CHAPTER 4

DESCRIPTION AND DISCUSSION OF RESULTS

4.1. INTRODUCTION

In this chapter the data obtained for the different sub-aims of this study will be described and discussed separately. Data description and discussion for each sub-aim will start with an introduction of the way the data will be presented, as well as indications of applicable test/recording sheets and/or rating scales where necessary.

4.2. DESCRIPTION AND DISCUSSION OF RESULTS FOR SUB-AIM ONE: NON-SPEECH ORAL MOVEMENTS (NSOM)

The goal of this sub-aim was to investigate the ability of normal, Afrikaans-speaking children in the age range 4;0 to 7;0 years, to plan and execute *isolated (I-OM)*, *two-sequence (2S-OM)*, and *three-sequence (3S-OM) voluntary, non-speech oral movements (NSOM)* on request, by the application of a comprehensive *rating scale* designed for assessing performance on these tasks.

Performance was rated in terms of three categories on the *Rating Scale for the Evaluation of Non-Speech Oral Movements* (Table 3.9) named *I. Associated Movements*, *II. Accuracy of Individual Movements* and *III. Sequencing* (see Chapter 3 for definitions of these categories). The results for the three sections of sub-aim one i.e. *isolated oral movements* (I-OM), *two sequence oral movements* (2S-OM) and *three sequence oral movements* (3S-OM) are presented in Tables 4.1, 4.2 and 4.3. Results for these sections will first be described separately, followed by a joint summary and discussion of the results for sub-aim one.

In the following discussion, target movement numbers correspond with the numbers in Table 3.3 as well as the *Test/Recording* and *Rating Sheets* compiled for sub-aim one in Appendix A. Roman numerals (e.g. II.) refer to categories on the rating scale (Table 3.9), while lower case letters (e.g. b) refer to ratings in each category of the scale. In all categories an (a)-rating indicated that *no problems* were displayed for that category. Ratings other than (a) will be referred to as error ratings.

4.2.1. DESCRIPTION OF RESULTS FOR SUB-AIM ONE

Results will be discussed in terms of the subjects' performance on the different target movements for isolated (I-OM), two sequence (2S-OM) and three sequence (3S-OM) oral movements.

4.2.1.1. Isolated oral movements (I-OM)

The results for I-OM are depicted in Table 4.1. It can be seen that all the subjects scored (a)-ratings in all three categories of target movements 1.1 *(Blowing out a candle)* and 1.2 *(Puffing the cheeks)*, indicating that no problems occurred with the execution of these movements. For target movement 1.3 *(Licking an ice cream)* only S6, S7, S8, and S9 scored (a)-ratings in all three categories. In summary, all the subjects were thus capable of voluntary execution of I-OM, but only four subjects scored (a)-ratings across all three target-movements. The following error ratings occurred in the three categories (refer to Table 4.1 for details):

* Category I (i.e. *Associated Movements)*: Error ratings that occurred for target movement 1.3 *(Licking an ice cream)* included one (b)-rating (i.e. *Associated movement/s of the articulators*), and one (c)-rating (i.e. *Associated movement/s of the body or non-articulators)*. These ratings were the result of subjects lifting their chins upwards or tilting their heads backwards. Results thus indicated that the majority of subjects were able to perform I-OM without associated movements.

TABLE 4.1: RESULTS FOR ISOLATED ORAL MOVEMENTS (I-OM)

SUBJECT	AGE (yrs)	RATING SCALE CATEGORIES						
		I. Associated Movements			II. Accuracy of Individual Movement/s			III. Sequencing
		a.*	b.*	c.*	a.*	d.*	f.*	a.*
1.1. Blow out a candle								
S1	4;0	*			*			
S2	4;1	*			*			
S3	4;8	*			*			
S4	5;0	*			*			
S5	5;3	*			*			
S6	5;4	*			*			
S7	5;4	*			*			
S8	5;6	*			*			
S9	6;1	*			*			
S10	6;7	*			*			
TOTAL:		*10*			*10*			
1.2. Puff cheeks								
S1	4;0	*			*			
S2	4;1	*			*			
S3	4;8	*			*			
S4	5;0	*			*			
S5	5;3	*			*			
S6	5;4	*			*			
S7	5;4	*			*			
S8	5;6	*			*			
S9	6;1	*			*			
S10	6;7	*			*			
TOTAL:		*10*			*10*			
1.3. Lick an ice-cream								
S1	4;0			*	*			
S2	4;1	*				*		
S3	4;8	*				*		
S4	5;0	*				*		
S5	5;3	*				*		
S6	5;4	*			*			
S7	5;4	*			*			
S8	5;6	*			*			
S9	6;1	*			*			
S10	6;7		*				*	
TOTAL:		*8*	*1*	*1*	*5*	*4*	*1*	

** Please refer to the Rating Scale for Non-Speech Oral Movements (TABLE 3.9) for definitions of these abbreviations*

* Category II *(Accuracy)*: Four children (S2, S3, S4, S5) scored (d)-ratings (*Some movements executed inaccurately in terms of placement*) and one (S10) an (f)-rating (*Some of the individual movements were incorrect*). Half of the subjects thus displayed some accuracy problems with upward tongue licking movements. Error performance was characterized by circular and/or in-out movements instead of upward-licking tongue movements. Some children also rested the tongue on the lower lip while performing licking movements. When inaccuracy continued to be demonstrated in the upward licking movements, in spite of demonstration and instruction, error ratings were assigned.

* Category III *(Sequencing):* Since these were isolated oral movements, sequencing was not rated.

