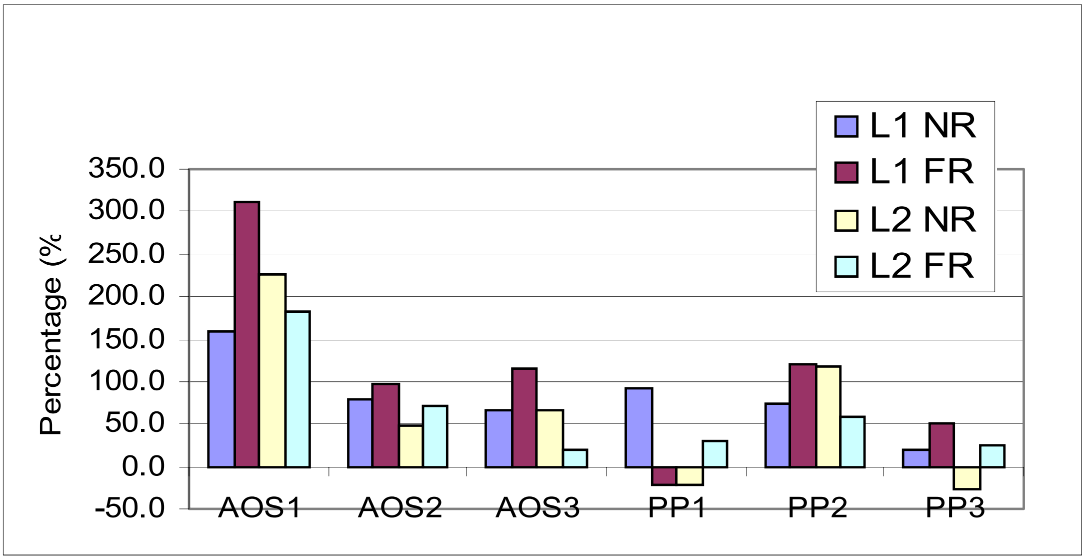

Figure 5.21 The SDs of vowel duration of each subject expressed as a percentage of the SD of the normal group for each context for the voiceless fricative utterance group

5.4.4 Determination of the context (L1NR, L1FR, L2NR and L2FR) in which *variability* of each subject is the greatest for *utterance duration* of utterances beginning with a *voiceless plosive*

The results regarding the percentage of utterances in the voiceless plosive utterance group which exhibited the greatest variability in each context are displayed in Table 5.36.

Table 5.36 The percentage of utterances in each context in the voiceless plosive utterance group which were assigned a value of one indicating the context where variability was the greatest for most utterances regarding UD

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	The context with the largest percentage of utterances displaying the greatest SD
AOS1	40	20	0	40	L1NR and L2FR
AOS2	0	20	20	60	L2FR
AOS3	20	20	20	40	L2FR
N1	20	20	60	0	L2NR
N2	0	0	20	80	L2FR
N3	0	60	20	20	L1FR
N4	0	20	40	40	L2NR and L2FR
N5	20	20	40	20	L2NR
NGR	0	0	60	40	L2NR
PP1	20	60	0	20	L1FR
PP2	20	40	20	20	L1FR
PP3	20	40	20	20	L1FR

From Table 5.36 it is evident that both AOS2 and AOS3 exhibited most utterances with the greatest variability (largest SDs) in L2FR. AOS1, on the other hand, exhibited an equal percentage of utterances with the greatest variability in L1NR and L2FR.

The normal group exhibited the greatest variability in L2NR indicating that this context led to the greatest variability in these subjects. In the normal group L2FR had the second largest percentage of utterance exhibiting the greatest variability. With an increase in speaking rate, speech production of these subjects thus became less variable. All three subjects with PP appear not to have been influenced by the L2 context regarding an increase in variability in that all three these subjects exhibited the most utterances with the greatest variability in L1FR. The latter result implies that L2 did not increase token-to-token variability in the subjects with PP.

In Figure 5.22 the SDs of each experimental subject are expressed as a percentage of the SDs of the normal group. From Figure 5.22 it is evident that the SDs of the experimental subjects were greater than those of the normal group across all four contexts with the exception of AOS3 for L2NR. However, the SD of AOS3 was only slightly less than that of the normal group in this context (-3.8%). The SDs of the subjects with PP were between 11.7% (PP3 for L2NR) and 140.6% (PP1 for L1FR) greater than those of the normal group, while the SDs of the subjects with AOS were between 32.3% (AOS2 for L1NR) and 221.7% (AOS1 for L1NR) greater than those of the normal group.

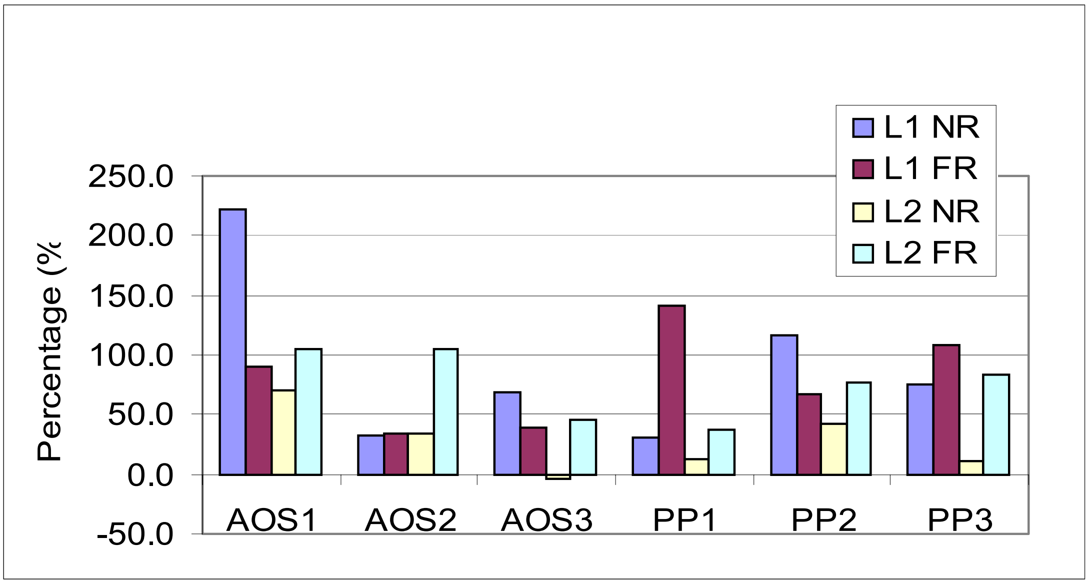

Figure 5.22 The SDs of utterance duration of each subject expressed as a percentage of the SD of the normal group for each context for the voiceless plosive utterance group

5.4.5 Determination of the context (L1NR, L1FR, L2NR and L2FR) in which *variability* of each subject is the greatest for *utterance duration* of utterances beginning with a *voiced plosive*

Table 5.37 displays the percentage of utterances in each context where the greatest variability occurred.

Table 5.37 The percentage of utterances in each context in the voiced plosive utterance group which were assigned a value of one indicating the context where variability was the greatest for most utterances regarding UD

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	The context with the largest percentage of utterances displaying the greatest SD
AOS1	0	20	80	0	L2NR
AOS2	20	0	0	80	L2FR
AOS3	0	60	20	20	L1FR
N1	40	20	40	0	L1NR and L2NR
N2	20	0	20	60	L2FR
N3	0	20	60	20	L2NR
N4	40	20	0	40	L1NR and L2FR
N5	20	40	0	40	L1FR and L2FR
NGR	20	20	20	40	L2FR
PP1	40	20	0	40	L1NR and L2FR
PP2	20	40	20	20	L1FR
PP3	20	0	60	20	L2NR

AOS1, as well as PP3 exhibited the largest percentage of utterances (80% of utterances for AOS1 and 60% for PP3) with the greatest variability in L2NR, while

AOS2 exhibited 80% of utterances with the greatest variability in L2FR. Subject AOS3 exhibited 60% of utterances with the greatest variability in L1FR and PP2 exhibited 40% in this context, indicating that the L2 contexts did not lead to the greatest variability in these two subjects. The normal group exhibited 40% percent of utterances with the greatest variability in L2FR, while the other three contexts each had 20% of utterances with the greatest variability. PP1 had an equal number of utterances with the greatest variability in L1NR and L2FR respectively, indicating that these two contexts led to the greatest variability for this subject. For utterances beginning with a voiced plosive, there does thus not appear to be a consistent pattern regarding the context which generally led to the greatest variability.

The SDs of the experimental subjects expressed as a percentage of the SDs of the normal group are displayed in Figure 5.23.

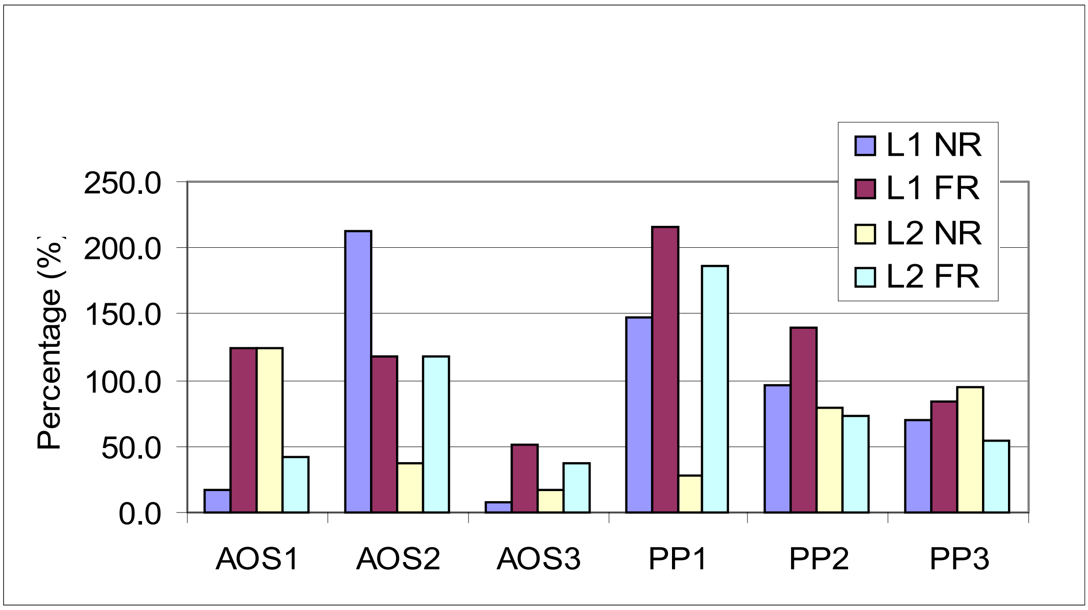

Figure 5.23 The SDs of utterance duration of each subject expressed as a percentage of the SD of the normal group for each context for the voiced plosive utterance group

From Figure 5.23 it is evident that all the experimental subjects exhibited greater SDs than the normal group across all four contexts. From Figure 5.23, it further appears as if the SDs of the subjects with PP are comparable, and in some instances even greater than some of the subjects with AOS. The subjects with AOS had SDs which were between 8.4% (AOS3 in L1NR) and 213.2% (AOS2 in L1NR) greater than those of the normal group, while the subjects with PP had SDs which were between 27.2% (PP1 for L2NR) and 215.3% (PP1 for L1FR) greater than those of the normal group.

5.4.6 Determination of the context (L1NR, L1FR, L2NR and L2FR) in which *variability* of each subject is the greatest for *utterance duration* of utterances beginning with a *voiceless fricative*

A fairly consistent pattern emerged regarding the context where the largest percentage of utterances exhibited the greatest variability, as is evident from Table 5.38.

Table 5.38 The percentage of utterances in each context in the voiceless fricative utterance group which were assigned a value of one indicating the context where variability was the greatest for most utterances regarding UD

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	The context with the largest percentage of utterances displaying the greatest SD
AOS1	50	25	0	25	L1NR
AOS2	25	75	0	0	L1FR
AOS3	0	25	25	50	L2FR
N1	25	25	50	0	L2NR
N2	0	25	50	25	L2NR
N3	0	25	50	25	L2NR
N4	0	25	50	25	L2NR
N5	0	25	75	0	L2NR
NGR	0	25	75	0	L2NR
PP1	25	25	50	0	L2NR
PP2	25	0	50	25	L2NR
PP3	0	25	25	50	L2FR

Subjects AOS3 and PP3 both exhibited 50% of utterances with the greatest variability in L2FR. PP2 and PP3, as well as all speakers in the normal group and the normal group, exhibited the greatest variability in L2NR. In AOS1 and AOS2, speech production in L2 did not result in greater variability than L1 contexts and these subjects exhibited the largest percentage of utterances with the greatest variability in the L1NR and L1FR context respectively.

The reader is referred to Figure 5.24 for a visual presentation of the SDs of each experimental subjects expressed as a percentage of the SDs of the normal group. From Figure 5.24, it is evident that all the experimental subjects, with the exception of PP3 for L1NR and L2FR, exhibited larger SDs than the normal group. The SDs of the subjects with AOS appear to be greater than those of the subjects with AOS and were between 32.3% (AOS2 for L2NR) and 243.8% (AOS1 for L2FR) larger than those of the normal group. The SDs of the subjects with PP were between 27.9% (PP2 for L1FR) and 153.3% (PP3 for L2FR) larger than those of the normal group.

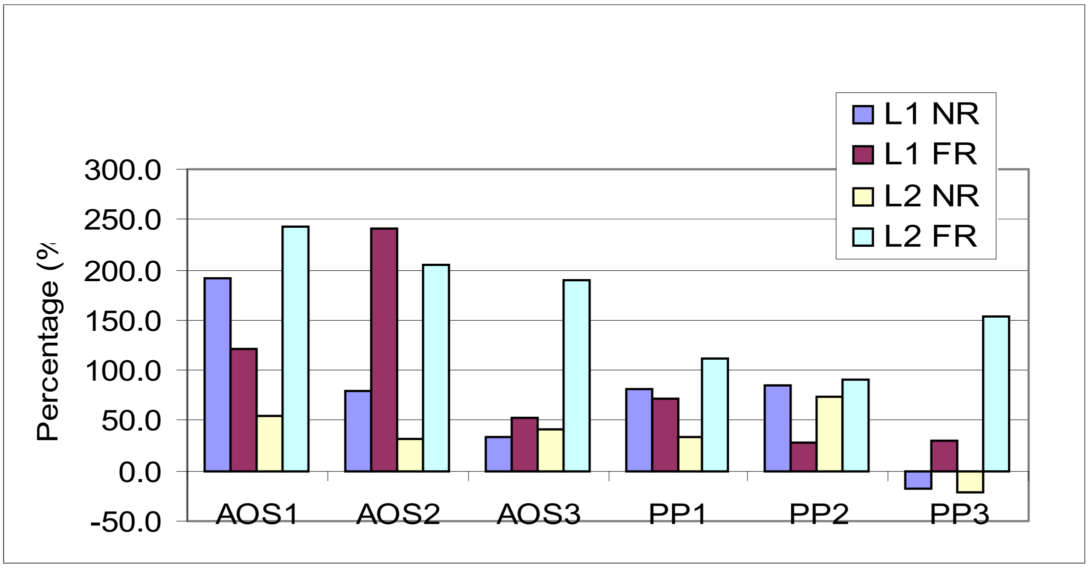

Figure 5.24 The SDs of utterance duration of each subject expressed as a percentage of the SD of the normal group for each context for the voiceless fricative utterance group

5.4.7 Determination of the context (L1NR, L1FR, L2NR and L2FR) in which *variability* of each subject is the greatest for *utterance onset duration* of utterances beginning with a *voiceless plosive*

The reader is referred to Table 5.39 for a summary of the percentage of utterances in each context where the greatest variability occurred. Regarding the context with the largest percentage of utterances exhibiting the greatest SD, it seems that only in subjects AOS1, N2, N3 and PP1, the L2 context led to greater variability. AOS1 exhibited an equal percentage of utterances with the greatest SD in L2NR and L2FR respectively (40% of utterances), indicating that these two contexts led to the same amount of variability regarding UOD in this subject.

Table 5.39 The percentage of utterances in each context in the voiceless plosive utterance group which were assigned a value of one indicating the context where variability was the greatest for most utterances regarding UOD

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	The context with the largest percentage of utterances displaying the greatest SD
AOS1	0	20	40	40	L2NR and L2FR
AOS2	40	0	40	20	L1NR and L2NR
AOS3	60	20	20	0	L1NR
N1	60	0	40	0	L1NR
N2	0	20	0	80	L2FR
N3	20	0	80	0	L2NR
N4	60	0	40	0	L1NR
N5	0	40	40	20	L1FR and L2NR
NGR	60	0	40	0	L1NR
PP1	40	0	60	0	L2NR
PP2	60	0	0	40	L1NR
PP3	40	20	0	40	L1NR and L2FR

The normal group exhibited the largest percentage of utterances with the greatest SD in the L1NR context. The latter was also true for AOS3, PP2 and some of the normal speakers (N1 and N4). AOS2 had an equal percentage of utterances with the greatest variability in L1NR and L2NR (40% of utterances for each context). PP3 had an equal percentage of utterances with the greatest variability in L1NR and L2FR respectively (40% of utterances each).

From Figure 5.25, displaying the SDs of each experimental subject as a percentage of the SDs of the normal group, it is evident that all subjects exhibited greater SDs than the normal group across all four contexts.

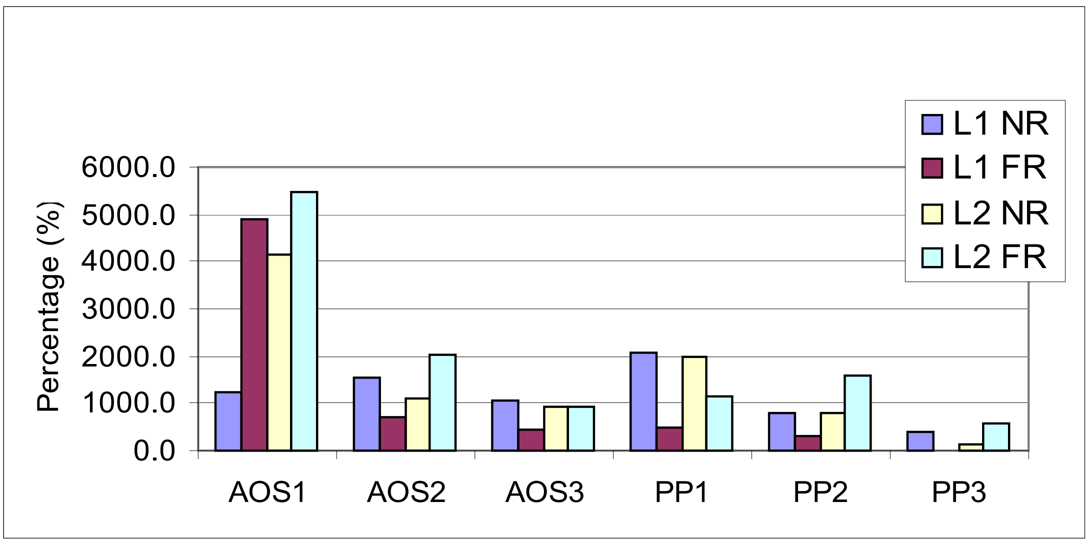

Figure 5.25 The SDs of utterance onset duration of each subject expressed as percentage of the SD of the normal group for each context for the voiceless plosive utterance group

From Figure 5.25, it is further evident that AOS1 had the greatest SDs, while PP3 had the smallest SDs and was thus the least variable regarding UOD. The fact that the SDs of the experimental subjects regarding UOD are much greater than those of the comparison group is because the subjects with AOS and PP often had long periods of time elapsing after production of the carrier phrase to the beginning of production of the target utterance, while other times the target utterance was produced immediately after the carrier phrase. The former behavior led to very large SDs being obtained for the experimental subjects compared to the normal group who consistently initiated the target utterance after the carrier phrase.

5.4.8 Determination of the context (L1NR, L1FR, L2NR and L2FR) in which *variability* of each subject is the greatest for *utterance onset duration* of utterances beginning with a *voiced plosive*

Table 5.40 displays the results regarding the percentage of utterances in each context where the greatest variability occurred.

Table 5.40 The percentage of utterances in each context in the voiced plosive utterance group which were assigned a value of one indicating the context where variability was the greatest for most utterances regarding UOD

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	The context with the largest percentage of utterances displaying the greatest SD
AOS1	0	20	60	20	L2NR
AOS2	20	40	40	0	L1FR and L2NR
AOS3	0	20	20	60	L2FR
N1	20	0	80	0	L2NR
N2	20	0	0	80	L2FR
N3	40	0	60	0	L2NR
N4	40	40	20	0	L1NR and L1FR
N5	0	20	0	80	L2FR
NGR	20	0	80	0	L2NR
PP1	40	20	20	20	L1NR
PP2	20	40	20	20	L1FR
PP3	20	20	20	40	L2FR

From Table 5.40 it is evident that AOS1, N1, N3 and the normal group exhibited the greatest SD in L2NR indicating that this context led to greater variability in these subjects. Subjects AOS3, N2, N5 and PP3 exhibited the largest percentage of utterances with the greatest variability in L2FR indicating that the increased motor demand together with the L2 context led to the greatest variability in these subjects.

As with the voiceless plosive utterance group, many subjects often displayed the largest or second largest percentage of utterances with the greatest variability in L1NR. This could possibly be due to the fact that the subjects were not exerting conscious processing strategies during production in L1, which is presumably an automated context of speech production, or they might not have been performing at their best yet due to the fact that L1 utterances were recorded first.

From Figure 5.26, which displays the SDs of each experimental subject expressed as a percentage of the SDs of the normal group, it is evident that all subjects exhibited SDs greater than those of the normal group across all contexts. As with the voiceless plosive group, AOS1 had the greatest SDs in all contexts with PP2 and PP3 generally exhibiting the smallest SDs compared to the normal group.

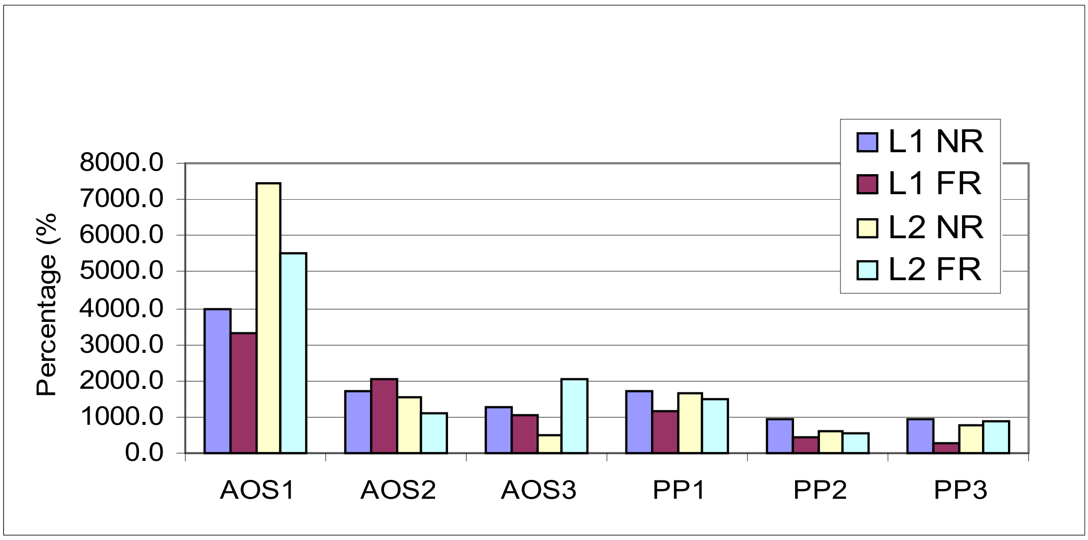

Figure 5.26 The SDs of utterance onset duration of each subject expressed as a percentage of the SD of the normal group for each context for the voiced plosive utterance group

5.4.9 Determination of the context (L1NR, L1FR, L2NR and L2FR) in which *variability* of each subject is the greatest for *voice onset time* of utterances beginning with a *voiceless plosive*

Table 5.41 indicates the percentage of utterances in each context that exhibited the greatest variability.

Table 5.41 The percentage of utterances in each context in the voiceless plosive utterance group which were assigned a value of one indicating the context where variability was the greatest for most utterances regarding VOT

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	The context with the largest percentage of utterances displaying the greatest SD
AOS1	40	0	40	20	L1NR and L2NR
AOS2	80	0	20	0	L1NR
AOS3	0	0	60	40	L2NR
N1	40	0	60	0	L2NR
N2	20	0	60	20	L2NR
N3	40	0	40	20	L1NR and L2NR
N4	60	20	20	0	L1NR
N5	0	80	60	0	L1FR
NGR	60	0	40	0	L1NR
PP1	40	0	60	0	L2NR
PP2	60	0	40	0	L1NR
PP3	0	0	60	40	L2NR

Three subjects, AOS3, PP1, PP3 and two normal speakers, N1 and N2, exhibited the largest percentage of utterances with the greatest variability in L2NR indicating that the L2 context presumably led to greater variability in these subjects. However, the L2FR context did not seem to lead to greater variability in these subjects. When rate had to be increased in L2FR, more conscious processing was possibly applied causing greater precision of repeated production of an utterance. All other experimental subjects and normal speakers exhibited the largest percentage of utterances with the greatest variability in L1NR with the exception of N5 where L1FR was the context with the largest percentage of utterances with the greatest variability. AOS1 and N3 had an equal percentage of utterances with the greatest variability in L1NR and L2NR. It is evident that all subjects were not affected similarly by the language and/or rate contexts regarding increased variability.

From Figure 5.27, displaying the SDs of each experimental subject as a percentage of the SDs of the normal group, it is evident that all the experimental subjects, with the exception of PP3 for L1NR, exhibited greater SDs than the normal group across all four contexts. AOS2 exhibited the smallest SDs which were between 12.7% and 71.4% greater than those of the normal group, while AOS2 exhibited the largest SDs which were between 15% and 274% greater than those of the normal group.

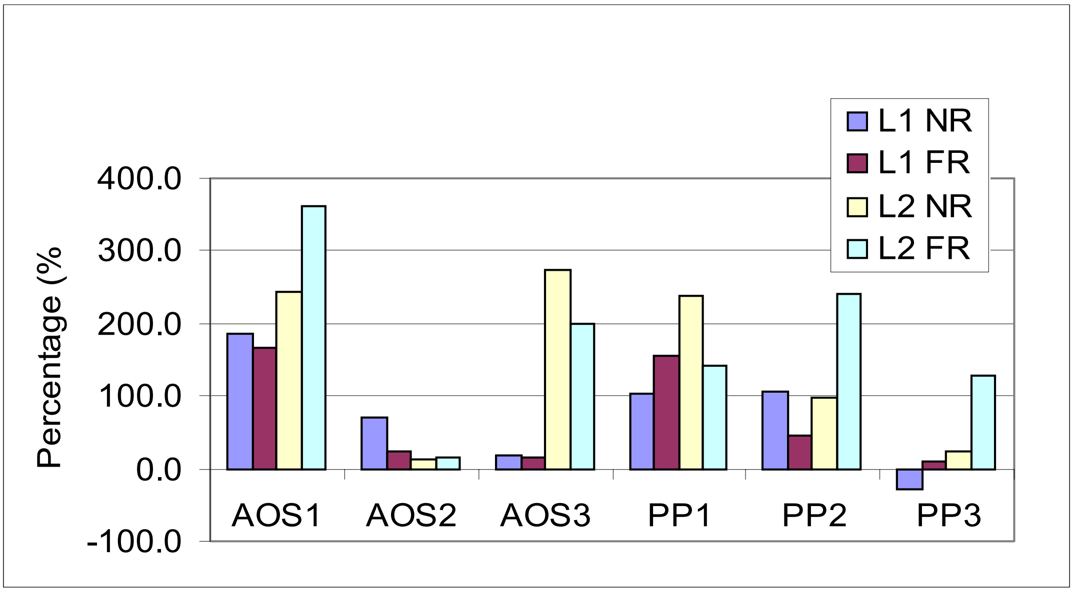

Figure 5.27 The SDs of voice onset time of each subject expressed as a percentage of the SD of the normal group for each context for the voiceless plosive utterance group

5.4.10 Determination of the context (L1NR, L1FR, L2NR and L2FR) in which *variability* of each subject is the greatest for *voice onset time* of utterances beginning with a *voiced plosive*

The results regarding the percentage of utterances in each context where the variability was the greatest for the voiced plosive group are displayed in Table 5.42.

Table 5.42 The percentage of utterances in each context in the voiced plosive utterance group which were assigned a value of one indicating the context where variability was the greatest for most utterances regarding VOT

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	The context with the largest percentage of utterances displaying the greatest SD
AOS1	0	20	40	40	L2NR and L2FR
AOS2	40	0	40	20	L1NR and L2NR
AOS3	40	40	20	0	L1NR and L1FR
N1	40	40	0	20	L1NR and L1FR
N2	60	0	20	20	L1NR
N3	60	0	40	0	L1NR
N4	80	0	20	0	L1NR
N5	0	40	0	60	L2FR
NGR	60	0	20	20	L1NR
PP1	40	40	0	20	L1NR and L1FR
PP2	0	40	60	0	L2NR
PP3	40	40	0	20	L1NR and L1FR

As with the voiceless plosive group, there does not appear to be a trend of the largest percentage of utterances with the greatest variability regarding VOT occurring in the L2NR or L2FR context. Three of the five normal speakers had the greatest variability in L1NR. N1 had an equal percentage of utterances with the largest SD in L1NR and L1FR, whereas N5 had the largest percentage of utterances with the greatest variability in L2FR. As a group, the normal speakers exhibited the largest percentage of utterances with the greatest variability in L1NR.

The L2 context appears to have led to greater variability in AOS1, since this speaker had an equal percentage of utterances with the greatest SD in L2NR and L2FR. AOS2 exhibited an equal percentage of utterances with the greatest variability in L1NR and L2NR, while AOS3 exhibited an equal percentage of utterances with the greatest variability in L1NR and L1FR. PP1 and PP3 both had an equal percentage of utterances with the greatest variability in L1NR and L1FR. Subject PP2 had the greatest variability in L2NR, indicating that the L2 context might have influenced variability in this subject, although repetitive productions of the same utterance became more accurate in the L2FR context.

From Figure 5.28, displaying the SDs of each experimental subject as a percentage of the SDs of the normal group, it is evident that none of the experimental subjects, with the exception of PP1, had greater SDs than the normal group across all four contexts. This is an interesting finding, since most of the experimental subjects generally exhibited greater SDs across all four contexts regarding the other temporal parameters which were measured.

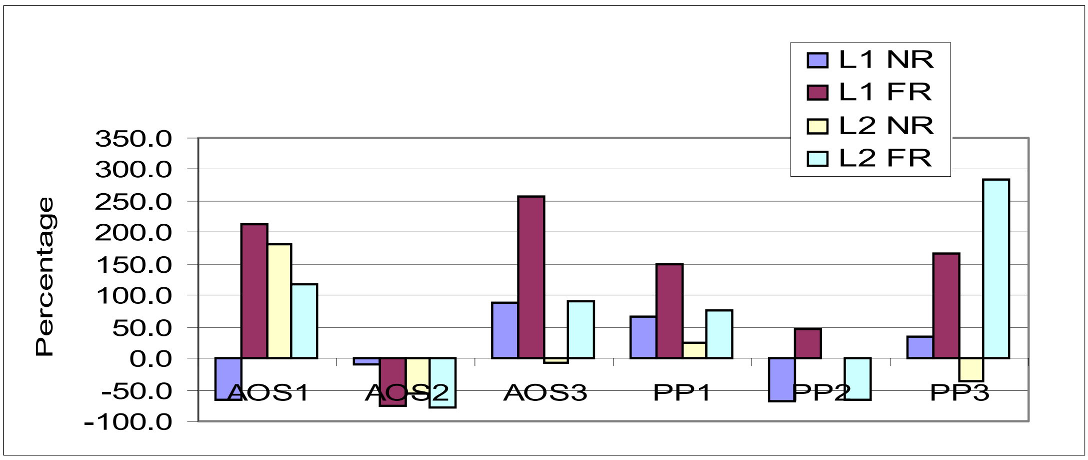

Figure 5.28 The SDs of voice onset time of each subject expressed as a percentage of the SD of the normal group for each context for the voiced plosive utterance group

5.4.11 Summary of results for sub-aim three

Table 5.43 presents a summary of the findings pertaining to sub-aim three. In Table 5.43, it is it indicated if the main predictions for sub-aim three were realized. It was predicted that the context which posed the greatest demands to the speech production mechanism would result in the greatest variability in subjects who have a compromised speech production mechanism. An increase in speaking rate was hypothesized to increase the demands to the speech mechanism and increased rate, in addition to speech production in L2, was predicted to be the context which would pose the greatest demands to the speech mechanisms of the experimental subjects. It was not certain how normal speakers would react to these increased demands, but since the test stimuli used were phonemically and phonetically similar and the normal speech motor mechanism is flexible in making adjustments to the context, it was predicted that normal speakers would be able to sufficiently adapt to the increased processing demands. The L2FR context would thus not necessarily have increased variability in speakers with normal speech and language abilities.

In Table 5.43 it is indicated with an X for each parameter and utterance group if a subject exhibited the largest percentage of utterances with the greatest SD either in L2NR (finding A, indicated in blue) or in L2FR (finding B, indicated in red). It is also indicated with an X (finding C, indicated in green) if a subject exhibited greater SDs than the normal group for a specific utterance group across all four contexts. When two contexts had an equal percentage of utterances exhibiting the greatest SD, the context equal to either L2NR or L2FR is cited under either finding A (equal to L2NR) or finding B (equal to L2FR), depending on the context to which it was equal.

For the experimental subjects individual patterns emerged regarding the context in which the most utterances had the greatest variability. In the normal speakers, however, it appears as if the L2NR and L2FR context generally rendered the largest percentage of utterances with the greatest SD, with the exception of VOT. This trend of the largest percentage of utterances with the greatest SDs occurring in either L2NR or L2FR was not as readily observed in the experimental subjects. The fact that the normal group generally exhibited the most utterances with the greatest variability in either L2NR of L2FR could be indicative of the fact that the L2 context generally led to greater variability and consequently made speech production less precise during repetitive production of a specific utterance for the normal speakers.

Table 5.43 Summarized findings related to sub-aim three indicating whether the context with the largest percentage of utterances exhibiting the greatest variability was either L2NR or L2FR and if the SDs of each experimental subject were greater than those of the normal group across all four contexts

	Utterance Group	Finding	AOS1	AOS2	AOS3	PP1	PP2	PP3	N1	N2	N3	N4	N5	NGR
Vowel duration	Voiceless Plosives													
		A	X			X	X		X	L1NR		X		X
		B	X	L1FR			X		X		L1FR			X
		C		X	X									
	Voiced Plosives													
		A							X	X				
		B	X				X				X	L1NR	X	X
		C	X	X	X	X	X	X						
	Voiceless Fricative													
		A	X	X			X		X	X				X
		B									X	X		
		C	X	X	X		X							
Utterance duration	Voiceless Plosives													
		A							X			X	X	X
		B	L1NR	X	X					X		X		
		C	X	X		X	X	X						
	Voiced Plosives													
		A	X					X	L1NR		X			
		B		X		L1NR				X		L1NR	L1FR	X
		C	X	X	X	X	X	X						
	Voiceless Fricative													
		A				X	X		X	X	X	X	X	X
		B			X			X						
		C	X	X	X	X	X							
Utterance onset duration	Voiceless Plosives													
		A	X	L1NR		X					X		L1FR	
		B	X					L1NR		X				
		C	X	X	X	X	X	X						
	Voiced Plosives													
		A	X	L1FR					X		X			X
		B			X			X		X			X	
		C	X	X	X	X	X	X						
Voice onset time	Voiceless Plosives													
		A	L1NR		X	X		X	X	X	L1NR			
		B												
		C	X	X	X	X	X							
	Voiced Plosives													
		A	X	L1NR			X							
		B	X										X	
		C				X								

A=The context which rendered the largest percentage of utterances with the greatest SD is L2NR
B=The context which rendered the largest percentage of utterances with the greatest SD is L2FR
C=The SD of the experimental subject was greater than that of the normal group across all four contexts

The specific L2 context (either L1NR or L1FR) in which the greatest variability occurred in the *normal speakers*, appeared to differ between subjects. Sometimes L2NR led to the greatest variability whereas other times L2FR led to the greatest variability. For the normal speakers as a group, more instances occurred in L2NR than L2FR where the largest percentage of utterances exhibited the greatest SDs. Apart from N1 who generally displayed the most utterances with the greatest variability in L2NR, the other normal subjects' results regarding the context with the greatest variability fluctuated between L2NR and L2FR. It was only for the voiceless fricative utterance group regarding UD that all normal speakers obtained the largest percentage of utterances with the greatest variability in L2NR. When speaking at a faster than normal rate, accuracy of repeated production thus appears to increase in normal speakers despite production in L2.

