CHAPTER FOUR
RESEARCH METHODOLOGY

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4.1 INTRODUCTION

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

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

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

4.2 RESEARCH AIMS

4.2.1 Main aim

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

4.2.2 Sub-aims

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

4.2.2.1 Sub-aim one

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

4.2.2.2 Sub-aim two

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

4.2.2.3 Sub-aim three

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

4.3 SUBJECTS

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

4.3.1 Criteria for subject selection

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

4.3.1.1 General criteria for all subject groups

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

- **Language and level of bilingualism**

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

Table 4.1 Sub-aims and rationales for their inclusion

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

- **Reading competence**

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

4.3.1.2 Criteria for inclusion in the normal group

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

4.3.1.3 Criteria for inclusion in the apraxia of speech group

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

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

1996)

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

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

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

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

4.3.1.4 Criteria for inclusion in the phonemic paraphasic group

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

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

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

4.3.2 Procedure for subject selection

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

4.3.3 Description of selected subjects

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

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

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

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

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

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

4.4 ETHICAL ISSUES

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

4.5 RESEARCH DESIGN

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

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

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

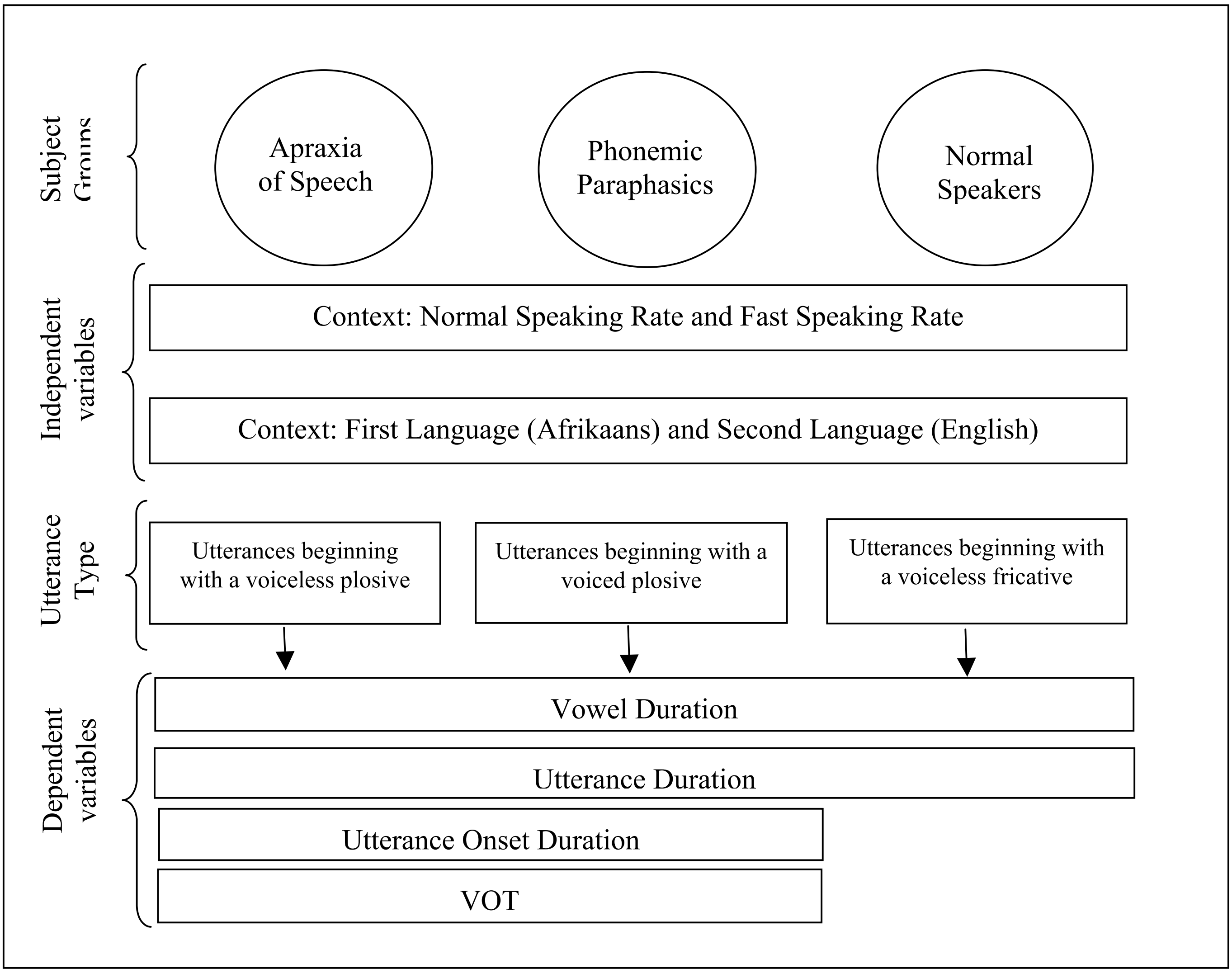

Figure 4.1 Schematic presentation of the methodology of the study

4.6 MEASUREMENT INSTRUMENTS

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

4.7 SPEECH MATERIAL

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

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

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

Table 4.3 Speech stimuli used in the study

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

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

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

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

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

4.8 DATA COLLECTION PROCEDURES

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

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

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

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

4.9 DATA ANALYSIS

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

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

4.9.1 Acoustic analysis to determine vowel duration

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

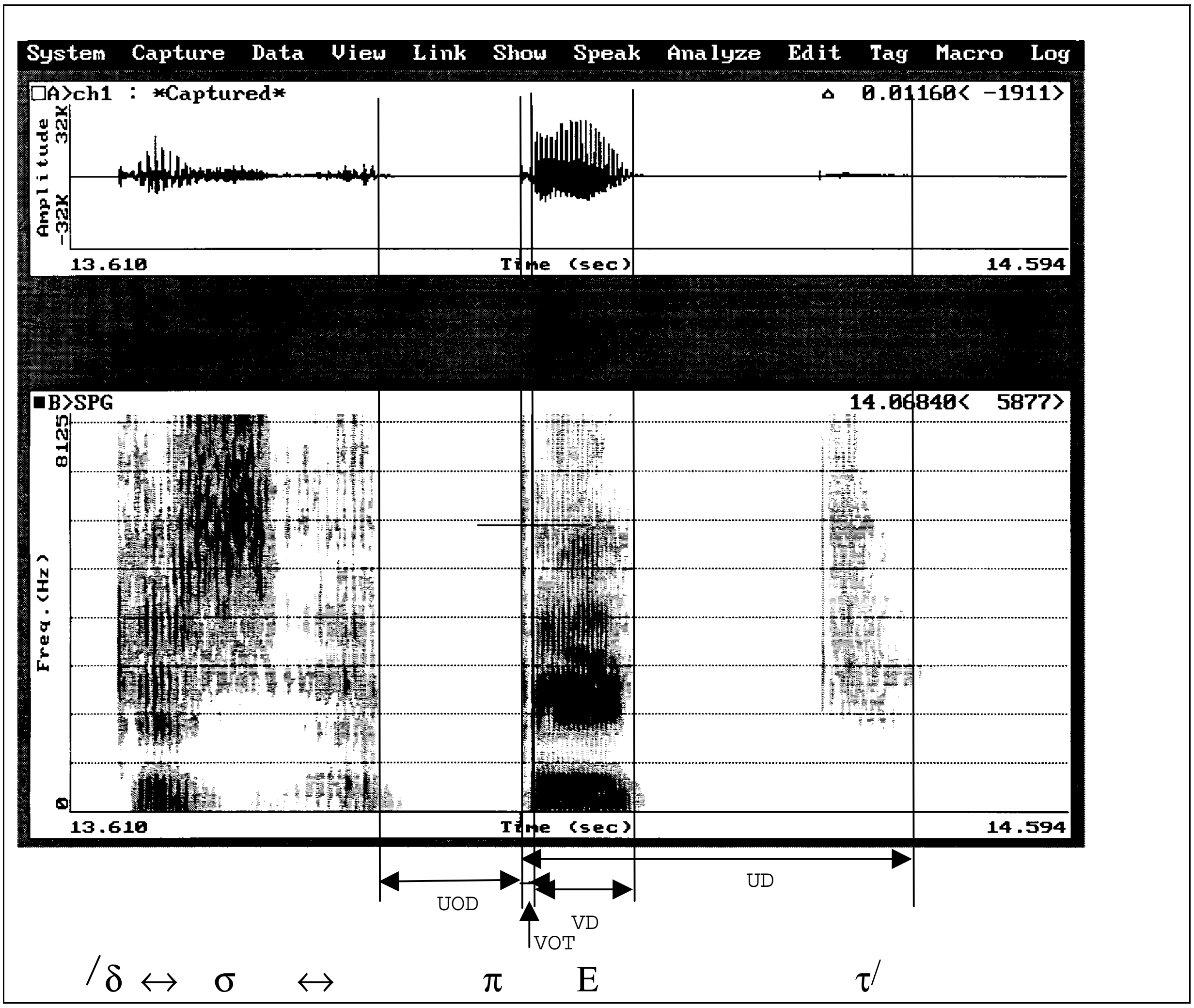

Figure 4.2 **A spectrograph of "Dis 'n pet" (English counterpart: "It's a pet") produced in L1NR by N5, indicating the four temporal parameters measured for utterances beginning with a voiceless plosive, namely utterance onset duration (UOD), voice onset time (VOT), vowel duration (VD) and utterance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