4.2.1.2. Two-sequence oral movements (2S-OM)

The results for 2S-OM are reported in Table 4.2. It can be seen from the results that all the subjects scored (a)-ratings for target movement 2.1 (i.e. *Blow a kiss and cough*) indicating no problems with this target movement. However, for movements 2.2 (i.e. *Pout lips and lateralize tongue outside mouth from lip corner to lip corner*), and 2.3 (i.e. *Puff cheeks and lateralize tongue outside mouth from lip corner to corner)* only S3, S6 and S8 scored (a)-ratings in all three categories for these two target movements. In summary, it can thus be seen from the data in Table 4.2 that although all subjects were capable of *voluntary* execution of 2S-OM, only three subjects scored (a)-ratings across all three target-movements.

Results indicated that error-ratings for target movements 2.2 (i.e. *Pout lips and lateralize tongue outside mouth from lip corner to lip corner*), and 2.3 (i.e. *Puff cheeks and lateralize tongue outside mouth from lip corner to corner)* occurred as follows in all three categories of the rating scale:

* Category I (i.e. *Associated Movements)*: Frequent (b)-error ratings (*Associated movement/s of articulators*) and one (c)-error rating occurred. (i.e. *Associated movement/s of the body or non-articulators).*

TABLE 4.2: RESULTS FOR TWO-SEQUENCE ORAL MOVEMENTS (2S-OM)

SUBJECT	AGE (yrs)	RATING SCALE CATEGORIES								
		I. Associated Movements			II. Accuracy of Individual Movement/s			III. Sequencing		
		a.*	b.*	c.*	a.*	d.*	f.*	a.*	c.*	f.*
2.1 Blow a kiss and cough										
S1	4;0	*			*			*		
S2	4;1	*			*			*		
S3	4;8	*			*			*		
S4	5;0	*			*			*		
S5	5;3	*			*			*		
S6	5;4	*			*			*		
S7	5;4	*			*			*		
S8	5;6	*			*			*		
S9	6;1	*			*			*		
S10	6;7	*			*			*		
TOTAL:		*10*			*10*			*10*		
2.2. Pout lips and lateralize tongue outside mouth from lip corner to corner										
S1	4;0			*		*	*	*		
S2	4;1		*			*			*	
S3	4;8	*			*			*		
S4	5;0		*			*		*		
S5	5;3		*		*			*		
S6	5;4	*			*			*		
S7	5;4		*		*			*		
S8	5;6	*			*			*		
S9	6;1		*		*			*		
S10	6;7		*		*			*		
TOTAL:		*3*	*6*	*1*	*7*	*3*	*1*	*9*	*1*	
2.3. Puff cheeks and lateralize tongue outside mouth from lip corner to corner										
S1	4;0	*					*			*
S2	4;1		*		*				*	
S3	4;8	*			*			*		
S4	5;0		*			*		*		
S5	5;3		*		*			*		
S6	5;4	*			*			*		
S7	5;4		*		*			*		
S8	5;6	*			*			*		
S9	6;1		*		*			*		
S10	6;7		*		*			*		
TOTAL:		*4*	*6*	*0*	*8*	*1*	*1*	*8*	*1*	*1*

** Please refer to the Rating Scale for Non-Speech Oral Movements(TABLE 3.9) for definitions of these abbreviations*

These errors consisted of accompanying head movement (displayed by youngest subject, S1) and frequent associated movements of the mandible. Results might have indicated a tendency for normal children between 4;0 and 6;7 years to display associated movements of the mandible in tongue lateralization tasks, since only three subjects (S3, S6, S8) showed no associated mandible movements (See Table 4.2).

* Category II (i.e. *Accuracy of Individual Movements)*: (d)-error ratings (i.e. *Some of the movements were executed inaccurately*) and (f)-error ratings (i.e. *Some of the movements were incorrect*) were displayed. Inaccurate behavior was characterized by occasional inadequate touching of the lip corners, sweeping of the tongue over the lower lip. Incorrect behavior included in-out tongue movements instead of lateralization, or lateralization movements inside, instead of outside the mouth. The majority of subjects displayed no problems in Category II, indicating that these normal children between 4;0 and 6;7 years were mostly capable of accurate execution of 2S-OM.

* Category III *(Sequencing)*: Two children (S1 and S2) displayed error ratings for 2S-OM in the form of two (c)-ratings (i.e. *Obtained completely correct sequencing but needed keywords before each movement)* and an (f)-rating (i.e. *Impossible to rate due to severely reduced accuracy)*. The (f)-rating was scored by the youngest subject (S1) on target movement 2.3 (i.e. *"Puff your cheeks and then touch your left and right lip corners fast with your tongue)*, indicating that this particular movement may be difficult to sequence for some four-year-olds. Sequencing problems for 2S-OM were thus restricted to the two youngest subjects.

4.2.1.3. Three-sequence oral movements (3S-OM)

Results for *3S-OM* are depicted in Table 4.3 and indicated that although all the subjects were capable of voluntary execution of the individual target movements, only two subjects (S4 & S6) obtained only (a)-ratings for both target movements. The following error ratings occurred for 3S-OM in the three categories:

* <u>Category I</u> *(Associated Movements)*: No error ratings occurred for target movement 3.1 (see Table 4.3). Five (c)-ratings (*Associated movements of body or non-articulators)* occurred for target movement 3.2 *(Blow a kiss, touch nose with tongue, blow out a candle),* since half of the subjects tended to tilt their heads backwards and/or lifted their chins when trying to touch their noses with their tongues. It can be speculated that this could have been the result of mere effort in trying to accomplish the task. Maybe a more achievable task such as "touch your upper lip with your tongue tip" for example, would not have resulted in this behavior. However, half of the subjects did manage to execute the task without any associated movements.