In some instances a L1 context had an equal percentage of utterances with the greatest variability as either L2NR or L2FR. The context which exhibited the same percentage of utterances with the greatest variability as either L2NR or L2FR was most often L1NR in the normal speakers. The finding of an L1 context exhibiting an equal percentage of utterances with the greatest SD as a L2 context, only occurred twice at most for a single normal speaker across all measured parameters and utterance groups.

Regarding the findings pertaining to sub-aim three for the *experimental subjects*, individual patterns emerged regarding the context where the greatest variability was generally observed. From Table 5.43 it is evident that subject AOS1 generally exhibited the most utterances with the greatest SDs in either L2NR or L2FR. AOS2, on the other hand, although exhibiting instances where the largest percentage of utterances had the greatest variability in either L2NR or L2FR, often had L1NR and L1FR sharing this position with either L2NR or L2FR. For this subject a consistent pattern regarding the context with the greatest variability did thus not emerge. For subject AOS3 the greatest variability was observed in L2FR for the voiceless plosive and voiceless fricative utterance groups regarding UOD and for the voiced plosive utterance group regarding UOD. AOS3 furthermore exhibited the largest percentage of utterances with the greatest SD in L2NR for the voiceless plosive utterance group regarding VOT. For VD the largest percentage of utterances with the greatest SD never occurred in either L2NR or L2FR for AOS3. The results of subject AOS3 thus imply that temporal control of certain parameters might be more subject to the influence of L2.

With the exception of VOT for the voiced plosive utterance group, all the subjects with AOS generally exhibited greater SDs than the normal group across all four contexts. Thus even though a consistent pattern did not emerge regarding the greatest variability occurring in either L2NR or L2FR, with the exception of AOS1, all subjects with AOS appear to be more variable than the normal group across all four contexts. The fact that the subjects with AOS are already much more variable than normal, might have made it more difficult for the effect of L2 to be visible in their results.

When viewing the data of the subjects with PP, it is evident that these subjects also exhibit fewer instances of the largest percentage of utterances with the greatest SDs occurring in either L2NR or L2FR compared to the normal group. Of the three subjects with PP, subject PP3 most frequently exhibited the largest percentage of utterances with the greatest SDs in either L2NR or L2FR. In the subjects with PP, the L2NR or L2FR context does not appear to have led to more utterances exhibiting the greatest variability. It is further evident that all the subjects with PP generally exhibited greater SDs than the normal group across all four contexts. There were a few instances in the subjects with PP (two instances in PP1, two in PP2 and five in PP3) where they did not exhibit greater SDs than the normal group across all four contexts. From examination of Figures 5.19 to 5.28, it is evident that the subjects with AOS generally had greater SDs than the subjects with PP regarding VD and UOD.

In summary, the results for sub-aim three, for the experimental subjects, with the exception of AOS1 do not appear to render a consistent pattern regarding the largest percentage of utterances with the greatest variability occurring in either L2NR or L2FR. For the normal group it does appear, however, that L2NR and L2FR generally led to the largest percentage of utterances with the greatest variability. Furthermore, the subjects with AOS and PP, with a few exceptions, generally exhibited greater SDs than the normal group across all four contexts. The subjects with AOS appeared to have greater SDs than the subjects with PP regarding VD and UOD. Although all subjects with PP had greater SDs than the normal group regarding VOT of the voiceless plosive utterance group, only PP1 exhibited this behavior regarding VOT of the voiced plosive utterance group.

5.5 SUMMARY OF CHAPTER FIVE

In this chapter, the results of the study were presented according to the formulated sub-aims. These results entailed description of specific temporal parameters of speech production across four contexts in normal speakers, persons with AOS and persons with PP. Chapter five serves as an introduction to chapter six where the results are interpreted and discussed with reference to relevant research and theoretical issues.

CHAPTER SIX
DISCUSSION OF RESULTS

CHAPTER SIX
DISCUSSION OF RESULTS

6.1 INTRODUCTION

This study examined the interaction between language and motor processes of speech production in normal speakers and persons with either AOS or PP. Specifically the study aimed to determine if a relationship exists between speech production in L2 and its motor execution in these groups of speakers. It was predicted that speech production in L2 might pose higher processing demands and consequently impact on the motor control of speech. The impact of the increased processing demands might consequently be visible in the temporal parameters of speech production as measured in the acoustic speech signal.

In this chapter, the results of the study will be discussed according to the three formulated sub-aims, whereafter a general discussion highlighting the main theoretical issues pertaining to the results, will be presented. Since the effect of L1 versus L2 production on the temporal parameters of speech production has not yet been undertaken, it is not possible to directly compare the findings of the present study, to the results of previous research. Where applicable, the results of related research will be discussed in relation to the results of the present study. The results of studies which included subjects with CA will be included in the discussion, since these persons were included in these studies because of the preponderance of PPs in their speech and are thus comparable to the subjects with PP in the present study.

6.2 DISCUSSION OF RESULTS FOR SUB-AIM ONE: DETERMINATION OF THE EXTENT OF DURATIONAL ADJUSTMENT IN L1 AND L2

Regarding sub-aim one, the discussion will be divided into three sections to deal with the questions which were posed for addressing this sub-aim. Firstly, the subjects' ability to accomplish durational adjustments with an increase in rate will be discussed. Secondly, the ability to accomplish durational adjustments will be compared between

L1 and L2 to determine if L2 led to greater difficulty regarding the accomplishment of durational adjustments. Lastly, results pertaining to the extent of the durational adjustment in L1 compared to L2 will be discussed in an attempt to determine if a greater extent of durational adjustment generally occurred in L1 compared to L2. Where relevant, each of the three sections will be discussed with reference to what the results pertaining to them reveal about the nature of the underlying impairment in AOS and PP and/or the effect of speech production in L2 on the temporal parameters of speech.

6.2.1 Accomplishment of durational adjustment

From the data regarding the extent of durational adjustment, it is evident that speakers with AOS and speakers with PP, exhibited greater difficulty than the normal group regarding decreasing the duration of temporal parameters in the FR compared to the NR. In the present study, the subjects with PP exhibited more instances regarding their results for utterances as a group, than the subjects with AOS where duration in the FR could not be decreased. There were, however, isolated instances in persons in the normal group as well, where the duration in the FR could not be decreased for the parameters VD, UD and UOD. For these three temporal parameters the results for the normal speakers *as a group* never demonstrated instances where the duration in the FR could not be decreased though.

6.2.1.1 The nature of the impairment in AOS and PP

The finding of acoustic durations decreasing in the FR, is in agreement with the results of previous studies which found that acoustic durations decrease when speaking rate is increased in both normal speakers and persons with speech and language impairments (Kent & McNeil, 1987; Kessinger & Blumstein, 1998; McNeil *et al*., 1990a). Furthermore, Kent and McNeil (1987) and McNeil *et al*. (1990a) also reported that subjects with AOS and subjects with CA had difficulty managing changes in speaking rate, thus decreasing durations, and that the acoustic durations of their control rate productions often overlapped with those of their fast rate productions. Robin *et al*. (1989) also reported difficulty with manipulation of speaking rate for syllable- and sentence-level material in their subjects with AOS, despite normal velocities of movements.

From the results of their study, McNeil *et al*. (1990a:154) speculated that "the pathologic subjects either did not make the cognitive distinction between the rate alteration requests or they were unable to accomplish the rate alterations due to a faulty speech motor control system". After examination of their data, McNeil *et al*. (1990a) concluded that the finding that their subjects were generally successful regarding accomplishment of the appropriate durational and time to peak velocity adjustments (shorter durations in the fast rate and longer durations in the slow rate), indicated that their experimental subjects had understood the instructions and had attempted to make appropriate rate adjustments. Consequently McNeil *et al*. (1990a) concluded that a speech motor control deficit was responsible for the difficulty with the adjustment of speech rate in the apraxic and conduction aphasic subjects in their study. Consistent with this conclusion, Kent and McNeil (1987:215) also posed that "Difficulty in rate management seems to point to a motoric inflexibility in the apraxic speaker".

The proposal of a motor control deficit and/or motor inflexibility in persons with either AOS or PP also seems to be a viable explanation for the difficulty experienced with durational adjustments by the experimental subjects in the present study. The fact that difficulty with temporal control occurs when speaking rate has to be increased, might implicate the possibility of a motor planning deficit underlying the nature of the speech deficit in the persons with AOS and those with PP in the present study. According to the framework proposed by Van der Merwe (1997), difficulty in accomplishing appropriate temporal adjustments or adaptations can be ascribed to the level of the motor planning of speech, since the temporal parameters of speech, for example, movement duration, are specified at this level of the speech production process. It has been proposed, however, that processing resources are shared amongst the different levels or processes of speech production or that these different levels or processes interact in a direct way (Strand & McNeil, 1996). In this sense, a deficit at the level of linguistic-symbolic planning might also manifest in aberrant temporal control. Kent and McNeil (1987) also proposed that the speech production mechanism might have a limited number of ways to exhibit breakdown. One would expect, though, that if a deficit regarding linguistic-symbolic planning is present, phoneme substitution errors should result when processing demands are increased. The fact that difficulty with the accomplishment of durational adjustments was evident in the subjects with PP in the present study, might indicate an accompanying motor deficit in these subjects. On the other hand, the subjects with PP might use slowed rate of production even though they speak slightly faster than their habitual rate in the FR, to exert controlled processing in an attempt to avoid making phonological errors, for example, errors of phoneme substitution and sequencing.

According to the framework proposed by Van der Merwe (1997), timing deficits could also possibly be ascribed to a deficit at the level of motor programming, since the temporal and spatial specification of muscle movements occur at this level. If motor programming is problematic, it would presumably result in deviant timing of articulatory movements as well, since the control of muscle movement underlies synchronized articulatory movement (Van der Merwe, 1997). It would be difficult to distinguish between deficits at the level of motor programming and planning, however, since deficits at a higher level of the speech production process might also influence the level/(s) below it. It is not certain at this point, however, how one would distinguish between these two levels of impairment experimentally.

The fact that some of the normal speakers in the present study also occasionally failed regarding decreasing duration in the FR, is indicative of the fact that even the normal motor speech system exhibits periods of inconsistent behavior when processing demands are increased, although this is rather the exception than the rule. The normal subjects in the present study who failed to decrease duration in the FR, generally exhibited only one utterance out of the five or four utterances in an utterance group, where the mean duration of a specific parameter indicated that duration was not decreased in the FR. It could also have been that the normal speakers produced the carrier phrase at a faster than usual rate, but not the target utterance which was used for analysis. In contrast to the results of the normal group, an inability to obtain a shorter duration in the FR, occurred much more frequently in persons with AOS or PP.

6.2.2 Accomplishment of durational adjustments in L1 compared to L2

In the present study, it was predicted that if a subject had difficulty accomplishing durational adjustments in the FR, this behavior would be more prevalent in a speaking context which posed greater processing demands to the speech production mechanism, especially in the presence of a neurologic lesion affecting the stages involved in speech and language processing. It was predicted that difficulty with the accomplishment of durational adjustments in the FR would be more prevalent in L2, since speech production in L2 is presumably less familiar due to the novelty of this context and consequently L2 production is less automatized. It was predicted that if a deficit regarding one of the stages of the speech production process existed, the inability to increase rate (decrease duration) would occur more often in L2 than in L1, since production of a novel and less automatized utterance would presumably place higher processing demands on the speech production mechanism and make it even more susceptible to breakdown. Since the utterances chosen as test stimuli in the present study were nearly phonemically and consequently motorically identical and normal speakers do not generally exhibit difficulty with accomplishment of durational adjustments, it was predicted that normal speakers would not be influenced by the L2 context regarding the accomplishment of durational adjustments.

The abovementioned prediction of exhibiting more difficulty with durational adjustments in the FR in L2 compared to L1, is supported by the results of the present study for both the subjects with AOS and those with PP. In the normal subjects the abovementioned prediction occurred in N5 regarding VD of the voiced and voiceless plosive group, in N2 regarding UD of the voiced plosive group, in N5 regarding UOD of the voiced plosive group and in N2 and N4 regarding VOT of the voiceless plosive utterance group. However, when the results of the normal subjects *as a group* are viewed, the abovementioned phenomenon never occurred for any of the temporal parameters and utterance groups. The latter finding is most probably due to the fact that the normal group did not exhibit difficulty with accomplishing a decrease in duration in the FR in either language.

In the subjects with either AOS or PP, more instances occurred in L2 than in L1, where the duration in the FR could not be decreased for the temporal parameters VD, UD and UOD. Although this finding was not as evident in AOS1, it was most likely masked by the fact that this subject was seldom able to decrease duration in the FR in either L1 or L2. PP1 exhibited more instances of difficulty with accomplishment of durational adjustments in L2 compared to L1, only regarding UD. Regarding VOT, the abovementioned prediction was only realized in AOS1, PP2, N2 and N4. VOT thus seems to be affected to a lesser extent by the L2 context than the other measured temporal parameters.

6.2.2.1 The effect of speech production in L2 on the temporal parameters of speech production

The fact that appropriate durational adjustments (decrease in duration in the FR) were generally less successfully accomplished by the experimental subjects when speaking in L2, implies that L2 might impose an additional demand on the speech production mechanism and cause temporal control to be less successfully exerted in circumstances where an additional demand has already been placed on the speech production mechanism with, in this study, an increase in speaking rate. In the present study, persons with AOS or PP thus seem to be more susceptible to breakdown (as manifested in an inability to accomplish appropriate durational adjustments) in the L2 context. Consequently speech production in L2 can be viewed as a more demanding context than speech production in L1. The fact that the persons with AOS and those with PP exhibited difficulty with durational adjustments in L2 more often than the normal subjects, indicates that these speakers are presumably affected by the L2 context or increased processing demands to a greater extent than the normal speakers as predicted.

6.2.2.2 The nature of the impairment in AOS and PP

As mentioned previously, increased processing demands to the speech production mechanism will require more conscious processing and control. Conscious processing, in turn, requires greater resources (Kent, 1990; Levelt, 1989). Persons with normal speech mechanisms are able to adapt and execute speech accurately in these circumstances due to the flexibility of their speech production mechanisms. The subjects with either AOS or PP in the present study, were more susceptible to breakdown (not being able to accomplish durational adjustments in the FR) when the processing demands were increased by the combined influence of L2 and an attempt to speak faster than usual. Speaking in L2 thus more often led to difficulty with accurate temporal control than L1 under the same circumstances, namely when attempting to increase speaking rate and consequently decrease duration. The fact that both subjects with AOS and those with PP exhibited a trend regarding an inability to achieve shorter durations in the FR more often in L2 compared to L1, indicates that both these groups of subjects are influenced by L2 in that it appears to pose a higher demand to their speech production mechanisms making them more susceptible to breakdown manifested in an inability to achieve motor targets.

Subject PP1 exhibited more instances of an inability to decrease duration in the FR in L2 compared to L1, only regarding UD and not for any of the other measured temporal parameters. Regarding the other parameters, PP1 was able to accomplish the appropriate durational adjustments regarding all utterance groups. Subject PP1 thus appears to function similarly to the normal group. Furthermore, the finding that difficulty regarding the accomplishment of durational adjustments only occurred regarding UD in this speaker might indicate that temporal control of some parameters might be more difficult or more prone to disruption when processing demands are increased.

6.2.3 Extent of durational adjustment in L1 compared to L2

Regarding the extent of durational adjustment in L1 compared to L2, it was predicted that subjects with compromised speech production mechanisms would generally exhibit a greater extent of durational adjustment in L1, since L1 is presumably more familiar and consequently more automatized. Utterance complexity in L1 is thus less than in L2, which is a more unfamiliar and novel context. The processing demands imposed by speech production in L1 were thus predicted to be less compared to the demands imposed by speech production in L2. Control of temporal parameters under circumstances of increased processing demands, induced by requiring an increase in speaking rate, would thus consequently be more successfully accomplished in L1 than in L2 in the presence of difficulty with one or more stages of the speech production process. It was thus predicted that the extent to which a subject would be able to decrease duration in the FR compared to the NR would be greater in L1 than in L2 in the experimental subjects. Due to the flexibility of the normal speech mechanism and the fact that the test stimuli were phonemically and phonetically basically identical, it was predicted that the influence of L2 on the extent of durational adjustment would possibly not be evident in the normal subjects in this study.

From the results of the study regarding the extent of durational adjustment in the FR in L1 compared to L2, it is evident that the L2 context appears to have posed a greater demand to the speech production mechanisms of most of the subjects with either AOS or PP regarding VD, UD and UOD. However, the results of the normal group do not indicate that normal speakers are affected by the L2 context regarding this behavior. In fact, the normal group often obtained a greater extent of durational adjustment in L2 compared to L1. The normal group only exhibited the abovementioned predicted behavior regarding UOD for all utterance groups and regarding UD for the fricative utterance group.

As with the prediction in 6.2.2 (exhibiting more instances in L2 than in L1 where duration in the FR could not be decreased), AOS1 does not appear to have exhibited the phenomenon of displaying a greater extent of durational adjustment in L1 compared to L2. The latter behavior might, once again, have been masked by the fact that AOS1 was seldom able to accomplish a decrease in duration in the FR successfully, in either L1 or L2. The motor impairment in this subject is thus presumably so severe that the task of accomplishing durational adjustments was seldom successful in either language. AOS1 also had the most severe AOS compared to the other two subjects with AOS in the study, as judged perceptually. All the other subjects with AOS or PP exhibited a greater extent of durational adjustment in the FR in L1 compared to L2 in at least one of the utterance groups regarding VD, UD and UOD. Of the experimental subjects, only subject PP1 did not exhibit a greater extent of durational adjustment in L1 compared to L2 for any utterance group, regarding both VD and VOT. This subject behaved similar to the normal group regarding VD and VOT.

6.2.3.1 The effect of speech production in L2 on the temporal parameters of speech production

The fact that most of the subjects with either AOS or PP exhibited a greater extent of durational adjustment in the FR in L1 than in L2, implies that temporal control in L1 was more successfully and presumably more easily exerted by these subjects under circumstances of increased processing demand, induced with an increase in speaking rate. The fact that L1 did not consistently render a greater extent of durational adjustment compared to L2, in either the experimental subjects or the normal group, indicates that performance is variable regarding specific utterance groups and temporal parameters. Consequently the L2 context did not unequivocally cause temporal control of all parameters and all utterance groups to be less successfully accomplished. The fact that the experimental subjects generally achieved a greater extent of durational adjustment in L1, strongly suggests though that when rate has to be increased, L2 further increases the processing demands in speakers with compromised speech and language processing. This increased demand, in turn, causes temporal adjustments to occur to a greater extent in L1, for which production is presumably more automatized.

Contrary to the behavior of the subjects with either AOS or PP, the normal subjects, with the exception of N2 and N5, did not show the tendency of accomplishing greater durational adjustment in the FR in L1 compared to L2 regarding VD and UD. Regarding VOT, only N2 and N4 exhibited a greater extent of durational adjustment in the FR in L1 compared to L2. Regarding UOD, a greater extent of durational adjustment occurred in L1 compared to L2 for all of the normal speakers, however, with the exception of N1. The results regarding the extent of durational adjustment in L1 versus L2 indicate that differences exist between normal speakers regarding the way they react to speech production in L2. For example, in some normal speakers, durational adjustments are greater in L1, whereas for others durational adjustments are greater in L2. This result could be due to the fact that some speakers might be more accustomed to speaking in L2 than others. Even though all the subjects in the present study had the same level of bilingualism, it might be that some subjects speak English more often in everyday life than others. The reason for different patterns regarding the extent of durational adjustment in L1 compared to L2, emerging for different normal speakers, could also be due to the fact that some speakers exert more conscious control whilst speaking in L2, since this is a more unfamiliar and novel speaking context than L1. This conscious control exerted by the normal speech motor system whilst speaking in L2, might then lead to the accomplishment of greater durational adjustments in L2 compared to L1.

6.2.3.2 Differences regarding the control of different temporal parameters

Regarding UOD the normal subjects, with the exception of N1, exhibited a greater extent of durational adjustment in L1. This latter result might indicate that this temporal parameter is more susceptible to the influence of increased processing demands than VD, UD and VOT. UOD in the normal speakers in the present study corresponds to stop gap duration which was measured by Seddoh *et al*. (1996b) in a study regarding speech timing in persons with AOS versus CA. Stop gap duration refers to the period of oral constriction (Kent *et al*., 1996) for a plosive sound. In the present study, the normal speakers initiated production of the plosive directly after the carrier phrase and this corresponds to the measure of stop gap duration by Seddoh *et al*. (1996b). UOD refers to how soon after the end of the carrier phrase, the constriction for the plosive was completed, since it was measured from the end of the last word in the carrier phrase, to the burst release of the target word. Stop gap duration, and in this study UOD, might be easier to accomplish in L1 when the processing demands are increased with an increase in speaking rate, since this language is more automatized and presumably produced more "automatically". The limits of equivalence to result in on-target production might be wider for the temporal parameters VD and UD and consequently their temporal control is not as easily influenced by the increased demands imposed by speech production in L2 in the FR. When the results of the normal speakers as a group are viewed, a greater extent of durational adjustment in L1 compared to L2 was only obtained regarding UOD for all utterance groups and regarding UD of the fricative utterance group.

The results for VOT appear to differ from the results obtained regarding VD, UD and UOD, since the subjects with AOS or PP, with the exception of PP2 and PP3, performed similarly to the normal group who did not exhibit a trend of achieving a greater extent of durational adjustment in L2 compared to L1. Regarding VOT, only AOS1, PP2, N2 and N4 had more instances in L2 than L1 where duration could not be decreased in the FR. Furthermore only subjects PP2, PP3, N2 and N4 exhibited a greater extent of durational adjustment in L2, whereas for all other subjects the opposite was true. From these results, it thus appears as if VOT is more individualized regarding the way it is affected by the L2 context. Even though VOT requires very precise timing, it seems less subject to influence by L2 than the other temporal parameters which were measured. Van der Merwe (1986) also found that VOT was less sensitive to the effects of sound structure and articulatory characteristics than the other temporal parameters measured in her study, namely UD and VD.

6.3 DISCUSSION OF RESULTS FOR SUB-AIM TWO: DETERMINATION OF THE CONTEXT (L1NR, L1FR, L2NR OR L2FR) IN WHICH THE DIFFERENCE BETWEEN EACH EXPERIMENTAL SUBJECT AND THE NORMAL GROUP IS THE GREATEST REGARDING EACH TEMPORAL PARAMETER

The discussion of the results regarding the duration of temporal parameters for normal and experimental subjects in the four measured contexts, will be divided into three sections. Firstly, the durations of the experimental subjects will be discussed in relation to the durations of the normal group to shed light on the underlying impairment of subjects with AOS and subjects with PP. Secondly, the durations of the subjects with AOS will be discussed in relation to the durations of the subjects with PP in an attempt to reveal differences in the nature of the deficits in these two groups of speakers. Lastly, trends regarding the context where the greatest difference occurred between the durations of the experimental subjects and the normal group will be discussed in an attempt to make inferences about the influence of speech production in L2 on temporal control in speakers with neurogenic speech or language disorders.

6.3.1 Duration of the temporal parameters of each experimental subject compared to the duration of the normal group

From the results of sub-aim two, it is evident that most of the subjects had instances where their mean duration for a specific utterance group and temporal parameter was longer than that of the normal group across all four contexts (L1NR, L1FR, L2NR, and L2FR). The result of longer than normal durations in subjects with AOS or PP, is in agreement with previous research indicating that persons with AOS or CA exhibit longer durations than normal speakers regarding VD and UOD (Seddoh *et al*., 1996b). Regarding VD and UOD, Seddoh *et al*. (1996b) found longer durations than normal speakers in both subjects with CA and AOS for monosyllabic words. Longer than normal VDs have also been reported for AOS (Collins *et al*., 1983; Freeman *et al*., 1978) and abnormal durations regarding segmental, intersegmental and word-level timing have been reported for CA (Kent & McNeil, 1987; McNeil & Adams, 1991; McNeil *et al*., 1990a). However, some researchers have not reported longer VD in subjects with either AOS or aphasia (Bauman, 1978; Duffy & Gawle, 1984; Gandour & Dardarananda, 1984; Mercaitis, 1983; Ryalls, 1984, 1986).

The fact that opposing results have been obtained regarding the duration of temporal parameters of speech in AOS and PP, could possibly be attributed to the specific vowel measures, method of elicitation of spoken stimuli, rate of presentation of stimuli and the degree to which the speakers with AOS had concomitant aphasia (Strand & McNeil, 1996). The severity of AOS and CA might also have led to differences in results. All these named factors pose different processing demands to the speech production mechanism and consequently burden the speech production systems of the subjects to varying degrees.

6.3.1.1 The nature of the impairment in AOS and PP

The finding of longer than normal durations in subjects with AOS or PP could be attributed to different factors. One explanation is that the longer than normal duration could possibly be indicative of an underlying motor impairment in the speech of these subjects leading to aberrant temporal control. Regarding deviant timing or synchronization patterns observed in the speech of speakers with neurogenic involvement, it has generally been concluded that such patterns are indicative of a deficit at the level of motor control (Tseng *et al*., 1990). Ballard *et al*. (2000:976) underscore this statement by saying "Examining disturbance of temporal characteristics of speech has proved fruitful in distinguishing motoric from linguistic disorders". Kent and McNeil (1987:213) from the results of their study also concluded that in CA temporal abnormalities associated with segment and intersegment duration, as well as VOT "are best interpreted as meaning that motoric planning, or execution, or both, are disrupted".

The source of longer durations in the speech of AOS and CA has also been attributed to "motoric limitations, compensation for motoric difficulties, or an attempt to reinstall effective self-monitoring" (Kent & McNeil, 1987:214). Kent and McNeil (1987:214) argued, however, that difficulty at the phonological level of speech production might also be reflected in the motor parameters of speech production, by saying "uncertainties or inefficiencies at a relatively abstract level of speech are reflected in the motor processes that they drive". These researchers also argue that it is possibly invalid to try and separate "phonetic representation" and "motor realization", since phonetic representation might be "accomplished in terms of motoric prescriptions" (Kent & McNeil, 1987:214). This view would be in agreement with that of researchers supporting action theory (Kent & McNeil, 1987). For this reason, it is difficult to unequivocally state that AOS and PP have the same underlying nature, namely a motoric deficit. It is probably more accurate to propose that the underlying nature of the disorder is manifested in much the same way regarding certain temporal characteristics of speech production in both these groups of speakers when the processing demands are increased. Furthermore, these two groups of speakers most probably share common underlying characteristics, although these characteristics might be qualitatively and quantitatively different.

6.3.2 Duration of the temporal parameters in subjects with AOS compared to the duration of temporal parameters in subjects with PP

An aspect which might be indicative of the *quantitative* difference between the speech characteristics of persons with AOS and PP is the severity of the disorder as determined by durational measures compared to normal speakers. In the present study subject AOS1 exhibited longer durations than the normal group across all four contexts for all temporal parameters (VD, UOD, UD and VOT) and utterance groups, thus for all nine instances measured. Subject AOS2 exhibited longer durations than the normal group across all four contexts, for all temporal parameters and utterance groups, with the exception of VOT, thus for eight of the nine measured instances. Regarding VD and UOD, AOS3 exhibited longer durations across all four contexts, but regarding UD longer durations across all four contexts were only exhibited for the voiceless fricative utterance group and not at all regarding VOT, thus for six instances.

Subject PP1 exhibited longer durations than the normal group across all four contexts for only the fricative utterance group regarding UD, but for all utterance groups regarding UOD and VOT, thus for four instances. Subject PP2 also exhibited greater durations than the normal group across all four contexts for all utterance groups regarding UD, UOD and VOT, but only for the fricative utterance group regarding VD, thus for seven instances. Subject PP3 did not exhibit longer durations than the normal group across all four contexts regarding either UD of the voiceless plosive group or any of the utterance groups regarding UOD and VOT. For all other utterance groups regarding VD and UD, longer durations across all four contexts were obtained by PP3, thus for five instances.

From the abovementioned results regarding the instances where longer durations were obtained across all four contexts, it is evident that the subjects with AOS generally had more instances than the subjects with PP where longer durations than the normal group were obtained across all four contexts. Only subject PP2 exhibited more instances than a subject with AOS (AOS3) regarding longer durations than the normal group across all four contexts. Subject AOS3 had the least severe AOS and this subject's speech problem was, perceptually judged, not as severe as that of subject PP2. The severity of the disorder thus appears to affect the duration of temporal parameters, in that subjects' durations will presumably deviate more from normal speakers if their speech and/or language disorder is more severe. Although the underlying disorder in AOS and PP appears to manifest in much the same way in the temporal parameters of speech production, it seems to be more severe in the subjects with AOS.

The durations of the subjects with AOS were also generally longer than those of the subjects with PP, although this finding was not consistent across all the temporal parameters and utterance groups measured. Seddoh *et al*. (1996b) also found that regarding UOD, VD and consonant-vowel duration the apraxic subjects in their study had longer durations than those with CA. However, the subjects with CA in their study had longer durations than the normal speakers regarding VD and consonant-vowel duration. Similarly, McNeil and Adams (1991) also found longer segment and sentence duration in subjects with AOS compared to subjects with CA. Kent and McNeil (1987) also reported longer segment and intersegment durations in AOS than in CA in control rate conditions in their study.

6.3.2.1 Differences regarding the control of different temporal parameters

Although subjects in the present study frequently exhibited longer durations than the normal group across all four contexts regarding VD, UD and UOD, the results regarding VOT were less consistent. In the present study, only AOS1, PP1 and PP2 had longer durations regarding VOT than the normal group across all four contexts. This implies that the other experimental subjects (AOS2, AOS3 and PP3) had VOTs that were comparable and even shorter than those of the normal group in certain contexts. Seddoh *et al*., (1996b) reported that subjects with CA in their study exhibited shorter mean VOTs than both the control speakers and subjects with AOS. For the subjects with AOS, Seddoh *et al*. (1996b) found contrasting results regarding VOT for different utterances. Other researchers have also reported normal VOTs in AOS or CA in some of the subjects in their studies (Collins *et al*., 1983; Itoh *et al*., 1982, Kent & McNeil, 1987, Kent & Rosenbek, 1983; Shewan *et al*., 1984). From the results of previous studies, as well as the present study, it thus appears as if VOT is less subject to disruption than the other temporal parameters and consequently not consistently affected in all speakers with either AOS or PP.

6.3.3 Trends regarding the context where the greatest difference existed between each experimental subject and the normal group

The results of the present study indicate that individual patterns emerged for subjects regarding the prediction that durational differences between the normal and experimental subjects would be most pronounced in L2FR, which was hypothesized to be the most demanding context. Experimental subjects AOS1, PP2 and PP3 generally deviated the most from the normal group in the L2FR context compared to any of the other three contexts (L2NR, L1NR and L1FR). Although this trend was also exhibited by AOS2 and AOS3, it occurred in fewer instances regarding the temporal parameters and utterance groups measured, than in AOS1, PP2 and PP3. In subject AOS2, the predicted trend was observed for at least one utterance group regarding VD, UD and VOT and for AOS3 it was observed for all utterance groups regarding UD and for the voiced plosive utterance group regarding UOD. Of all the experimental subjects, only PP1 did not exhibit the trend of durations differing most from the normal group in L2FR at all. Subject PP1 obtained the highest aphasia quotient on the WAB (Kertesz, 1982), with the implication that this subject had the least severe aphasia. The severity of the disorder could thus possibly influence the way in which a subject is affected by increased processing demands.

6.3.3.1 The effect of speech production in L1 versus L2 on the temporal parameters of speech

From the abovementioned results it can be argued that the L2FR context appears to have been the most challenging for some of the subjects with neurogenic speech and/or language disorders, although individual differences existed between speakers regarding the utterance groups and temporal parameters where this behavior was exhibited. In subjects AOS1, PP2 and PP3 the trend of exhibiting the greatest difference from the normal group in L2FR, occurred for all utterance group regarding VD, UD and UOD. The fact that the L2FR condition generally led to the greatest difference between the mean durations of these experimental subjects and the normal group, implies that L2 posed an additional demand to the speech production mechanism of the above mentioned subjects compared to L1. The reason for assuming that it was the L2 context in the FR condition which led to the increased difference between normal and experimental subjects, is deduced from the fact that the utterances in both languages were phonologically and consequently motorically the same. The phonemic and phonetic demands were thus similar for L1 and L2. The greater difference occurring in the L2FR condition is thus most likely the result of the added L2 demand in the FR context, since increasing rate is already challenging for the compromised speech mechanism as in persons with motor speech disorders. From the above line of reasoning, it can be concluded that L2 can be seen as a context for speech production influencing the temporal parameters of speech as measured in the acoustic signal.

However, the experimental subjects did not exhibit a trend of differing more from the normal group in L2NR compared to L1NR. It thus seems as if the speech production demands are most probably similar for the utterances produced in either L1 or L2 when speaking at a self-selected rate, especially since the utterances chosen for the study were phonologically almost identical. In these circumstances (speaking at a self-selected rate), the L2 context thus most probably did not pose an increased processing demand to the subjects in the present study. When speaking at a faster speaking rate, however, additional processing demands are placed on the speech mechanism, since both phonological and motor processing need to occur at a faster than usual rate. Increased rate can thus increase both linguistic-symbolic and motor processing demands. Subjects with an impairment regarding either level of the speech production process would thus be subject to breakdown regarding accurate speech production under circumstances of increased demand as with an increase in speaking rate. When an additional demand was placed on the speech production mechanism by having subjects produce speech in L2, together with an increase in speaking rate, differences between some experimental subjects and the normal group became more pronounced than when speaking in L1 in the FR. This led to the deduction that speech production in L2 places additional processing demands on the speech production mechanism and that speech production in L2 can be seen as a context influencing the temporal parameters of speech production as measured in the acoustic signal.

The fact that deviances from the normal group tended to become more visible in the L2FR context, which was predicted to pose greater processing demands than the other contexts, implies that the normal speakers were not equally influenced by these increased processing demands. Since normal speakers do not have compromised speech production mechanisms, they appear to be able to adapt to increased processing demands, whereas persons with AOS or PP appear to be limited in their ability to adjust successfully to increased processing demands. The experimental subjects thus tend to deviate to a greater extent from normal speakers in circumstances of increased processing demand.

6.3.3.2 The nature of the impairment in AOS and PP

It is interesting to note that despite the longer durations and deviance from the normal group, the subjects with AOS or PP, still managed to obtain perceptually accurate speech. This could possibly be indicative of a certain degree of retained flexibility regarding speech production in these speakers. Thus despite deviances noted on a microsegmental level, these "abnormalities" were not noted perceptually, since only perceptually on-target tokens were used for analysis. Speakers with sensorimotor speech disorder might thus retain a certain degree of flexibility in dealing with increased demands in order to obtain perceptually accurate tokens. These speakers might thus compensate for their deficits in the presence of increased demands by adapting either the spatial and/or temporal parameters of speech production, although these parameters stay within the boundaries of equivalence. If these speakers were to exceed these boundaries, distortion would presumably result. Seddoh *et al*. (1996a) also postulate the possibility of a functional operating range within which a speaker must perform to obtain a perceptually adequate response. Furthermore, these authors pose that speakers with AOS may compensate for the limitations to varying degrees and in different ways, depending on the severity of their impairment and the demands of the stimuli.

6.3.3.3 Differences regarding the control of different temporal parameters

Not all subjects were influenced by the L2 context in a similar manner. Although subjects with AOS or PP generally exhibited the greatest difference from the normal group in at least one utterance group for the temporal parameters VD, UD and UOD, this tendency was not exhibited regarding VOT. Regarding VOT, only AOS1 exhibited the greatest difference from the normal group in L2FR and subject PP3 differed equally from the normal group in L1NR and L2FR for the voiceless plosive utterance group regarding VOT. VOT thus appears to be less influenced by the L2 context than the other parameters which were measured.

6.4 RESULTS FOR SUB-AIM THREE: DETERMINATION OF THE CONTEXT IN WHICH VARIABILITY IS THE GREATEST FOR EACH EXPERIMENTAL SUBJECT AND FOR THE NORMAL GROUP REGARDING EACH TEMPORAL PARAMETER

6.4.1 Variability of the experimental subjects compared to the variability of the normal group

In the present study, the experimental subjects generally exhibited greater variability than the normal group across all four speaking contexts (L1NR, L1FR, L2NR, L2FR). The latter finding was true for the majority of subjects for all measured parameters and utterance groups, with the exception of VOT for the voiced plosive group (except for PP1) and regarding VD for the voiceless plosive utterance groups, where only AOS2 and AOS3 exhibited greater variability than the normal group across all four contexts.

The finding of greater token-to-token variability regarding durational measures in AOS than in normal speakers is in agreement with the results of previous studies indicating that speakers with AOS are more variable than normal speakers regarding the control of temporal parameters (Kent & McNeil, 1987; McNeil *et al*., 1989; Seddoh *et al*., 1996a, b; Strand & McNeil, 1996). Greater than normal variability has also been reported for subjects with CA, although the results in this regard have been less consistent. Kent & McNeil (1987) reported larger SDs for the subjects with CA in their study compared to the normal speakers, for temporal parameters of utterances produced at a fast speaking rate. In the normal rate condition, however, the CA subject performed similarly to the control speakers regarding variability of the measured temporal parameters. Seddoh *et al*. (1996b) reported differences in variability between the CA and control subjects in their study, regarding consonant-vowel duration, but not regarding stop gap duration and VD.