4.9.2 Acoustic analysis to determine utterance duration

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

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

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

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

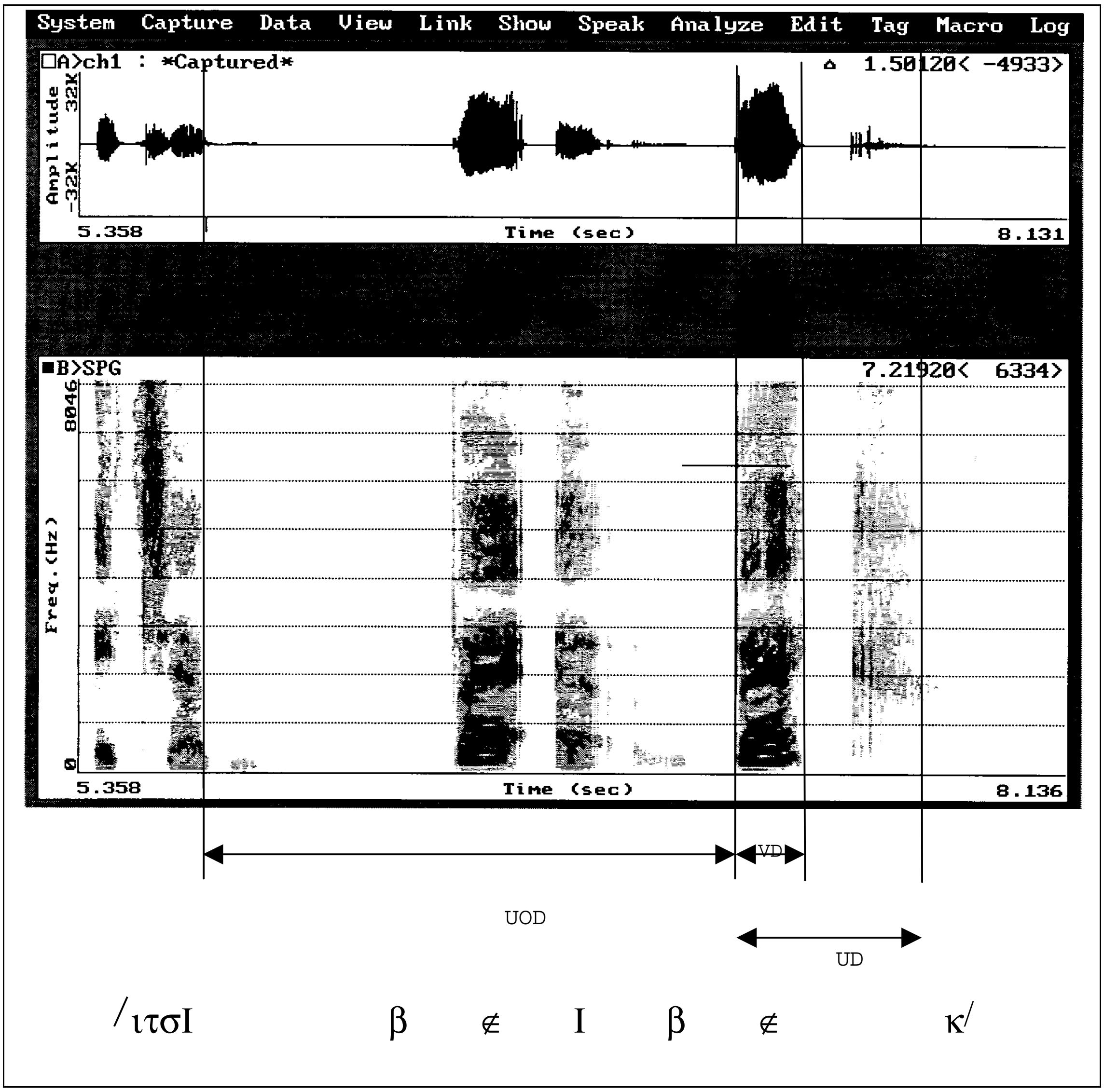

Figure 4.3 **A spectrograph of "It's a back" in L2FR produced by AOS2 as /ιτσΙ β∉ Ι β∉κ/, indicating the four temporal parameters measured for utterances beginning with a voiced plosive, namely utterance onset duration (UOD), vowel duration (VD), utterance duration (UD) and VOT as zero, since the release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