* <u>Category II</u> *(Accuracy of Individual Movements)*: Two subjects (S2 and S10) scored (c)-ratings (i.e. *Slow but accurate execution of target movements)* and one subject a (d)-ratings (i.e. *Some of the movements were executed inaccurately in terms of placement),* while eight subjects showed no accuracy problems at all for the two target movements. It appeared as if slow execution occurred in an attempt of some children to manage the sequencing aspects of 3S-OM. The one error of inaccuracy was an instance where the subject did not perform a very well-executed upward tongue movement, but instead rested the tongue on the bottom lip for the most part of it. Accuracy thus did not appear to have been much of a problem in the execution of 3S-OM.

* <u>Category III</u> (Sequencing): Frequent (c)-error ratings occurred for the two target movements (i.e. *Obtained completely correct sequencing but needed key words before each movement*) and one subject scored a (d)-rating (i.e. *Partly correct sequencing -forgot or omitted some target movement or inserted incorrect ones -even with key words provided*). Six subjects scored no errors ratings with movement 3.1 and four subjects scored no error ratings with movement 3.2. The results thus indicated that some children between 4;0 and 6;7 years may experience auditory memory related problems with sequencing of 3S-OM. Syntactic processing demands could also have contributed to their problems, but the fact that the examiner modeled the target behavior, and that key words were provided, reduced this possibility. The subjects' performance usually improved as a result of the provision of key words.

TABLE 4.3: RESULTS FOR THREE-SEQUENCE ORAL MOVEMENTS (3S-OM)

SUB-JECT	AGE (yrs)	RATING SCALE CATEGORIES							
		I. Associated Movements		II. Accuracy of Individual Movements			III. Sequencing		
		a.*	c.*	a.*	c.*	d.*	a.*	c.*	d.*
3.1. Pout lips, puff cheeks, stick out tongue									
S1	4;0	*		*				*	
S2	4;1	*			*		*		
S3	4;8	*		*			*		
S4	5;0	*		*			*		
S5	5;3	*		*					*
S6	5;4	*		*			*		
S7	5;4	*		*			*		
S8	5;6	*		*				*	
S9	6;1	*		*			*		
S10	6;7	*			*			*	
TOTAL:		*10*		*8*	*2*		*6*	*3*	*1*
3.2. Blow a kiss, touch nose with tongue, blow out a candle									
S1	4;0	*		*			*		
S2	4;1		*	*				*	
S3	4;8		*	*				*	
S4	5;0	*		*			*		
S5	5;3		*	*				*	
S6	5;4	*		*			*		
S7	5;4		*	*				*	
S8	5;6	*		*				*	
S9	6;1		*	*			*		
S10	6;7	*			*	*		*	
TOTAL:		*5*	*5*	*9*	*1*	*1*	*4*	*6*	

** Please refer to the Rating Scale for Non-Speech Oral Movements (TABLE 3.9) for definitions of these abbreviations.*

4.2.2. SUMMARY AND DISCUSSION OF RESULTS FOR SUB-AIM ONE (I-OM, 2S-OM AND 3S-OM)

4.2.2.1. General findings

The categories and ratings on the compiled *Rating Scale for the Evaluation of Non-speech Oral Movements* (Table 3.9), were useful in describing and rating the behavior displayed by the normal children, providing valuable information about the characteristics of their performance on the target movements. By applying the rating scale, the traditional assessment of NSOM was expanded and basic normative information regarding the execution of NSOM by children in this age range was obtained. A tentative database has thus been established to which the performance of Afrikaans-speaking children with developmental speech disorders on these tasks can be clinically compared.

In summary, the results for sub-aim one indicated that all subjects were capable of voluntary execution of the individual components of all target movements in all three sections, indicating no signs of oral apraxia in these normal subjects (as expected). However, the *quality* of execution of these movements varied, indicating that normal children between the ages of 4;0 and 6;7 years can still display some minor associated movements, slight problems with accuracy and occasional sequencing problems in some areas of NSOM.

When the data in Tables 4.1 (I-OM), Table 4.2 (2S-OM) and Table 4.3 (3S-OM) were compared, it was found that only one subject, namely S6 (aged 5;4 years) scored perfect ratings (i.e. only a-ratings) in all three sections of sub-aim one. Even when the results for the three sections were separately reviewed, it was observed that only a few subjects were capable of executing *all* the target-movements of each section with perfect accuracy, sequencing and with no associated movements. For example, only four subjects (i.e. S6, S7, S8, S9, or 40% of the subjects) scored perfect ratings with I-OM, only three subjects (i.e. S3, S6, S8, or 30% of the subjects) scored perfect ratings with 2S-OM, and two subjects (i.e. S4, S6, or 20%) scored perfect ratings for 3S-OM. The finding that I-OM yielded less error ratings than 2S-OM, which in turn yielded less error ratings than 3S-OM, is much what one might predict, since it can be argued that remembering, planning and executing a series of different movements "...presumably place more demands upon the motor system than simple repetition." (Ansel et al,1992:10).

Although this is a very small study, with results only limited to the assessed tasks and categories rated, results seem to indicate the possibility that although the majority of normal children between 4;0 and 6;7 years can plan and execute non-speech oral movements, their performance are not yet adult-like in all respects.

However, it was found that some children (although in the minority) did display more seemingly adult-like performance on the assessed tasks, indicating individual trends in performance.

4.2.2.2. Types of errors

Associated movements occurred and were characterized in the section I-OM by lifting the chin and tilting the head during upward tongue licking movements (displayed by half of the subjects). Associated mandible movements were frequently displayed in *tongue lateralization* tasks (2S-OM), with only three subjects not displaying these movements. In the section 3S-OM, the associated movement of backwards head tilting occurred in half of the subjects, but this could be interpreted as a result of effort due to the relative impossibility of the task of "touching the nose with the tongue", rather than being a true associated movement. On the other hand, half of the subjects did not display this behavior. In summary, results thus indicated that normal children between the ages of 4;0 and 6;7 years may display some possibly *task-related associated movements* (e.g. in upward tongue-licking movements or when trying to touch the nose with the tongue). Further, results seem to indicate that the majority of normal children between 4;0 and 7;0 years may still find it difficult to execute *tongue lateralization* tasks without accompanying associated movements.