6.4.1.1 The nature of the impairment in AOS and PP

The increased level of variability in persons with speech impairments has been ascribed to various factors. So, for instance, increased variability has been argued to indicate instability in the motor control system (Janssen & Wieneke, 1987; Kent & Forner, 1980; Sharkey & Folkins, 1985; Smith 1992b, 1994b; Smith & Kenney, 1994; Tingley & Allen, 1975; Wieneke & Janssen, 1987). In normal developing children, it has been found that token-to-token variability for the parameters which have been studied decreases with an increase in age (Ballard, Robin, Woodworth & Zimba, 2001; DiSimoni, 1974a, b; Kent & Forner, 1980; Smith, 1995; Tingley & Allen, 1975). The latter finding is taken as evidence that increased variability indicates less stability of the speech motor system, since the speech motor systems of children are believed to be less mature and consequently less stable than those of adults (Sharkey & Folkins, 1985; Smith, 1995; Smith, Goffman & Stark, 1995).

Another example of variability in speech production comes from research in persons who stutter. Researchers have reported that token-to-token variability in the speech of these subjects is indicative of instability in the speech motor control system (Janssen & Wieneke, 1987; Wieneke & Janssen, 1987). Similarly, greater variability in AOS and PP could thus be indicative of instability in the motor control implying “reduced control in reaching intended motor targets due to impairment” (Ballard *et al*., 2000:978). According to Seddoh *et al*. (1996a), speech as a motor task requires that performance take place within a functional operating range. Because of increased token-to-token variability exhibited by subjects with AOS, these persons are more likely to perform outside this range. Consequently speech errors result due to the occurrence of erroneous movement patterns (Seddoh *et al*., 1996a).

Contrary to the view that increased token-to token variability is indicative of reduced stability of the motor control system, Folkins (1985) has argued that increased variability might reflect increased flexibility in compensating for an unstable motor control system in an attempt to achieve perceptually accurate tokens. According to Seddoh *et al*. (1996a), subjects who obtain perceptually accurate speech and exhibit greater variability presumably compensate more than those who exhibit less variability in the presence of on-target production. Furthermore, these researchers postulate that large variability and good compensation might be used as a prognostic indicator for recovery and treatment success.

The reason that most experimental subjects generally exhibited greater variability than the normal group across all four contexts might thus indicate that the speech production mechanisms of these groups of speakers are presumably less stable than those of the normal speakers. The fact that the experimental subjects in the present study were able to produce perceptually accurate target words, despite longer durations and greater variability than the normal group, might be indicative of the fact that they somehow compensate for their impairment, be it phonologic or phonetic-motoric in nature. These subjects were thus able to stay within the boundaries of equivalence, even though they might be more susceptible to operate outside these boundaries (Seddoh *et al*., 1996a) when the demands of the speaking context increases. Similarly to the subjects with AOS in the study by Seddoh *et al*. (1996a), the increased variability might reflect their efforts to compensate for an unstable motor system. This compensation reflects a degree of retained flexibility in the experimental subjects in the present study. This compensation appears to be sufficient to result in perceptually accurate speech, even though the control of the temporal parameters of speech production is aberrant and consequently differs from that of normal speakers.

6.4.1.2 Differences regarding variability of the different temporal parameters

Another finding of the present study which warrants discussion is the fact that greater variability than the normal group was not consistently present across all the temporal parameters measured in both AOS and PP. For example, none of the experimental subjects, with the exception of PP1, exhibited greater variability than the normal group across all four contexts, regarding VOT of the voiced plosive utterance group. Furthermore, less variability compared to the normal group occurred in all experimental subjects, with the exception of AOS2, in at least one context (L1NR, L1FR, L2NR or L2FR) regarding VD, UD or UOD of at least one utterance group. Subjects AOS1, AOS3, PP1 and PP2 each had only one instance where the aforementioned behavior occurred, whereas subject PP3 had two or more instances of the described behavior. It must be mentioned, however, that although instances occurred, in the aforementioned subjects, where less variability than the normal group was present, this often occurred in only one of the four contexts. In three of the four contexts, variability was thus still greater than that of the normal speakers. If greater than normal variability was present in three of the four contexts, this was not indicated in the summary table for this sub-aim (see Table 5.43), since it was only indicated if greater variability than the normal group occurred across *all four contexts,* for the sake of condensing the data in a sensible manner in order to highlight trends.

Seddoh *et al*. (1996b) also found that differences in variability between their AOS and control subjects were less evident on measures of VOT for certain words. Seddoh *et al*. (1996a) also reported variability regarding VOT and second formant transition duration in AOS subjects, which was comparable to that of normal speakers. Subjects with AOS were also less variable than normal controls regarding VOT, in a study by Van der Merwe (1986). The result of displaying greater variability than normal speakers on most, but not all parameters and utterance groups, could indicate that some temporal parameters are “easier” to control than others. All temporal parameters are thus not equally susceptible to disruption under circumstances of increased processing demands. In this regard, Seddoh *et al*. (1996b:601) also concluded “some aspects of temporal control may be preserved in AOS despite the motoric impairment”. Van der Merwe (1986) also concluded that temporal control of VOT might be preserved in some subjects despite deviances regarding temporal control of the other measured parameters.

6.4.1.3 Differences regarding variability of different utterance groups

Another aspect influencing variability might be related to the complexity of the utterance. In the present study it does not seem, however, as if there are specific utterance groups where subjects generally exhibited less variability than the normal group regarding the control of a certain temporal parameter compared to another. The only two instances where the majority of experimental subjects did not exhibit greater variability than the normal group across all four contexts, was for VD of the voiceless plosive group and for VOT of the voiced plosive group. Temporal control might thus have been easier in these two instances, although this is only speculative. In the present study, the aim was not to compare the performance of subjects across utterance groups and the data were thus not analyzed with this aim in mind.

Other studies have found trends regarding variability for specific utterances. Production of some speech sounds is presumably motorically more difficult than others, especially in persons with AOS (Dunlop & Marquardt, 1977; Johns & Darley, 1970; Shankweiler & Harris, 1966; Trost & Canter, 1974). Strand and McNeil (1996), for example, in their study regarding the effect of length and linguistic complexity on VD and between-word segment durations, found larger SDs in subjects with AOS for VD of target words containing the diphthong /e✋/, compared to words containing the vowel sound, /✞/. Strand and McNeil (1996:1030) explained this finding by saying "the diphthong requires more complex movement of the lips and tongue in order to arrive at the particular articulatory configuration". Seddoh *et al*. (1996b) reported larger SDs regarding VOT in AOS subjects for the words "pea" and "bee", containing a high front unrounded vowel, than for the words "pop" and "Bob", which contain a low back vowel. Seddoh *et al*. (1996b) argued that articulatory constraints might have arisen from the motoric demands for production of the tense vowel /i/ compared to production of the lax vowel /□/. From the findings of the abovementioned studies, it can thus be concluded that production of some utterance groups might be more difficult and lead to greater variability regarding specific temporal parameters than other utterance groups.

6.4.1.4 Conclusion regarding variability in subjects with AOS and PP

In summary, it is thus evident that subjects with AOS and those with PP generally exhibited greater than normal token-to-token variability. Furthermore, the degree of greater token-to-token variability differed between subjects with AOS or PP. These patterns of greater token-to-token variability do not, however, occur consistently across all parameters and utterance groups and individual subject differences were evident in the present study. The fact that the variability across all four contexts did not consistently occur regarding all the temporal parameters and utterance groups in some subjects with AOS or PP in the present investigation, is possibly characteristic of the nature of the impairment in these subjects and indicative of motoric instability. Due to their impairment, be it phonologic or phonetic-motoric in nature, subjects with AOS or PP are generally inconsistent regarding the "accuracy" of repeated productions in any context.

6.4.2 Variability of subjects with AOS compared to variability of subjects with PP: Quantitative and qualitative differences

Although subjects with AOS or PP both exhibited greater variability than the normal group, differences regarding the degree and pattern of variability were evident between these two groups of speakers. The *degree of variability* in speech production is one aspect which researchers have used to differentiate persons with AOS and CA (Ballard *et al*., 2000). In the present study, when the SDs of the experimental subjects are compared by means of visual inspection of the figures representing the SDs of each experimental subject as a percentage of the SD of the normal group (Figures 5.19 to 5.28), it is evident that the subjects with AOS generally exhibited greater SDs than the subjects with PP, across all four contexts regarding VD and UOD. Regarding UD, the SDs of the voiceless plosive utterance group, were comparable for these two groups of speakers. For UD of the voiced plosive group, the subjects with PP generally had greater SDs than the subjects with AOS across all four contexts. Regarding VOT, the subjects with PP generally had greater SDs than the subjects with AOS across all four contexts.

From the results of the present study, it is thus evident that subjects with AOS generally exhibited greater variability regarding temporal parameters than subjects with PP regarding VD, UOD and UD of the voiceless fricative utterance group. Regarding a *quantitative* difference in token-to-token variability of temporal parameters in person with AOS and CA, Seddoh *et al*. (1996b) found that their subjects with CA and AOS, were differentiated by the degree of variability, even though they could not be clearly differentiated by measures of mean segmental and intersegmental duration. The AOS subjects in the study by Seddoh *et al*. (1996b) exhibited greater token-to-token variability (SDs) as individuals and as a group regarding stop gap duration, VD and consonant-vowel duration compared to the control speakers. Furthermore, the AOS subjects in the study by Seddoh *et al*. (1996b) exhibited greater variability than the CA subjects regarding stop gap duration and consonant-vowel duration, whereas the CA and AOS subjects did not exhibit significant differences regarding variability of VD. Regarding the degree of variability of temporal parameters in AOS and CA, Kent and McNeil (1987) also reported greater variability in performance in their AOS subjects than in their subjects with CA, particularly when speaking rate had to be increased. Kent and McNeil (1987) concluded that although subjects with AOS display greater variability than subjects with CA, some temporal parameters of speech are affected in both these groups of speakers. McNeil *et al*. (1990a) replicated the study by Kent and McNeil (1987) and confirmed greater variability of absolute durations in subjects with AOS compared to CA in both normal and fast speaking rate conditions.

From the abovementioned studies, it thus appears as if the impairment in AOS and PP is *quantitatively* different. Because of the greater variability in subjects with AOS, the nature of the impairment in this group has generally been argued to indicate a motoric deficit (Kent & McNeil, 1987; Seddoh *et al*., 1996b). The fact that the subjects with CA have generally exhibited less variability than subjects with AOS on temporal parameters, has been taken as evidence that a "motoric deficit may be unlikely as the only source of the abnormal timing in this population" (Seddoh *et al*., 1996b:601). A phonological level deficit has consequently been offered as the source of aberrant temporal control in subjects with CA (Kent & McNeil, 1987; Seddoh *et al*., 1996b).

Furthermore, the fact that the pattern which emerges regarding variability of various temporal parameters is different for subjects with either AOS or PP, implies that the underlying impairment in these two groups of speakers is also *qualitatively* different. Contrary to variability on other parameters, the subjects with PP in the present study, generally had greater SDs than the subjects with AOS regarding UD of the voiced plosive utterance group. This latter result is in agreement with the results from other studies which have indicated that subjects with CA exhibited greater variability for certain parameters and utterances, than subjects with AOS. In the study by Seddoh *et al*. (1996b) for instance, the subjects with CA had the largest SDs regarding VD for the word "pop", whereas the AOS subjects generally exhibited larger SDs than the control and CA subjects regarding most other utterances and parameters. Although the AOS subjects in the study by Seddoh *et al*. (1996b) generally had larger SDs than the normal controls regarding all measured parameters, the CA subjects had significantly greater variability than the control speakers, only regarding consonant-vowel duration. From these results, Seddoh *et al*. (1996b:599) concluded "the patterns of temporal dissolution exhibited by the two groups of subjects take different shapes, both qualitatively and quantitatively". Furthermore Seddoh *et al*. (1996b:599) concluded that "If the underlying source of the deficit is the same for both groups, then it would be difficult to account for why they do not exhibit approximately similar patterns of output in their performances".

6.4.3 The influence of speech production in L1 versus L2 on variability

The results of the individual subjects in the normal group, as well as the normal group results, indicate that these subjects generally exhibited the largest percentage of utterances with the greatest variability in either L2NR or L2FR. However, regarding VOT of the voiced and voiceless plosive utterance groups, very few normal subjects exhibited the abovementioned behavior. More specifically, for VOT of the voiceless plosive utterance group, only N1 and N2 exhibited the largest percentage of utterances with the greatest SD in an L2 context, namely, L2NR. Regarding VOT of the voiced plosive group, only N5 exhibited the largest percentage of utterances with the greatest SD in an L2 context, namely, L2FR. It was expected, however, that speech production in L2 in the present investigation would not necessarily cause increased variability in the normal group. The reason for this is that the target stimuli were phonemically and consequently phonetically similar. Furthermore, the carrier phrases in which these utterances were embedded were very simple regarding grammatical structure in both languages. From the results of the study it seems, however, that speech production in L2 led to greater variability in normal speakers.

The fact that the normal group generally exhibited the most utterances with the greatest variability in either L2NR or L2FR indicates that the L2 context generally led to greater variability and resulted in the temporal parameters being less precise during repeated production of a specific utterance. This decrease in precision of repeated productions could be due to the fact that the L2 context possibly posed greater processing demands to the speech production mechanism, leading to instability regarding temporal control. The greater processing load is presumably due to the fact that speech production in L2 is not as automatized and over-learnt as speech production in L1. Consequently repeated production of a target word in L2, might be less consistent than in L1.

Another explanation for the increased variability which was exhibited by the normal group in the L2 contexts could be the fact that motor planning in L2 is presumably not as automatized as in L1 since it is not spoken as often as L1. The operations involved in motor planning of L2 utterances, for example, recall of motor plans, sequential organization of movements, coarticulation, adaptation of the core motor plan in terms of the spatial and temporal parameters for production of the specific target word, are consequently not as automatized as in L1. Maner *et al*. (2000) state that trial-to-trial variability should decrease as a person becomes highly skilled in a motor task. Since L2 has not been "practiced" as often as L1, L2 speakers are consequently not as skilled in its production. Consequently, the spatial and temporal parameters during L2 production will differ more from one production to the next, compared to L1 which is automatized owing to the fact that it the person's L1 or mother tongue. Although the normal speakers are able to adjust to the increased processing demands and produce perceptually accurate speech, evidence of the increased demands or processing load, and/or the less automatized nature of L2, is visible in the greater variability which is displayed in this context. The greater variability in normal speakers does thus not necessarily reflect instability in these subjects when producing speech in L2, but might be indicative of the less automatized nature of speech production in L2.

From the data of the normal speakers, it is evident that the L1NR and L1FR context occasionally exhibited the same percentage of utterances with the greatest SD as the L2NR or L2FR context. The latter finding is surprising, since one would expect the L1 context to be more automatized than L2 and consequently more consistent production during repeated production of an utterance should presumably occur. However, this phenomenon only occurred twice at the most for a specific normal speaker across all parameters and utterances groups. This finding might be indicative of the fact that even within normal speech production, a certain degree of variability is to be expected. Any phenomenon in speech production will thus be variable to a certain extent. Compared to the experimental subjects, the normal subjects were still generally less variable regarding the measured temporal parameters.

An interesting finding in the present study is the individual patterns which emerged for the experimental subjects, regarding the context in which the greatest variability generally occurred. In this regard, the results of the subjects with AOS will be discussed firstly, whereafter the results for the subjects with PP will be discussed. AOS1, who had the most severe AOS as judged perceptually, performed similar to the normal group regarding exhibiting the greatest variability in either the L2NR or L2FR context. Subjects AOS2 and AOS3 each had only three and four instances respectively, where the greatest variability was displayed in either the L2NR or L2FR context. The specific parameters and utterance groups for which the greatest variability occurred, also differed between these two speakers. With the exception of AOS1, speech production in L2 does therefore not seem to have increased variability in the subjects with AOS.

The reason that two of the three subjects with AOS do not seem to have been influenced by the L2 context regarding their variability, could be due to the following reasons. As is evident from the data, the subjects with AOS were generally more variable than the normal group across all four contexts, except for VOT of the voiced plosive utterance group. As discussed, the greater variability in these subjects presumably indicates less stability regarding temporal control. When the processing demands were increased with an increase in rate and speaking in L2, the influence of the L2 context might have led these subjects to apply more controlled or conscious processing, since L2 is also not as automatized as speaking in L1. This controlled processing might have led these subjects to produce slower speech, resulting in the longer durations as was evident from the results for sub-aim two. Because these subjects were speaking more slowly they might have been more precise regarding repeated production.

Although the variability of temporal parameters of speech production in normal speakers has been found to increase when speaking at a slower than normal rate (Crystal & House, 1988), this might not necessarily be the case for speakers with neurogenic speech disorders, since slow speech rate is characteristic of speech production in AOS, for example (McNeil *et al*., 1997). The slow rate exhibited by subjects with AOS might be a compensatory strategy employed due to the complexity of production of a particular utterance (Van der Merwe, 1997). Even normal speakers use the slowing of speaking rate as a compensatory strategy to increase accuracy and presumably ease of production in novel speaking contexts or when a complex utterance has to be produced (Van der Merwe, 1997). For normal speakers, it is more "unnatural", however, to reduce their speaking rate and apply controlled processing in "normal" speaking contexts.

The fact that subject, AOS1 performed differently from the other subjects with AOS could be because although AOS1 might also have attempted to apply more conscious processing, the severity of the motor impairment in this subject might have not allowed for successful execution of conscious processing under circumstances of increased processing demands. For this reason, the L2 context appears to have led to greater variability in this subject. The increase in variability in this subject presumably reflects greater instability of the speech mechanism under increased demands and/or unsuccessful application of controlled processing.

From the above discussion, the question arises as to why the normal speakers did not employ more conscious processing to result in less variable production in L2 than in L1, if the AOS subjects were able to employ such a strategy. The reason for this might be that the greater variability displayed by the normal speakers possibly indicates greater flexibility in compensating for the increased processing demands. Another reason might be that L2 was not necessarily perceived as a more difficult context requiring controlled processing by the normal subjects and that the increased variability was merely the result of the less automatized nature of speech production in L2, as discussed. The reason for the greater variability of the normal group in L2, is thus presumably due to a different reason than the increased variability in AOS1. Despite the greater variability exhibited by the normal group in the L2 context, their durations were still substantially shorter than those of the subjects with AOS with the implication that they adapted to the L2 context with greater flexibility and not by slowing down their speed of production.

When viewing the results of the subjects with PP, it is evident that in these subjects, the L2 context also did not generally lead to greater variability compared to speech production in L1. Furthermore, there was not a consistent pattern amongst the subjects with PP regarding the utterance groups and temporal parameters in which they exhibited the greatest SDs in L2. As is the case with subjects AOS2 and AOS3, the L2 context seems to have had a lesser influence on variability in the subjects with PP than in the normal group. The fact that the mean durations of the subjects with PP were generally longer than those of the comparison also possibly implies, as with the subjects with AOS, that these subjects successfully applied more conscious processing or control in the L2 context. The result of this controlled processing possibly led to their absolute durations increasing and deviating more from the normal group in the context imposing the greatest processing demands, namely, L2FR. The latter was evident in PP2 and PP3.

Even though the durations of PP2 and PP3 generally deviated more from the normal group in the L2FR than in the other contexts, their variability in this context was not generally the largest. The latter is possibly due to the fact that they were more "consistent" regarding their deviant production or when applying controlled processing resulting in slower speech and longer durations. On the other hand, this latter result could also indicate that a trade-off exists, namely, that subjects choose to decrease rate and consequently increase duration under increased processing demands in an attempt to be more consistent in production. Subject PP1 reacted similar to the other subjects with PP regarding the limited influence of L2 on variability, but did not generally display the greatest difference from the normal group in the L2FR context though. This indicates a qualitative difference between the speech of this subject and the other two subjects with PP. As mentioned, previously, subject PP1 obtained the highest aphasia quotient on the WAB (Kertesz, 1982) and consequently exhibited the mildest aphasia of the subjects with PP in this study. The severity of the impairment can thus possibly influence performance under increased processing demands.

Although no studies have examined the effect of the L2 context on temporal parameters of speech production as such, results from related studies can be drawn upon to make conclusions regarding the results obtained in the present investigation. The fact that the L2 context appears to have had an influence on the variability in normal speakers supports the conclusion drawn by Maner *et al*. (2000) that an interaction exists between language processes and speech motor performance. These researchers used a measure called the spatio-temporal index (STI) which reflects the contributions of spatial and temporal variations (Maner *et al*., 2000). This measure has been found useful in determination of stability of performance in the absence of overt speech errors (Smith & Goffman, 1998). Specifically, these researchers examined the effect of length and linguistic complexity on the STI, with higher STI values indicating greater variability. Maner *et al*. (2000) found that longer and linguistically more complex utterances led to greater variability in both adults and children. This study thus supports the finding that higher level processing demands can influence motor control processes. In the present study the higher level processing demands are related to speech production in L2.

6.4.4 The influence of speech production in L1 versus L2 on variability of the different temporal parameters

The fact that the normal speakers did not exhibit a trend of the largest percentage of utterances exhibiting the greatest SD in either L2NR or L2FR regarding VOT, especially in the voiced plosive utterance group, could indicate that this temporal parameter is not as easily influenced by increased processing demands as the other measured temporal parameters. Van der Merwe (1986) also reported that VOT was not influenced by sound structure or articulatory characteristics as the other temporal parameters measured in her study. Furthermore, the fact that VOT is a temporal feature of plosives in both L1 and L2 and the fact that the specific plosives are used frequently in both languages might result in this temporal parameter not being as susceptible to the influence of the language context as such.

6.5 GENERAL DISCUSSION

The general discussion will entail a discussion of the main theoretical issues which emerged from the results of the study, where after a schematic presentation of the influence of contextual factors on speech and language processing will be presented as a theoretical framework for explanation of speech production under circumstances of increased processing demands. The main theoretical issues which emerged pertain to the following: The importance of contextual factors in the study of normal and disordered speech production, speech rate as a context for speech production, L1 versus L2 as a context for speech production and the nature of the impairment in persons with either AOS or PP. Since this is a general discussion, it is important to mention that only the main trends which emerged from the results will be incorporated and highlighted. It is important to bear in mind, however, that these trends did not occur consistently in all subjects, regarding all parameters and utterance groups.

6.5.1 The importance of studying the effect of contextual factors on speech production

The results of the present study indicate that language can be viewed as a contextual factor which influences the complexity of speech production. It appears as if the effect of the increased processing demands imposed by speaking in L2, is manifested in the duration of temporal parameters of speech production in some persons with speech and/or language disorders. The cognitive processing involved in speech production in L2, thus appears to impact on the motor output level, in persons with compromised speech production systems, resulting in less successful implementation of more complex control strategies. However, individual differences appear to be present regarding the impact of these increased processing demands on various temporal parameters and utterance groups.

The results indicating that higher level processing impacts on speech motor performance are consistent with Van der Merwe's (1997:6) view that certain contextual factors require greater skill to perform and that "contextual factors affect the dynamics of motor control". Regarding the influence of contextual factors, Van der Merwe (1997) refers to the coalition of neural structures involved in the various stages of speech production which are influenced by increased processing demands. In other words, Van der Merwe (1997) relates the influence of context to the neurophysiological level of speech production. However, this researcher also states that these contexts can impact on the motor parameters of speech production. Van der Merwe (1997) emphasizes the importance of studying the influence of these various contextual influences on speech production, since certain apraxic symptoms have been found to vary depending on a given context (Kent & Rosenbek, 1983; Van der Merwe *et al*., 1987, 1988, 1989). Van der Merwe (1997) underscores the importance of studying contextual factors by saying "Variation in contextual factors, however, will influence both treatment and research results" (Van der Merwe, 1997:6).

Van der Merwe (1997) states that production of an utterance is adapted, if the context in which it is to be produced is found to be too complex. Van der Merwe (1997) poses an internal feedback loop which is responsible for monitoring and adapting the utterance if complexity is found to be too high. According to Van der Merwe (1997) this adaptation results in compensatory strategies being implemented by persons with sensorimotor speech disorders, for example, production of syllabic speech, phonological changes, such as shortening a word or slowed speech rate (Kent & Rosenbek, 1983; Van der Merwe & Grimbeek, 1990; Van der Merwe *et al*., 1987, 1988, 1989; Wertz *et al*., 1984). In effect the context of production is thus adapted. Van der Merwe (1997) further states that even normal speakers might employ such strategies under circumstances of increased processing demands, for example, when producing an unfamiliar and long word. In the latter instance a normal speaker might consciously slow speaking rate in an attempt to concentrate on production more carefully. In such a situation more controlled processing is exerted, which in turn utilizes more processing resources (Kent, 1990; Levelt, 1989). The study of the influence of various contextual factors which might lead to breakdown in different speech and language disorders will influence research results and is also imperative for compilation of assessment and treatment programs.

6.5.1.1 Speaking rate as a context for speech production

The results of sub-aim one pertain to the effect of speech rate on temporal control. From the results of the study, it is evident that the speakers with AOS and those with PP attempted to decrease duration in the FR, but were not consistently successful in doing so. Thus, although these speakers achieve perceptually accurate speech production, the motor goal of decreasing duration was often not obtained. As discussed, difficulty with rate adjustments points to a motoric inflexibility in these speakers. Speaking rate can thus be viewed as a context for speech production which increases the complexity of production.

An increase in rate implies an increase in motor complexity (Van der Merwe, 2002). As learning occurs, a motor act can be performed at a higher rate (Jaric, Corcos, Argarwal & Gottlieb, 1993), implying that skill is needed for faster performance. Speaking at a faster than normal rate will presumably increase the processing demands on both a linguistic (Fossett *et al*., 2001) and motor level (Kent & McNeil, 1987; Van der Merwe, 1997, 2002). Operations involved in linguistic-symbolic planning, for example, phoneme selection and sequencing will need to occur more rapidly. On a motor level, operations involved in motor planning, for example, recall of motor plans, sequential organization of movements and coarticulation will need to occur more rapidly (Van der Merwe, 2002). Increased rate has consequently been proposed as a contextual factor which increases the complexity of the motor task, in this case speech production (Van der Merwe, 2002). Van der Merwe (1997:6) underscores the fact that “Certain variants of a specific contextual factor may require more complex control strategies than others”. Persons with motor deficits will thus presumably be more susceptible to breakdown in contexts where speaking rate has to be increased, since they might not be able to apply these complex control strategies under circumstances of increased processing demand due to difficulty at one or more levels of the speech production process.

Because persons with AOS are believed to have difficulty regarding the motor planning of speech, entailing difficulty with, for example, the construction of the core motor plan, recall thereof, sequential organization of movements, control of IAS and adaptation of temporal and spatial features to the phonetic environment (Van der Merwe, 1997, 2002), speech production is problematic even whilst speaking at a self-selected rate. Persons with PP who have difficulty with the linguistic-symbolic stage of speech production (Van der Merwe, 1997), and possibly an accompanying motor planning deficit (Kent & McNeil, 1987), will under "normal" speaking conditions, exhibit difficulty with the operations involved in linguistic-symbolic planning, for example, phoneme selection and sequencing. Because of these respective presumed difficulties, more than normal resources are already required to perform processing operations involved in the various stages of speech sensorimotor control in order to obtain perceptually accurate speech. When the processing demands are increased with an increase in speaking rate, the operations involved in the various speech production stages need to occur at a faster than usual rate. In this regard Van der Merwe (2002) states that the difficulty regarding the motor planning of speech exhibited by persons with AOS will be intensified by an increase in contextual demands. Consequently the resources of these subjects might be more easily exceeded when having to speak at a faster rate, than when speaking at a self-selected rate. Speaking at a faster rate will thus cause subjects with difficulty at any level of the speech production process, to be more susceptible to the erroneous production or deviation from normal speakers. Since greater skill is required for speaking at a faster than normal rate, difficulty at any level of the speech production process, will cause persons with difficulty regarding speech and/or language processing to be more susceptible to breakdown.

Another explanation for the difficulties experienced by persons with AOS and those with PP when speaking rate has to be increased, could be due to a compensatory strategy employed by these subjects under any circumstances which increases processing demands. For example, when having to increase speaking rate, persons with either AOS or PP might, as a result of the increased processing demands, automatically slow down their speech rate (resulting in increased durations) and apply more conscious processing as a compensatory strategy to achieve perceptually accurate speech. A trade-off thus results between the achievement of the motor goal (increasing rate) and achievement of perceptually accurate speech. One possible explanation for this trade-off could be that the resources of these subjects are more easily exceeded leading to susceptibility to breakdown regarding speech production, since motor and/or linguistic processing demands already take up more of the available resources than normal. If the goal of increasing rate is achieved, phonemic integrity might be compromised (McNeil *et al.*, 1997). On the other hand, if perceptually accurate speech is achieved, the motor goal of increasing rate might not be realized.

6.5.1.2 Speech production in L2 as a context for speech production

The aim of the present study was to determine if speech production in L2 posed additional demands to the speech production mechanism which would be manifested in the temporal parameters of speech production in normal speakers and persons with either AOS or PP. In summary, the results of the present investigation indicated that speech production in L2 poses additional processing demands to the speech production mechanisms of speakers with AOS or PP. In the experimental subjects, the influence of L2 was manifested in the acoustic speech signal as a greater extent of durational adjustment in FR speech production occurring in L1 compared to L2, as well as difficulty with durational adjustments (decreasing duration in the FR) occurring more frequently in L2 than L1. Furthermore, durational differences between individual experimental subjects and the normal group were more pronounced in L2 when speaking at a faster than normal rate. In normal speakers, L2 appears to impact on the temporal parameters of speech production regarding the degree of variability exhibited by these speakers in the L2 context, although this was not evident in the experimental subjects. The normal speakers did not show the same trend of experiencing difficulty with achievement of durational adjustments and with accomplishing a greater extent of durational adjustment in L1 compared to L2. The normal group was thus flexible in the contexts which imposed increased processing demands.

The reason for L2 being viewed as a contextual factor imposing greater processing demands can be twofold. Firstly, L2 as a contextual factor can be related to the concept of automaticity. A task becomes "automatic" with practice (Magill, 2001;

Schmidt, 1988). Once it reaches the level of automaticity, little conscious control needs to be exerted for execution thereof (Kent, 1990). Speech production in a person's L2 is not produced with the same degree of automaticity as L1 due to the fact that it has not been "practised" as often as L1. Consequently more conscious processing on a linguistic and motor level is required for its production, resulting in increased processing demands being imposed on the speech production mechanism by L2. The level of automaticity which L2 reaches will depend on the level of bilingualism of a particular subject. If L2 was acquired early on in life a greater level of automaticity will presumably be reached. The level of bilingualism of the subjects in the present investigation was the same, in that English (L2) had been introduced as a second language in primary school.

Secondly, and related to the concept of automaticity, is the fact that L2 can be seen as a novel and fairly unfamiliar speaking context. Utterances in L1 are presumably more familiar and consequently easier to produce (Van der Merwe, 2002). More novel utterances, such as words in L2, are less familiar and consequently increase linguistic and motor processing demands. The novelty and less automatized nature of speech production in L2 thus contribute to the complexity of the utterance, requiring more complex control strategies for successful execution.

The fact that subjects with AOS presumably have difficulty regarding the motor planning of speech might cause these speakers to be less successful with the operations involved in motor planning when the processing demands are increased by a novel and less automatized utterance. Similarly, persons with PP, who have difficulty regarding linguistic-symbolic planning, might find the operations involved in this stage of speech production more difficult when the processing demands are increased by speech production in L2. Regarding the motor planning of speech, recall and adaptation of motor plans for L2 might be less automatized and consequently L2 contributes to the complexity of the utterance. Similarly, regarding linguistic-symbolic planning, selection and sequencing of phonemes in L2 might be less automatized and contribute to greater complexity of the utterance. The greater complexity of the utterance in turn leads to more conscious processing being required resulting in a need for greater resources. Persons with AOS or PP, in reaching the limits of their capacity, might thus not have sufficient resources for executing a more complex task (speech production in L2) as successfully as a more automatized task (speech production in L1).

Speech production in L2, which in the context of the present study can be seen as a linguistic factor since the motor aspects of the task in both languages were equal, consequently impacted on the motor control level of performance in subject with AOS and subjects with PP. The deficits regarding higher level processes (linguistic-symbolic and/or motor planning and programming) were thus manifested on the execution level in the temporal parameters of speech production in both persons with AOS and persons with PP. It thus seems as if speaking in L2 is a context posing additional demands when combined with speaking in a faster than habitual rate. Consequently more complex control strategies need to be employed (Van der Merwe, 1997). Most of the subjects with AOS or PP in the present study seem incapable of exerting this additional control consistently in a successful manner when speaking in L2.

In normal speakers, speaking in L2 should presumably not be problematic under ideal circumstances (producing simple phrases with words which are phonemically and phonetically similar), since the normal speech motor system is flexible in adjusting to increased demands. Furthermore, the operations involved in the various stages of the speech production process do not require more than normal resources, as in persons with neurogenic involvement, since difficulty with speech and language processing is not present in normal speakers. Normal speakers thus exhibit greater flexibility in dealing with increased demands, whereas persons with neurogenic involvement have difficulty executing the operations involved in one or more stages of the speech production process even under normal circumstances. Increased processing demands as imposed by L2, for example, thus contribute to the complexity of production, making them more susceptible to breakdown.

The finding that L2 influences the temporal parameters of speech production is consistent with the conclusions drawn by of other researchers examining the effect of linguistic variables on speech production. These researchers concluded that increased processing demands at a “higher level” of the speech production process, influence “lower level” processes and consequently the motor output stage of speech production

(Abbedutto, 1985; Maner *et al*., 2000; Strand & McNeil, 1996). Maner *et al*. (2000:569) posed that the greater variability exhibited by the subjects in their study when producing more complex sentences "reflects the fact that the neural networks that generate the motor commands to the muscles have less stable patterns of activity when processing demands are higher" Maner *et al*. (2000:567) further said that "This decrease in the stability or consistency of the pattern generation circuitry for speech production could be the result of its interaction with cognitive, linguistic, and premotor networks operating in parallel".

Regarding the effect of linguistic variables on the temporal parameters of speech, Strand and McNeil (1996:103) stated "It may be reasonable to assume that different levels or processes of the speech production mechanism either interact in a direct way or share common underlying processing resources that could generate or contribute to errors". In this view, the influence of L2 on the temporal parameters of speech production can be explained due to the simultaneous demands of L2 language formulation and motor control processes on processing resources. When the processing demands are increased with an increase in speaking rate and speaking in L2, both motor and linguistic levels of speech production compete for processing resources. The latter results in one or both of these levels being more susceptible to breakdown, depending on the nature of the disordered process/(es).

From the results of their study investigating the effect of length and linguistic complexity on temporal parameters of speech production, Strand and McNeil (1996:1018) concluded that "different mechanisms for executing motor programs for varying linguistic stimuli" might exist. In the same sense different mechanisms might exist for executing motor programs for different languages. Van der Merwe and Tesner (2000) have postulated the possibility of differential processing patterns in the brain during production of L1 and L2. Klein *et al*. (1995) reported activation of the left putamen during a speech repetition task in L2, which was not evident during the repetition of words in L1. The latter finding led Klein *et al*. (1995:31) to propose that "activation of the left putamen is a function of the increased articulatory demands imposed by speaking a language learned later in life". Speech production in L2 thus appears to impose demands regarding the motor planning and/or programming of speech. Consequently L2 could increase utterance complexity compared to speech production in L1.

In summary, it can thus be concluded that increased processing demands at a "higher level" of the speech production process, influence "lower level" processes and consequently the motor output stage of speech production. The result of the increased processing demands imposed by speech production in L2 appear to be visible in the temporal parameters of speech production as measured in the acoustic speech signal in persons with AOS or PP in the present study.

6.5.2 The nature of the impairment in AOS and PP

The fact that persons with AOS and those with PP demonstrated longer than normal durations with regard to the measured temporal parameters when speaking in the FR and in L2, indicate that both these groups of speakers exhibit deficits regarding temporal control when processing demands are increased. It is difficult to ascribe the level of deficit to a single level of the speech production process, since deficits at one level might influence the levels below it. As discussed, Kent and McNeil (1987) stated that difficulty at the level of phoneme selection might also be reflected in the temporal parameters of speech production. The subjects with PP might thus have increased duration due to difficulty with linguistic-symbolic planning, whereas the person with AOS might have increased duration due to difficulty with motor planning and/or programming of speech. Increased durations might also be a compensatory strategy which is applied by both these groups of speakers when the processing demands are increased. The nature of the deficit in AOS and PP is thus not necessarily similar.

