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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 /eɪ/, compared to words containing the vowel sound, /ɛ/. 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 /ɪ/. 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-learned 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 is 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 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.

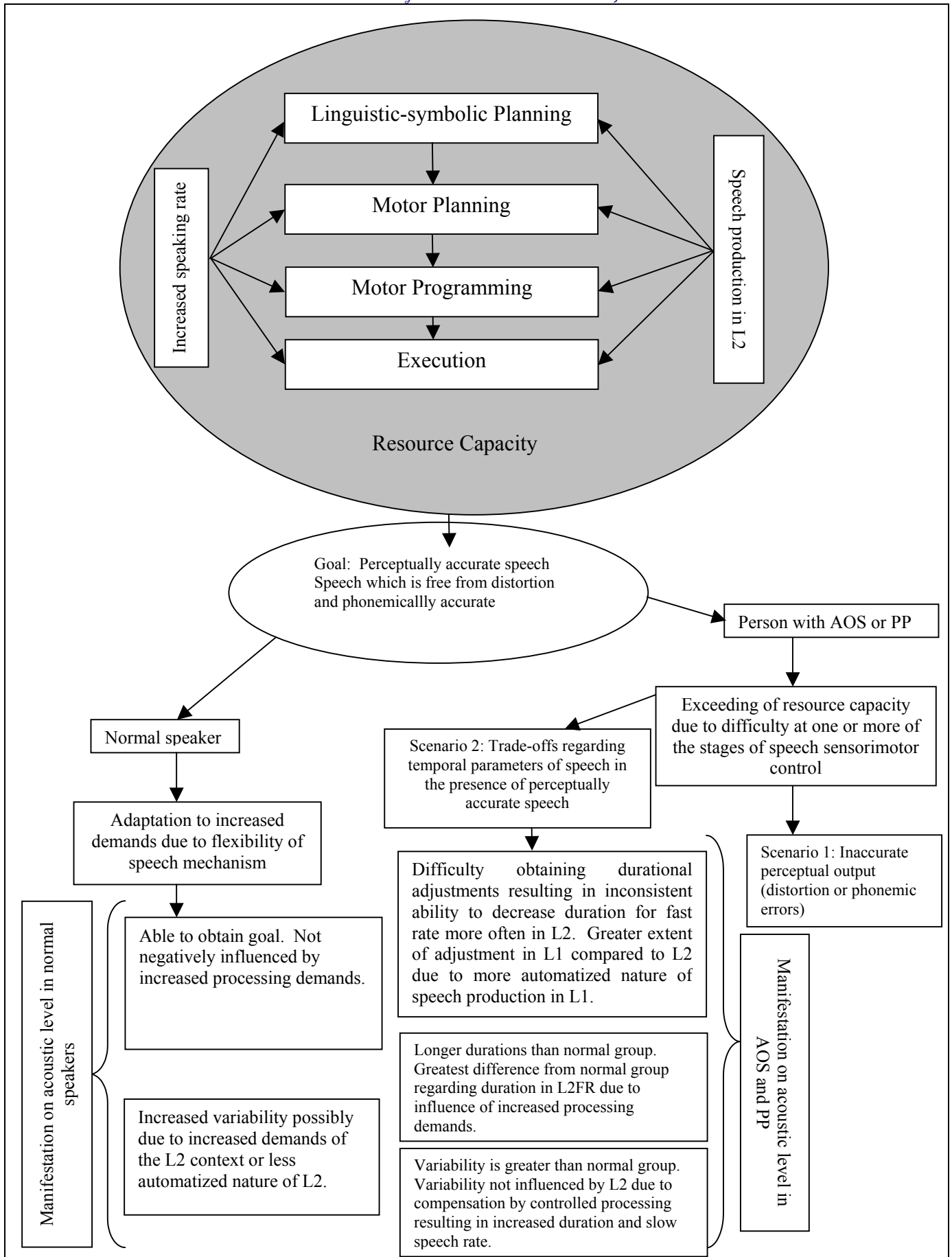


Figure 6.1 Schematic presentation of the acoustic manifestation of increased processing demands imposed by an increased speaking rate and speech production in L2 in normal speakers and persons with either AOS or PP.

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.