Accuracy problems occurred and were characterized by problems *with upward tongue licking movements* in half of the subjects in the section of I-OM (e.g. in-out and circular movements instead of up-down movements). In 2S-OM inadequate touching of the lip corners, in-out instead of left-right tongue movements, lateralization inside instead of outside the mouth, and sweeping of the tongue over the bottom lip occurred in *lateralization* tasks but the majority of subjects was capable of accurate execution of 2S-OM. In the section 3S-OM accuracy problems only occurred in 20% of the subjects and were restricted to *slow but accurate* execution in a possible attempt to accomplish correct sequencing. Although some error ratings occurred on lateralization and upward tongue licking movements, the subjects generally did not display accuracy problems with the execution of NSOM.

Robbins and Klee (1987) accordingly found that some 4;0 to 6;11-year-olds have not reached adult precision on oral-motor speech and non-speech movements. However, they used a simple three-point rating scale i.e. 2=adult function; 1=emerging skill (e.g. an approximation of target but lacking adult precision) and 0=absent function (e.g. no approximation of the target behavior) to judge their subjects' performance on functional tasks (e.g. lip rounding, pitch variation, tongue mobility). Their protocol did not include *sequenced* oral speech movements or descriptions of how normal children's performance deviated from what was expected to be 'normal' or 'adult-like' (e.g. whether associated movements occurred or what imprecision of movements entailed), all of which limit comparison of results.

Sequencing problems also occurred. In 2S-OM it was restricted to the two *youngest* subjects (four-year-olds) who needed key words in order to accomplish correct sequencing. However, sequencing problems occurred more profoundly with 3S-OM, where only three subjects (30%) obtained correct sequencing without any key words provided. *Auditory memory* problems seem to have contributed to sequencing errors, since most subjects were able to execute the target movements in the correct sequence when key words were provided.

Bernstein (1980) also found that Afrikaans-speaking five to six year-old children displayed problems with the execution of a three-step and some two-step non-speech oral movement sequencing tasks, and needed demonstration in order to accomplish correct sequencing. In a pilot attempt to assess volitional oral movements in children aged three to six years, Ansel et al. (1992) found that although the children could execute isolated oral movements in imitation, they had difficulty sequencing these gestures. They noted that pre-school children could only perform three-sequence pictured non-speech tasks with "...extensive rehearsal..." (Ansel et al.,1992:10) and recommended that if combinatory sequences are included in tests of NSOM, they should compromise of two items only, at least for four to five-year-old children. In the present study similar observations were made since the two four year-old subjects displayed the most problems with sequencing.

Results thus indicated that normal children aged 4;0 to 6;7 years, may still show some errors in the execution of voluntary NSOM in terms of associated movements, sequencing and accuracy, although not profound in nature. Extensive research with larger, normal subject groups is needed in order to expand these basic observations and to clarify observations.

4.3. DESCRIPTION AND DISCUSSION OF RESULTS FOR SUB-AIM TWO: NON-SPEECH ORAL DIADOCHOKINESIS (NSO-DDK)

The goal of this sub-aim was to investigate the ability of normal, Afrikaans-speaking children in the age range 4;0 to 7;0 years, to plan and execute *repetitive, non-speech movements* of the tongue, lips and jaw in *non-speech, oral diadochokinesis (NSO-DDK)*, imitative tasks, by the application of a comprehensive *rating scale* designed for assessing performance on these tasks.

Performance was rated in terms of four categories on the *Rating Scale for Non-Speech Diadochokinesis* (Table 3.10), termed *I. Associated Movements, II. Accuracy of Individual Movements, III. Sequencing* and *IV. Continuity*. The results for all four target movements are presented in Table 4.4. Performance on these movements will be jointly discussed in terms of the categories on the rating scale.

In the following discussion, target movement numbers correspond with the numbers in Table 3.4 as well as the recording/rating sheet compiled for sub-aim two (Appendix B). Roman numerals (e.g. II.) represent categories on the rating scale (Table 3.10), while lower case letters (e.g. b) represent ratings in each category of the scale.

TABLE 4.4: RESULTS FOR NON-SPEECH ORAL DIADOCHOKINESIS

SUB-JECT	AGE (yrs)	I. Associated Movements				II. Accuracy of Individual Movements			III. Sequencing			IV. Continuity		
		a.*	b.*	c.*	d.*	a.*	d.*	f.*	a.*	c.*	f.*	a.*	b.*	d.*
1. Tongue lateralization outside the mouth														
S1	4;0				*			*			*			*
S2	4;1		*			*			*			*		
S3	4;8	*				*			*			*		
S4	5;0		*				*		*			*		
S5	5;3		*				*		*			*		
S6	5;4	*				*			*			*		
S7	5;4	*				*			*			*		
S8	5;6	*				*			*			*		
S9	6;1		*			*			*			*		
S10	6;7		*			*			*			*		
TOTAL:		*4*	*5*		*1*	*7*	*2*	*1*	*9*		*1*	*9*		*1*
2. Tongue in and out of the mouth														
S1	4;0		*			*			*			*		
S2	4;1		*				*		*				*	
S3	4;8		*			*			*			*		
S4	5;0	*				*			*			*		
S5	5;3				*		*				*			*
S6	5;4		*			*			*					*
S7	5;4	*				*			*			*		
S8	5;6		*			*			*			*		
S9	6;1	*				*			*			*		
S10	6;7	*				*			*			*		
TOTAL:		*5*	*5*		*1*	*8*	*2*		*9*		*1*	*7*	*1*	*2*
3. Lips pout and stretch														
S1	4;0			*			*		*			*		
S2	4;1	*				*			*			*		
S3	4;8	*				*			*			*		
S4	5;0	*				*			*			*		
S5	5;3	*				*			*			*		
S6	5;4	*				*			*			*		
S7	5;4	*				*			*			*		
S8	5;6		*					*			*	*		
S9	6;1	*				*			*			*		
S10	6;7	*				*				*				*
TOTAL:		*8*	*1*	*1*		*8*	*1*	*1*	*8*	*1*	*1*	*9*		*1*