Although the experimental subjects in the present study were not more variable in L2 compared to L1, they were generally more variable than the normal group across all contexts. The subjects with AOS, in turn were generally more variable than the subjects with PP. The result of the experimental subjects generally exhibiting greater variability than the normal group across all contexts, suggests a possible motor deficit underlying the nature of AOS and PP. The speech motor systems of these speakers are thus more unstable regardless of the context.

Maner *et al*. (2000) state that a person who is highly skilled with regard to a motor task will exhibit low performance variability from trial to trial. In this regard, it has been found that children, for example, are more variable and exhibit less stability than adults regarding execution of movement patterns for repeated productions of an utterance (Goffman & Smith, 1999; Smith & Goffman, 1998). In the same sense, it appears that the experimental subjects are less skilled than the normal group in the present study and exhibit greater instability of the motor speech system, resulting in more variable durations. Difficulty with automaticity might also be present in subjects exhibiting greater variability in that repeated planning and/or feedforward of the adapted core motor plan might be affected. The speaker thus needs to consciously monitor his/her speech and in certain instances production and feedforward occur more easily than in others, without any particular reason (Van der Merwe, 1986).

The fact that the subjects with AOS generally exhibited greater variability than subjects with PP and the fact that the patterns of variability for different parameters and utterances differ between subjects with AOS and those with PP, suggest that the nature of the impairment in these two groups of speakers is not the same. Furthermore, the durations of the subjects with AOS were generally longer than those of the subjects with PP. The motor impairment in AOS thus appears to be more severe than in PP. Similarly to the conclusion drawn by Seddoh *et al*. (1996b), it is postulated that the greater variability in the subject with AOS indicates impairment at the level of motor planning and/or programming, whereas the deficit in the subjects with PP, cannot be solely attributed to impairment at this level of the speech production process. Although a motor component might thus be part of the pathogenesis of persons with PP, it does not appear to be the sole contributing factor to their communication deficit.

6.5.3 Individual trends amongst subjects regarding the effect of L2 on the temporal parameters of speech production

From the results of the study, it is evident that individual trends occasionally emerged regarding the influence of L2 on the temporal parameters of speech production. For example, the finding that PP1 does not appear to have been influenced by the L2 context in that durational differences between this subject and the normal group were not more pronounced in L2FR, might indicate that this subject had the most stable speech production system. Another explanation might be that this subject is able to adjust to increased processing demands more successfully. PP1 obtained the highest aphasia quotient on the WAB compared to the other subjects with PP and consequently this subject had the mildest aphasia. PP1 might also be more fluent in L2 due to possibly having had more exposure to speaking in L2 later in life, compared to the other subjects with PP. The fact that PP1 did not appear to be influenced by the increased processing demands of L2, could also be indicative of the fact that persons with neurogenic speech involvement might have different ways of compensating for their deficits when the processing demands are increased (Seddoh *et al*., 1996a).

Regarding variability of speech performance, Maner *et al*. (2000) found increased variability for production of a phrase embedded in a complex sentence compared to the baseline condition, for only four of their eight normal adult subjects. From this result, Maner *et al*. (2000:572) concluded that normal adult speakers, might be "heterogeneous in the effects of length/complexity on motor execution" compared to children who were affected more homogeneously. In the same sense some speakers with neurogenic involvement might also be affected heterogeneously or react differently to an increase in processing demands. Some speakers might adapt their temporal parameters, whilst others might choose to adapt spatial parameters of speech production. These adaptations will need to be within the limits of equivalence, however, to prevent distortion in production. Measurement of spatial parameters was not undertaken in the present study, although investigation of this aspect might reveal difficulty in this regard as well.

The finding of individual patterns emerging for some of the subjects (AOS2 and AOS3) regarding the parameters and utterance groups where they exhibited the greatest difference from the normal group in L2FR, might also indicate that temporal control of some temporal parameters might be more difficult than others for a specific speaker. A specific subject might thus find temporal control of a specific parameter more difficult for only a specific utterance or utterance group. Different contexts of speech production could also influence subjects with a specific speech disorder differently.

The finding of intersubject differences in persons with AOS and PP, is in agreement with the results of Clark and Robin (1998) who examined three aspects of motor programming, namely, generalized motor program accuracy, temporal parameterization accuracy and amplitude parameterization accuracy in subjects with AOS, CA and normal speakers using a non-speech motor task. These researchers reported inter-subject variability amongst their subjects with AOS regarding deficits in parameterization and GMP accuracy respectively, although a clear pattern did not emerge for their subjects with CA. Clark and Robin (1998) concluded that persons with AOS might exhibit performance trade-offs, since the AOS subjects exhibited either reduced GMP or parameterization inaccuracy, but not both. Furthermore, the pattern of this deviation differed for the various subjects with AOS in their study.

Clark and Robin (1998:709) concluded that these trade-offs might be explained by the fact that "subjects may only have enough processing resources correctly to programme either the GMP or the parameters, but not both". These researchers proposed that one possible explanation for the different performance patterns in subjects with AOS is that the different patterns might reflect different resource allocation strategies used by their AOS subjects and that when the limit of their capacity is reached, they are forced to choose some aspects of motor programming to which they would attend, since attention cannot be given to all the programming processes (Clark & Robin, 1998). One subject with CA in the study by Clark and Robin (1998) also performed differently from the other three CA subjects by exhibiting reduced amplitude parameterization accuracy in two of the conditions which were employed in their study. Intersubject differences were also reported by Seddoh *et al*. (1996a) regarding variability of speech production in subjects with

AOS, in that one of their five subjects with AOS exhibited a relatively normal range for duration of all measured variables.

The fact that different subjects with the same speech disorder can react differently to contextual factors, underscore the importance of studying the behavior of individual subjects in a group. Grouping subjects with different levels of severity regarding a specific speech disorders might provide unreliable results. If a particular subject's results differ substantially from those of other members in the group, the group results might reflect one particular subject's performance, especially when the number of persons in the group is very small. For this reason it is more reliable to describe the performance of individual subjects within a small group.

6.5.4 Differences regarding temporal control of different parameters

From the discussion of the results of the study, it is evident that VOT did not seem to be affected as consistently by speech production in L2 as the other temporal parameters which were measured. Durations of VOT for some experimental subjects were often shorter and less variable than those of the normal group. Furthermore, VOT for voiced plosives did not seem to be influenced by L2 regarding variability in the normal subjects to the same extent as the other temporal parameters. It can thus be concluded that VOT is less susceptible to the influence of language and furthermore that this aspect of speech timing might be preserved in some of the subjects with AOS or PP in the present study. Van der Merwe (1986) also found that VOT in her subjects with AOS was not influenced by the contextual factors which she studied, namely, sound structure and articulatory characteristics of an utterance. Furthermore ranges for VOT were often smaller in her subjects with AOS than in normal speakers.

Smaller and less variable VOTs in some subjects with either AOS or PP might reflect that IAS as measured by VOT might be more consciously controlled by some subjects with a deficit at one or more of the stages of the speech production process in an attempt to keep production within the boundaries of equivalence (Van der Merwe, 1986). Regarding VD and UD, the subjects with AOS in the study by Van der Merwe

(1986) were more variable than normal speakers compared VOT results, implying that normal speakers exert better control over VD and UD than subjects with AOS and can consequently maintain this control over repeated production of an utterance. In the present study VD, UD and UOD were more influenced by the L2 context and variability and duration of these parameters differed more between the experimental and normal subjects with the implication that temporal control of these parameters is more problematic in the subjects with AOS or PP in the present study than control of VOT.

6.5.5 Schematic presentation of the influence of contextual factors on speech and language processing

In summary, the results of the present investigation will be presented and related to Figure 6.1. In Figure 6.1 the possible reactions of normal and disordered speech mechanisms to increased processing demands, imposed by an increase in speaking rate and speech production in L2, are depicted with reference to the four-level framework of speech sensorimotor control proposed by Van der Merwe (1997). Since the framework proposed by Van der Merwe (1997) incorporates principles of motor control, includes language formulation processes and also makes reference to the influence of various contextual factors on the control strategies employed by the brain in normal and disordered speakers, it is particularly useful in elucidation of the findings of the present study related to normal speakers and persons with either AOS or PP.

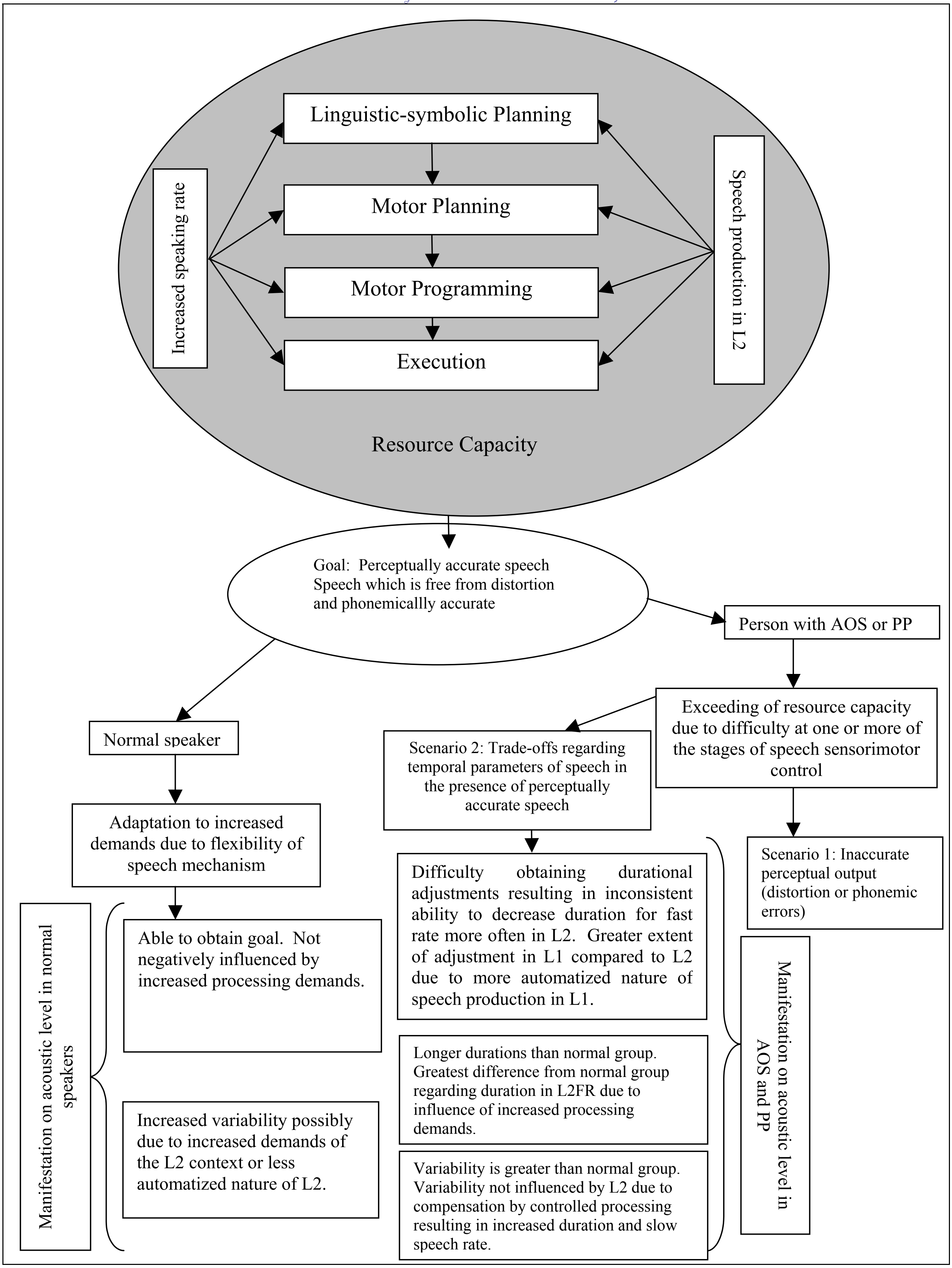

Figure 6.1 Schematic presentation of the acoustic manifestation of increased processing demands imposed by an increased speaking rate and speech production in L2 in normal speakers and persons with either AOS or PP.

In Figure 6.1, the four stages in the speech production process as proposed by Van der Merwe (1997) are displayed as occurring within the context of a person's specific resource capacity. In other words, a limit exists regarding the extent to which the speech and language processing system can be "loaded" before resulting in perceptually inaccurate speech or speech which deviates from that of normal speakers. Depending on the extent of the difficulty experienced with one or more of the four stages of speech production, the resources of persons with either AOS or PP might be more easily exceeded due to speech and language processing already taking up more of the available resources than normal. In other words, depending on the level of breakdown, a certain contextual factor might be more difficult for a specific speaker and cause deviance from normal speakers more readily.

From Figure 6.1, it is evident that the goal of the speaker is to obtain perceptually accurate speech within the context of the available processing resources, despite difficulty with one or more of the stages involved in speech and language processing. Perceptually accurate speech entails that a specific sound or word is perceived as the intended sound or word. The latter implies that the correct phonemes were selected and correctly sequenced and that the production was free from distortion. In order to prevent distortion, all the parameters which are specified and adapted during the motor planning of speech production need to stay within the boundaries of equivalence (Van der Merwe, 1997).

It is further proposed in Figure 6.1 that the contextual influences of the present study (increased speaking rate and speaking in L2) can impact on all levels of the speech production process to varying degrees, requiring adjustment in control strategies which are employed by the brain (Van der Merwe, 1997). Only L2 and fast rate production are indicated in Figure 6.1, but these two contextual factors can be substituted by any context which increases the processing demands to the speech production system. It cannot be said with certainty to which extent a certain factor will impact on a specific level of the speech production process, although it would be expected that increased demands would lead to susceptibility to breakdown at the level where the deficit exists, since the operations in this stage of the speech production process are already problematic. When the processing demands are increased, a person with a deficit at the level of linguistic-symbolic planning will, for example, presumably exhibit errors of phoneme substitution and sequencing. A person with difficulty regarding the motor planning of speech will, for example, presumably exhibit errors regarding the temporal and spatial parameters of speech production, since these parameters are specified and adapted during speech motor planning.

In normal speakers, the increased demands of the speaking context are presumably met with increased flexibility due to normal speech and language processing skills in these speakers. In persons with AOS or PP the resource capacity can, however, presumably be exceeded more easily when the processing demands of a particular speaking context are too high, due to difficulty with one or more of the stages involved in speech production. One of two scenarios presumably results when the processing demands are too high in speakers with neurogenic involvement, although similar behavior might occur in normal speakers if the processing demands of the context become too high and result in breakdown, in other words, when the processing demands exceed the capabilities of a person.

In the first scenario, the target of perceptually accurate speech cannot be achieved. If perceptually accurate speech is not achieved due to a motor planning problem, the specified spatial and temporal parameters might exceed the boundaries of equivalence and distortion of speech sounds will presumably result. If perceptually accurate speech cannot be achieved due to difficulty at the level of linguistic-symbolic planning, phonemic errors might result, for example, errors regarding phoneme selection and sequencing. However, phonemic errors might not necessarily indicate sole difficulty with linguistic-symbolic planning. As mentioned previously, difficulty at a relatively abstract level of speech production might also become visible in the acoustic speech signal as temporal abnormalities (Kent & McNeil, 1987). It is generally accepted, though, that timing deficits reflect difficulty at the level of speech motor control (Ballard *et al*., 2000).

In the second scenario, when the processing demands are too high, trade-offs might occur, which in the present study resulted in temporal and/or spatial parameters deviating from those of normal speakers. In this instance, although the temporal and spatial parameters deviate from those of normal speakers, they still remain within the boundaries of equivalence in order to result in perceptually accurate speech (free from distortion) despite rate of production possibly being slower than normal. Furthermore, it can be accepted that linguistic-symbolic planning of the utterance was successful, since it was perceived as the intended utterance. The achievement of perceptually accurate speech despite deviation of temporal parameters from normal speakers, presumably indicates that persons with speech and language disorders are somehow able to compensate for their difficulty regarding the operations involved in one or more stages of the speech production process in order to obtain perceptually accurate speech.

The reaction of the subjects in the present study to the increased demands imposed by an increase in speaking rate and L2, can be explained according to the scheme depicted in Figure 6.1. For sub-aim one, both speakers with AOS and those with PP attempted to decrease duration in the FR, but were not consistently successful in doing this. Thus, although these speakers achieve perceptually accurate speech production, the motor goal of decreasing duration was not obtained. The fact that this was more prevalent in L2 indicates that this context imposed greater processing demands, leading to breakdown more often than in L1. Furthermore, a greater extent of durational adjustment was generally achieved in L1 compared to L2. The above two findings imply that L2 posed a more difficult context for speech production when the additional demand of increasing rate was imposed. The normal speakers, due to normal abilities regarding speech sensorimotor control, were able to adjust flexibly to the increased demands and obtain the motor goal of shorter duration, as well as perceptually on-target speech.

Regarding sub-aim two, it is evident that the speakers with either AOS or PP generally exhibited longer durations than the normal speakers across all contexts (L1NR, L1FR, L2NR and L2FR). The difference in duration between the individual experimental subjects and the normal group was generally most pronounced in the L2FR context, with the exception of PP1. This result indicates that speech and language processing was more difficult in the L2 context for the majority of experimental subjects. Although the experimental subjects might thus, in some instances, have accomplished appropriate durational adjustments, they were influenced by the increased demands of speaking at a faster than normal rate and by speaking in L2. Consequently these subjects probably compensated by increasing duration in these more demanding contexts in order to obtain perceptually accurate speech. A trade-off thus appears to have occurred, in that shorter duration was traded for perceptually accurate speech, in other words for speech which is free from distortion and which is phonemically accurate. Processing demands related to speaking in L2, thus seem to affect speech motor execution as indicated by the longer durations in the experimental subjects compared to the normal group in the L2 context. According to the framework proposed by Van der Merwe (1997), it thus appears as if the experimental subjects were not successful in applying more complex control strategies when the processing demands were increased in order to achieve all targets in a specific speaking context.

Regarding sub-aim three, it was apparent that the L2 context did not lead to greater variability in the experimental subjects, compared to L1. This might be because the experimental subjects decreased their speech rate to a greater extent in this context as is evident from the fact that their durations generally differed more from those of the normal group in this context. The experimental subjects presumably applied more controlled processing in this context resulting in longer durations, but decreased variability. A trade-off thus once again occurred. The experimental subjects were thus presumably more consistent regarding their erroneous production. All trade-offs displayed by the experimental subjects occurred within the boundaries of equivalence, however, hence the achievement of perceptually accurate speech. The increase of duration in the experimental subjects could be an example of different control strategies which are applied when the processing demands of the context increases, as proposed by Van der Merwe (1997).

In the normal group, speaking in L2 appears to have led to greater variability. As discussed, the greater variability exhibited in L2 by the normal group might be indicative of their attempts to apply compensatory strategies when the processing demands are increased and/or the less automatized nature of speech production in L1 rather than instability regarding speech motor control in this context. The reason for the latter conclusion is that although the experimental subjects in the present study did not display greater variability in the L2 context compared to the other contexts (with the exception of AOS1), they generally exhibited greater variability than the normal group across all contexts. The greater variability than the normal group in the experimental subjects is presumably indicative of less stability regarding speech motor control (DiSimoni, 1974a, b; Janssen & Wieneke, 1987; Kent & Forner, 1980; Sharkey & Folkins, 1985; Smith, 1992b, 1994; Smith & Kenney, 1994; Tingley & Allen, 1975; Wieneke & Janssen, 1987), since the normal subjects exhibited much smaller SDs than the experimental subjects across contexts. It could be, however, that the greater variability displayed in L2 by the normal group, suggests less stability in their speech production mechanisms under circumstances of increased processing demand despite still being less variable than the experimental subjects.

6.6 SUMMARY OF CHAPTER SIX

In this chapter the results of the study were interpreted and discussed according to the formulated sub-aims. The purpose of this chapter was to relate the results of this study to the limited relevant research available and to explain the findings within the context of relevant literature on normal and pathological speech sensorimotor control. The results of this study indicated that speech production in L2 increases processing demands in normal speakers and persons with either AOS or PP. These increased processing demands in turn impact on the temporal parameters of speech production as measured in the acoustic speech signal. From the results of the study, conclusions were drawn regarding speech production in L1 versus L2, as well as regarding the nature of the disorder in AOS and PP. Although a motor deficit seems to accompany the phonological deficit in PP, the disorder in these persons appears to be both quantitatively and qualitatively different to AOS.

CHAPTER SEVEN

CONCLUSIONS AND IMPLICATIONS

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"If speech is so easy, should not the study of speech be easy? The higher we look into the nervous system, however, the less we know. We know a substantial amount about the sounds which emerge from the mouth of a speaker, and from acoustic analysis have derived information on production…We can infer from information on muscle activity something about the nerve impulses which fire the muscles. We know little, however, about the organization and coordination of these impulses in the brain and even less about how these impulse patterns are derived from stored linguistic knowledge and ultimately from thought." (Borden & Harris, 1984:45)

7.1 INTRODUCTION

The main aim of this study was to obtain information regarding the effect of speech production in L1 versus L2 on specific temporal parameters of speech production in bilingual normal speakers and bilingual speakers with either AOS or PP. In order to achieve the main aim of the study, specific sub-aims were formulated. The findings of the study are preliminary in nature, since a study regarding the effect of speech production in L1 versus L2 on temporal parameters of speech production in persons with either AOS or PP has not yet been undertaken. Although the results of the study cannot be generalized, owing to the limited number of subjects who participated in the study, specific trends emerged which have the potential to inform on the nature of AOS and PP and speech production in these subjects under circumstances of increased processing demand imposed by increasing speaking rate and speech production in L2. The results of this study also serve to stimulate further research related to bilingual speech production in AOS and PP.

In the following section, the conclusions that can be drawn from the results of the study will be discussed with reference to the main and sub-aims of the study. The theoretical and clinical implications of the current study will then be presented and discussed, whereafter a critical review of the methodology will be provided and recommendations for further research will be made.

7.2 CONCLUSIONS BASED ON THE RESULTS OF THE STUDY

The current conclusions apply only to the subjects and test stimuli of the present study. Only further research with more subjects, different test stimuli and other methods of investigation of speech production in L1 versus L2 will reveal the extent to which these conclusions can be generalized. The fact that some of the results are in agreement with the findings of previous studies, indicates that the findings of the present study are characteristic of persons with either AOS or PP.

The conclusions that can be drawn from the results of the study will be divided into three sections in terms of their theoretical relevance.

7.2.1 Conclusions regarding the influence of speech production in L2 on temporal parameters of speech production

The nature of the influence of L2 on temporal parameters of speech production was deduced from the findings related to the accomplishment of durational adjustments in L1 compared to L2, the extent of durational adjustment in L1 compared to L2, the extent to which the experimental subjects differed from the normal group in L1 compared to L2 and the variability exhibited in L1 compared to L2. The results regarding the aforementioned aspects led to the formulation of the following conclusions:

7.2.1.1 The accomplishment of durational adjustments in L1 compared to L2

- Normal speakers are flexible in the accomplishment of durational adjustments in that they are mostly successful in shortening durations in the FR, which indicates that their speech motor systems are highly skilled and can adjust to circumstances of increased demands.
- Speech production in L2 causes difficulty with the *achievement of durational adjustments* in persons with either AOS or PP when increased demands have

already been imposed by an attempt to increase speaking rate. Consequently persons with AOS and PP experience more difficulty with durational adjustments (decreasing durations in the FR) in L2 compared to L1. This leads to the conclusion that, under circumstances of increased processing demand, speech production in L1 is presumably "easier" than in L2.

7.2.1.2 Extent of durational adjustment in L1 compared to L2

- In normal speakers as a group, the extent of durational adjustment (decrease of duration in the FR) was not greater in L1 compared to L2, regarding VD and VOT for all utterance groups and regarding UD for two of the three utterance groups. Durational adjustments were thus accomplished to a greater extent in L2 in the majority of instances for the normal group, which implied that achievement of durational adjustments was generally presumably not more difficult in the L2 context for the test stimuli used in the present study. However, individual normal speakers were affected differently by L2 regarding the extent of durational adjustment in L1 compared to L2. Two of the normal speakers generally exhibited a greater extent of durational adjustment in L1 compared to L2 regarding all measured parameters, while the other three did not exhibit this trend, except with regard to UOD. The latter finding leads to the conclusion that in some normal speakers, speech production in L2 might be less automatized than in other speakers, causing the extent of durational adjustments to be smaller in this language. Temporal control is thus presumably more difficult for these speakers in L2.
- The effect of speech production in L2 on temporal control is evident in the experimental subjects in that *durational adjustments* (decrease of duration in the FR) are generally greater in these persons when speaking in L1. The latter finding indicates that durational adjustment is presumably more easily accomplished in L1 than in L2.

7.2.1.3 The extent of difference between experimental subjects and the normal group

- In subjects AOS1, PP2 and PP3, the difference between their durations and those of the normal group was most pronounced in the L2FR context, which was hypothesized to impose the greatest processing demand. Subjects AOS2 and AOS3 also occasionally exhibited the greatest extent of difference from the normal group in L2FR, but did so less often than AOS1, PP2 and PP3. Only one subject, PP1, did not exhibit any tendency to differ most from the normal group in L2FR. These former findings indicate that although L2FR appeared to be the most difficult speaking context for some of the experimental subjects because of the deviation from the normal group being most pronounced in this context, it is not equally true for all subjects. This finding might be due to different strategies applied by subjects with either AOS or PP when speaking in more demanding contexts. Furthermore, this finding might point towards the fact that some speakers might have been more fluent in and more accustomed to speaking in L2 than others. Consequently the L2 context did not impose increased processing demands on the speech mechanisms of those subjects. In other words, those subjects did not perceive speech production in L2 as being more difficult compared to L1 contexts.

7.2.1.4 Variability in L1 compared to L2

- In the normal group, variability generally tended to be the greatest in either L2NR or L2FR regarding VD, UD and UOD, which indicated that the L2 context might have led to greater variability in these subjects. The greater variability in the L2 context could be the result of instability regarding motor control because of increased processing demands imposed by the L2 context. Another explanation for the increased variability in the L2 context could be that speech production in L2 was less automatized and consequently resulted in less consistency on repeated productions of a specific utterance. Increased variability thus appeared to be a normal reaction when the processing demands were increased. Variability of temporal parameters might thus be useful for determining which contextual factors impose increased processing demands and consequently lead to greater complexity of production.

- In the normal group, variability was more often greater in L2 *normal rate* than in L2 *fast rate*. When speaking at a faster than normal rate, normal speakers presumably can become more precise regarding repeated production of a word despite the increased demand of speaking in L2. This could be due to controlled processing being applied in the L2FR context, since it is expected to be a more difficult/demanding context. The boundaries of equivalence might also be smaller when speaking at a rate that is faster than the habitual rate, necessitating more precise movements and consequently controlled processing. The controlled processing thus caused these subjects to be more precise during repeated productions of a word when they spoke at a faster than normal rate. This controlled processing might not always be successful, however, due to the demands becoming too high with the combined demand imposed by L2 and a faster than normal speaking rate.
- In the experimental subjects no consistent trend emerged regarding the tendency for variability to be the greatest in the L2NR or L2FR context, with the exception of AOS1, who generally exhibited greater variability in either of these contexts. This finding might indicate that these speakers applied more controlled processing whilst speaking in L2, or that they compensated by slowing down their speaking rate and consequently increased duration. The slower rate that was then employed by these subjects presumably led to more consistent production on repeated trials of a specific utterance.

7.2.1.5 Final conclusion regarding the influence of speech production in L2 on temporal parameters of speech production

Speech production in L2, compared to L1, appears to have posed greater processing demands on persons with either AOS or PP in the present study, which influenced the temporal parameters of speech production in those speakers. This influence was evident from the fact that difficulty with the accomplishment of durational adjustments was experienced more frequently in L2 compared to L1. Furthermore, in the experimental subjects, a greater extent of durational adjustment was generally achieved in L1 and the greatest difference from the normal group generally occurred in L2. In the normal group, L2 led to greater variability, but other than this, this group was able to adjust successfully to the increased demands. Speech production in L2 can thus be regarded as a contextual factor which increases the complexity of production. The increased processing demands imposed by speech production in L2 are most probably related to the novel and less automatized nature of speech production in L2 compared to L1, which is presumably more familiar and more automatized.

The fact that language influences the motor parameters of speech production implies that higher level cognitive processes impact on the motor control of speech. All levels of processing involved in speech production thus presumably share processing resources, causing these to be more easily exceeded when difficulty with one or more levels of the speech production process is present owing to the impaired processes requiring more than normal resources. When the available resources are exceeded, persons experiencing difficulty with speech and language processing are more susceptible to erroneous production or deviation from normal speakers.

7.2.2 Conclusions regarding the nature of AOS and PP

7.2.2.1 Conclusions regarding the nature of AOS and PP derived from results relating to the duration of temporal parameters

- The majority of the experimental subjects with AOS generally exhibited longer durations than the normal group across all four contexts regarding VD, UD and UOD, indicating difficulty with temporal control in these speakers. The fact that longer than normal durations were present in all speaking contexts could indicate that slow speaking rate, or longer durations could be a core characteristic of AOS and not necessarily only a compensatory strategy that is employed when the demands of the speaking context become too high. Regarding UD, subject AOS3 did not constantly exhibit longer durations than the normal group across all four contexts. Subject AOS3 had the least severe

AOS, which might imply that the severity of the disorder influenced the extent of difficulty experienced with regard to temporal control.

- Since temporal control is exerted during all the motor stages of speech production (motor planning, motor programming and execution) as specified in the four-level framework of speech sensorimotor control (Van der Merwe, 1997), it is difficult to determine exactly to which level of the speech production process the difficulty of the subjects with AOS regarding temporal control can be attributed. Furthermore, difficulty at one level of the speech production process will influence operations involved in the lower levels. In relation to Schmidt's schema theory (Schmidt, 1975), the deficit in the subjects with AOS in the present study might be related to difficulty with parameterization of the GMP, in other words, with specification of the absolute values of the temporal (and spatial) parameters for movement execution and, in this case, speech production. The correct GMPs were presumably selected, since perceptually on-target speech was produced.
- Although the subjects with PP often had longer durations than the normal group across all four contexts, they generally exhibited less instances of this behavior than the subjects with AOS. Although a deficit regarding temporal control thus appears to be part of the pathogenesis in subjects with PP, it appears to be less consistent than in the subjects with AOS. In the present study, the subjects with PP were thus successful more often than subjects with AOS with regard to temporal control when processing demands were increased. The longer durations in the subjects with PP might therefore be due to a compensatory strategy (slowing rate), which is applied when the processing demands become too high, and are not necessarily a core feature of PP.
- The subjects with AOS generally had longer durations regarding the measured temporal parameters than the subjects with PP, indicating that the severity of the motor disorder in AOS is greater than it is in PP.

7.2.2.2 Conclusions regarding the nature of AOS and PP derived from results on token-to-token variability of temporal parameters

- Most of the experimental subjects exhibited greater token-to-token variability regarding durational measures, as measured using SDs, than the normal group across all four contexts. This seems to point towards the presence of a motor control deficit underpinning the disorder in both these groups of speakers. Greater token-to-token variability also presumably points towards less stable motor control systems in these subjects.
- Variability demonstrated by the subjects with AOS was generally greater than that demonstrated by the subjects with PP regarding VD and UOD for all utterance groups and regarding UD for the voiceless fricative utterance group. This finding indicates that the underlying causes of greater than normal variability in both AOS and PP might be different.

7.2.2.3 General conclusions regarding the nature of AOS and PP

- The fact that only on-target utterances were analyzed in the present study and stilled revealed differences from the normal group, implies that speakers with AOS or PP are somehow able to compensate for their impairments and still obtain perceptually accurate speech. As discussed in chapter six, trade-offs might occur regarding the achievement of various motor goals under circumstances of increased processing demand. A degree of flexibility in the speech production mechanisms of persons with AOS and those with PP thus seems to be preserved, despite difficulty regarding one or more of the stages of speech production. The extent to which subjects are able to compensate, in spite of their speech and/or language impairments, might be used as a prognostic indicator (Seddoh *et al*., 1996a).

7.2.3 Conclusions regarding the influence of speaking rate on temporal parameters of speech production

- Normal speakers were generally successful with decreasing duration in the FR, whereas both subjects with AOS and those with PP had occasional difficulty accomplishing durational adjustments. This finding might point towards a motoric inflexibility in subjects with either AOS or PP (Kent & McNeil, 1987).
- Speaking at a faster than normal speaking rate appears to increase both the linguistic and motor demands, since the operations involved in both these processes have to take place at a faster than normal rate. The increased speaking rate, together with speech production in L2, thus causes subjects with speech and language deficits to be more susceptible to breakdown in respect of temporal control.

7.2.4 Conclusions regarding the effect of speech production in L2 on the control of different temporal parameters

- Normal speakers generally had a greater extent of durational adjustment in the FR in L1 compared to L2 regarding UOD, although this trend was not observed for the other measured parameters. The latter finding might indicate that this aspect of temporal control might be more sensitive to the influence of the language of production (L1 versus L2) than UD, VD and VOT. UOD in the normal speakers in the present study is equivalent to the stop gap duration, in other words, the period of silence preceding the release for a stop consonant. This period of constriction precedes the burst release for plosive production and the onset of voicing in order to produce either a voiced or a voiceless plosive. Consequently, it might be a more difficult parameter to control.
- *VOT* appears to be less sensitive to the influence of increased processing demands imposed by speaking at a faster than normal rate and by speech production in L2. This is substantiated by the following findings:

a) Very few experimental and normal subjects exhibited a greater extent of durational adjustment in L1 compared to L2 regarding VOT, even though they exhibited this behavior regarding the other temporal parameters which were measured, namely VD, UD and UOD. The latter finding might be due to the fact that a change in VOT could lead to the production of a voiced consonant instead of a voiceless consonant and vice versa. The boundaries of equivalence might thus be narrower for VOT than for the other measured parameters, causing subjects to exert more conscious control regarding production of either a voiced or a voiceless plosive.

b) Subjects AOS2 and AOS3 generally exhibited longer durations than the normal group across all four contexts regarding VD, UD and UOD. This behavior did not occur regarding VOT, which indicates that temporal control of this parameter might be preserved to a greater extent in these subjects compared to the other parameters. However, AOS1, the most severe apraxic, exhibited longer durations than the normal group across all four contexts regarding VOT as well as the other measured temporal parameters. The latter finding indicates that the extent to which temporal control is affected might be dependant on the severity of the impairment. Although the VOTs of the experimental subjects were longer than those of the normal group, they did not result in substitution of voiced plosives for voiceless plosives. The longer than normal VOT durations were thus still within the boundaries of equivalence. If the VOTs had exceeded the boundaries of equivalence, a voiced plosive might have been replaced by a voiceless plosive.

c) The durations of PP2 and PP3 never differed most from the normal group in L2FR regarding VOT, even though their durations differed most from the normal group in L2FR regarding most utterance groups for VD, UD and UOD. This finding indicates that VOT was influenced differently by the increased demands, compared to the other temporal parameters in PP2 and PP3.

d) Only one of the experimental subjects, PP1, exhibited greater than normal variability regarding VOT across all four contexts. This implies that not one of the other experimental subjects exhibited greater variability regarding VOT across all four contexts, even though greater than normal variability was generally exhibited by these subjects regarding the other measured parameters.

e) In the normal group the greatest variability was never exhibited in either L2NR or L2FR regarding VOT, even though this group generally exhibited the greatest variability in either L2NR or L2FR regarding VD, UD and UOD.

- In the theoretical framework of speech sensorimotor control proposed by Van der Merwe (1997), it is posed that IAS, of which VOT is an example, is an independent operation in the motor planning of speech. Other operations include, for example, sequential organization of movements and planning of consecutive movements. It thus appears as if the different operations involved in the motor planning of speech can be affected selectively. The fact that VOT is not affected to the same extent as the other temporal parameters by the increased demands might also indicate that some aspects of motor control are less prone to disruption than others in the presence of a neurologic lesion.

7.3 IMPLICATIONS OF THE STUDY

7.3.1 Theoretical implications

The present study is the first acoustic study to investigate the effect of speech production in L1 versus L2 on temporal parameters of speech production in bilingual speakers with AOS. Up to now bilingual speech production in AOS has been greatly ignored. Ignorance regarding bilingual speech production in AOS is most probably due to the fact that speech and language processes are often regarded as operating independently. Previous studies have challenged the latter view and have shown that "higher level language processes" impact on "lower level motor processes" (Maner *et al*., 2000; Strand & McNeil, 1996). From the results of the current study and a previous perceptual study by Van der Merwe and Tesner (2000), it can be concluded that bilingual AOS is as much a reality as bilingual aphasia (Van der Merwe, & Tesner, 2000). Considering that it is estimated that approximately half the world's population is bilingual (Grosjean, 1982), it is imperative that bilingualism in AOS be acknowledged and dealt with in both the clinical and research settings.