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

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

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

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

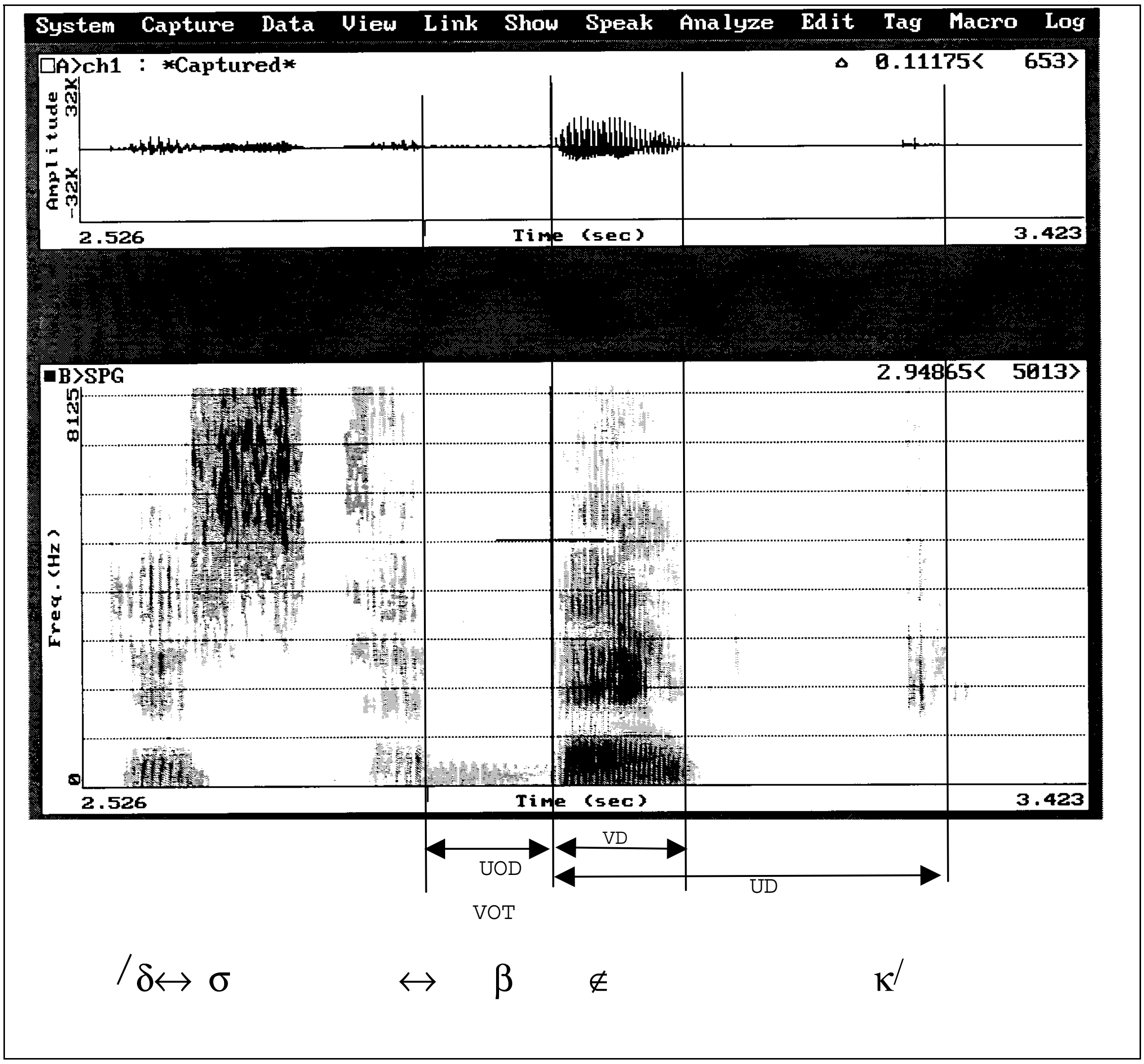

Figure 4.4 **Spectrograph of "Dis 'n bek" (English counterpart: "It's a back") produced in L1NR by one of the normal subjects (N5), indicating the four temporal parameters measured for utterances beginning with a voiced plosive, namely utterance onset duration (UOD), voice onset time (VOT) (in this case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