** Please refer to the Rating Scale for Non-Speech Oral Movements (TABLE 3.10) for definitions of these abbreviations*

TABLE 4.4 (-CONTINUED): RESULTS FOR NON-SPEECH ORAL DIADOCHOKINESIS

SUB-JECT	AGE (yrs)	I. Associated Movements				II. Accuracy of Individual Movements			III. Sequencing			IV. Continuity		
		a.*	b.*	c.*	d.*	a.*	d.*	f.*	a.*	c.*	f.*	a.*	b.*	d.*
4. Jaw open and close														
S1	4;0	*				*			*			*		
S2	4;1	*						*			*	*		
S3	4;8	*				*			*			*		
S4	5;0	*				*			*			*		
S5	5;3	*				*			*			*		
S6	5;4	*				*			*			*		
S7	5;4	*				*			*			*		
S8	5;6	*				*			*			*		
S9	6;1	*				*			*			*		
S10	6;7		*				*				*	*		
TOTAL:		*9*	*1*			*8*	*1*	*1*	*8*		*2*	*10*		

** Please refer to the Rating Scale for Non-Speech Oral Movements (TABLE 3.10) for definitions of these abbreviations*

In all categories an (a)-rating indicated that *no problems* were displayed for that category. Ratings other than (a) will be referred to as error ratings.

4.3.1. DESCRIPTION OF RESULTS FOR CATEGORY I (ASSOCIATED MOVEMENTS)

From the data in Table 4.4 it can be seen that the most error ratings occurred with target movements one (i.e. *Tongue lateralization/wagging the tongue outside the mouth*) and two (i.e. *Tongue in and out of mouth*), with only one error rating each on target movement three (i.e. *Lips pout and stretch*) and target movement four (i.e. *Jaw open and close*). Further, the data showed that only one subject (S7) scored perfect ratings (i.e. only (a)-ratings) in all four target movements. Error ratings in terms of associated movements for the four target movements consisted of frequent (b)-ratings (i.e. *Associated movement/s of the articulators*), one (c)-rating (i.e. *Associated movements of the body*) two (d)-ratings (i.e. *Associated movements of body and articulators*). It should be noted that some subjects executed the target movements very fast, which also resulted in associated movements. In such cases error ratings were not assigned. When children are asked to perform these movements it is thus important to emphasize that they should "not go too fast". Results thus indicated that some normal 4;0 to 6;7 year-olds may show a tendency to perform repeated tongue movement tasks (e.g. lateralization and in-out movements) with some associated movements of other articulators.

4.3.2. DESCRIPTION OF RESULTS FOR CATEGORY II (ACCURACY OF INDIVIDUAL MOVEMENTS)

The data in Table 4.4 indicated very few error ratings in terms of accuracy. Four subjects (S3, S6, S7 and S9) obtained no error ratings in any target movement, while the rest of the subjects only occasionally displayed an error rating. The few error ratings that occurred consisted of only (d)-ratings (i.e. *Some of the movements were executed inaccurately in terms of placement*) and (f)-ratings (i.e. *Some of the individual movements were executed incorrectly*). Behavior ranged from 'in-out' instead of 'left-right' tongue movements, mouth opening which interfered with lip pout-stretch movements to chewing movements with jaw opening and closing. In general, subjects thus did not display problems with accuracy. Accuracy was sometimes reduced due to a too fast execution rate, in which instances the subjects were not penalized.

4.3.3. DESCRIPTION OF RESULTS FOR CATEGORY III (SEQUENCING)

The data in Table 4.4 indicated that sequencing errors seldom occurred. Only one (c)-rating (i.e. *Obtained completely correct sequencing but needed key words before each movement*) and a few (f)-ratings (i.e. *Impossible to rate due to reduced accuracy or incorrect movements*) were displayed by different subjects (i.e. S1, S2, S5, S8 and S10) across all four target movements. The rest of the subjects scored perfect ratings (i.e. only a-ratings) for all the target movements in Category III. Overall results thus indicated that sequencing in these simple tasks was not problematic for these normal subjects and that only occasional errors occurred.

4.3.4. DESCRIPTIONS OF RESULTS FOR CATEGORY IV (CONTINUITY)

The subjects generally performed well, with only five error ratings occurring across all subjects and target movements (see Table 4.4 for details). Error ratings consisted of occasional (d)-ratings (i.e. *Intermittent/arythmic*) and one (b)-rating (i.e. *Sustained and rhythmic but with slow execution rate*). Five subjects (S3, S4, S7, S8 and S9) displayed no error ratings in any of the target movements.

4.3.5. DISCUSSION OF RESULTS FOR SUB-AIM TWO

In summary, the majority of subjects were thus capable to perform repetitive productions of non-speech movements with good accuracy, sequencing, and continuity. However, associated movements occurred more often, since mandible movements frequently accompanied tongue lateralizations tasks (which corresponds to the findings for voluntary NSOM that was previously reported). Only one subject (S7) never displayed associated movements in any task, which may indicate a general tendency for normal children in this age range to show occasional associated movements in NSO-DDK-tasks.