The present study contributes to the growing database relating to the acoustic characteristics of persons with AOS or PP. Furthermore, information was obtained regarding speech production in these groups of speakers under circumstances of increased processing demand, as imposed by an attempt to increase speaking rate and speech production in L2. This information highlights the fact that speech production in L2 poses increased demands to the speech production mechanisms of persons with either AOS or PP. Furthermore, it underscores the importance of recognizing the effect of language processing, specifically L1 versus L2 speech production, on speech motor control. The results of the present study also rendered information regarding the underlying nature of the impairment in AOS and PP. In this regard the nature of the impairment in AOS and PP appears to be similar in L1 and L2, but more pronounced during speech production in L2. Speech production in L2 is presumably motorically more difficult due to the novel and less automatized nature of L2 compared to L1, and this intensifies the motor deficit in bilingual speakers with AOS. The study of bilingual AOS provides the opportunity to learn more about the nature of this disorder, as well as about the interaction of speech and language processing in the brain.

The results of the present investigation indicate the need to incorporate both motor and language aspects when compiling models of speech production for the explanation and the study of aspects of normal and pathological speech motor control. The importance of this is underscored by the fact that the different stages involved in speech production appear to interact and influence one another. Speech is a fine motor skill, but cannot be completely understood without the incorporation of the language processes that precede production (Kent, 1990). Motor and language processes appear to interact in a direct and complex way, with the result that the complexity of speech and language processing cannot be fully understood and studied when either of these perspectives is neglected. The framework of speech sensorimotor control proposed by Van der Merwe (1997) incorporates both these elements and can account for the deficits observed in persons with either AOS or PP in the present study. The results of the study underscore the need for a comprehensive framework of speech motor control within which to explain and interpret findings.

7.3.2 Clinical implications

Although every research project renders only a minute contribution towards the vast potential knowledge base relating to a particular subject, the thoughts and subsequent research stimulated by each new study reaches far beyond the reported results. In order to truly benefit the field of study, however, the results of the empirical study need to lend themselves to clinical application. Research should thus aim to enhance the performance of the clinician in the clinical setting by, for example, providing a clearer description of disorders, assisting in differential diagnosis, improving understanding of the nature of various disorders and ultimately by providing a backdrop for the development of more effective assessment and treatment methods. In this regard, the results of the present study also have important clinical implications. The clinical implications of the present study will be discussed below.

- The fact that L2 increases the processing demands to the speech production mechanism implies that L2, as a contextual factor, needs to be taken into account when compiling assessment and treatment procedures for persons with either AOS or PP. When a speaker has to perform speech production tasks in L2, performance might deteriorate depending on the nature of the other demands imposed by the speaking context. It is consequently important to take the language in which evaluation and treatment is conducted into account. Furthermore, if it is not possible to provide therapy in a person's L1, other contextual factors which have the potential to increase the processing demands need to be limited during the initial stages of therapy, for example, increasing speaking rate and linguistic complexity of an utterance. As the person's motor skills improve, more demanding contexts can be employed. In her therapy program for speech motor learning for persons with AOS, Van der Merwe (1985) emphasizes the importance of grading task complexity when conducting therapy with persons with AOS. In the present study, the accomplishment of changes in speaking rate appears to be a difficult task for persons with both motor and linguistic-symbolic planning deficits. Furthermore, a reduction in speech rate appears to be employed by some speakers as a compensatory strategy when the demands of the speaking context are increased. In such instances, slowed speaking rate is presumably the result of the application of more conscious and controlled processing. Slowing speech rate might consequently be useful as a technique for obtaining on-target speech during the initial stages of therapy. During on-target speech production subjects are given the opportunity to build up a sensorimotor memory of correct production for the utterances that are targeted.

- The fact that different contextual factors influence persons with various speech and language disorders differently emphasizes the need for experimenting with different contexts of speech production in different speakers. Since some contextual factors might not lead to breakdown in certain speakers, these contexts can be used in therapy whilst other more demanding contexts, leading to breakdown or greater deviation from normal speakers, should be avoided in the initial stages of therapy. For example, if accomplishment of on-target speech production is more difficult in L2 in a bilingual speaker with AOS, L1 sounds and utterances should be targeted first in therapy. Once the phonemic repertoire of L1 has been mastered, L2 speech sounds and utterances can be targeted.
- From the results of the study it is evident that subjects with either AOS or PP might share common features. Unlike the traditional belief, subjects with PP might thus also exhibit difficulty regarding certain aspects of speech motor control. It is important to recognize the presence of common characteristics when attempting differential diagnosis in persons with AOS or PP. Characteristics identified in the present study as relating to AOS include slower than normal speaking rate, longer than normal durations regarding VD, UD and UOD, and greater than normal variability regarding the aforementioned durational measures. The characteristics that were reported for the subjects with AOS also apply to the subjects with PP in the present study, but were more severe and occurred more consistently in the subjects with AOS.
- The results of the present study indicate the underlying impairment in AOS to be motoric in nature. Therapy programs, such as the Speech Motor Learning (SML) Program (Van der Merwe, 1985) would thus be effective for treatment of AOS, since this program incorporates principles of motor learning and aims to facilitate speech motor planning and control. The fact that persons with PP also appear to exhibit a motor component underlying the nature of their impairment implies that these speakers might also benefit from the SML Program (Van der Merwe, 1985).

However, this will need experimental confirmation. A preliminary study by Van der Merwe and Tesner (2000) has shown that the SML Program (Van der Merwe, 1985) might be useful in facilitating generalization from L1 to L2 regarding improved speech production. Consequently this program might be useful for improving speech production in bilingual speakers with AOS, and possibly also for those with PP.

7.4 EVALUATION OF THE RESEARCH METHODOLOGY

Although an attempt was made to structure the experimental design according to the guidelines for scientific research (Smit, 1983), certain aspects may be subject to criticism. The first of these pertain to the *limited number of subjects* who participated in the study. Pure AOS is seldom encountered and consequently subjects who meet the inclusion criteria are few. In this regard McNeil *et al*. (2000:229) state that "it is our experience that "pure" AOS is so rare that practicing clinicians will be unlikely to observe it more than once or twice in the course of their careers. This is likely to be the case even if they are sensitized to its importance and are exposed to a full and continuing caseload of neurogenic communication disorders". The time-consuming nature of the analysis method used in the present study further makes inclusion of large subject numbers impractical for a single researcher. In the present study, an attempt was made to include subjects with the purest possible form of either AOS or PP. It was thus decided to obtain a reliable sample from a small number of "pure" subjects, rather than obtain unreliable data from a larger number of subjects who did not meet the inclusion criteria. The advantage of using smaller groups and even single cases is documented in the relevant literature (Kamhi, 1985; Siegel & Spradlin, 1985). Most recent acoustic studies in AOS and PP included groups of four to five subjects (Clark & Robin, 1998; Seddoh *et al*., 1996a, b; Strand & McNeil, 1996).

Another possible criticism pertains to the fact that some experimental subjects were *not completely homogeneous regarding the severity* of their disorders. Subject AOS1, for example, exhibited more severe AOS than subjects AOS2 and AOS3. Subject AOS3, although exhibiting apraxic speech characteristics, was a much more fluent communicator than AOS1, whose speech was hesitant and laborious. For this reason it was decided not to group the subjects, but to describe the results of each subject individually. The latter aspect is disadvantageous since statistically significant results cannot be obtained through using descriptive statistics in this manner. On the other hand, the use of descriptive statistics for each individual subject can be regarded as an advantage, since this has potential to reveal individual differences between subjects that have the same speech and/or language disorder, but different levels of severity. The latter might lead to the identification of subtypes of AOS, as suggested by the results of certain studies, for example, a study by Square-Storer and Apeldoorn (1991). Descriptive results of individual subjects thus have the potential to more accurately describe the behavior of a specific subject with a specific speech and/or language disorder. Furthermore, if the severity of the problems experienced by the subjects differs and a particular subject's level of severity or behavior differs significantly from that of the other subjects in the group, the group results might reflect the performance of this particular subject and might not be representative of the general behavior of persons in the specific group.

Because of the *amount of descriptive data* in the present study and the *large number of variables* that had to be incorporated (the four contexts of speech production, four temporal parameters and fourteen utterances), many aspects of the data could not be discussed and specific aspects had to be singled out in an attempt to answer the research question. Consequently only the main trends pertaining to the main and sub-aims could be highlighted. Furthermore, since the *number of utterances* that were analyzed was quite large, it was difficult to view the results of specific utterances in detail. The use of fewer utterances might allow for more detailed analysis regarding the influence of the articulatory characteristics of an utterance, whereas a larger number of utterances might be more representative of the influence of L2 across utterances.

The *speech stimuli* used for analysis in the present study were *virtually identical* in L1 and L2, with the exception of the carrier phrase which preceded the test utterance. Use of these test utterances might thus not be representative of the processing demands imposed by spontaneous speech production in L1 and L2 respectively. The *similar nature of the L1 and L2 utterances in the present study* might thus have limited the potential to reveal differences regarding speech production in L1 versus L2. In other words, if speech production in L2 was more demanding to the speech production mechanism, the nature of the test stimuli might not have been able to reveal this adequately. To limit the influence of other variables, for example, the motor complexity of the utterance itself, it was necessary to use utterances in L1 and L2 that were phonemically and phonetically similar. If the utterances had differed phonemically, differences that were obtained regarding speech production in L1 and L2 might have reflected the motoric demands of the utterances in each language and not necessarily the effect of the language variable (L1 versus L2) as such. However, despite the very similar nature of the utterances in L1 and L2, trends regarding the influence of speech production in L2 still emerged.

Another aspect of the empirical study that requires consideration concerns the *parameters* that were examined. It might be necessary to study other aspects of the acoustic signal in addition to the temporal parameters of the present study, to determine the influence of speech production in L2. Studying other temporal factors, such as, second formant transition duration and between-word segment durations might reveal differences regarding speech production in L1 and L2 more clearly. A study of other aspects of the acoustic signal, for example formant trajectories using linear predictive coding, could reveal aspects about the accuracy of spatial parameters during production. Furthermore, if spatial parameters were studied in conjunction with temporal parameters, more information might come to light about the different operations involved in the motor control of speech.

Pertaining to the *data collection procedure*, an aspect which might have influenced the results is the fact that speaking at a faster than normal rate was not controlled in the present study. In other words, subjects were merely requested to speak as fast as they could whilst still maintaining accuracy of production. Some subjects might thus have spoken at a faster rate than others and often the experimental subjects were not able to speak faster than their control rate. Although an external cue for the required rate could have been employed, for example by using a metronome, subjects might still not have been able to achieve speech production successfully at the required rate. Valuable information was obtained by observing the subject's ability to achieve durational adjustments without cueing.

7.5 RECOMMENDATIONS FOR FUTURE RESEARCH

From the results of the study it is evident that bilingual AOS is as much a reality as bilingual aphasia (Van der Merwe & Tesner, 2000). However, speech production in bilingual speakers with AOS has seldom been systematically investigated. Since speech production in L2 appears to pose higher processing demands to the speech production mechanisms of some persons, it is important to study the influence of speech production in L1 versus L2 in greater depth and in different ways to determine how it impacts on the various aspects of speech production in normal speakers and speakers with communication impairments. From the results of the present study, the need for further research regarding bilingual AOS becomes evident. In this regard the following recommendations for further research are made:

- Since it became evident that not all temporal parameters were affected equally by the increased processing demands (speaking in L2 and at a faster than normal rate), it is recommended that a comparison be made between temporal control of different temporal parameters. By comparing different temporal parameters, or determining whether a relationship exists between them, it would become possible to establish whether temporal control of some temporal parameters is more difficult than that of others, especially when processing demands are increased by speech production in L2. More could thus be learned about temporal control of different parameters in normal and disordered speakers under circumstances of increased processing demand.
- Since not all normal and experimental subjects appear to be affected in the same way by speech production in L2, it becomes evident that it is important to study the speech of individual subjects over a wide range of behaviors in order to determine specific trends amongst various subjects in different subject groups. By studying individual subject performance, more can be learned about the different strategies employed by subjects under circumstances of increased processing demand.
- An analysis of spatial parameters, together with temporal parameters of speech production, might be useful in highlighting the extent and nature of deficits in AOS and PP, as well as the occurrence of trade-offs during speech production in

L1 and L2 respectively. Some persons might exhibit spatial deficits whilst others might exhibit deficits regarding temporal control only. A third group might exhibit both temporal and spatial deficits. By studying various aspects of motor control, subtypes of AOS might be identified.

- Related to the identification of subtypes of AOS, is the study of non-speech oral-motor behavior though determination of visuomotor tracking ability in AOS as suggested by Clark and Robin (1998). Since language processing is not involved in the study of non-speech oral-motor control, the study of this aspect might be useful in identifying motor control disturbances related to AOS without biasing data through the use of either L1 or L2. This would be particularly useful when subjects cannot be evaluated in their first language due to the examiner not being fluent in that particular language.
- A study of the effect of speech production in L1 versus L2 on the frequency and type of errors produced using perceptual analysis could potentially provide information on the difficulty of speech production in L1 versus L2 and the perceptual consequences. The study by Van der Merwe and Tesner (2000) was the only study which could be found in this regard.
- An investigation of the effect of various treatment programs on parameters of speech production in L1 and L2, in order to determine if carryover of speech motor learning took place from the language in which therapy was conducted to the production of the second language, would be useful in determining which therapy programs are relevant for use with bilingual speakers. Specifically, the study of subphonemic aspects of speech production which have been used to identify the core features of AOS, for example, segmental and intersegmental durations and variability of durations (McNeil *et al*., 2000) in L1 and L2 should thus be assessed before and after treatment to determine the influence of treatment on these parameters in both languages. In this regard, Van der Merwe and Tesner (2000) found that carryover from L1 to L2 took place when the Speech Motor Learning Program of Van der Merwe (1985) was used with the bilingual speaker with AOS who participated in their study. The study by Van der Merwe and Tesner (2000) used perceptual analysis of speech errors.
- A study of different aspects of motor control during speech production in L1 and L2 should aid in determining whether similar aspects of speech production are affected in both languages, for example, coarticulation, IAS and speaking rate. By

determining whether similar aspects of speech motor control are affected in L1 and L2, more will be revealed about bilingual speech and language processing. Differential processing patterns might become evident for speech production in L1 versus L2.

- The operating range during repeated production of an utterance can be determined by deducting the smallest duration of a specific parameter from the largest duration in L1 and L2 respectively. This might provide insight regarding the operating range within which one has to stay to remain within the boundaries of equivalence for the production of speech sounds. It should be interesting to see if this operating range differs between L1 and L2. The latter has the potential to reveal more about the boundaries of equivalence and speech motor control in L1 and L2 respectively.
- Different levels of analysis, for example, electromyographic, kinematic, acoustic and perceptual methods, could be used to determine whether breakdown at different levels of the speech production process occurs in each language. It should be interesting to see if different methods of analysis reveal similar patterns of deficit in L1 and L2. Furthermore, one would also be able to see whether different parameters of speech production are affected similarly, for example acoustic and kinematic parameters.
- The study of parameters of speech production in persons with different levels of bilingualism and even multilingualism has the potential to reveal more about the linguistic and motor control of more than one language. From the aforementioned it could be determined if persons who are more fluent in a specific language are more skilled regarding motor and/or linguistic control in this language compared to persons who learned a second language later on in life and are less fluent. The investigation of the aforementioned will be particularly informative in the presence of a neurologic lesion.
- The influence of various contextual factors, for example, linguistic complexity and sound structure on the parameters of speech production (temporal and spatial) could be studied in an attempt to determine how these factors should be implemented to facilitate speech production, or how they should be limited during therapy until a greater level of skill has been achieved. The effect of contextual factors will therefore influence the compilation of both assessment and treatment procedures.

- The study of speech production in L1 versus L2 can be conducted in persons with other types of speech production difficulties, for example, persons who stutter or those with dysarthria, to determine if L2 is more difficult to produce in these populations. This could in turn reveal more about the nature of speech motor control in L1 and L2 in persons with deficits at different levels of the speech production process.

7.6 CONCLUDING REMARKS

The accurate description and characterization of the salient characteristics of neurogenic speech disorders and the influence of various contextual factors on these is essential for differential diagnosis, the compilation of effective assessment and treatment procedures and the development of models of speech production for explanation of normal and disordered speech motor control.

The results of the present study pertain to several theoretical issues and make an important contribution towards the available knowledge regarding the nature of the impairment in persons with either AOS or PP and the influence of contextual factors on speech production of these persons. The main aim of this study was realized in determining that L2 imposes additional processing demands to the speech production mechanism. It was determined that the result of the increased processing demands is manifested in specific aspects of temporal control in persons with either AOS or PP, as well as in greater token-to-token variability regarding durational measures in normal speakers. The results of the study led to the identification of differences in the nature of the underlying deficits in persons with AOS or PP. Furthermore, conclusions could be drawn regarding normal and disordered speech motor control under circumstances of increased processing demand.

In summary, the results of the study have shown that both speakers with AOS and those with PP exhibit deficits regarding temporal control, which is intensified by an increase in the processing demands induced by speaking at a faster than normal rate and speech production in L2. The deficits exhibited by these groups of speakers are presumably due to a deficit regarding speech motor control, since greater variability than normal was exhibited in both these groups of speakers. Longer than normal durations were more consistently present in speakers with AOS than in those with PP, which could imply that slow speaking rate is a core characteristic of AOS. In subjects with PP, longer than normal durations were not as consistently present, which could imply that slow rate might be a compensatory strategy that is applied when the processing demands increase. Furthermore, the durations in the subjects with AOS were generally longer than those in the subjects with PP regarding VD, UOD and VOT. The variability in the subjects with AOS was also generally greater than in the subjects with PP regarding VD and UD. The motor deficit in AOS thus appears to be more severe than in PP, with the implication that the underlying deficit in PP might be only partly attributable to a deficit regarding speech motor control.

The results of the study suggest that more studies investigating the influence of contextual factors, specifically speech production in L1 versus L2, on the speech of normal speakers and speakers with neurogenic speech and language disorders are needed, using other parameters of speech production as well as different methods of analysis and speech material. Further research of this type is imperative for a better understanding of speech and language disorders, and ultimately for optimization of assessment and treatment protocols for bilingual or multilingual speakers.

7.7 SUMMARY OF CHAPTER SEVEN

In this chapter the conclusions that were drawn from the results of the study were presented and the theoretical and clinical implications were discussed with reference to the results of the empirical research. This was followed by a critical review of the research methodology. Finally, recommendations for further research were made, whereafter it was concluded that the main and sub-aims of the study had been realized as it was concluded that L1 and L2 can be regarded as contextual factors that influence the complexity of production. The languages of the bilingual or multilingual speaker thus need to be taken into account in the clinical and research setting when dealing with subjects with either AOS or PP.

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Information conveyed to subjects for obtaining consent for participation in the study and use of collected data for research purposes	**Page 2**

Obtaining of permission for participation in a research study and for use of information obtained for research purposes

The following information was conveyed to each potential subject to obtain permission for participation in the study and for use of the recorded speech sample for research purposes. After conveying the information to each potential subject verbally, since most of the subjects exhibited deficits regarding reading and writing, oral consent was obtained.

Mr/Mrs..

I would like to request your permission for participation as a subject in my doctoral studies. The data collection procedure will entail that you read short phrases from cards in both English and Afrikaans while a tape recording is made. The recording sessions will last approximately thirty minutes. I would also like to obtain your permission to use the recorded speech sample for research purposes. You will remain anonymous at all times and are free to withdraw from the study at any time. Before the recording session, you will have to attend a session in which your speech and language will be assessed using a standardized aphasia test. The testing will take approximately sixty minutes. Do you give your consent to the aforementioned? Do you have any questions?

Appendix B

Mean *vowel duration (in ms)* of each subject's five repetitions of each utterance in each context for utterances beginning with a *voiceless plosive*

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	124.0	136.2	117.9	129.2	108.3	115.7	120.3	119.2	75.2	86.8	90.3	102.2	125.9	146.4	124.1	124.5	75.4	98.4	98.4	102.9
AOS2	137.3	129.1	106.6	106.8	147.5	142.5	150.4	162.4	83.0	72.2	67.8	56.0	111.5	113.9	111.8	107.8	119.4	128.3	117.9	128.7
AOS3	113.3	87.1	91.1	85.7	145.8	117.8	128.0	113.0	94.9	75.0	69.2	65.9	121.9	109.8	107.5	116.9	99.6	93.1	90.8	105.8
N1	74.7	69.2	100.7	77.3	99.7	89.8	102.1	73.3	62.6	56.1	68.3	54.7	101.9	89.5	96.6	78.9	75.8	68.5	83.5	69.1
N2	109.1	100.9	131.6	112.1	128.2	113.6	134.5	112.4	80.4	68.4	79.4	69.9	111.0	100.4	127.6	106.9	104.2	108.9	122.4	112.8
N3	92.7	94.7	88.3	88.0	91.6	88.1	90.8	81.0	63.5	71.9	71.6	66.8	90.2	90.1	91.0	84.1	76.4	79.5	81.5	63.7
N4	100.1	92.6	106.1	97.0	90.6	83.3	99.6	85.0	56.5	55.4	60.9	58.4	92.9	79.0	95.3	72.3	94.4	79.6	83.8	79.8
N5	89.1	74.3	89.8	98.4	94.3	78.1	82.5	79.0	67.8	54.3	62.7	58.8	94.4	78.8	89.9	86.9	89.9	74.3	85.1	84.0
NGR	93.1	86.3	103.3	94.6	100.9	90.6	101.9	86.1	66.2	61.2	68.6	61.7	98.1	87.6	100.1	85.8	88.1	82.2	91.2	81.9
PP1	101.5	104.9	95.1	71.9	87.2	91.2	92.1	81.5	48.4	45.4	52.5	46.0	93.4	86.9	86.4	74.2	84.2	64.8	76.3	68.8
PP2	85.2	95.9	91.8	98.8	93.6	101.8	99.6	100.7	81.0	85.8	80.1	70.0	95.9	95.0	90.8	106.3	70.2	66.0	78.6	85.4
PP3	121.6	126.9	104.5	114.8	108.4	130.9	115.6	133.0	74.2	73.7	72.1	76.3	115.1	127.7	102.6	107.9	102.5	102.7	92.8	107.0

Mean *vowel duration (in ms)* of each subject's five repetitions of each utterance in each context for utterances beginning with a *voiced plosive*

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	169.0	149.0	196.1	195.0	107.0	131.7	113.5	145.7	152.5	165.6	208.8	193.3	135.7	171.4	172.1	159.6	172.9	155.3	160.8	148.7
AOS2	197.0	170.7	202.1	189.5	143.9	129.1	129.5	125.0	175.5	163.8	177.6	169.4	192.2	189.6	186.5	184.6	161.0	144.6	150.6	143.3
AOS3	217.2	192.5	206.0	192.5	163.9	112.8	142.9	122.3	254.4	202.6	210.5	168.1	209.0	188.2	195.4	168.7	186.5	157.2	152.5	155.9
N1	151.7	129.0	177.7	122.6	110.2	105.7	111.7	99.9	152.0	132.1	146.3	111.8	123.1	122.0	132.2	105.3	114.0	110.5	115.3	90.3
N2	172.0	136.8	185.2	152.6	144.3	123.5	146.7	130.3	176.1	144.2	178.3	152.0	173.2	142.1	169.5	141.7	151.8	120.2	151.3	126.1
N3	133.3	121.4	131.1	105.5	115.2	105.0	106.3	96.1	140.4	123.8	146.5	123.0	137.7	128.5	144.9	113.8	121.4	105.7	109.0	92.1
N4	155.1	144.3	173.4	143.6	128.9	127.0	130.8	126.7	181.7	155.4	162.1	143.5	153.3	137.4	172.7	147.2	139.4	108.7	139.1	116.2
N5	132.1	111.7	113.1	105.7	108.1	89.2	103.2	105.3	143.8	127.2	131.1	127.0	127.5	109.6	117.0	110.3	107.3	96.8	98.9	96.2
NGR	148.8	128.6	156.1	126.0	121.3	110.1	119.7	111.7	158.8	136.5	152.8	131.4	143.0	127.9	147.2	123.7	126.8	108.4	122.7	104.2
PP1	135.9	117.5	143.2	120.5	122.4	107.8	116.4	96.2	160.6	128.9	159.0	119.7	145.5	126.0	166.9	130.0	115.8	110.6	109.3	104.2
PP2	176.9	189.1	170.5	176.8	119.3	104.4	112.8	122.5	147.6	139.5	130.7	134.8	123.5	113.7	128.7	148.7	102.9	105.9	109.7	115.0
PP3	137.0	133.3	142.5	136.7	143.3	139.3	117.6	124.1	168.8	166.1	169.1	165.3	151.4	136.8	182.4	193.3	141.7	132.9	124.9	130.3

Mean *vowel duration (in ms)* of each subject's five repetitions of each utterance in each context for utterances beginning with a *voiceless fricative*

	"set"/set				"vas"/fuss				"feit"/fête				"voet"/foot			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	127.1	130.5	124.1	136.9	156.3	162.8	130.5	139.3	151.2	161.8	225.6	189.0	99.3	117.0	111.8	144.9
AOS2	166.6	127.3	160.0	136.8	144.0	141.4	148.4	146.3	188.9	174.4	189.1	194.8	100.7	89.4	84.4	93.3
AOS3	144.6	113.8	129.3	113.3	192.7	156.6	181.3	147.5	198.0	168.2	181.9	196.4	108.6	67.8	77.9	74.4
N1	105.6	99.4	96.9	89.1	132.8	124.8	144.2	110.7	154.2	119.7	164.9	114.5	68.7	67.6	82.1	73.3
N2	129.3	113.5	125.3	110.4	150.4	132.9	155.4	141.7	144.7	122.6	155.1	133.3	67.6	55.8	106.2	87.8
N3	95.3	111.1	94.3	102.7	110.1	112.1	114.0	100.9	118.7	116.7	128.3	112.8	70.2	74.4	92.1	82.5
N4	104.2	100.7	109.9	102.5	126.9	113.5	118.5	116.7	134.3	120.5	157.9	121.4	82.8	54.9	89.6	69.8
N5	103.8	83.1	95.4	81.2	133.1	109.3	113.9	105.4	133.8	100.6	118.3	104.8	81.8	65.7	80.8	73.4
NGR	107.6	101.6	104.3	97.2	130.7	118.5	129.2	115.1	137.1	116.0	144.9	117.4	74.2	63.7	90.2	77.3
PP1	84.8	87.2	88.1	78.6	151.3	109.4	141.2	117.3	111.3	106.4	137.9	105.8	63.7	58.3	107.9	103.0
PP2	107.2	122.3	109.9	122.5	153.7	144.0	136.1	140.8	172.2	204.6	199.6	249.8	89.7	86.0	99.8	90.6
PP3	117.8	126.2	129.4	134.8	141.8	159.3	150.7	168.8	126.7	132.4	119.5	121.3	81.3	85.7	79.6	95.4

Mean *utterance duration (in ms)* of each subject's five repetitions of each utterance in each context for utterances beginning with a *voiceless plosive*

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	585.1	537.9	575.4	624.6	490.0	528.7	675.4	548.8	753.4	523.9	544.5	518.9	582.1	586.7	565.8	549.6	461.2	410.8	498.0	440.7
AOS2	633.5	447.9	633.5	511.4	677.0	474.4	633.8	547.3	638.9	480.0	572.5	479.3	728.1	560.5	737.7	718.4	696.5	434.4	650.2	430.2
AOS3	360.4	324.0	363.3	295.7	407.3	316.7	409.1	317.5	429.9	322.2	361.5	286.4	399.3	364.3	431.1	439.2	308.4	346.8	328.0	383.3
N1	316.6	284.8	414.1	289.0	376.3	308.7	398.4	274.5	349.8	279.9	406.6	279.2	389.9	281.5	387.0	290.6	367.6	265.1	354.2	260.0
N2	419.6	392.5	487.2	362.5	459.4	391.5	514.9	462.1	448.9	397.8	517.6	401.6	419.2	357.8	450.3	356.8	402.2	363.8	366.2	349.1
N3	310.2	279.4	322.2	311.4	397.2	362.6	373.7	327.2	412.0	376.8	445.5	389.2	386.7	385.1	428.9	349.6	454.0	380.2	466.7	351.0
N4	457.8	342.8	467.8	381.7	472.1	394.4	511.1	421.4	459.8	406.2	453.5	382.7	483.7	401.8	527.6	381.1	423.0	371.9	476.3	374.0
N5	364.2	310.0	300.1	216.1	430.1	336.4	361.2	284.8	469.2	309.0	354.1	296.7	433.3	328.6	354.8	281.2	395.3	220.6	331.7	309.2
NGR	373.7	321.9	398.3	312.1	427.0	358.7	431.9	354.0	427.9	353.9	435.4	349.9	422.6	350.9	429.7	331.9	408.4	320.3	399.0	328.7
PP1	455.0	460.2	368.9	397.0	538.9	469.4	447.9	414.2	517.1	419.1	385.6	426.6	509.0	383.0	445.0	336.8	484.2	430.8	432.1	279.0
PP2	773.0	622.6	644.0	717.0	689.9	724.0	691.0	693.7	663.3	573.4	636.6	628.1	719.9	603.7	740.0	769.2	621.3	537.0	558.1	604.5
PP3	485.4	467.2	470.1	389.8	522.7	562.8	579.5	601.2	520.0	498.7	502.3	514.1	514.2	524.0	503.5	517.7	478.8	424.4	376.5	381.0

Mean *utterance duration (in ms)* of each subject's five repetitions of each utterance in each context for utterances beginning with a *voiced plosive*

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	664.7	578.5	747.2	662.1	563.2	490.0	562.6	530.5	754.9	653.9	793.0	621.0	575.6	561.5	619.0	579.2	628.9	534.5	706.5	599.7
AOS2	723.7	506.3	677.9	583.8	629.8	462.4	606.4	474.2	1053.8	615.1	702.8	537.0	693.5	484.3	576.4	547.1	750.5	528.7	657.5	598.1
AOS3	489.4	403.3	452.0	397.8	425.4	319.8	358.9	328.9	556.3	445.7	531.3	513.6	412.1	408.4	425.3	364.6	484.3	363.5	425.2	360.8
N1	432.9	321.0	458.3	319.1	397.0	293.1	402.6	307.8	457.0	336.1	448.5	303.6	371.9	315.1	419.5	299.1	353.8	301.0	393.1	293.4
N2	498.8	439.2	567.3	662.1	418.6	357.9	434.5	372.1	559.1	486.9	573.3	519.5	552.5	451.9	520.0	365.7	454.1	344.3	514.1	502.6
N3	415.6	332.5	481.7	351.3	365.6	301.8	345.6	295.0	407.0	342.2	408.3	317.0	364.9	324.0	385.4	300.5	397.8	362.6	366.1	331.8
N4	527.6	454.8	602.2	421.1	462.6	414.3	538.5	438.4	666.5	467.2	662.7	517.5	498.0	390.4	544.1	382.2	523.9	432.5	687.6	440.4
N5	475.0	379.9	367.5	310.7	435.9	276.1	281.5	259.0	635.1	555.8	580.3	395.0	483.1	294.8	345.9	335.7	417.4	386.5	396.9	333.9
NGR	470.0	385.5	495.4	412.9	415.9	328.6	400.5	334.4	544.9	437.6	534.6	410.5	454.1	355.3	443.0	336.6	429.4	365.4	471.6	380.4
PP1	586.6	479.6	505.4	424.3	493.0	436.5	437.9	189.6	525.1	454.7	433.3	595.2	633.7	455.1	455.3	375.6	593.2	423.1	426.0	383.9
PP2	770.2	695.3	814.8	798.5	625.6	601.1	674.6	708.3	783.4	629.6	775.5	786.8	704.7	706.1	668.0	709.9	670.3	664.3	674.9	693.1
PP3	570.8	596.0	603.1	427.7	523.1	456.7	548.2	489.9	754.5	637.6	700.7	624.7	495.2	466.5	538.1	505.4	532.7	516.1	500.1	546.5

Mean *utterance duration (in ms)* of each subject's five repetitions of each utterance in each context for utterances beginning with a *voiceless fricative*

	"set"/set				"vas"/fuss				"feit"/fête				"voet"/foot			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	791.4	784.5	830.9	860.9	793.7	779.3	844.8	857.6	878.3	688.1	894.1	871.9	773.2	724.8	825.4	737.8
AOS2	919.0	673.0	758.9	716.2	953.7	831.1	894.6	855.5	801.6	759.4	910.5	938.3	805.5	590.6	720.3	612.3
AOS3	657.3	514.0	710.4	548.3	688.0	546.6	691.7	525.9	640.2	476.2	614.1	561.6	574.5	444.2	557.8	517.0
N1	574.2	432.8	603.0	419.0	682.6	460.1	654.7	412.5	626.1	410.8	616.2	412.0	563.1	374.7	541.5	347.8
N2	650.6	540.1	668.8	564.5	713.1	569.5	679.2	565.6	651.3	496.1	689.1	598.0	625.5	488.0	664.0	534.2
N3	564.6	440.8	541.3	481.3	518.0	389.7	511.1	388.3	528.8	440.6	583.2	424.7	497.2	442.7	476.7	396.3
N4	673.1	625.8	693.1	569.1	850.8	696.8	820.0	643.0	690.3	526.2	760.9	607.8	657.8	454.5	689.2	536.2
N5	599.3	398.0	498.0	374.1	732.3	508.2	703.8	434.8	584.1	408.0	532.8	395.3	528.2	444.6	466.1	385.2
NGR	612.4	487.5	600.8	481.6	699.3	524.9	673.8	488.8	616.1	456.4	636.4	487.6	574.4	440.9	567.5	439.9
PP1	783.5	551.2	592.7	594.3	786.6	601.4	748.1	598.6	764.6	544.2	649.1	481.6	725.2	565.1	574.7	583.9
PP2	756.0	724.7	852.7	831.2	824.6	788.7	987.2	866.0	883.5	807.4	898.5	911.0	691.5	818.5	801.5	743.8
PP3	672.0	550.8	595.4	550.6	744.8	640.0	648.2	759.6	594.6	610.6	565.1	586.6	564.9	540.2	602.8	541.2

Mean *utterance onset duration (in ms)* of each subject's five repetitions of each utterance in each context for utterances beginning with a *voiceless plosive*

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	429.2	950.1	1128.6	845.9	756.6	484.5	1059.2	1425.0	957.6	1571.9	1193.1	1578.7	514.2	577.1	1174.3	1177.9	589.9	1029.8	675.4	763.5
AOS2	601.4	494.0	445.6	964.2	508.6	278.5	296.8	565.7	633.3	407.4	655.4	496.9	839.6	350.0	348.4	749.1	390.8	397.8	504.6	314.6
AOS3	311.8	165.8	176.9	185.3	390.1	227.0	620.1	432.2	475.7	204.7	211.8	244.8	340.1	402.0	262.3	272.1	534.9	248.3	178.5	147.8
N1	196.4	119.9	218.8	101.6	214.2	107.9	215.5	89.0	228.0	117.6	197.1	96.0	200.3	107.5	191.7	88.2	195.8	117.0	193.7	96.4
N2	191.7	101.4	186.1	136.7	212.2	121.1	195.3	109.9	201.5	121.1	178.8	119.2	203.2	115.1	171.0	125.9	182.0	118.4	179.9	122.4
N3	145.0	95.7	134.9	91.1	137.4	87.6	136.7	96.8	140.8	95.4	127.6	110.9	121.0	87.1	154.8	100.0	129.2	84.9	127.6	97.0
N4	229.2	179.3	200.0	177.2	208.9	168.9	234.0	162.7	234.1	152.5	184.3	155.6	261.2	187.6	189.3	173.8	213.3	178.0	186.6	153.4
N5	150.0	123.1	134.7	129.5	145.2	113.3	129.0	113.7	154.1	113.3	142.9	119.7	143.3	113.0	139.5	125.1	136.6	116.8	140.4	125.0
NGR	182.5	123.9	174.9	127.2	183.6	119.8	182.1	114.4	191.7	120.0	166.1	120.3	185.8	122.1	169.3	122.6	171.4	123.0	165.6	118.9
PP1	354.6	252.7	585.8	254.3	292.3	119.8	759.1	249.2	321.7	132.8	244.0	195.5	1133.6	112.0	326.2	160.1	902.5	262.5	520.8	213.2
PP2	1195.9	258.6	632.0	573.9	183.4	172.8	183.1	176.4	242.6	165.8	167.0	249.3	192.0	241.0	270.9	370.0	187.4	163.0	146.4	195.2
PP3	137.4	110.2	214.5	499.8	137.4	118.3	98.8	106.3	141.8	97.5	107.1	99.3	155.7	91.9	112.0	138.4	288.7	106.0	128.7	92.5

Mean *utterance onset duration (in ms)* of each subject's five repetitions of each utterance in each context for utterances beginning with a *voiced plosive*