4.9.3 Acoustic analysis to determine utterance onset duration

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

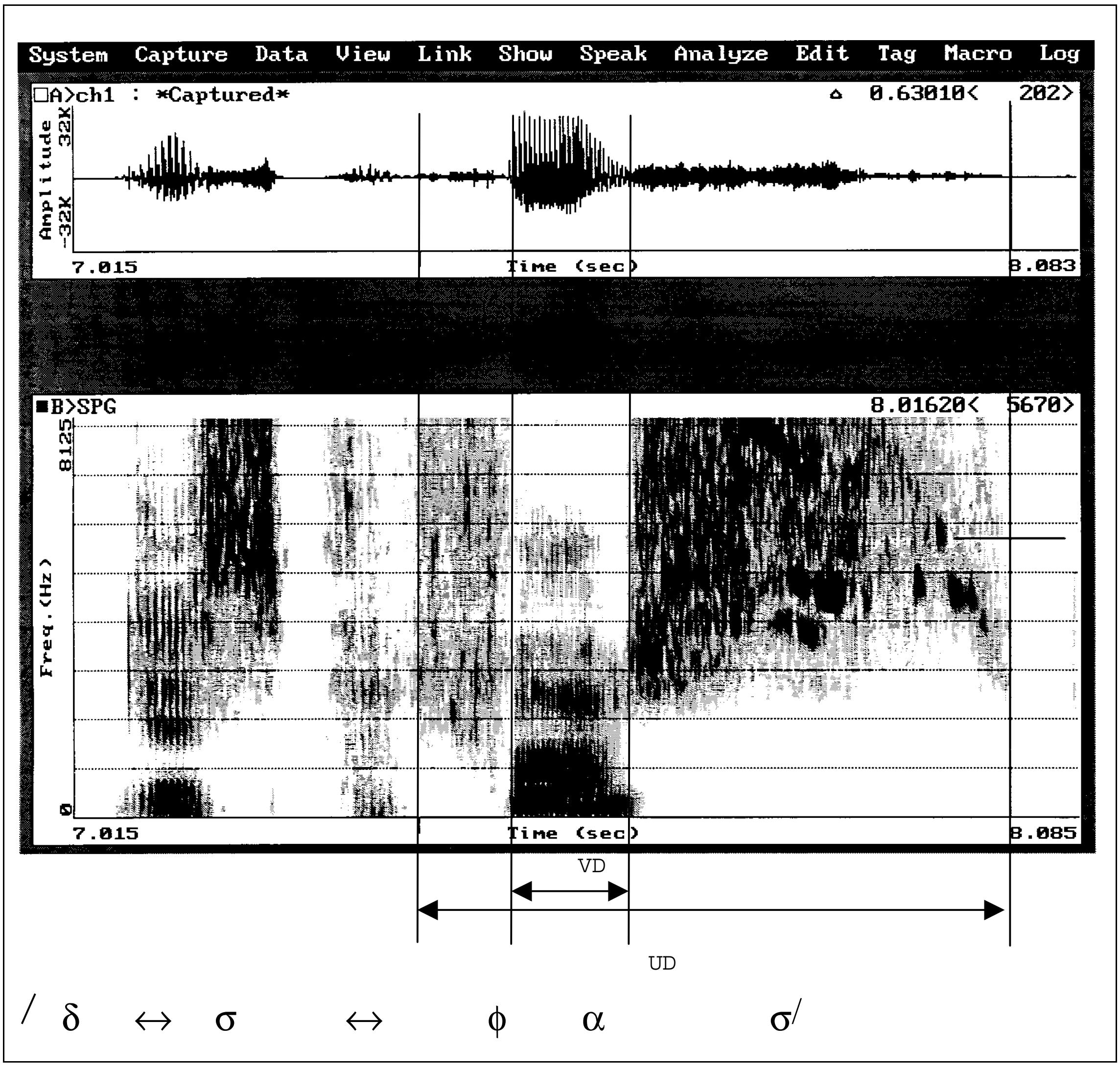

Figure 4.5 **A spectrograph of "Dis 'n vas" (English counterpart: "It's a fuss") produced in L1NR by one of the normal speakers (N5), indicating the two temporal parameters measured for utterances beginning with a voiceless fricative, namely vowel duration (VD) and utterance duration (UD).**

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

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

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

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

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

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

4.9.4 Acoustic analysis to determine voice onset time

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

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

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

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

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

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

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

4.10 RELIABILITY

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

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

4.11 DATA PROCESSING

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

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

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

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

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

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

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

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

- Determination of the extent of durational adjustment

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

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

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

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

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

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

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

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

4.11.1.2 Data processing for utterance groups for sub-aim one

- Determination of the extent of durational adjustment

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

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

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

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

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

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

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

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

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

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

Sub-aim One

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

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

DATA PROCESSING: Step 1

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

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

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

↓

Step 2

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

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

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

↓

Step 3

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

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

↓

Step 4

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

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

↓

Step 5

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

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

4.11.2.1 Data processing for individual utterances for sub-aim two

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

4.11.2.2 Data processing for utterance groups for sub-aim two

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

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

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

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

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

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

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

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

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

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

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

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

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

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

Sub-aim Two

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

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

DATA PROCESSING: Step 1

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

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

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

↓

Step 2

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

↓

Step 3

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

↓

Step 4

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

↓

Step 5

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

↓

Step 6

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

↓

Step 7

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

Figure 4.7 Summary of data processing for sub-aim two

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

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

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

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

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

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

↓

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

↓

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

↓

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

↓

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

↓

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

Figure 4.8 Summary of data processing for sub-aim three

4.12 SUMMARY OF CHAPTER FOUR

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