It can be concluded that the categories and ratings on the compiled *Rating Scale for the Evaluation of Non-speech Oral Diadochokinesis* (Table 3.10), were useful in describing and rating the performance of these normal children. By applying this rating scale, the traditional assessment of repetitive non-speech oral movements was expanded. Basic descriptive normative information regarding the execution of these movements by normal children (aged 4;0 to 6;7 years) were obtained, to which the performance of Afrikaans-speaking children with DSD on these tasks can be clinically compared with.

In the opinion of the examiner *behavioral descriptions* of children's performance on these non-speech diadochokinetic tasks (such as accomplished through the application of the rating scale) may firstly be more practical (i.e. easier to accomplish in a clinical setting) and secondly, may provide more descriptive information regarding symptom patterns in children with DSD, than a mere reporting of diadochokinetic rate (DDR) on these non-speech tasks would do. Unfortunately no comparative studies for this aim was identified, which limits further discussion of these results.

4.4. DESCRIPTION AND DISCUSSION OF RESULTS FOR SUB-AIM THREE: SPEECH DIADOCHOKINESIS (S-DDK)

The goal of this sub-aim was to investigate the ability of normal, Afrikaans-speaking children aged 4;0 to 7;0 years to produce repetitive speech movements in speech diadochokinesis (S-DDK) tasks, involving tongue, lip, velar and glottal movements as elicited in single, two-place and three-place, imitative articulation tasks, by firstly *calculating diadochokinetic rate (DDR)* on these tasks, and secondly, by applying a comprehensive *rating scale* designed for assessing performance on these tasks (perceptual analysis).

The description and discussion of the results for this sub-aim will be divided into two parts. Firstly; various normative *diadochokinetic rate (DDR)-data* will be presented, described and discussed. This will be followed by a joint description and discussion of the perceptual (qualitative) analysis of *overall* S-DDK-performance, based on the application of the compiled *Rating Scale for the Evaluation of Speech Diadochokinesis* (Table 3.11).

Results in both sections of this sub-aim refer to six types of S-DDK. These are *velar* diadochokinesis (DDK)-results (repetitions of [dənə]), *glottal* DDK (repetitions of [pəbə]), *tongue* DDK (repetitions of [tə] and [kə]), *lip DDK* (repetitions of [pə]), *combined DDK in two-place articulation syllable strings* (repetitions of [pəkə], [təkə], [kəpə] and [kətə]), and *combined DDK in three-place articulation syllable strings* (repetitions of [pətəkə], [kətəpə] and [təpəkə]).

4.4.1. DESCRIPTION AND DISCUSSION OF DIADOCHOKINETIC RATE (DDR) RESULTS

Diadochokinetic rate (DDR)-data are presented in Tables 4.5, 4.6, 4.7 and 4.8. Since this study aimed to collect specific normative information regarding diadochokinetic rates, all of the following information were included in these tables in order make the data widely applicable for reference and assessment purposes:

-the ***range*** of repetitions of the target word produced in a *five-second time-period* (note that the word 'range' is not used here as a statistical term, but merely indicates the minimum and maximum number of repetitions produced in the five-second time-period)
-the ***mean*** number of repetitions produced in the five-second time-period
-the mean ***percentage correct score*** (PC-score), which indicates how many of the repetitions were produced with complete accuracy
-the ***diadochokinetic rate*** (DDR), which represents the number of repetitions produced per second (rep/sec) and makes the data comparable to norms

In these tables data are reported for *each specific age group*, namely *four*-year-olds (n=3), *five*-year-olds (n=5) and *six*-year-olds (n=2). However, these age-specific group data are merely reported for completeness and possible future comparison of normative data and should be regarded as preliminary due to the small number of subjects per age group it is based on. In addition, data for the *subjects as a group* (n=10) are also reported, which thus represents DDR-data for normal children in the age range 4;0 to 6;7 years.

It is emphasized that the data for the ten *subjects as a group* can clinically speaking be considered to be of higher application value than the *specific* age group data because of several aspects. Firstly, the specific age group data only represent very few children of each age, while the data for the subjects as a group represent ten children. Secondly, data of the subjects as a group provide a *range* of expected DDR's which may be more appropriate for normative assessment purposes. It is widely reported in both adult and child studies of S-DDK that large inter-subject and intra-subject variability can occur (Kent,1997). In a clinical setting for example (e.g. assessment of DSD), it may thus be more appropriate to determine whether a child displays DDR-data outside the *normal range* reported for 4;0 to 6;7 year-old normal children in this study, than to compare the child's performance to the norms for his/her specific age group or mean DDR's. The *standard deviation* from the mean for the subjects as a group is thus also reported in the data for reference purposes. As a result of all these factors, the description and discussion of diadochokinetic rate results will mainly focus on the DDR-data of the *subjects as a group (n=10)*.

Combined description and discussion of the DDR-results for all the material presented in Tables 4.5 to 4.8 will take place with reference to existing DDR-norms, individual or specific age group trends in performance and data for the different material (i.e. different S-DDK tasks).