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	869.5	374.9	1691.8	2193.6	686.5	573.9	1792.1	1048.0	1483.6	1647.0	900.2	413.2	1382.2	693.4	2429.1	2025.6	376.7	254.0	1970.9	1274.9
AOS2	494.9	501.3	329.8	313.4	521.7	276.0	652.2	429.1	478.7	505.9	323.0	310.8	538.4	574.7	974.4	618.1	417.6	361.4	374.1	280.7
AOS3	337.0	122.3	265.4	398.3	395.8	191.4	280.1	149.8	308.6	315.2	243.9	406.6	354.6	141.4	222.1	457.1	208.4	263.2	141.7	174.8
N1	150.9	80.7	175.7	68.5	188.6	84.0	265.0	71.8	148.1	82.6	192.2	69.8	150.3	89.8	193.1	72.3	154.8	80.3	170.6	75.8
N2	171.9	84.0	144.6	84.9	165.9	91.2	154.3	105.8	150.3	86.4	147.8	87.6	169.9	98.1	131.4	90.6	171.4	84.2	155.9	83.8
N3	114.6	60.8	96.4	74.4	105.3	67.4	119.0	80.6	100.8	62.5	99.0	74.5	111.5	69.8	108.9	83.2	107.1	74.2	113.5	78.6
N4	153.0	133.8	166.4	113.1	139.7	129.0	155.1	111.4	136.2	122.3	114.6	105.3	149.4	118.5	136.8	114.9	133.9	109.6	132.0	129.8
N5	111.2	84.3	104.3	111.5	123.2	94.3	100.1	98.1	102.3	81.9	99.1	89.5	112.8	88.2	100.6	91.0	110.3	81.5	103.3	95.2
NGR	140.3	88.7	137.4	90.5	144.5	93.2	158.7	93.6	127.5	87.1	130.5	85.3	138.8	92.9	134.2	90.4	135.5	85.9	135.0	92.6
PP1	288.8	107.1	754.0	204.9	272.0	115.0	616.7	456.7	609.6	96.3	156.2	136.7	185.0	493.3	278.2	220.3	496.8	81.7	629.5	100.5
PP2	161.0	122.2	382.0	270.1	192.9	145.1	191.6	261.1	425.4	194.1	215.1	140.2	190.7	188.5	133.3	135.5	128.3	182.8	134.2	141.7
PP3	141.3	65.6	89.3	193.6	124.5	149.1	105.7	80.3	90.9	59.9	82.2	183.3	289.3	75.7	75.4	67.8	83.3	86.9	328.5	114.8

Mean *voice onset time (in ms)* of each subject's five repetitions of each utterance in each context for utterances beginning with a *voiceless plosive*

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	27.8	27.8	31.0	25.5	24.5	23.9	28.8	25.9	20.6	30.7	29.0	30.1	26.4	24.8	30.5	32.7	20.5	20.4	24.4	26.5
AOS2	13.7	14.1	11.3	13.4	10.3	10.3	12.0	7.6	14.7	14.2	13.4	12.1	13.3	14.6	12.1	8.7	14.5	12.2	8.0	9.9
AOS3	10.5	11.2	22.2	15.1	13.1	8.6	19.9	19.7	12.4	10.2	18.0	14.8	11.5	14.5	35.7	14.3	12.5	9.1	25.9	12.8
N1	8.0	6.7	12.1	7.5	6.8	6.7	12.1	7.1	8.5	7.6	15.0	7.9	7.4	6.7	9.8	7.6	9.4	6.5	10.3	8.7
N2	11.1	13.8	12.3	11.3	10.9	13.7	14.3	11.9	11.2	9.9	11.9	12.4	15.1	11.7	12.5	12.5	12.4	11.7	10.9	11.9
N3	14.4	14.0	17.5	14.6	12.9	15.5	17.0	14.3	19.2	14.8	12.5	12.0	12.8	14.0	16.9	17.2	13.1	14.1	17.5	20.9
N4	14.3	12.4	9.3	9.5	12.6	10.6	12.8	13.7	11.7	12.3	15.1	13.1	12.3	9.7	10.3	9.6	10.1	10.0	10.1	9.7
N5	10.3	9.9	13.0	9.1	10.0	10.1	12.0	10.5	10.9	9.6	11.5	11.2	10.7	9.8	9.4	9.3	11.8	9.9	14.6	9.2
NGR	11.6	11.4	12.8	10.4	10.6	11.3	13.6	11.5	12.3	10.8	13.2	11.3	11.6	10.4	11.8	11.2	11.4	10.4	12.7	12.1
PP1	20.5	15.7	18.4	15.4	17.4	19.4	28.5	17.2	19.3	16.7	15.2	15.3	23.6	17.0	31.2	18.5	15.8	16.9	25.0	17.9
PP2	37.8	18.2	20.4	21.1	13.7	12.1	10.5	14.2	15.6	10.6	17.6	18.2	17.9	13.4	11.7	17.0	14.2	15.9	12.0	21.5
PP3	12.2	13.0	10.7	13.1	12.3	12.6	14.2	11.7	10.9	11.8	12.3	13.2	12.2	12.5	11.4	11.0	12.4	8.1	11.3	8.9

Mean *voice onset time (in ms)* of each subject's five repetitions of each utterance in each context for utterances beginning with a *voiced plosive*

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	27.6	-41.7	-110.4	22.9	16.4	7.3	-79.0	26.7	26.0	28.4	-58.1	-18.4	27.8	-4.6	3.0	-19.8	10.1	9.9	-9.9	-8.5
AOS2	8.4	13.3	12.2	9.3	11.1	13.8	11.4	6.3	-45.2	11.9	9.7	5.4	8.0	6.5	31.5	11.2	8.6	13.7	10.4	8.5
AOS3	-159.9	-71.7	1.9	-43.1	-154.0	-56.7	-46.7	-64.0	-141.7	-92.7	-60.7	-98.6	-58.7	-68.2	0.0	-54.3	-52.2	-82.2	9.8	-119.1
N1	1.2	-80.7	3.8	-68.5	4.6	-84.0	3.1	-57.4	-21.2	-82.6	7.9	-52.9	-23.0	-89.8	4.7	-72.3	6.3	-80.3	4.5	-75.8
N2	-63.8	-84.0	-85.7	-84.9	-165.9	-91.2	-123.5	-105.8	-150.0	-86.4	2.8	-87.6	-66.2	-98.1	-43.0	-64.5	-131.9	-84.2	-123.3	-62.0
N3	-114.6	-60.8	-96.4	-74.4	-81.3	-67.4	-77.7	-80.6	-100.8	-62.5	-78.1	-74.5	-111.5	-69.8	-108.9	-83.2	-107.1	-74.2	-113.5	-78.6
N4	-42.6	-21.8	-17.6	-96.3	-139.7	-82.0	-45.0	-111.4	-106.2	-106.3	-91.7	-105.3	-43.8	-80.2	-109.9	-114.9	-68.1	-93.4	-106.3	-85.1
N5	-101.5	-84.3	-104.3	-87.2	-123.2	-69.2	-100.1	-66.6	-102.3	-69.3	-99.1	-89.5	-112.8	-88.2	-100.6	-91.0	-110.3	-81.5	-103.3	-95.2
NGR	-64.3	-66.3	-60.0	-82.3	-101.1	-78.7	-68.6	-84.4	-96.1	-81.4	-51.6	-82.0	-71.5	-85.2	-71.6	-85.2	-82.2	-82.7	-88.4	-79.3
PP1	73.8	-37.1	86.0	14.2	141.7	-115.0	73.6	74.7	103.5	-83.3	99.5	26.8	143.7	-58.9	95.0	84.3	71.9	-62.6	118.7	71.7
PP2	7.3	17.7	6.8	11.5	3.7	8.9	2.5	7.7	8.0	10.8	15.4	8.4	11.4	25.4	13.4	10.8	8.6	10.0	22.0	10.3
PP3	141.3	68.5	89.3	66.9	71.2	149.1	105.7	80.3	90.9	59.9	82.2	-38.8	72.9	75.7	75.4	67.8	83.3	86.9	77.9	81.2

Appendix B

Mean durations and standard deviations of each subject and the normal group regarding each temporal parameter, utterance and context **Page 2-5**

Standard deviations* of *vowel duration* of each subject in each context for utterances beginning with a *voiceless plosive

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	8.5	18.7	11.8	4.3	5.7	12.0	21.7	9.0	4.4	20.3	10.2	24.8	5.2	24.2	26.8	18.7	7.9	15.9	14.3	18.3
AOS2	21.2	26.1	13.5	12.8	12.4	7.7	12.1	13.9	4.8	4.4	9.6	2.2	11.1	12.8	12.2	12.9	7.9	15.7	12.4	9.0
AOS3	38.5	19.4	16.9	19.5	2.7	8.4	6.7	8.3	22.8	20.2	7.8	6.6	6.2	9.5	9.9	8.4	7.4	15.4	29.2	30.4
N1	16.6	8.7	11.2	7.1	3.6	1.2	9.9	5.0	9.2	6.6	11.5	4.1	10.9	11.6	9.3	11.8	7.4	6.3	9.1	9.2
N2	16.2	7.6	9.8	7.7	8.0	5.3	11.1	2.5	8.5	7.4	12.4	3.3	8.3	5.2	1.3	7.8	6.2	16.6	5.8	12.6
N3	8.5	11.1	10.4	9.0	12.2	11.7	8.4	13.1	12.0	6.2	10.1	6.5	7.6	11.0	8.1	7.3	6.2	9.7	8.0	15.0
N4	14.0	7.1	4.2	9.5	9.6	2.0	12.7	9.1	6.4	5.8	9.0	5.1	6.0	10.0	6.4	22.7	8.0	8.2	6.8	5.8
N5	10.2	5.4	5.8	10.9	8.5	6.6	4.6	3.9	8.9	3.1	5.9	8.5	8.4	5.9	4.4	5.8	9.3	5.0	7.1	4.0
NGR	13.1	8.0	8.3	8.8	8.4	5.4	9.3	6.7	9.0	5.8	9.8	5.5	8.3	8.7	5.9	11.1	7.4	9.2	7.3	9.3
PP1	5.1	7.4	9.6	8.7	9.1	7.3	9.4	8.0	8.8	6.8	5.7	2.3	8.4	7.7	9.0	5.7	7.6	7.6	10.6	3.5
PP2	9.6	6.2	4.4	15.1	11.1	8.9	4.7	6.7	6.9	4.6	7.7	7.3	1.9	7.3	5.8	19.6	8.7	6.8	13.7	5.9
PP3	9.4	15.4	13.0	6.4	1.9	11.0	9.8	13.9	8.9	12.5	7.6	11.5	5.9	21.6	10.0	12.2	9.2	6.3	8.2	16.1

Standard deviations* of *vowel duration* of each subject in each context for utterances beginning with a *voiced plosive

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	23.6	34.0	34.9	34.0	18.9	13.7	15.3	28.5	16.8	16.3	20.9	29.3	16.6	33.1	20.2	28.2	18.0	23.1	19.6	29.8
AOS2	9.2	11.4	24.8	24.0	18.5	13.6	9.1	11.4	13.1	28.5	11.9	12.7	19.1	11.0	9.7	12.3	13.9	14.8	5.0	8.7
AOS3	12.6	58.6	18.8	41.1	13.7	14.8	24.5	32.1	53.4	24.4	27.1	38.7	18.5	7.2	24.2	20.9	18.8	28.3	10.5	14.1
N1	8.2	7.1	30.5	10.3	8.8	5.7	10.8	10.4	11.1	4.8	11.6	16.6	7.5	12.8	10.4	13.1	9.7	13.5	23.2	9.7
N2	19.5	4.8	24.1	9.5	4.0	3.8	8.7	9.1	12.9	7.0	13.2	11.0	13.5	14.3	7.9	9.2	14.3	4.8	9.2	10.6
N3	13.9	5.3	10.6	10.4	8.2	10.3	10.0	10.8	6.5	8.9	9.8	12.6	3.7	7.1	12.8	15.1	6.6	7.4	5.2	10.1
N4	7.0	4.6	5.4	12.7	6.2	8.2	5.3	11.5	9.3	19.8	4.5	8.1	12.7	10.3	5.1	10.9	16.6	9.4	7.1	10.8
N5	9.4	7.4	9.0	14.0	9.7	5.7	12.6	13.0	10.4	5.5	9.9	9.1	10.4	5.4	9.4	2.8	2.0	6.2	1.8	6.6
NGR	11.6	5.8	15.9	11.4	7.4	6.7	9.5	11.0	10.0	9.2	9.8	11.5	9.5	10.0	9.1	10.2	9.8	8.3	9.3	9.6
PP1	15.3	3.5	7.2	7.2	9.1	5.4	24.4	6.2	18.8	7.5	14.9	17.3	15.2	11.7	11.0	10.0	8.6	18.8	13.8	20.8
PP2	28.1	22.2	27.1	34.9	10.5	7.5	4.4	23.5	6.0	10.7	7.4	11.5	6.0	8.1	11.6	8.0	16.2	4.8	15.9	8.3
PP3	21.2	7.7	12.3	16.2	13.2	18.2	8.5	16.1	15.9	10.1	11.6	6.7	9.0	7.2	21.1	14.2	13.6	4.7	8.7	12.0

Standard deviations* of *vowel duration* of each subject in each context for utterances beginning with a *voiceless fricative

	"set"/set				"vas"/fuss				"feit"/fête				"voet"/foot			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	9.7	17.8	33.2	13.9	49.4	37.0	20.5	17.1	15.4	24.0	63.7	36.7	19.2	53.2	12.7	46.4
AOS2	13.7	15.6	11.5	21.2	10.4	19.6	5.8	10.1	26.5	19.8	30.8	26.2	11.1	7.5	12.4	8.7
AOS3	12.2	24.8	15.0	7.9	20.1	7.9	9.7	14.5	5.5	18.1	31.2	12.7	15.8	16.5	12.0	11.1
N1	5.4	5.9	8.4	7.8	10.7	8.3	18.9	10.7	2.5	7.1	19.0	9.5	7.8	11.7	10.4	10.0
N2	6.6	5.8	6.4	5.4	8.3	8.7	7.6	6.1	6.9	8.4	14.7	13.1	4.8	10.3	14.6	13.2
N3	5.2	12.1	9.2	15.9	9.7	12.0	13.7	5.1	5.6	10.5	7.3	15.4	5.9	8.6	12.3	13.6
N4	5.8	6.4	4.7	10.1	11.0	7.6	9.5	12.8	16.7	6.1	8.0	5.8	7.1	5.5	17.3	13.0
N5	8.9	8.5	5.6	6.6	13.7	5.5	12.7	8.1	23.2	5.7	8.9	6.1	8.5	4.4	3.7	7.2
NGR	6.4	7.7	6.8	9.2	10.7	8.4	12.5	8.6	11.0	7.5	11.6	10.0	6.8	8.1	11.7	11.4
PP1	8.2	3.1	5.4	2.8	39.9	6.2	16.3	12.9	11.6	10.3	6.0	9.8	10.9	5.2	6.5	27.6
PP2	5.1	17.1	5.8	13.7	15.9	12.2	15.5	10.8	29.5	30.5	62.5	28.1	13.2	9.0	14.3	8.9
PP3	12.1	15.3	6.4	7.9	9.6	18.6	8.7	17.1	9.9	9.1	2.8	8.2	7.4	5.3	11.9	14.6

Standard deviations* of *utterance duration* of each subject in each context for utterances beginning with a *voiceless plosive

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	41.2	37.6	72.4	197.2	159.9	59.8	146.3	68.9	430.9	75.9	32.6	42.9	29.0	126.3	99.7	58.4	56.2	72.5	64.0	90.9
AOS2	50.3	21.1	51.3	74.4	48.1	37.1	47.1	99.3	30.2	99.9	47.2	77.1	75.1	105.0	43.3	194.3	32.1	22.8	137.9	18.0
AOS3	58.8	74.1	46.2	50.4	50.3	53.0	57.2	45.8	114.7	92.5	19.9	48.1	50.8	14.0	65.0	85.3	53.6	40.3	50.8	129.6
N1	22.3	14.8	36.2	15.0	8.4	22.2	36.3	16.2	25.7	15.8	35.2	16.2	22.6	25.4	25.2	17.1	19.0	7.7	18.5	9.4
N2	22.0	39.6	50.1	51.8	45.0	53.7	32.4	88.4	61.2	30.7	92.3	134.4	37.0	24.5	66.9	54.9	61.9	15.3	59.6	87.0
N3	8.5	23.7	37.7	75.3	53.6	89.5	40.2	49.3	21.7	32.5	51.1	42.3	50.9	72.4	42.6	32.8	57.9	59.0	27.1	47.0
N4	35.9	22.3	75.7	36.3	23.3	57.5	52.4	63.3	81.2	105.8	37.8	21.9	55.3	52.0	89.9	79.2	35.6	39.1	55.2	88.3
N5	26.5	67.0	51.2	9.2	33.4	31.7	53.9	38.5	97.3	67.0	78.0	35.3	51.4	38.0	68.9	31.9	52.1	13.1	67.9	78.5
NGR	23.1	33.5	50.2	37.5	32.7	50.9	43.0	51.1	57.4	50.3	58.9	50.0	43.4	42.5	58.7	43.2	45.3	26.8	45.7	62.0
PP1	42.4	66.5	65.9	144.5	73.7	77.4	51.2	25.9	49.1	42.5	41.9	37.0	51.7	53.5	35.4	38.9	18.7	172.3	82.2	56.4
PP2	77.8	37.2	72.3	124.0	89.6	72.7	48.7	62.8	74.3	82.6	57.2	71.2	115.4	32.3	154.2	93.5	34.3	91.7	43.1	46.6
PP3	41.1	63.6	93.2	88.9	95.3	109.7	44.5	96.6	69.5	85.2	40.1	95.3	26.3	80.1	37.1	58.4	103.6	74.8	63.0	101.1

Standard deviations* of *utterance duration* of each subject in each context for utterances beginning with a *voiced plosive

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	71.8	79.5	93.3	62.4	16.9	69.7	82.4	76.1	98.5	48.3	109.0	55.4	57.3	126.0	83.6	57.1	28.5	42.2	143.1	73.8
AOS2	58.3	56.1	76.5	85.9	20.6	62.3	38.4	63.0	457.2	53.9	52.7	32.6	81.8	80.4	23.0	157.2	93.6	135.5	136.1	166.1
AOS3	47.3	137.2	52.0	67.4	33.4	23.8	43.9	91.2	71.3	93.5	72.1	84.3	46.1	13.4	70.6	27.4	50.5	77.5	25.2	39.2
N1	24.6	21.6	44.6	25.4	24.0	29.7	19.7	22.4	43.1	21.3	24.6	34.2	33.6	27.5	33.1	18.0	22.9	15.0	33.4	18.1
N2	6.1	42.8	81.8	50.8	44.5	25.3	19.8	81.7	65.4	56.0	75.3	81.2	55.5	13.2	39.9	72.8	58.5	34.6	38.7	47.5
N3	42.4	37.0	71.0	28.0	19.2	18.4	38.8	32.7	26.1	22.9	40.0	26.4	40.7	13.8	20.4	53.2	33.0	42.4	33.5	30.8
N4	87.4	47.8	61.4	18.6	61.7	20.2	38.4	69.8	9.2	35.4	32.4	61.8	84.8	40.0	71.7	52.2	72.1	78.6	59.3	57.8
N5	66.7	90.1	35.2	30.0	45.2	17.2	36.4	31.7	76.0	218.1	111.8	88.4	64.4	37.5	32.3	79.1	49.4	47.1	81.6	94.3
NGR	45.4	47.9	58.8	30.6	38.9	22.2	30.6	47.7	44.0	70.8	56.9	58.4	55.8	26.4	39.5	55.1	47.2	43.5	49.3	49.7
PP1	63.2	80.3	34.1	21.8	52.6	150.3	44.7	435.3	73.0	53.8	80.1	112.1	321.2	139.1	63.4	104.9	103.5	55.5	64.3	31.7
PP2	78.5	65.3	103.6	149.8	70.6	41.8	75.1	31.1	167.1	72.7	65.6	38.6	73.3	165.4	103.7	70.9	54.9	62.9	45.9	58.5
PP3	47.7	106.7	108.4	69.8	70.9	63.9	47.1	72.3	66.0	14.2	76.4	42.2	57.5	48.2	105.0	40.7	147.0	88.4	115.7	122.7

Standard deviations* of *utterance duration* of each subject in each context for utterances beginning with a *voiceless fricative

	"set"/set				"vas"/fuss				"feit"/fête				"voet"/foot			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	29.8	68.4	44.4	167.8	103.9	146.1	65.6	129.3	207.1	124.5	141.4	113.7	163.5	111.1	151.0	130.3
AOS2	109.7	60.7	34.8	83.3	89.9	163.0	123.6	156.2	76.7	302.8	132.3	125.8	44.6	134.3	56.6	102.8
AOS3	56.8	78.8	277.4	151.1	56.4	74.5	50.5	89.4	60.2	60.7	28.9	46.0	59.6	86.7	61.5	176.6
N1	32.8	29.9	37.3	13.6	38.3	41.4	33.2	35.3	54.4	24.3	51.1	26.2	44.3	15.1	70.3	33.4
N2	36.2	53.8	125.6	34.1	22.1	53.4	29.9	25.4	51.7	78.3	50.3	78.4	25.6	63.7	88.3	81.1
N3	54.1	31.4	77.4	89.2	28.9	39.3	55.1	9.6	23.9	22.8	46.2	25.1	25.4	37.6	28.3	27.5
N4	36.0	52.0	70.3	52.3	63.8	178.2	91.2	51.8	49.9	50.7	79.9	91.8	55.1	43.8	89.1	56.6
N5	60.0	38.2	92.8	12.2	95.0	45.9	114.3	33.6	56.4	33.1	96.9	6.4	32.5	92.4	33.9	23.1
NGR	43.9	41.1	80.7	40.3	49.6	71.7	64.7	31.1	47.3	41.8	64.9	45.6	36.6	50.5	62.0	44.3
PP1	111.8	38.3	62.4	63.0	109.4	84.1	143.3	81.7	88.0	78.6	132.1	56.7	23.2	145.2	20.6	135.1
PP2	58.0	81.8	44.6	83.7	92.9	58.4	187.2	31.9	115.1	37.6	67.3	101.3	65.5	71.1	152.9	102.6
PP3	48.9	27.9	41.6	91.2	76.7	183.4	19.0	135.3	24.1	50.7	111.7	51.1	5.1	36.4	38.7	106.5

Standard deviations* of *utterance onset duration* of each subject in each context for utterances beginning with a *voiceless plosive

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	110.4	908.1	1165.0	589.1	256.9	377.2	713.9	565.8	495.3	825.3	796.1	1433.1	168.7	483.2	747.5	816.9	243.3	1380.2	463.8	636.0
AOS2	471.8	227.0	82.0	336.6	238.7	71.5	51.3	218.2	332.3	123.0	407.0	218.2	503.2	118.9	107.7	635.5	175.9	118.2	295.4	102.8
AOS3	133.2	51.5	26.2	66.8	219.7	73.7	768.6	309.5	189.7	37.7	64.4	117.1	233.3	236.1	157.5	102.8	283.2	80.7	57.4	41.4
N1	51.0	18.5	34.7	10.0	16.9	7.8	31.0	8.4	28.0	13.6	23.8	11.6	20.2	12.6	16.9	8.2	18.9	18.2	19.8	6.8
N2	11.2	9.4	10.2	27.3	15.6	44.5	10.1	17.0	11.7	14.8	10.8	28.1	12.7	18.3	11.1	23.7	9.8	15.5	17.5	17.9
N3	17.4	10.4	20.9	8.0	12.8	7.9	26.3	8.8	15.4	14.4	13.8	12.4	6.8	15.8	40.1	9.0	12.7	7.2	14.4	8.0
N4	28.3	24.3	28.7	15.6	16.2	18.4	30.5	9.8	50.9	24.8	8.8	17.4	79.2	49.7	12.9	24.9	26.5	11.3	22.8	17.3
N5	12.2	13.6	6.5	12.9	7.8	12.6	17.3	8.2	8.8	13.8	13.2	18.0	5.4	4.9	18.6	9.9	8.9	20.4	5.4	15.3
NGR	24.0	15.2	20.2	14.7	13.9	18.2	23.0	10.5	23.0	16.3	14.1	17.5	24.9	20.3	19.9	15.2	15.4	14.5	16.0	13.0
PP1	324.2	226.6	589.4	297.4	139.8	20.9	328.2	196.6	209.1	14.1	142.3	89.5	1053.1	13.3	164.5	34.4	531.2	164.6	674.8	195.3
PP2	773.4	161.4	648.6	527.1	27.3	21.1	15.9	13.8	162.6	9.4	27.2	114.1	60.1	169.6	196.6	511.2	26.7	9.5	13.6	79.9
PP3	17.2	11.4	118.8	325.8	16.5	38.8	13.8	38.4	40.7	19.3	25.7	57.7	66.3	17.5	15.4	55.9	279.1	13.9	43.5	21.3

Standard deviations* of *utterance onset duration* of each subject in each context for utterances beginning with a *voiced plosive

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	761.1	141.1	1508.9	955.8	319.8	302.4	1843.5	750.9	879.4	1334.3	636.3	196.1	782.9	571.3	1317.1	1730.9	60.7	59.1	2187.0	966.4
AOS2	70.9	436.9	133.6	149.2	480.1	47.1	581.7	215.8	328.0	218.4	77.5	108.6	418.1	450.7	918.0	495.4	197.4	206.3	189.6	61.3
AOS3	270.6	11.0	103.1	519.4	239.7	153.1	309.8	82.4	107.6	228.3	119.1	595.0	256.6	34.6	134.2	409.5	156.2	267.2	29.7	100.6
N1	8.3	9.2	35.3	5.1	50.1	11.3	71.4	6.3	29.2	5.9	45.7	10.0	17.3	25.2	50.2	8.2	43.5	8.3	35.1	3.1
N2	7.3	8.6	7.8	15.9	11.5	14.3	8.6	29.7	6.2	11.9	11.5	23.7	15.7	11.0	15.8	22.1	22.9	11.5	14.6	18.7
N3	24.5	5.7	15.2	2.6	15.8	12.6	35.8	11.3	6.9	16.2	18.9	13.3	2.7	7.4	20.4	9.7	16.0	7.6	11.1	10.1
N4	14.4	25.0	21.8	23.0	27.7	24.3	28.7	15.6	16.8	16.1	14.9	10.8	17.0	22.1	18.9	18.5	22.4	7.6	12.0	19.2
N5	5.4	11.2	5.2	37.8	13.2	14.5	14.3	36.2	13.1	22.4	5.2	13.3	10.0	5.9	13.4	29.0	9.3	13.9	4.2	14.3
NGR	12.0	11.9	17.0	16.9	23.7	15.4	31.8	19.8	14.5	14.5	19.2	14.2	12.5	14.3	23.7	17.5	22.8	9.8	15.4	13.1
PP1	146.3	18.0	725.2	259.9	149.5	13.9	463.6	740.9	663.0	4.8	46.0	102.4	91.2	868.9	200.0	316.5	419.5	6.7	289.8	21.2
PP2	15.5	17.8	394.8	307.6	98.1	34.3	112.6	263.1	564.8	101.3	136.9	8.7	77.0	116.4	10.2	18.1	21.0	83.1	11.0	7.1
PP3	133.3	10.3	44.5	295.7	79.8	171.4	68.6	22.5	17.9	16.7	18.8	301.6	439.9	8.5	7.1	8.0	12.4	61.8	559.8	102.8

Standard deviations **of** ***voice onset time*** **of each subject in each context for utterances beginning with a** ***voiceless plosive***

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	16.0	5.0	13.3	4.0	8.5	6.7	13.8	9.0	2.9	7.1	11.7	11.1	12.0	6.7	16.1	16.8	7.0	6.5	2.6	5.5
AOS2	7.1	3.2	2.1	2.0	4.8	2.3	5.7	1.6	4.3	2.2	2.1	0.9	6.2	3.9	4.4	3.6	5.4	3.2	4.8	2.8
AOS3	2.1	4.4	5.5	5.7	3.8	2.4	4.4	9.6	2.9	1.4	4.7	4.2	4.7	4.2	33.7	2.8	5.1	1.7	8.1	4.0
N1	2.5	1.8	4.9	0.4	0.9	0.6	6.5	0.6	1.9	0.8	1.8	1.6	2.0	0.5	2.5	0.4	5.2	0.7	2.2	1.6
N2	2.0	2.0	2.6	0.9	2.4	2.8	1.4	2.9	3.3	1.4	3.7	2.1	2.3	0.6	2.1	1.9	2.6	1.2	3.0	1.1
N3	6.7	5.6	6.2	2.1	3.5	4.4	5.5	1.1	6.3	3.3	4.9	2.1	4.2	5.5	6.5	5.3	4.9	2.9	3.7	7.0
N4	6.1	1.2	2.9	1.2	4.2	3.0	3.5	3.1	2.5	3.7	3.4	2.8	4.7	1.1	1.6	2.6	2.8	2.7	4.8	2.3
N5	1.3	3.3	1.7	0.6	2.2	3.5	3.5	2.4	2.3	2.5	3.1	1.8	1.9	3.1	0.9	1.1	2.7	3.1	3.1	0.4
NGR	3.7	2.8	3.6	1.1	2.6	2.9	4.1	2.0	3.3	2.3	3.4	2.1	3.0	2.2	2.7	2.3	3.6	2.1	3.4	2.5
PP1	8.9	7.7	8.1	4.9	6.6	5.8	20.9	5.0	4.6	4.5	2.5	2.2	6.9	7.7	15.8	4.8	6.1	5.3	10.3	4.6
PP2	15.7	4.0	12.5	9.1	4.7	2.0	3.0	4.2	4.2	2.2	2.6	2.3	4.8	4.0	7.4	6.2	5.1	4.9	7.6	6.4
PP3	3.3	3.2	2.3	5.0	1.2	3.0	3.3	2.8	1.2	3.0	3.8	3.4	2.5	3.3	7.6	3.9	3.8	1.2	2.6	5.1

Standard deviations **of** ***voice onset time*** **of each subject in each context for utterances beginning with a** ***voiced plosive***

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	6.9	147.5	144.4	5.2	2.6	26.7	172.9	5.7	10.2	12.1	82.7	87.2	9.7	74.1	85.3	64.0	32.4	23.8	71.7	76.6
AOS2	5.1	5.4	7.6	2.1	2.0	2.4	3.1	3.8	114.1	3.4	6.3	5.4	6.2	6.4	54.6	12.2	5.3	5.0	1.9	0.8
AOS3	41.7	65.7	4.2	46.9	48.6	46.9	73.6	42.8	92.3	68.1	69.9	81.4	89.1	77.0	0.0	35.8	50.6	72.0	11.0	32.6
N1	2.7	9.2	3.5	5.1	2.6	11.3	2.9	32.7	49.6	5.9	3.7	30.2	60.1	25.2	2.7	8.2	5.6	8.3	2.6	3.1
N2	95.7	8.6	86.4	15.9	11.5	14.3	74.1	29.7	6.4	11.9	12.4	23.7	103.2	11.0	71.6	42.2	80.9	11.5	75.1	42.0
N3	24.5	5.7	15.2	2.6	57.4	12.6	57.2	11.3	6.9	16.2	55.5	13.3	2.7	7.4	20.4	9.7	16.0	7.6	11.1	10.1
N4	75.3	47.5	67.1	48.8	27.7	43.0	79.8	15.6	65.7	40.2	60.8	10.8	80.9	62.9	55.0	18.5	77.4	30.3	51.7	66.0
N5	17.4	11.2	5.2	65.4	13.2	44.7	14.3	39.9	13.1	21.0	5.2	13.3	10.0	5.9	13.4	29.0	9.3	13.9	4.2	14.3
NGR	43.1	16.4	35.4	27.6	22.5	25.2	45.7	25.8	28.4	19.0	27.5	18.3	51.4	22.5	32.6	21.5	37.8	14.3	29.0	27.1
PP1	53.1	66.9	66.1	45.5	35.7	13.9	69.4	76.6	66.3	30.7	44.6	49.6	50.3	67.4	55.1	16.6	83.6	47.3	12.7	48.6
PP2	6.7	48.2	7.0	11.1	15.0	8.2	21.2	10.8	11.6	6.5	47.8	7.7	7.3	74.1	8.3	10.1	8.3	5.9	69.4	6.3
PP3	133.3	15.0	44.5	22.9	40.6	171.4	68.6	22.5	17.9	16.7	18.8	25.2	44.7	8.5	7.1	8.0	12.4	61.8	2.0	32.7

Appendix C

Vowel duration **in the fast rate expressed as a percentage of *vowel duration* in the normal rate for utterances beginning with a *voiceless plosive***

	"pak"/puck		"pet"/pet		"pit"/pit		"pad"/putt		"pap"/pup		Utterance group	
	L1	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**
AOS1	-9.8	-9.6	-6.9	0.9	-15.4	-13.1	-16.3	-0.3	-30.4	-4.5	-15.8	-5.3
AOS2	6.0	-0.2	3.4	-8.0	13.0	17.5	-2.2	3.6	-7.4	-9.1	2.6	0.8
AOS3	23.1	5.9	19.2	11.8	20.9	4.7	9.9	-8.8	6.5	-16.5	15.9	-0.6
N1	7.4	23.2	10.0	28.2	10.4	19.9	12.2	18.4	9.6	17.2	9.9	21.4
N2	7.5	14.8	11.4	16.4	14.9	12.0	9.5	16.2	-4.5	7.8	7.8	13.5
N3	-2.2	0.3	3.8	10.8	-13.3	6.6	0.1	7.6	-4.1	21.9	-3.1	9.4
N4	7.4	8.6	8.1	14.6	2.0	4.1	15.0	24.1	15.7	4.7	9.6	11.2
N5	16.6	-9.6	17.2	4.2	19.9	6.2	16.5	3.4	17.4	1.3	17.5	1.1
NGR	7.3	8.5	10.2	15.5	7.5	10.0	10.7	14.3	6.8	10.3	8.5	11.7
PP1	-3.4	24.4	-4.6	11.5	6.1	12.4	7.0	14.1	23.1	9.8	5.6	14.5
PP2	-12.7	-7.6	-8.8	-1.1	-5.8	12.5	0.9	-17.1	5.9	-8.6	-4.1	-4.4
PP3	-4.3	-9.9	-20.8	-15.1	0.7	-5.8	-11.0	-5.1	-0.2	-15.3	-7.1	-10.2

Vowel duration **in the fast rate expressed as a percentage of *vowel duration* in the normal rate for utterances beginning with a *voiced plosive***

	"byt"/bait		"bak"/buck		"bas"/bus		"bek"/back		"bed"/bet		Utterance group	
	L1	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**
AOS1	11.8	0.6	-23.0	-28.4	-8.5	7.4	-26.3	7.3	10.2	7.5	-7.2	-1.1
AOS2	13.3	6.3	10.3	3.5	6.7	4.6	1.4	1.0	10.2	4.9	8.4	4.0
AOS3	11.4	6.5	31.2	14.4	20.4	20.1	10.0	13.7	15.7	-2.2	17.7	10.5
N1	15.0	31.0	4.1	10.5	13.1	23.6	0.9	20.4	3.1	21.7	7.2	21.4
N2	20.5	17.6	14.4	11.2	18.1	14.7	17.9	16.4	20.8	16.6	18.4	15.3
N3	8.9	19.5	8.9	9.6	11.8	16.0	6.7	21.4	12.9	15.5	9.8	16.4
N4	6.9	17.2	1.4	3.1	14.5	11.5	10.4	14.8	22.1	16.5	11.1	12.6
N5	15.5	6.5	17.5	-2.1	11.5	3.1	14.1	5.7	9.8	2.7	13.7	3.2
NGR	13.6	19.3	9.3	6.7	14.0	14.0	10.5	16.0	14.5	15.1	12.4	14.2
PP1	13.5	15.9	11.9	17.3	19.7	24.7	13.4	22.1	4.5	4.6	12.6	16.9
PP2	-6.8	-3.7	12.4	-8.6	5.5	-3.2	7.9	-15.5	-2.9	-4.8	3.2	-7.1
PP3	2.7	4.1	2.8	-5.5	1.6	2.3	9.7	-6.0	6.2	-4.3	4.6	-1.9

Vowel duration **in the fast rate expressed as a percentage of *vowel duration* in the normal rate for utterances beginning with a *voiceless fricative***