TABLE 4.5: DIADOCHOKINETIC RATE DATA FOR [tə], [pə] AND [kə]

Age Range	[tə]			[pə]			[kə]		
	Range	Mean	Mean PC	Range	Mean	Mean PC	Range	Mean	Mean PC
4;0 to 4;8 years	16-18	17	100	15-18	16	100	17-18	17	96
DDR (rep/sec)	3.4			3.2			3.4		
5;0 to 5;6 years	15-25	20	99	16-24	20	100	14-26	19	98
DDR (rep/sec)	4			4			3.8		
6;1 to 6;7 years	14-22	18	100	16-22	19	100	18-20	19	100
DDR (rep/sec)	3.6			3.8			3.8		
4;0 to 6;7 years	14-25	19	97	15-24	19	100	14-26	19	98
DDR (rep/sec)	**2.8 - 5 Mean: 3.8** (STDEV=3.6)			**3 - 4.8 Mean: 3.8** (STDEV=3.1)			**2.8 - 5.2 Mean: 3.8** (STDEV=3.5)		

ABBREVIATIONS: STDEV=Standard deviation Rep/sec=Number of repetitions per second PC=Percentage correct score DDR=Diadochokinetic rate (reported in repetitions per second)

TABLE 4.6: DIADOCKINETIC RATE DATA FOR [pəbə] AND [dənə]

Age Range	[pəbə]			[dənə]		
	Range	Mean	Mean PC	Range	Mean	Mean PC
4;0 to 4;8 years	6-10	8	27	9	9	100
DDR (rep/sec)	1.6			1.8		
5;0 to 5;6 years	8-12	10	24	10-12	11	98
DDR (rep/sec)	2			2.2		
6;1 to 6;7 years	5-7	6	86	8-10	9	85
DDR (rep/sec)	1.2			1.8		
4;0 to 6;7 years	5-12	9	37	8-12	10	96
DDR (rep/sec)	**1 - 2.4 Mean: 1.8** (STDEV=2.3)			**1.6 – 2.4 Mean: 2** (STDEV=1.3)		
DDR based on accurate productions only (S4 and S10)	Distribution: 5-8 Mean: 6.5 DDR: **1 to 1.6**					

ABBREVIATIONS: STDEV=Standard deviation Rep/sec=Number of repetitions per second PC=Percentage correct score DDR=Diadochokinetic rate (reported in repetitions per second)

TABLE 4.7: DIADOCHOKINETIC RATE DATA FOR [pəkə], [təkə], [kəpə] AND [kətə]

Age Range	[pəkə]			[təkə]		
	Range	Mean	Mean PC	Range	Mean	Mean PC
4;0 to 4;8 years	8-10	9	100	7-9	8	92
DDR (rep/sec)	1.8			1.6		
5;0 to 5;6 years	9-14	11	88	9-13	10	98
DDR (rep/sec)	2.2			2		
6;1 to 6;7 years	10-11	11	100	11	11	100
DDR (rep/sec)	2.2			2.2		
4;0 to 6;7 years	8-14	11	94	7-13	10	97
DDR (rep/sec)	**1.6 - 2.8 Mean: 2.2** (STDEV=1.7)			**1.4 - 2.6 Mean: 2** (STDEV=1.8)		

ABBREVIATIONS: STDEV=Standard deviation Rep/sec=Number of repetitions per second PC=Percentage correct score DDR=Diadochokinetic rate (reported in repetitions per second)

TABLE 4.7 (-CONTINUED): DIADOCHOKINETIC RATE DATA FOR [pəkə], [təkə], [kəpə] AND [kətə]

Age Range	[kəpə]			[kətə]		
	Range	Mean	Mean PC	Range	Mean	Mean PC
4;0 to 4;8 years	5-9	7	67	7-8	7	95
DDR (rep/sec)	1.4			1.4		
5;0 to 5;6 years	10-13	11	100	9-10	10	96
DDR (rep/sec)	2.2			2		
6;1 to 6;7 years	8-9	9	94	8-9	9	100
DDR (rep/sec)	1.8			1.8		
4;0 to 6;7 years	5-13	10	89	7-10	9	96
DDR (rep/sec)	**1 - 2.6** Mean: **2** (STDEV=2.3)			**1.4 - 2** Mean: **1.8** (STDEV=1.2)		

ABBREVIATIONS: STDEV=Standard deviation Rep/sec=Number of repetitions per second PC=Percentage correct score DDR=Diadochokinetic rate (reported in repetitions per second)

TABLE 4.8: DIADOCHOKINETIC RATE DATA FOR [pətəkə],[kətəpə] AND [təpəkə]

Age Range	[pətəkə]			[kətəpə]			[təpəkə]		
	Range	Mean	Mean PC	Range	Mean	Mean PC	Range	Mean	Mean PC
4;0 to 4;8 years	5	5	87	4-5	5	50	4-5	5	60
DDR (rep/sec)		1			1			1	
5;0 to 5;6 years	6-9	7	74	5-7	6	91	3-6	5	75
DDR (rep/sec)		1.4			1.2			1	
6;1 to 6;7 years	6	6	100	4-5	5	68	5-6	6	59
DDR (rep/sec)		1.2			1			1.2	
4;0 to 6;7 years	5-9	6	83	4-7	5	74	4-6	5	67
DDR (rep/sec)	**1 - 1.8** Mean: **1.2** (STDEV=1.3)			**0.8 - 1.4** Mean: **1** (STDEV=0.9)			**0.8 - 1.2** Mean: **1** (STDEV=1.1)		

ABBREVIATIONS: STDEV=Standard deviation Rep/sec=Number of repetitions per second PC=Percentage correct score DDR=Diadochokinetic rate (reported in repetitions per second)

4.4.1.1. Description and discussion of general trends in DDR-data

Results indicated that the fastest DDR's were obtained for [tə], [pə], and [kə], with a DDR-range for the subjects as a group ranging from of 2.8 to 5.2 rep/sec across these words (see Table 4.5). The second fastest DDR's occurred for two-syllable strings ([pəbə], [dənə], [pəkə], [təkə], [kəpə] and [kətə]), with a DDR-range for the subjects as a group ranging from 1 to 2.8 rep/sec across these words (see Tables 4.6 and 4.7). The slowest DDR's occurred with three-syllable strings [pətəkə], [kətəpə] and [təpəkə]), with DDR's for the subjects as a group ranging from 1 to 1.8 rep/sec (see Table 4.8). An overview of the data in Tables 4.5 to 4.8 thus indicated that DDR's decreased as the syllable length of the material increased, which is in agreement with previously reported data (Fletcher,1972;

Yoss & Darley,1974; Ludwig,1983; Robbins & Klee,1987; Kent,1997). (Note that the percentage correct score data will be discussed in the following section on perceptual results).