	"set"/set		"vas"/fuss		"feit"/fête		"voet"/foot		Utterance group	
	L1	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**
AOS1	-2.7	-10.3	-4.2	-6.7	-6.9	16.2	-17.9	-29.7	-7.9	-7.6
AOS2	23.6	14.5	1.8	1.4	7.7	-3.0	11.2	-10.6	11.1	0.6
AOS3	21.3	12.4	18.8	18.6	15.1	-8.0	37.6	4.4	23.2	6.9
N1	5.9	8.0	6.0	23.3	22.4	30.6	1.6	10.7	9.0	18.1
N2	12.2	11.9	11.6	8.8	15.2	14.0	17.5	17.3	14.1	13.0
N3	-16.5	-8.9	-1.8	11.5	1.7	12.1	-5.9	10.5	-5.6	6.3
N4	3.3	6.7	10.5	1.6	10.2	23.1	33.7	22.2	14.4	13.4
N5	19.9	14.9	17.9	7.5	24.8	11.4	19.7	9.2	20.6	10.7
NGR	5.7	6.9	9.3	10.9	15.4	19.0	14.2	14.2	11.1	12.8
PP1	-2.8	10.8	27.7	16.9	4.3	23.3	8.4	4.5	9.4	13.9
PP2	-14.0	-11.4	6.4	-3.4	-18.8	-25.2	4.2	9.2	-5.6	-7.7
PP3	-7.2	-4.2	-12.3	-12.0	-4.5	-1.5	-5.5	-19.9	-7.4	-9.4

Utterance duration* in the fast rate expressed as a percentage of *utterance duration* in the normal rate for utteranc beginning with a *voiceless plosive

	"pak"/puck		"pet"/pet		"pit"/pit		"pad"/putt		"pap"/pup		Utterance group	
	L1	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**
AOS1	8.1	-8.5	-7.9	18.8	30.5	4.7	-0.8	2.9	10.9	11.5	8.2	5.9
AOS2	29.3	19.3	29.9	13.6	24.9	16.3	23.0	2.6	37.6	33.8	29.0	17.1
AOS3	10.1	18.6	22.2	22.4	25.0	20.8	8.8	-1.9	-12.5	-16.9	10.7	8.6
N1	10.1	30.2	18.0	31.1	20.0	31.3	27.8	24.9	27.9	26.6	20.7	28.8
N2	6.5	25.6	14.8	10.3	11.4	22.4	14.7	20.8	9.5	4.7	11.4	16.7
N3	9.9	3.4	8.7	12.4	8.5	12.6	0.4	18.5	16.3	24.8	8.8	14.3
N4	25.1	18.4	16.4	17.5	11.7	15.6	16.9	27.8	12.1	21.5	16.4	20.2
N5	14.9	28.0	21.8	21.1	34.1	16.2	24.2	20.8	44.2	6.8	27.8	18.6
NGR	13.9	21.6	16.0	18.0	17.3	19.6	17.0	22.8	21.6	17.6	17.1	19.9
PP1	-1.1	-7.6	12.9	7.5	18.9	-10.6	24.8	24.3	11.0	35.4	13.3	9.8
PP2	19.5	-11.3	-4.9	-0.4	13.6	1.3	16.1	-4.0	13.6	-8.3	11.6	-4.5
PP3	3.8	17.1	-7.7	-3.7	4.1	-2.3	-1.9	-2.8	11.4	-1.2	1.9	1.4

Utterance duration* in the fast rate expressed as a percentage of *utterance duration* in the normal rate for utteranc beginning with a *voiced plosive

	"byt"/bait		"bak"/buck		"bas"/bus		"bek"/back		"bed"/bet		Utterance group	
	L1	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**
AOS1	13.0	11.4	13.0	5.7	13.4	21.7	2.4	6.4	15.0	15.1	11.4	12.1
AOS2	30.0	13.9	26.6	21.8	41.6	23.6	30.2	5.1	29.6	9.0	31.6	14.7
AOS3	17.6	12.0	24.8	8.4	19.9	3.3	0.9	14.3	24.9	15.2	17.6	10.6
N1	25.8	30.4	26.2	23.5	26.5	32.3	15.3	28.7	14.9	25.4	21.7	28.1
N2	11.9	-16.7	14.5	14.4	12.9	9.4	18.2	29.7	24.2	2.2	16.4	7.8
N3	20.0	27.1	17.4	14.6	15.9	22.3	11.2	22.0	8.8	9.4	14.7	19.1
N4	13.8	30.1	10.4	18.6	29.9	21.9	21.6	29.8	17.4	35.9	18.6	27.3
N5	20.0	15.5	36.6	8.0	12.5	31.9	39.0	2.9	7.4	15.9	23.1	14.8
NGR	18.0	16.7	21.0	16.5	19.7	23.2	21.8	24.0	14.9	19.3	19.1	19.9
PP1	18.2	16.0	11.5	56.7	13.4	-37.4	28.2	17.5	28.7	9.9	20.0	12.6
PP2	9.7	2.0	3.9	-5.0	19.6	-1.5	-0.2	-6.3	0.9	-2.7	6.8	-2.7
PP3	-4.4	29.1	12.7	10.6	15.5	10.8	5.8	6.1	3.1	-9.3	6.5	9.5

Utterance duration* in the fast rate expressed as a percentage of *utterance duration* in the normal rate for utteranc beginning with a *voiceless fricative

	"set"/set		"vas"/fuss		"feit"/fête		"voet"/foot		Utterance group	
	L1	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**	**L1**	**L2**
AOS1	0.9	-3.6	1.8	-1.5	21.7	2.5	6.3	10.6	7.7	2.0
AOS2	26.8	5.6	12.9	4.4	5.3	-3.1	26.7	15.0	17.9	5.5
AOS3	21.8	22.8	20.6	24.0	25.6	8.5	22.7	7.3	22.7	15.7
N1	24.6	30.5	32.6	37.0	34.4	33.1	33.5	35.8	31.3	34.1
N2	17.0	15.6	20.1	16.7	23.8	13.2	22.0	19.5	20.7	16.3
N3	21.9	11.1	24.8	24.0	16.7	27.2	11.0	16.9	18.6	19.8
N4	7.0	17.9	18.1	21.6	23.8	20.1	30.9	22.2	19.9	20.5
N5	33.6	24.9	30.6	38.2	30.1	25.8	15.8	17.3	27.5	26.6
NGR	20.4	19.8	24.9	27.4	25.9	23.4	23.2	22.5	23.6	23.3
PP1	29.7	-0.3	23.5	20.0	28.8	25.8	22.1	-1.6	26.0	11.0
PP2	4.1	2.5	4.3	12.3	8.6	-1.4	-18.4	7.2	-0.3	5.2
PP3	18.0	7.5	14.1	-17.2	-2.7	-3.8	4.4	10.2	8.4	-0.8

Utterance onset duration **in the fast rate expressed as a percentage of** ***utterance onset duration*** **in the normal rate for utterances beginning with a** ***voiceless plosive***

	"pak"/puck		"pet"/pet		"pit"/pit		"pad"/putt		"pap"/pup		Utterance group	
	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2
AOS1	-121.4	25.1	36.0	-34.5	-64.2	-32.3	-12.2	-0.3	-74.6	-13.1	-47.3	-11.0
AOS2	17.8	-116.4	45.2	-90.6	35.7	24.2	58.3	-115.0	-1.8	37.7	31.1	-52.0
AOS3	46.8	-4.7	41.8	30.3	57.0	-15.6	-18.2	-3.7	53.6	17.2	36.2	4.7
N1	38.9	53.6	49.6	58.7	48.4	51.3	46.3	54.0	40.2	50.2	44.7	53.5
N2	47.1	26.6	42.9	43.8	39.9	33.4	43.3	26.4	34.9	32.0	41.6	32.4
N3	34.0	32.4	36.2	29.1	32.3	13.0	28.0	35.4	34.3	23.9	33.0	26.8
N4	21.8	11.4	19.1	30.5	34.8	15.6	28.2	8.2	16.5	17.8	24.1	16.7
N5	18.0	3.8	22.0	11.9	26.5	16.3	21.2	10.3	14.5	11.0	20.4	10.7
NGR	32.1	27.3	34.8	37.2	37.4	27.6	34.3	27.6	28.2	28.2	33.4	29.6
PP1	28.7	56.6	59.0	67.2	58.7	19.9	90.1	50.9	70.9	59.1	61.5	50.7
PP2	78.4	9.2	5.8	3.6	31.7	-49.3	-25.5	-36.6	13.0	-33.3	20.7	-21.3
PP3	19.8	-133.0	13.9	-7.5	31.2	7.3	41.0	-23.5	63.3	28.1	33.8	-25.7

Utterance onset duration **in the fast rate expressed as a percentage of** ***utterance onset duration*** **in the normal rate for utterances beginning with a** ***voiced plosive***

	"byt"/bait		"bak"/buck		"bas"/bus		"bek"/back		"bed"/bet		Utterance group	
	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2
AOS1	56.9	-29.7	16.4	41.5	-11.0	54.1	49.8	16.6	32.6	35.3	28.9	23.6
AOS2	-1.3	5.0	47.1	34.2	-5.7	3.8	-6.7	36.6	13.4	25.0	9.4	20.9
AOS3	63.7	-50.1	51.6	46.5	-2.1	-66.7	60.1	-105.8	-26.3	-23.4	29.4	-39.9
N1	46.5	61.0	55.4	72.9	44.2	63.7	40.2	62.5	48.1	55.6	46.9	63.2
N2	51.2	41.3	45.0	31.4	42.5	40.7	42.2	31.1	50.9	46.2	46.4	38.1
N3	47.0	22.8	36.1	32.3	38.0	24.8	37.5	23.6	30.7	30.7	37.8	26.8
N4	12.5	32.0	7.7	28.2	10.2	8.1	20.7	16.0	18.2	1.7	13.9	17.2
N5	24.1	-6.9	23.4	2.0	20.0	9.6	21.8	9.6	26.1	7.8	23.1	4.4
NGR	36.8	34.2	35.5	41.0	31.7	34.6	33.1	32.6	36.6	31.4	34.7	34.8
PP1	62.9	72.8	57.7	25.9	84.2	12.5	-166.6	20.8	83.6	84.0	24.4	43.2
PP2	24.1	29.3	24.8	-36.3	54.4	34.9	1.1	-1.7	-42.5	-5.6	12.4	4.1
PP3	53.6	-116.9	-19.8	24.0	34.1	-123.1	73.9	10.2	-4.3	65.0	27.5	-28.2

Voice onset time **in the fast rate expressed as a percentage of** ***voice onset time*** **in the normal rate for utterances beginning with a** ***voiceless plosive***

	"pak"/puck		"pet"/pet		"pit"/pit		"pad"/putt		"pap"/pup		Utterance group	
	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2
AOS1	0.2	17.6	2.8	10.1	-49.4	-4.0	6.3	-7.4	0.8	-8.6	-7.9	1.5
AOS2	-2.8	-18.6	-0.2	36.5	3.5	9.0	-9.6	27.8	16.4	-22.8	1.5	6.4
AOS3	-6.4	31.9	34.8	1.0	17.4	17.5	-26.0	59.9	26.6	50.5	9.3	32.2
N1	15.5	38.3	1.8	41.4	10.5	47.5	9.3	21.8	30.7	15.6	13.6	32.9
N2	-24.3	8.2	-25.4	16.6	11.5	-4.7	22.9	-0.4	5.6	-8.7	-2.0	2.2
N3	3.0	16.2	-19.5	16.1	23.0	4.2	-9.7	-1.2	-7.1	-19.3	-2.1	3.2
N4	13.6	-1.9	16.2	-6.9	-4.9	13.8	20.5	6.7	0.8	4.0	9.2	3.1
N5	3.7	29.9	-1.0	12.4	12.1	2.7	8.4	1.1	15.8	36.6	7.8	16.5
NGR	2.3	19.0	-6.1	15.7	11.9	14.4	10.9	4.5	8.1	4.8	5.4	11.7
PP1	23.4	16.1	-11.9	39.8	13.6	-0.7	28.0	40.9	-7.3	28.6	9.1	24.9
PP2	51.9	-3.3	11.4	-35.1	32.0	-3.3	25.2	-45.4	-12.3	-79.8	21.6	-33.4
PP3	-6.7	-22.8	-2.4	17.1	-7.7	-6.7	-3.1	3.2	34.6	21.1	2.9	2.4

Appendix D

Processed data for sub-aim two: Duration of each temporal parameter of each experimental subject expressed as a percentage of the duration of the normal group for each utterance and utterance group for each of the four contexts (L1NR, L1FR, L2NR, L2FR) **Page 2-4**

Vowel duration **of each experimental subject expressed as a percentage of the vowel duration of the normal group for utterances beginning with a *voiceless plosive***

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	33.1	57.7	14.1	36.6	7.3	27.8	18.0	38.3	13.7	41.8	31.7	65.5	28.4	67.2	24.0	45.0	-14.4	19.7	7.9	25.7	13.6	42.8	19.1	42.2
AOS2	47.5	49.5	3.2	13.0	46.2	57.3	47.6	88.5	25.4	17.9	-1.1	-9.4	13.6	30.1	11.7	25.6	35.5	56.1	29.2	57.1	33.6	42.2	18.1	35.0
AOS3	21.6	0.9	-11.8	-9.4	44.5	30.1	25.6	31.1	43.4	22.6	0.8	6.7	24.3	25.4	7.4	36.2	13.0	13.3	-0.5	29.2	29.4	18.5	4.3	18.8
PP1	9.0	21.5	-8.0	-24.0	-13.6	0.6	-9.7	-5.4	-26.9	-25.8	-23.5	-25.5	-4.8	-0.8	-13.7	-13.5	-4.4	-21.1	-16.4	-16.0	-8.1	-5.1	-14.2	-16.9
PP2	-8.6	11.1	-11.1	4.4	-7.3	12.4	-2.3	16.8	22.5	40.1	16.7	13.5	-2.2	8.5	-9.3	23.9	-20.4	-19.6	-13.9	4.3	-3.2	10.5	-4.0	12.6
PP3	30.6	47.0	1.2	21.4	7.4	44.5	13.5	54.4	12.1	20.3	5.1	23.5	17.3	45.8	2.5	25.7	16.3	25.0	1.7	30.7	16.7	36.5	4.8	31.1

Vowel duration **of each experimental subject expressed as a percentage of the vowel duration of the normal group for utterances beginning with a *voiced plosive***

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	13.5	15.8	25.6	54.7	-11.8	19.6	-5.2	30.5	-3.9	21.3	36.6	47.0	-5.1	34.0	16.9	29.0	36.4	43.3	31.0	42.8	5.8	26.8	21.0	40.8
AOS2	32.4	32.7	29.5	50.3	18.6	17.2	8.2	11.9	10.5	20.0	16.2	28.9	34.4	48.2	26.7	49.3	27.0	33.4	22.7	37.5	24.6	30.3	20.7	35.6
AOS3	45.9	49.7	31.9	52.8	35.1	2.5	19.4	9.5	60.2	48.4	37.7	27.9	46.2	47.1	32.7	36.4	47.1	45.1	24.3	49.6	46.9	38.5	29.2	35.2
PP1	-8.7	-8.6	-8.3	-4.4	0.9	-2.1	-2.8	-13.8	1.1	-5.6	4.0	-8.9	1.8	-1.5	13.4	5.1	-8.7	2.0	-11.0	0.1	-2.7	-3.2	-0.9	-4.4
PP2	18.9	47.0	9.2	40.3	-1.7	-5.1	-5.8	9.7	-7.1	2.2	-14.5	2.5	-13.6	-11.1	-12.6	20.2	-18.9	-2.3	-10.6	10.3	-4.5	6.1	-6.9	16.6
PP3	-8.0	3.6	-8.7	8.5	18.1	26.6	-1.7	11.1	6.3	21.7	10.7	25.7	5.9	6.9	23.9	56.3	11.7	22.7	1.8	25.1	6.8	16.3	5.2	25.3

Vowel duration **of each experimental subject expressed as a percentage of the vowel duration of the normal group for utterances beginning with a *voiceless fricative***

	"set"/set				"vas"/fuss				"feit"/fête				"voet"/foot				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	18.0	28.5	18.9	40.9	19.6	37.4	1.0	21.0	10.3	39.4	55.7	61.1	33.7	83.8	24.0	87.4	20.4	47.3	24.9	52.6
AOS2	54.7	25.3	53.3	40.8	10.2	19.3	14.8	27.1	37.7	50.3	30.5	65.9	35.7	40.4	-6.5	20.6	34.6	33.8	23.0	38.6
AOS3	34.3	12.1	24.0	16.6	47.5	32.1	40.3	28.2	44.4	45.0	25.6	67.3	46.3	6.5	-13.6	-3.8	43.1	23.9	19.1	27.1
PP1	-21.2	-14.1	-15.6	-19.1	15.8	-7.7	9.3	2.0	-18.9	-8.3	-4.8	-9.8	-14.2	-8.5	19.6	33.2	-9.6	-9.6	2.1	1.6
PP2	-0.4	20.4	5.4	26.1	17.7	21.5	5.4	22.4	25.6	76.3	37.7	112.9	20.9	35.0	10.7	17.2	15.9	38.3	14.8	44.6
PP3	9.4	24.3	24.0	38.8	8.5	34.4	16.6	46.7	-7.6	14.1	-17.5	3.3	9.5	34.6	-11.8	23.3	5.0	26.8	2.8	28.0

Utterance duration **of each experimental subject expressed as a percentage of the utterance duration of the normal group for utterances beginning with a *voiceless plosive***

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	56.6	67.1	44.5	100.1	14.7	47.4	56.4	55.0	76.1	48.0	25.1	48.3	37.8	67.2	31.7	65.6	12.9	28.2	24.8	34.1	39.6	51.6	36.5	60.6
AOS2	69.5	39.1	59.1	63.8	58.6	32.2	46.8	54.6	49.3	35.6	31.5	37.0	72.3	59.7	71.7	116.5	70.6	35.6	63.0	30.9	64.0	40.5	54.4	60.6
AOS3	-3.6	0.7	-8.8	-5.3	-4.6	-11.7	-5.3	-10.3	0.5	-9.0	-17.0	-18.1	-5.5	3.8	0.3	32.3	-24.5	8.3	-17.8	16.6	-7.5	-1.6	-9.7	3.0
PP1	21.8	43.0	-7.4	27.2	26.2	30.8	3.7	17.0	20.8	18.4	-11.4	21.9	20.5	9.1	3.5	1.5	18.6	34.5	8.3	-15.1	21.6	27.2	-0.7	10.5
PP2	106.9	93.4	61.7	129.7	61.6	101.8	60.0	95.9	55.0	62.0	46.2	79.5	70.4	72.0	72.2	131.8	52.1	67.6	39.9	83.9	69.2	79.4	56.0	104.2
PP3	29.9	45.1	18.0	24.9	22.4	56.9	34.2	69.8	21.5	40.9	15.4	46.9	21.7	49.3	17.2	56.0	17.3	32.5	-5.6	15.9	22.5	44.9	15.8	42.7

Utterance duration **of each experimental subject expressed as a percentage of the utterance duration of the normal group for utterances beginning with a *voiced plosive***

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	41.4	50.1	50.8	60.4	35.4	49.1	40.5	58.6	38.5	49.4	48.3	51.3	26.8	58.1	39.7	72.1	46.5	46.3	49.8	57.6	37.7	50.6	45.8	60.0
AOS2	54.0	31.3	36.8	41.4	51.4	40.7	51.4	41.8	93.4	40.6	31.5	30.8	52.7	36.3	30.1	62.5	74.8	44.7	39.4	57.2	65.3	38.7	37.8	46.8
AOS3	4.1	4.6	-8.8	-3.7	2.3	-2.7	-10.4	-1.7	2.1	1.8	-0.6	25.1	-9.2	14.9	-4.0	8.3	12.8	-0.5	-9.8	-5.2	2.4	3.6	-6.7	4.6
PP1	24.8	24.4	2.0	2.8	18.5	32.8	9.3	-43.3	-3.6	3.9	-18.9	45.0	39.6	28.1	2.8	11.6	38.2	15.8	-9.7	0.9	23.5	21.0	-2.9	3.4
PP2	63.9	80.4	64.5	93.4	50.4	82.9	68.4	111.8	43.8	43.9	45.1	91.7	55.2	98.7	50.8	110.9	56.1	81.8	43.1	82.2	53.9	77.5	54.4	98.0
PP3	21.5	54.6	21.7	3.6	25.8	39.0	36.9	46.5	38.5	45.7	31.1	52.2	9.1	31.3	21.5	50.1	24.1	41.2	6.1	43.7	23.8	42.4	23.4	39.2

Utterance duration **of each experimental subject expressed as a percentage of the utterance duration of the normal group for utterances beginning with a *voiceless fricative***

	"set"/set				"vas"/fuss				"feit"/fête				"voet"/foot				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	29.2	60.9	38.3	78.8	13.5	48.5	25.4	75.4	42.6	50.8	40.5	78.8	34.6	64.4	45.4	67.7	30.0	56.1	37.4	75.2
AOS2	50.1	38.1	26.3	48.7	36.4	58.3	32.8	75.0	30.1	66.4	43.1	92.4	40.2	33.9	26.9	39.2	39.2	49.2	32.3	63.8
AOS3	7.3	5.4	18.2	13.9	-1.6	4.1	2.7	7.6	3.9	4.4	-3.5	15.2	0.0	0.7	-1.7	17.5	2.4	3.7	3.9	13.5
PP1	28.0	13.1	-1.4	23.4	12.5	14.6	11.0	22.5	24.1	19.2	2.0	-1.2	26.3	28.2	1.3	32.7	22.7	18.8	3.2	19.3
PP2	23.5	48.7	41.9	72.6	17.9	50.3	46.5	77.2	43.4	76.9	41.2	86.8	20.4	85.6	41.2	69.1	26.3	65.4	42.7	76.4
PP3	9.7	13.0	-0.9	14.3	6.5	21.9	-3.8	55.4	-3.5	33.8	-11.2	20.3	-1.6	22.5	6.2	23.0	2.8	22.8	-2.4	28.3

Utterance onset duration **of each experimental subject expressed as a percentage of the utterance onset duration of the normal group for utterances beginning with a *voiceless plosive***

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	135.2	667.0	545.3	564.8	312.1	304.6	481.6	1145.4	399.6	1210.3	618.2	1212.6	176.7	372.8	593.8	860.6	244.2	737.0	307.8	542.4	253.6	658.3	509.3	865.2
AOS2	229.6	298.8	154.8	657.8	177.0	132.6	63.0	394.4	230.4	239.6	294.5	313.2	351.8	186.8	105.9	510.9	128.1	223.3	204.7	164.6	223.4	216.2	164.6	408.2
AOS3	70.9	33.9	1.1	45.6	112.5	89.6	240.5	277.7	148.2	70.6	27.5	103.6	83.0	229.4	55.0	121.9	212.1	101.8	7.8	24.4	125.3	105.0	66.4	114.6
PP1	94.3	104.0	234.9	99.9	59.2	0.1	316.8	117.8	67.8	10.7	46.9	62.5	510.1	-8.2	92.7	30.6	426.7	113.3	214.4	79.4	231.6	44.0	181.2	78.0
PP2	555.4	108.8	261.4	351.0	-0.1	44.3	0.5	54.2	26.6	38.2	0.5	107.3	3.3	97.4	60.0	201.8	9.4	32.5	-11.6	64.3	118.9	64.2	62.2	155.7
PP3	-24.7	-11.0	22.6	292.8	-25.2	-1.2	-45.7	-7.1	-26.0	-18.7	-35.5	-17.5	-16.2	-24.7	-33.8	12.9	68.5	-13.9	-22.3	-22.2	-4.7	-13.9	-23.0	51.8

Utterance onset duration **of each experimental subject expressed as a percentage of the utterance onset duration of the normal group for utterances beginning with a *voiced plosive***

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	519.7	322.6	1130.9	2324.7	374.9	515.9	1029.2	1020.2	1063.3	1790.6	589.5	384.2	896.0	646.6	1710.6	2140.6	178.0	195.6	1359.5	1276.4	606.4	694.3	1163.9	1429.2
AOS2	252.7	465.1	140.0	246.4	260.9	196.3	311.0	358.7	275.4	480.8	147.4	264.2	288.0	518.7	626.3	583.8	208.2	320.6	177.0	203.1	257.0	396.3	280.3	331.2
AOS3	140.2	37.8	93.1	340.3	173.8	105.4	76.5	60.1	142.0	261.8	86.8	376.4	155.5	52.2	65.6	405.7	53.8	206.2	4.9	88.7	133.1	132.7	65.4	254.2
PP1	105.8	20.8	448.6	126.5	88.1	23.4	288.6	388.1	378.0	10.5	19.7	60.2	33.3	431.1	107.3	143.6	266.7	-5.0	366.1	8.5	174.4	96.2	246.1	145.4
PP2	14.8	37.7	178.0	198.5	33.5	55.7	20.7	179.0	233.6	122.8	64.8	64.2	37.4	102.9	-0.7	49.9	-5.3	112.7	-0.7	53.0	62.8	86.4	52.4	108.9
PP3	0.7	-26.1	-35.0	114.0	-13.9	60.1	-33.4	-14.1	-28.7	-31.3	-37.1	114.8	108.5	-18.6	-43.8	-25.1	-38.5	1.2	143.2	24.0	5.6	-2.9	-1.2	42.7

Voice onset time **of each experimental subject expressed as a percentage of the voice onset time of the normal group for utterances beginning with a *voiceless plosive***

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup				utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	139.5	144.5	141.3	145.5	130.5	111.2	111.4	125.5	67.5	184.1	119.4	166.5	127.1	138.6	158.9	191.4	80.8	95.2	92.5	119.5	109.1	134.7	124.7	149.7
AOS2	18.3	24.4	-11.8	29.1	-3.2	-8.6	-11.8	-33.6	19.5	30.9	1.1	7.5	14.0	40.2	2.8	-22.3	28.0	16.4	-36.7	-18.4	15.3	20.7	-11.3	-7.5
AOS3	-9.5	-1.6	72.5	45.0	23.4	-24.3	46.0	71.5	0.9	-5.4	36.2	31.2	-0.9	40.0	203.0	27.3	9.6	-12.4	104.5	6.3	4.7	-0.7	92.4	36.2
PP1	76.5	38.3	43.2	48.3	63.2	72.1	109.4	49.5	57.3	54.4	15.1	35.3	102.4	63.5	165.3	64.3	39.0	62.3	97.4	48.0	67.7	58.1	86.1	49.1
PP2	225.5	60.3	59.1	102.9	28.3	7.1	-22.7	23.8	26.9	-2.0	33.3	60.8	53.8	29.1	-0.9	50.8	25.1	52.8	-5.7	78.1	71.9	29.5	12.6	63.3
PP3	4.8	14.4	-16.7	26.2	15.3	11.2	4.0	2.2	-11.0	8.8	-6.5	16.6	4.4	20.7	-3.5	-2.2	9.5	-22.1	-11.1	-26.3	4.6	6.6	-6.8	3.3

Appendix E

Processed data for sub-aim two to determine the context (L1NR, L1FR, L2NR or L2FR) in which each experimental subject differed most from the normal group **Page 2-10**

Assigned values of one to four indicative of the extent each pathologic subject differed from the normal group across the four contexts regarding *vowel duration* for individual utterances in the *voiceless plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
“pak”/puck	3	1	4	2	2	1	4	3	1	2	4*	3*	2	1	3*	4*	3*	1	4*	2	2	1	4	3
“pet”/pet	4	2	3	1	4	2	3	1	1	3	4	2	4*	1	3*	2*	4*	2	3*	1	4	2	3	1
“pit”/pit	4	2	3	1	1	2	3*	4*	1	2	4	3	4*	3*	1*	2*	2	1	3	4	3	2	4	1
“pad”/putt	3	1	4	2	3	1	4	2	3	2	4	1	2*	1*	4*	3*	3*	2	4*	1	3	1	4	2
“pap”/pup	4*	2	3	1	3	2	4	1	3	2	4*	1	1*	4*	3*	2*	4*	3*	2*	1	3	2	4	1

A value of one indicates that the difference in duration between the subject and the normal group was the greatest, whereas a value of four indicates the difference was the least.
* The duration of the experimental subject was shorter than that of the normal group

The percentage of utterances in each context for the *voiceless plosive utterance group* which were assigned a value of one, for determination of the context where the difference between the *vowel duration* of each pathologic subject and the normal group was generally the greatest

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	Context with the largest percentage of utterances assigned a value of one
AOS1	0	40	0	60	L2FR
AOS2	20	40	0	40	L1FR and L2FR
AOS3	60	0	0	40	L1NR
PP1	20	60	20	0	L1FR
PP2	0	40	0	60	L2FR
PP3	0	40	0	60	L2FR

Assigned values of one to four indicative of the extent each pathologic subject differed from the normal group across the four contexts regarding *vowel duration* for individual utterances in the *voiced plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"byt"/bait	4	3	2	1	3	2	4	1	3	2	4	1	4*	3*	2*	1*	3	1	4	2	3*	2	4*	1
"bak"/buck	4*	2	3*	1	1	2	4	3	1	4	2	3	1	2*	3*	4*	2*	3*	4*	1	2	1	4*	3
"bas"/bus	4*	3	2	1	4	2	3	1	1	2	3	4	2	3*	1	4*	3*	2	4*	1	4	2	3	1
"bek"/back	4*	1	3	2	3	2	4	1	2	1	4	3	3	4*	1	2	4*	2*	3*	1	4	3	2	1
"bed"/bet	3	1	4	2	3	2	4	1	2	3	4	1	3*	1	4*	2	4*	2*	3*	1	3	2	4	1

A value of one indicates that the difference in duration between the subject and the normal group was the greatest, whereas a value of four indicates the difference was the least.
* The duration of the experimental subject was shorter than that of the normal group

The percentage of utterances in each context for the *voiced plosive utterance group* which were assigned a value of one, for determination of the context where the difference between the *vowel duration* of each pathologic subject and the normal group was generally the greatest

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	Context with the largest percentage of utterances assigned a value of one
AOS1	0	40	0	60	L2FR
AOS2	20	0	0	80	L2FR
AOS3	40	20	0	40	L1NR and L2FR
PP1	20	20	40	20	L2NR
PP2	0	20	0	80	L2FR
PP3	0	20	0	80	L2FR

Assigned values of one to four indicative of the extent each pathologic subject differed from the normal group across the four contexts regarding *vowel duration* for individual utterances in the *voiceless fricative utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
“set”/set	4	2	3	1	1	4	2	3	1	4	2	3	4*	1*	2*	3*	4*	2	3	1	4	2	3	1
“vas”/fuss	3	1	4	2	4	2	3	1	1	3	2	4	1	4*	2	3	3	2	4	1	4	2	3	1
“feit”/fête	4	3	2	1	3	2	4	1	3	2	4	1	4*	2*	1*	3*	4	2	3	1	3*	1	4*	2
“voet”/foot	3	2	4	1	2	1	4*	3	1	2	4*	3*	4*	3*	2	1	2	1	4	3	3	1	4*	2

A value of one indicates that the difference in duration between the subject and the normal group was the greatest, whereas a value of four indicates the difference was the least.

* The duration of the experimental subject was shorter than that of the normal group

The percentage of utterances in each context for the *voiceless fricative utterance group* which were assigned a value of one, for determination of the context where the difference between the *vowel duration* of each pathologic subject and the normal group was generally the greatest

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	Context with the largest percentage of utterances assigned a value of one
AOS1	0	25	0	75	L2FR
AOS2	25	25	0	50	L2FR
AOS3	75	0	0	25	L1NR
PP1	25	25	25	25	All four contexts are equal
PP2	0	25	0	75	L2FR
PP3	0	50	0	50	L1FR and L2FR

Assigned values of one to four indicative of the extent each experimental subject differed from the normal group across the four contexts regarding *utterance duration* for individual utterances in the *voiceless plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"pak"/puck	3	2	4	1	1	4	3	2	2*	1	4*	3*	3	1	4*	2	2	3	4	1	2	1	4	3
"pet"/pet	4	3	1	2	1	4	3	2	1*	4*	2*	3*	2	1	4	3	3	1	4	1	4	2	3	1
"pit"/pit	1	3	4	2	1	3	4	2	1	2*	3*	4*	2	3	4*	1	3	2	4	2	3	2	4	1
"pad"/putt	3	1	4	2	2	4	3	1	4*	2	3	1	1	2	3	4	4	3	2	1	3	2	4	1
"pap"/pup	4	2	3	1	1	3	2	4	4*	2	3*	1	2	1	3	4*	3	2	4	1	2	1	4*	3

A value of one indicates that the difference in duration between the subject and the normal group was the greatest, whereas a value of four indicates the difference was the least.
* The duration of the experimental subject was shorter than that of the normal group.

The percentage of utterances in each context for the *voiceless plosive utterance group* which were assigned a value of one, for determination of the context where the difference between the *utterance duration* of each experimental subject and the normal group was generally the greatest

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	Context with the largest percentage of utterances assigned a value of one
AOS1	20	20	20	40	L2FR
AOS2	80	0	0	20	L1NR
AOS3	40	20	0	40	L1NR and L2FR
PP1	20	60	0	20	L1FR
PP2	0	20	0	80	L2FR
PP3	0	40	0	60	L2FR

Assigned values of one to four indicative of the extent each experimental subject differed from the normal group across the four contexts regarding *utterance duration* for individual utterances in the *voiced plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"byt"/bait	4	3	2	1	1	4	3	2	2	1	4*	3*	1	2	4	3	4	2	3	1	3	1	2	4
"bak"/buck	4	2	3	1	1/2	4	1/2	3	1	3*	4*	2*	2	1	3	4*	4	2	3	1	4	2	3	1
"bas"/bus	4	2	3	1	1	2	3	4	2	3	4*	1	3*	2	4*	1	4	3	2	1	3	2	4	1
"bek"/back	4	2	3	1	2	3	4	1	4*	1	3*	2	1	2	4	3	3	2	4	1	4	2	3	1
"bed"/bet	3	4	2	1	1	3	4	2	1	2*	4*	3*	1	2	4*	3	3	2	4	1	3	2	4	1

A value of one indicates that the difference in duration between the subject and the normal group was the greatest, whereas a value of four indicates the difference was the least.
* The duration of the experimental subject was shorter than that of the normal group.

The percentage of utterances in each context for the *voiced plosive utterance group* which were assigned a value of one, for determination of the context where the difference between the *utterance duration* of each experimental subject and the normal group was generally the greatest

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	Context with the largest percentage of utterances assigned a value of one
AOS1	0	0	0	100	L2FR
AOS2	80	0	20	20	L1NR
AOS3	40	40	0	20	L1NR and L1FR
PP1	60	20	0	20	L1NR
PP2	0	0	0	100	L2FR
PP3	0	20	0	80	L2FR

Assigned values of one to four indicative of the extent each experimental subject differed from the normal group across the four contexts regarding *utterance duration* for individual utterances in the *voiceless fricative utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"set"/set	4	2	3	1	1	3	4	2	3	4	1	2	1	3	4*	2	4	2	3	1	3	2	4*	1
"vas"/fuss	4	2	3	1	3	2	4	1	4*	2	3	1	3	2	4	1	4	2	3	1	3	2	4*	1
"feit"/fête	3	2	4	1	4	2	3	1	3	2	4*	1	1	2	3	4*	3	2	4	1	3*	1	4*	2
"voet"/foot	3	2	3	1	1	3	4	2	3	2	4*	1	3	2	4	1	4	1	3	2	4*	2	3	1

A value of one indicates that the difference in duration between the subject and the normal group was the greatest, whereas a value of four indicates the difference was the least.
* The duration of the experimental subject was shorter than that of the normal group.

The percentage of utterances in each context for the *voiceless fricative utterance group* which were assigned a value of one, for determination of the context where the difference between the *utterance duration* of each experimental subject and the normal group was generally the greatest

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	Context with the largest percentage of utterances assigned a value of one
AOS1	0	0	0	100	L2FR
AOS2	50	0	0	50	L1NR and L2FR
AOS3	0	0	25	75	L2FR
PP1	50	0	0	50	L1NR and L2FR
PP2	0	25	0	75	L2FR
PP3	0	25	0	75	L2FR

Assigned values of one to four indicative of the extent each experimental subject differed from the normal group across the four contexts regarding *utterance onset duration* for individual utterances in the *voiceless plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"pak"/puck	4	1	3	2	3	2	4	1	1	3	4	2	4	2	1	3	1	4	3	2	4*	3*	2	1
"pet"/pet	3	4	2	1	2	3	4	1	3	4	2	1	3	4	1	2	4*	2	3	1	3*	1*	4*	2*
"pit"/pit	4	2	3	1	4	3	2	1	1	3	4	2	1	4	3	2	3	2	4	1	3*	2*	4*	1*
"pad"/putt	4	3	2	1	2	3	4	1	3	1	4	2	1	4*	2	3	4	2	3	1	2*	3*	4*	1
"pap"/pup	4	1	3	2	4	1	2	3	1	2	4	3	1	3	2	4	3	2	4*	1	1	2*	4*	3*

A value of one indicates that the difference in duration between the subject and the normal group was the greatest, whereas a value of four indicates the difference was the least.
* The duration of the experimental subject was shorter than that of the normal group.

The percentage of utterances in each context for the *voiceless plosive utterance group* which were assigned a value of one, for determination of the context where the difference between the *utterance onset duration* of each experimental subject and the normal group was generally the greatest

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	Context with the largest percentage of utterances assigned a value of one
AOS1	0	40	0	60	L2FR
AOS2	0	20	0	80	L2FR
AOS3	60	20	0	20	L1NR
PP1	60	0	40	0	L1NR
PP2	20	0	0	80	L2FR
PP3	20	20	0	60	L2FR

Assigned values of one to four indicative of the extent each experimental subject differed from the normal group across the four contexts regarding *utterance onset duration* for individual utterances in the *voiced plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"byt"/bait	3	4	2	1	2	1	4	3	2	4	3	1	3	4	1	2	4	3	2	1	2	3*	4*	1
"bak"/buck	4	3	1	2	3	4	2	1	1	2	3	4	3	4	2	1	3	2	4	1	2*	1	4*	3*
"bas"/bus	2	1	3	4	2	1	4	3	3	2	4	1	1	4	3	2	1	2	3	4	2*	3*	4*	1
"bek"/back	3	4	2	1	4	3	1	2	2	4	3	1	4	1	3	2	3	1	4*	2	1	2*	4*	3*
"bed"/bet	4	3	1	2	2	1	4	3	3	1	4	2	2	4*	1	3	4*	1	3*	2	4*	3	1	2

A value of one indicates that the difference in duration between the subject and the normal group was the greatest, whereas a value of four indicates the difference was the least
* The duration of the experimental subject was shorter than that of the normal group.

The percentage of utterances in each context for the *voiced plosive utterance group* which were assigned a value of one, for determination of the context where the difference between the *utterance onset duration* of each experimental subject and the normal group was generally the greatest

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	Context with the largest percentage of utterances assigned a value of one
AOS1	0	20	40	40	L2NR and L2FR
AOS2	0	60	20	20	L1FR
AOS3	20	20	0	60	L2FR
PP1	20	20	40	20	L2NR
PP2	20	40	0	40	L1FR and L2FR
PP3	20	20	20	40	L2FR

Assigned values of one to four indicative of the extent each experimental subject differed from the normal group across the four contexts regarding *voice onset time* for individual utterances in the *voiceless plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
“pak”/puck	4	2	3	1	3	2	4*	1	4*	3*	1	2	1	4	3	2	1	3	4	2	3	2	4*	1
“pet”/pet	1	4	3	2	1*	2*	3*	4*	3	4*	2	1	3	2	1	4	1	3	4*	2	1	2	3	4
“pit”/pit	4	1	3	2	2	1	4	3	3	4*	1	2	1	2	4	3	3	4*	2	1	4*	2	3*	1
“pad”/putt	4	3	2	1	2	1	3	4*	4*	2	1	3	2	4	1	3	1	3	4*	2	2	1	4*	3*
“pap”/pup	4	2	3	1	1	2	4*	3*	2	4*	1	3	4	2	1	3	3	2	4*	1	1	3*	2*	4*

A value of one indicates that the difference in duration between the subject and the normal group was the greatest, whereas a value of four indicates the difference was the least.
* The duration of the experimental subject was shorter than that of the normal group.

The percentage of utterances in each context for the *voiceless plosive utterance group* which were assigned a value of one, for determination of the context where the difference between the *voice onset time* of each experimental subject and the normal group was generally the greatest

	L1NR (%)	L1FR (%)	L2NR (%)	L2FR (%)	Context with the largest percentage of utterances assigned a value of one
AOS1	20	20	0	60	L2FR
AOS2	40	40	0	20	L1NR and L1FR
AOS3	0	0	80	20	L2NR
PP1	40	0	60	0	L2NR
PP2	60	0	0	40	L1NR
PP3	40	20	0	40	L1NR and L2FR

Appendix F

Processed data for sub-aim three to determine the context (L1NR, L1FR, L2NR or L2FR) in which variability was generally the greatest for each subject **Page 2-6**

Assigned values of one to four indicative of the extent of variability regarding *vowel duration* across the four contexts for utterances in the *voiceless plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
“pak”/puck	3	1	2	4	2	1	3	4	1	3	4	2	4	3	1	2	2	3	4	1	3	1	2	4
“pet”/pet	4	2	1	3	2	4	3	1	4	1	3	2	2	4	1	3	1	2	4	3	4	2	3	1
“pit”/pit	4	2	3	1	2	3	1	4	1	2	3	4	1	2	3	4	3	4	1	2	3	1	4	2
“pad”/putt	4	2	1	3	4	2	3	1	4	2	1	3	2	3	1	4	4	2	3	1	4	1	3	2
“pap”/pup	4	2	3	1	4	1	2	3	4	3	2	1	2/3	2/3	1	4	2	3	1	4	2	4	3	1

	N1				N2				N3				N4				N5				NGR			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
“pak”/puck	1	3	2	4	1	4	2	3	4	1	2	3	1	3	4	2	2	4	3	1	1	4	3	2
“pet”/pet	3	4	1	2	2	3	1	4	2	3	4	1	2	4	1	3	1	2	3	4	2	4	1	3
“pit”/pit	2	3	1	4	2	3	1	4	1	4	2	3	2	3	1	4	1	4	3	2	2	3	1	4
“pad”/putt	3	2	4	1	1	3	4	2	3	1	2	4	4	2	3	1	1	2	4	3	3	2	4	1
“pap”/pup	3	4	2	1	3	1	4	2	4	2	3	1	2	1	3	4	1	3	2	4	3	2	4	1

A value of one indicates that the standard deviation was the greatest, whereas a value of four indicates the standard deviation was the smallest.

Assigned values of one to four indicative of the extent of variability regarding *vowel duration* across the four contexts for utterances in the *voiced plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
“byt”/bait	4	2/3	1	2/3	4	3	1	2	4	1	3	2	1	4	2/3	2/3	2	4	3	1	1	4	3	2
“bak”/buck	2	4	3	1	1	2	4	3	4	3	2	1	2	4	1	3	2	3	4	1	3	1	4	2
“bas”/bus	3	4	2	1	2	1	4	3	1	4	3	2	1	4	3	2	4	2	3	1	1	3	2	4
“bek”/back	4	1	3	2	1	3	4	2	3	4	1	2	1	2	3	4	4	2	1	3	3	4	1	2
“bed”/bet	4	2	3	1	2	1	4	3	2	1	4	3	4	2	3	1	1	4	2	3	1	4	3	2

	N1				N2				N3				N4				N5				NGR			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
“byt”/bait	3	4	1	2	2	4	1	3	1	4	2	3	2	4	3	1	2	4	3	1	2	4	1	3
“bak”/buck	3	4	1	2	3	4	2	1	4	2	3	1	3	2	4	1	3	4	2	1	3	4	2	1
“bas”/bus	3	4	2	1	2	4	1	3	4	3	2	1	2	1	4	3	1	4	2	3	2	4	3	1
“bek”/back	4	2	3	1	2	1	4	3	4	3	2	1	1	3	4	2	1	3	2	4	3	2	4	1
“bed”/bet	3/4	2	1	3/4	1	4	3	2	3	2	4	1	1	3	4	2	3	2	4	1	1	4	3	2

A value of one indicates that the standard deviation was the greatest, whereas a value of four indicates the standard deviation was the smallest.

Assigned values of one to four indicative of the extent of variability regarding *vowel duration* across the four contexts for utterances in the *voiceless fricative utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
“set”/set	4	2	1	3	3	2	4	1	3	1	2	4	1	3	2	4	4	1	3	2	2	1	4	3
“vas”/fuss	1	2	3	4	2	1	4	3	1	4	3	2	1	4	2	3	1	3	2	4	3	1	4	2
“feit”/fête	4	3	1	2	2	4	1	3	4	2	1	3	1	2	4	3	3	2	1	4	1	2	4	3
“voet”/foot	3	1	4	2	2	4	1	3	2	1	3	4	2	4	3	1	2	3	1	4	3	4	2	1

	N1				N2				N3				N4				N5				NGR			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
“set”/set	4	3	1	2	1	3	2	4	4	2	3	1	3	2	4	1	1	2	4	3	4	2	3	1
“vas”/fuss	2/3	4	1	2/3	2	1	3	4	3	2	1	4	2	4	3	1	1	4	2	3	2	4	1	3
“feit”/fête	4	3	1	2	4	3	1	2	4	2	3	1	1	3	2	4	1	4	2	3	2	4	1	3
“voet”/foot	4	1	2	3	4	3	1	2	4	3	2	1	3	4	1	2	1	3	4	2	4	3	1	2

A value of one indicates that the standard deviation was the greatest, whereas a value of four indicates the standard deviation was the smallest.

Assigned values of one to four indicative of the extent of variability regarding *utterance duration* across the four contexts for utterances in the *voiceless plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
“pak”/puck	3	4	2	1	3	4	2	1	2	1	4	3	4	2	3	1	2	4	3	1	4	3	1	2
“pet”/pet	1	4	2	3	2	4	3	1	3	2	1	4	2	1	3	4	1	2	4	3	3	1	4	2
“pit”/pit	1	2	4	3	4	1	3	2	1	2	4	3	1	2	3	4	2	1	4	3	3	2	4	1
“pad”/putt	4	1	2	3	3	2	4	1	3	4	2	1	2	1	4	3	2	4	1	3	4	1	3	2
“pap”/pup	4	2	3	1	2	3	1	4	2	4	3	1	4	1	2	3	4	1	3	2	1	3	4	2

	N1				N2				N3				N4				N5				NGR			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
“pak”/puck	2	4	1	3	4	3	2	1	4	3	2	1	3	4	1	2	3	1	2	4	4	3	1	2
“pet”/pet	4	2	1	3	3	2	4	1	2	1	4	3	4	2	3	1	3	4	1	2	4	2	3	1
“pit”/pit	2	4	1	3	3	4	2	1	4	3	1	2	2	1	3	4	1	3	2	4	2	3	1	4
“pad”/putt	3	1	2	4	3	4	1	2	2	1	3	4	3	4	1	2	2	3	1	4	2	4	1	3
“pap”/pup	1	4	2	3	2	4	3	1	2	1	4	3	4	3	2	1	3	4	2	1	3	4	2	1

A value of one indicates that the standard deviation was the greatest, whereas a value of four indicates the standard deviation was the smallest.

Assigned values of one to four indicative of the extent of variability regarding *utterance duration* across the four contexts for utterances in the *voiced plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"byt"/bait	3	2	1	4	3	4	2	1	4	1	3	2	2	1	3	4	3	4	2	1	4	2	1	3
"bak"/buck	4	3	1	2	4	2	3	1	3	4	2	1	3	2	4	1	2	3	1	4	2	3	4	1
"bas"/bus	2	4	1	3	1	2	3	4	4	1	3	2	3	4	2	1	1	2	3	4	2	4	1	3
"bek"/back	3	1	2	4	2	3	4	1	2	4	1	3	1	2	4	3	3	1	2	4	2	3	1	4
"bed"/bet	4	3	1	2	4	3	2	1	2	1	4	3	1	3	2	4	3	1	4	2	1	4	3	2

	N1				N2				N3				N4				N5				NGR			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"byt"/bait	3	4	1	2	4	3	1	2	2	3	1	4	1	3	2	4	2	1	3	4	3	2	1	4
"bak"/buck	2	1	4	3	2	3	4	1	3	4	1	2	2	4	3	1	1	4	2	3	2	4	3	1
"bas"/bus	1	4	3	2	3	4	2	1	3	4	1	2	4	2	3	1	4	1	2	3	4	1	3	2
"bek"/back	1	3	2	4	2	4	3	1	2	4	3	1	1	4	2	3	2	3	4	1	1	4	3	2
"bed"/bet	2	4	1	3	1	4	3	2	3	1	2	4	2	1	3	4	3	4	2	1	3	4	2	1

A value of one indicates that the standard deviation was the greatest, whereas a value of four indicates the standard deviation was the smallest.

Assigned values of one to four indicative of the extent of variability regarding *utterance duration* across the four contexts for utterances in the *voiceless fricative utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"set"/set	4	2	3	1	1	3	4	2	4	3	1	2	1	4	3	2	3	2	4	1	2	4	3	1
"vas"/fuss	3	1	4	2	4	1	3	2	3	2	4	1	2	3	1	4	2	3	1	4	3	1	4	2
"feit"/fête	1	3	2	4	4	1	2	3	2	1	4	3	2	3	1	4	1	4	3	2	4	3	1	2
"voet"/foot	1	4	2	3	4	1	3	2	4	2	3	1	3	1	4	2	4	3	1	2	4	3	2	1

	N1				N2				N3				N4				N5				NGR			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"set"/set	2	3	1	4	3	2	1	4	3	4	2	1	4	3	1	2	2	3	1	4	2	3	1	4
"vas"/fuss	2	1	4	3	4	1	2	3	3	2	1	4	3	1	2	4	2	3	1	4	3	1	2	4
"feit"/fête	1	4	2	3	3	2	4	1	3	4	1	2	4	3	2	1	2	3	1	4	2	4	1	3
"voet"/foot	2	4	1	3	4	3	1	2	4	1	2	3	3	4	1	2	3	1	2	4	4	2	1	3

A value of one indicates that the standard deviation was the greatest, whereas a value of four indicates the standard deviation was the smallest.

Assigned values of one to four indicative of the extent of variability regarding *utterance onset duration* across the four contexts for utterances in the *voiceless plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"pak"/puck	4	2	1	3	1	3	4	2	1	3	4	2	2	4	1	3	1	4	2	3	3	4	2	1
"pet"/pet	4	3	1	2	1	3	4	2	3	4	1	2	3	4	1	2	1	2	3	4	3	1	4	2
"pit"/pit	4	2	3	1	2	4	1	3	1	4	3	2	1	4	2	3	1	4	3	2	2	4	3	1
"pad"/putt	4	3	2	1	2	3	4	1	2	1	3	4	1	4	2	3	4	3	2	1	1	3	4	2
"pap"/pup	4	1	3	2	2	3	1	4	1	2	3	4	2	4	1	3	2	4	3	1	1	4	2	3

	N1				N2				N3				N4				N5				NGR			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"pak"/puck	1	3	2	4	2	4	3	1	2	3	1	4	2	3	1	4	3	1	4	2	1	3	2	4
"pet"/pet	2	4	1	3	3	1	4	2	2	4	1	3	3	2	1	4	4	2	1	3	3	2	1	4
"pit"/pit	1	3	2	4	3	2	4	1	1	2	3	4	1	2	4	3	4	2	3	1	1	3	4	2
"pad"/putt	1	3	2	4	3	2	4	1	4	2	1	3	1	2	4	3	3	4	1	2	1	2	3	4
"pap"/pup	2	3	1	4	4	3	2	1	2	4	1	3	1	4	2	3	3	1	4	2	2	3	1	4

A value of one indicates that the standard deviation was the greatest, whereas a value of four indicates the standard deviation was the smallest.

Assigned values of one to four indicative of the extent of variability regarding *utterance onset duration* across the four contexts for utterances in the *voiced plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"byt"/bait	3	4	1	2	4	1	3	2	2	4	3	1	3	4	1	2	4	3	1	2	2	4	3	1
"bak"/buck	3	4	1	2	2	4	1	3	2	3	1	4	3	4	2	1	3	4	2	1	2	1	3	4
"bas"/bus	2	1	3	4	1	2	4	3	4	2	3	1	1	1	3	2	1	3	2	4	3	4	2	1
"bek"/back	3	4	2	1	4	3	1	2	2	4	3	1	4	4	3	2	2	1	4	3	1	2	4	3
"bed"/bet	3	4	1	2	2	1	3	4	2	1	4	3	1	4	2	3	2	1	3	4	4	3	1	2

	N1				N2				N3				N4				N5				NGR			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"byt"/bait	3	2	1	4	4	2	3	1	1	3	2	4	4	1	3	2	3	2	4	1	3	4	1	2
"bak"/buck	2	3	1	4	3	2	4	1	2	3	1	4	2	3	1	4	4	2	3	1	2	4	1	3
"bas"/bus	2	4	1	3	4	2	3	1	4	2	1	3	1	2	3	4	3	1	4	2	2/3	2/3	1	4
"bek"/back	3	2	1	4	3	4	2	1	4	3	1	2	4	1	2	3	3	4	2	1	4	3	1	2
"bed"/bet	1	3	2	4	1	4	3	2	1	4	2	3	1	4	3	2	3	2	4	1	1	4	2	3

A value of one indicates that the standard deviation was the greatest, whereas a value of four indicates the standard deviation was the smallest.

Assigned values of one to four indicative of the extent of variability regarding *voice onset time* across the four contexts for utterances in the *voiceless plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"pak"/puck	1	3	2	4	1	2	3	4	4	3	2	1	1	3	2	4	1	4	2	3	2	3	4	1
"pet"/pet	3	4	1	2	2	3	1	4	3	4	2	1	2	3	1	4	1	4	3	2	4	2	1	3
"pit"/pit	4	3	1	2	1	2	3	4	3	4	1	2	1	2	3	4	1	4	2	3	4	3	1	2
"pad"/putt	3	4	2	1	1	3	2	4	2	3	1	4	3	2	1	4	3	4	1	2	4	3	1	2
"pap"/pup	1	2	4	3	1	3	2	4	2	4	1	3	2	3	1	4	3	4	1	2	2	4	3	1

	N1				N2				N3				N4				N5				NGR			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"pak"/puck	2	3	1	4	2/3	2/3	1	4	1	3	2	4	1	3/4	2	3/4	3	1	2	4	1	3	2	4
"pet"/pet	2	3/4	1	3/4	3	2	4	1	3	2	1	4	1	4	2	3	4	1/2	1/2	3	3	2	1	4
"pit"/pit	1	4	2	3	2	4	1	3	1	3	2	4	4	1	2	3	3	2	1	4	2	3	1	4
"pad"/putt	2	3	1	4	1	4	2	3	4	2	1	3	1	4	3	2	2	1	4	3	1	4	2	3
"pap"/pup	1	4	2	3	2	3	1	4	2	4	3	1	2	3	1	4	3	1/2	1/2	4	1	4	2	3

A value of one indicates that the standard deviation was the greatest, whereas a value of four indicates the standard deviation was the smallest.

Assigned values of one to four indicative of the extent of variability regarding *voice onset time* across the four contexts for utterances in the *voiced plosive utterance group*

	AOS1				AOS2				AOS3				PP1				PP2				PP3			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"byt"/bait	3	1	2	4	3	2	1	4	3	1	4	2	3	1	2	4	4	1	3	2	1	4	2	3
"bak"/buck	4	2	1	3	4	3	2	1	2	3	1	4	3	4	2	1	2	4	1	3	3	1	2	4
"bas"/bus	4	3	2	1	1	4	2	3	1	4	3	2	1	4	3	2	2	4	1	3	3	4	2	1
"bek"/back	4	2	1	3	4	3	1	2	1	2	4	3	3	1	2	4	4	1	3	2	1	2	4	3
"bed"/bet	3	4	2	1	1	2	3	4	2	1	4	3	1	3	4	2	2	4	1	3	3	1	4	2

	N1				N2				N3				N4				N5				NGR			
	L1		L2		L1		L2		L1		L2		L1		L2		L1		L2		L1		L2	
	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR	NR	FR
"byt"/bait	4	1	3	2	1	4	2	3	1	3	2	4	1	4	2	3	2	3	4	1	1	4	2	3
"bak"/buck	4	2	3	1	4	3	1	2	1	3	2	4	3	2	1	4	4	1	3	2	4	3	1	2
"bas"/bus	1	3	4	2	4	3	2	1	4	2	1	3	1	3	2	4	3	1	4	2	1	3	2	4
"bek"/back	1	2	4	3	1	4	2	3	4	3	1	2	1	2	3	4	3	4	2	1	1	3	2	4
"bed"/bet	2	1	4	3	1	4	2	3	1	4	2	3	1	4	3	2	3	2	4	1	1	4	2	3

A value of one indicates that the standard deviation was the greatest, whereas a value of four indicates the standard deviation was the smallest.

Appendix G

Standard deviations of each temporal parameter of each experimental subject expressed as a percentage of the standard deviation of the normal group for each utterance and utterance group for each of the four contexts (L1NR, L1FR, L2NR and L2FR) **Page 2-4**

The *standard deviation* of *vowel duration* of each experimental subject expressed as a percentage of the *standard deviation* of the normal group for utterances beginning with a *voiceless plosive*

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	-35.2	134.2	43.1	-51.1	-31.6	125.0	132.2	34.5	-51.6	249.4	4.7	350.2	-37.5	176.9	355.4	69.0	5.8	73.1	95.0	95.9	-30.0	151.7	126.1	99.7
AOS2	62.1	227.7	62.8	45.3	48.2	44.7	29.5	106.6	-47.2	-23.8	-1.9	-59.9	34.8	46.1	107.9	16.2	5.9	71.4	68.4	-3.6	20.8	73.2	53.3	20.9
AOS3	194.0	143.1	104.0	121.5	-67.1	57.7	-28.3	22.9	152.4	246.8	-19.9	20.7	-25.1	8.2	67.4	-23.9	0.1	67.5	297.4	226.1	50.9	104.7	84.1	73.5
PP1	-61.0	-6.7	16.3	-1.4	8.6	36.3	0.7	19.1	-2.5	17.2	-41.5	-57.3	1.5	-11.4	53.3	-49.0	1.7	-16.6	44.3	-62.9	-10.3	3.8	14.6	-30.3
PP2	-26.9	-21.9	-46.8	71.3	32.3	65.5	-50.1	-1.1	-23.6	-20.5	-21.7	32.0	-76.6	-16.5	-1.8	77.1	16.6	-25.4	87.0	-37.1	-15.7	-3.8	-6.7	28.4
PP3	-28.4	92.8	56.5	-27.9	-77.5	104.9	5.4	106.6	-1.7	114.8	-22.8	109.2	-28.9	147.0	70.4	10.0	24.1	-31.2	11.2	72.0	-22.5	85.7	24.1	54.0

The *standard deviation* of *vowel duration* of each experimental subject expressed as a percentage of the standard deviation of the normal group for utterances beginning with a *voiced plosive*

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	103.4	482.7	119.0	198.4	155.6	103.2	60.9	159.8	67.6	77.2	113.2	155.9	73.8	230.4	121.0	177.2	82.7	179.9	110.8	211.4	96.6	214.7	105.0	180.5
AOS2	-20.8	95.8	55.9	110.4	149.9	101.3	-3.7	3.6	30.2	210.2	21.1	10.7	99.8	10.4	6.3	20.6	41.5	78.5	-46.0	-8.6	60.1	99.2	6.7	27.4
AOS3	8.9	903.1	18.2	260.3	84.9	119.4	158.2	192.7	431.9	165.4	176.5	237.8	93.4	-27.7	165.0	105.1	90.8	241.8	12.5	47.8	142.0	280.4	106.1	168.7
PP1	31.4	-39.5	-54.6	-37.0	23.8	-19.2	157.5	-43.4	87.2	-17.9	51.9	51.1	58.8	16.9	20.0	-1.9	-12.8	127.0	48.3	117.9	37.7	13.5	44.6	17.4
PP2	142.2	280.4	69.8	206.1	41.7	11.5	-54.1	114.4	-39.9	16.5	-24.1	0.3	-37.1	-19.4	26.4	-21.7	65.2	-42.4	71.0	-13.5	34.4	49.3	17.8	57.1
PP3	82.5	31.9	-23.1	42.0	78.9	170.3	-10.4	47.0	57.9	9.9	18.1	-41.2	-5.5	-27.6	130.5	39.4	38.6	-42.6	-6.3	25.6	50.5	28.4	21.8	22.6

The *standard deviation* of *vowel duration* of each experimental subject expressed as a percentage of the standard deviation of the normal group for utterances beginning with a *voiceless fricative*

	"set"/set				"vas"/fuss				"feit"/fête				"voet"/foot				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	52.5	130.3	385.2	51.3	363.4	338.6	64.2	99.8	40.3	217.8	449.7	267.4	181.2	556.4	8.6	306.8	159.3	310.8	226.9	181.3
AOS2	115.2	101.1	68.5	131.3	-2.3	132.2	-53.3	18.1	141.3	162.8	165.9	162.9	62.9	-7.2	6.7	-23.5	79.3	97.2	46.9	72.2
AOS3	92.4	220.4	119.1	-13.4	88.3	-6.3	-22.2	69.0	-50.0	140.4	168.9	27.2	131.1	103.2	3.0	-2.3	65.4	114.4	67.2	20.1
PP1	28.4	-59.7	-21.7	-69.3	274.2	-26.8	30.8	51.1	5.8	36.1	-48.0	-2.3	59.4	-35.9	-44.3	142.1	92.0	-21.6	-20.8	30.4
PP2	-19.9	121.1	-15.1	50.1	48.8	45.0	23.9	25.8	168.4	304.8	439.1	181.9	93.9	11.0	22.6	-22.0	72.8	120.5	117.6	58.9
PP3	90.6	97.6	-7.0	-13.6	-9.9	120.8	-30.3	100.0	-9.8	21.3	-75.7	-18.3	9.1	-34.1	1.7	27.9	20.0	51.4	-27.8	24.0

The *standard deviation* of *utterance duration* of each experimental subject expressed as a percentage of the *standard deviation* of the normal group for utterances beginning with a *voiceless plosive*

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	78.6	12.2	44.2	425.7	388.4	17.5	239.9	34.8	650.5	50.7	-44.7	-14.3	-33.2	197.2	69.9	35.3	24.2	170.1	40.0	46.6	221.7	89.5	69.9	105.6
AOS2	118.3	-36.9	2.3	98.2	46.9	-27.2	9.4	94.3	-47.3	98.4	-19.8	54.0	73.0	147.3	-26.2	350.1	-29.1	-15.0	201.8	-71.0	32.3	33.3	33.5	105.1
AOS3	155.3	121.2	-7.8	34.4	53.6	4.1	32.8	-10.4	99.7	83.8	-66.2	-3.8	17.0	-67.0	10.8	97.6	18.4	50.3	11.3	109.0	68.8	38.5	-3.8	45.3
PP1	83.8	98.6	31.3	285.2	125.2	52.1	18.9	-49.3	-14.5	-15.5	-28.8	-26.0	19.0	25.9	-39.6	-9.8	-58.6	542.0	79.8	-9.2	31.0	140.6	12.3	38.2
PP2	237.7	11.2	44.1	230.4	173.5	42.7	13.1	22.8	29.4	64.1	-2.8	42.2	165.7	-23.9	162.7	116.4	-24.2	241.9	-5.8	-24.8	116.4	67.2	42.3	77.4
PP3	78.1	89.8	85.7	137.0	191.0	115.4	3.5	88.9	21.1	69.3	-31.9	90.4	-39.5	88.7	-36.7	35.2	128.8	178.7	37.8	62.9	75.9	108.4	11.7	82.9

The *standard deviation* of *utterance duration* of each experimental subject expressed as a percentage of the *standard deviation* of the normal group for utterances beginning with a *voiced plosive*

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	57.9	66.2	58.8	104.4	-56.5	214.5	169.1	59.5	124.0	-31.7	91.8	-5.1	2.7	378.0	111.8	3.7	-39.5	-3.1	190.2	48.4	17.7	124.8	124.3	42.2
AOS2	28.3	17.2	30.2	181.3	-46.9	180.8	25.5	32.2	939.7	-23.8	-7.3	-44.2	46.5	204.9	-41.8	185.6	98.3	211.1	176.0	234.0	213.2	118.0	36.5	117.8
AOS3	4.2	186.8	-11.5	120.5	-14.1	7.5	43.5	91.3	62.2	32.2	26.8	44.5	-17.5	-49.0	78.8	-50.2	7.0	78.0	-48.9	-21.1	8.4	51.1	17.8	37.0
PP1	39.0	67.7	-41.9	-28.8	35.2	578.1	46.0	813.0	66.0	-23.9	41.0	92.1	475.6	427.3	60.5	90.6	119.4	27.4	30.4	-36.3	147.0	215.3	27.2	186.1
PP2	72.7	36.3	76.3	390.1	81.4	88.7	145.5	-34.7	279.9	2.8	15.3	-33.9	31.4	527.4	162.7	28.7	16.4	44.4	-7.0	17.6	96.4	139.9	78.6	73.5
PP3	4.9	122.9	84.3	128.5	82.3	188.1	54.0	51.7	50.0	-79.9	34.4	-27.7	3.1	82.9	166.0	-26.1	211.7	103.1	134.6	146.8	70.4	83.4	94.7	54.6

The *standard deviation* of *utterance duration* of each experimental subject expressed as a percentage of the *standard deviation* of the normal group for utterances beginning with a *voiceless fricative*

	"set"/set				"vas"/fuss				"feit"/fête				"voet"/foot				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	-32.0	66.6	-45.0	316.6	109.3	104.0	1.3	315.3	338.2	197.4	117.9	149.5	347.0	119.9	143.6	193.9	190.6	122.0	54.5	243.8
AOS2	150.2	47.8	-56.9	106.8	81.1	127.5	91.0	401.7	62.3	623.7	103.9	176.1	21.9	165.7	-8.7	131.8	78.9	241.2	32.3	204.1
AOS3	29.6	91.9	243.8	275.2	13.6	4.0	-21.9	187.2	27.4	45.1	-55.5	0.9	63.0	71.5	-0.8	298.3	33.4	53.1	41.4	190.4
PP1	154.8	-6.8	-22.7	56.4	120.4	17.4	121.4	162.5	86.1	87.8	103.6	24.5	-36.6	187.3	-66.7	204.6	81.2	71.4	33.9	112.0
PP2	32.2	99.2	-44.7	107.8	87.2	-18.4	189.1	2.4	143.6	-10.0	3.7	122.3	79.0	40.8	146.6	131.4	85.5	27.9	73.7	91.0
PP3	11.6	-32.0	-48.5	126.5	54.5	155.9	-70.7	334.4	-49.1	21.1	72.2	12.1	-86.0	-28.0	-37.6	140.2	-17.3	29.3	-21.1	153.3

The *standard deviation* of *utterance onset duration* of each experimental subject expressed as a percentage of the *standard deviation* of the normal group for utterances beginning with a *voiceless plosive*

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	359.2	5859.3	5670.9	3894.1	1754.2	1969.5	2999.7	5314.2	2057.8	4969.6	5561.3	8097.9	578.7	2283.5	3652.3	5287.5	1483.5	9401.8	2800.2	4773.4	1246.7	4896.7	4136.9	5473.4
AOS2	1863.0	1389.4	306.1	2182.6	1622.9	292.0	122.9	1988.1	1347.6	655.8	2794.4	1148.4	1924.7	486.5	440.5	4091.3	1044.8	713.7	1747.3	687.6	1560.6	707.5	1082.2	2019.6
AOS3	454.3	237.9	30.0	353.2	1485.9	304.2	3237.1	2861.4	726.3	131.3	358.3	569.7	838.8	1064.6	690.6	577.8	1742.6	455.5	259.0	217.2	1049.6	438.7	915.0	915.9
PP1	1248.8	1387.1	2819.9	1916.7	909.2	14.7	1325.3	1781.5	810.9	-13.4	912.0	412.3	4137.8	-34.2	725.5	126.7	3356.4	1033.4	4120.0	1396.9	2092.6	477.5	1980.5	1126.8
PP2	3117.8	959.2	3112.8	3473.7	97.0	15.9	-30.8	32.1	608.3	-42.3	93.3	552.8	142.0	736.8	886.6	3271.4	73.4	-34.7	-14.7	512.3	807.7	327.0	809.5	1568.5
PP3	-28.5	-25.0	488.6	2109.2	19.2	113.0	-40.2	267.0	77.1	18.5	83.0	230.0	166.7	-13.9	-22.6	268.7	1716.1	-4.2	171.9	63.4	390.1	17.7	136.1	587.7

The *standard deviation* of *utterance onset duration* of each experimental subject expressed as a percentage of the *standard deviation* of the normal group for utterances beginning with a *voiced plosive*

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	6260.1	1082.5	8758.7	5561.2	1251.6	1862.7	5704.1	3687.4	5981.8	9106.4	3208.6	1277.4	6148.0	3891.9	5453.6	9785.0	166.3	502.8	14077.1	7286.8	3961.6	3289.3	7440.4	5519.6
AOS2	492.6	3560.1	684.2	783.7	1929.3	205.6	1731.4	988.3	2168.4	1406.6	303.0	662.6	3236.5	3049.0	3770.7	2729.3	765.6	2006.0	1129.2	368.9	1718.5	2045.4	1523.7	1106.6
AOS3	2161.3	-7.9	505.1	2976.4	913.1	894.0	875.3	315.5	644.1	1475.5	519.3	4079.1	1947.7	141.9	466.0	2238.6	584.9	2627.7	92.5	668.8	1250.2	1026.2	491.6	2055.7
PP1	1122.2	51.0	4157.7	1439.4	531.8	-10.0	1359.5	3636.9	4485.3	-67.2	139.4	619.5	627.6	5971.2	743.3	1707.7	1739.0	-31.5	1778.6	61.7	1701.2	1182.7	1635.7	1493.0
PP2	29.7	49.3	2217.6	1721.7	314.6	122.5	254.4	1227.1	3806.3	598.6	611.7	-39.1	514.2	713.4	-57.0	3.5	-7.8	747.7	-28.9	-46.1	931.4	446.3	599.6	573.4
PP3	1013.6	-13.5	161.2	1651.5	237.2	1012.5	116.1	13.5	23.8	15.3	-2.2	2018.9	3410.8	-40.4	-70.2	-54.4	-45.7	530.5	3528.8	685.4	927.9	300.9	746.7	863.0

The *standard deviation* of *voice onset time* of each experimental subject expressed as a percentage of the *standard deviation* of the normal group for utterances beginning with a *voiceless plosive*

	"pak"/puck				"pet"/pet				"pit"/pit				"pad"/putt				"pap"/pup				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	328.7	80.7	265.8	274.6	222.0	135.3	239.8	341.5	-12.0	203.1	245.6	434.0	293.7	212.0	486.4	636.0	93.6	208.1	-21.2	120.3	185.2	167.8	243.3	361.3
AOS2	91.6	14.4	-42.3	86.1	83.5	-19.3	40.1	-20.0	31.4	-6.7	-38.9	-57.9	102.6	78.2	61.1	58.5	47.7	53.7	43.5	13.2	71.4	24.1	12.7	16.0
AOS3	-44.9	58.5	52.6	432.2	45.9	-17.8	8.5	371.3	-11.6	-41.3	39.1	103.3	55.7	94.0	1128.8	24.3	41.2	-18.4	141.3	61.1	17.3	15.0	274.0	198.4
PP1	137.7	176.8	122.9	356.0	148.6	101.4	412.7	145.2	39.3	90.2	-27.2	8.2	126.6	258.2	476.1	112.9	68.8	151.9	206.4	87.0	104.2	155.7	238.2	141.8
PP2	321.1	45.7	243.7	753.1	77.7	-28.9	-25.7	107.3	29.5	-4.0	-22.8	12.8	56.5	83.8	167.9	172.2	39.2	130.7	127.6	157.7	104.8	45.4	98.2	240.6
PP3	-11.6	14.0	-36.8	371.1	-54.8	4.3	-18.3	36.5	-62.4	26.7	12.8	63.0	-18.2	52.6	177.2	70.9	3.7	-44.9	-21.2	104.5	-28.7	10.5	22.8	129.2

The *standard deviation* of *voice onset time* of each experimental subject expressed as a percentage of the *standard deviation* of the normal group for utterances beginning with a *voiced plosive*

	"byt"/bait				"bak"/buck				"bas"/bus				"bek"/back				"bed"/bet				Utterance group			
	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR	L1NR	L1FR	L2NR	L2FR
AOS1	-83.9	796.6	121.4	-93.8	-88.4	6.0	278.7	-78.0	-64.0	-36.7	200.4	377.2	-81.1	229.9	161.7	197.3	-14.4	66.4	147.5	182.6	-66.4	212.5	181.9	117.1
AOS2	-88.1	-67.1	-88.4	-97.5	-91.0	-90.5	-93.2	-85.3	302.4	-82.2	-77.2	-70.7	-88.0	-71.7	67.4	-43.3	-86.0	-64.9	-93.3	-96.9	-10.1	-75.3	-56.9	-78.7
AOS3	-3.3	299.2	-93.6	-43.8	116.1	86.0	61.2	65.6	225.4	257.7	153.8	345.9	73.4	242.7	-100.0	66.2	33.8	402.4	-62.1	20.4	89.1	257.6	-8.1	90.9
PP1	23.0	306.6	1.3	-45.5	59.0	-45.0	52.0	196.4	133.9	61.1	62.0	171.8	-2.2	200.0	69.1	-22.9	120.9	229.9	-56.1	79.5	66.9	150.5	25.6	75.9
PP2	-84.5	193.3	-89.2	-86.7	-33.3	-67.6	-53.6	-58.2	-59.0	-65.9	73.5	-57.7	-85.7	229.9	-74.5	-53.0	-78.1	-58.5	139.5	-76.8	-68.1	46.2	-0.9	-66.5
PP3	209.1	-8.8	-31.8	-72.6	80.8	579.8	50.3	-12.9	-36.9	-12.2	-31.7	1551.5	-12.9	-62.0	-78.4	-62.9	-67.3	331.2	-93.0	20.8	34.6	165.6	-36.9	284.8