Table 4.9 provides a comparison of existing DDR-norms for English on similar material, with the norms obtained in this study. (It should be noted that the present study is unique in the sense that it aimed to collect DDR's about a variety of S-DDK material). Since it represents normative information of a wider variety of S-DDK-tasks than those reported in other studies, only limited discussion of some material is possible).

TABLE 4.9: DDR'S OBTAINED BY AGE GROUPS IN THIS STUDY COMPARED WITH PREVIOUSLY REPORTED MEAN DDR'S (MEASURED IN REPETITIONS PER SECOND)

TARGET (*Afrikaans and English*)	REPORTED DDR's (measured in repetitions per second)							
	Fletcher (1972) (English)	**Yoss and Darley (1974) (English)**	**Bernstein (1980) (Afrikaans)**	**Ludwig (1983) (English)**	**Robbins and Klee (1987) (English)**	**Irwin and Becklund (1953) (English)**	**Kent (1997) (Based on mean data reported in literature for English)**	**Present Study (Afrikaans)**
[pə] / [pʌ]	4yrs: - 5yrs: - 6yrs: 4.2	4yrs: - 5yrs: 4.2 6yrs: 4.5		4yrs: 3.6 5yrs: 4.2 6yrs: -	4yrs: 4.9 5yrs: 4.8 6yrs: **5.4**	4yrs: - 5yrs: - 6yrs: 2.5 - 4.7 (M: 3.6)	4yrs: 4.7 5yrs: 4.9 6yrs: 5.3	4yrs: **3.2** 5yrs: 4 6yrs: 3.8
[tə] / [tʌ]	4yrs: - 5yrs: - 6yrs: 4.1	4yrs: - 5yrs: 4.2 6yrs: 4.5		4yrs: 4.3 5yrs: 4.3 6yrs: -	4yrs: 4.8 5yrs: 4.8 6yrs: 5.3	4yrs: - 5yrs: - 6yrs: **2.4** - 4.6 (M: 3.4)	4yrs: 4.7 5yrs: 4.9 6yrs: 5.3	4yrs: 3.4 5yrs: 4 6yrs: 3.6
[kə] / [kʌ]	4yrs: - 5yrs: - 6yrs: 3.6	4yrs: - 5yrs: 3.9 6yrs: 4.3		4yrs: 3.9 5yrs: 3.9 6yrs: -	4yrs: 4.6 5yrs: 4.6 6yrs: 4.9	4yrs: - 5yrs: - 6yrs: 2.3 - 4.3 (M: 3.2)	4yrs: 4.3 5yrs: 4.7 6yrs: 4.8	4yrs: 3.4 5yrs: 3.8 6yrs: 3.8
[pətəkə] / [pʌtʌkʌ]	4yrs: - 5yrs: - 6yrs: 1	4yrs: - 5yrs: 3.4 6yrs: **3.8**	4yrs: - 5yrs: 1.3 6yrs: -	4yrs: 1 5yrs: **0.9** 6yrs: -				4yrs: **1** 5yrs: **1.4** 6yrs: 1.2

NOTES: (1): Norms from the different studies were converted to repetitions per second in order to make data comparable irrespective of whether the 'count-by-time' or 'time-by-count' method of assessment was used. (2) This study also reported data for additional material (see description and discussion of results) ABBREVIATIONS: M=Mean yrs=years

When the data in Table 4.9 are reviewed it can be seen that the range of DDR-values obtained by the age groups in this study for [tə], [pə], [kə] (i.e. ranging overall from 3.2 to 4 rep/sec), fell *within the range* of DDR's previously reported for these syllables (i.e. ranging overall from 2.4 to 5.4 rep/sec). The range of DDR-values obtained by the subjects in this study for [pətəkə] (i.e. ranging overall from 1 to 1.4 rep/sec) also fell *within the range* of DDR's previously reported for these syllables (i.e. ranging overall from 0.9 to 3.8 rep/sec).

However, the ***mean*** DDR's for the age groups on [tə], [pə], and [kə] for example, agreed well with those norms reported by Ludwig (1983) and Irwin and Buckland (1953), but were slightly *slower* than the data of Robbins and Klee (1987) and Kent (1997). DDR's for [pətəkə] agreed with norms reported by Ludwig (1983), Bernstein (1980) and Fletcher (1972) but were again *slower* than the norms reported for normal control subjects by Yoss and Darley (1974). No reported norms could be found for the rest of the material used in this study, but the DDR's displayed by the subjects for [dənə], [pəbə], [pəkə], [təkə], [kəpə] and [kətə] also fell within in the reported distribution in Table 4.9. DDR's for two-place syllable strings were slightly slower than the DDR's for CV-syllables, yet faster than the DDR's for three-place syllable strings. This is in agreement with the general expectation that shorter syllable strings will lead to faster DDR's than longer syllable strings (Baken,1987).

4.4.1.2. Discussion of instances of slower DDR's found in this study than those reported in some other studies

Some explanations can be offered for the sometimes slower DDR's displayed by subjects in this study than those reported in some other studies (e.g. Robbins & Klee,1987). Firstly, it has to be mentioned that slightly different vowels are applicable for English and Afrikaans material (i.e. [ə] vs. [ʌ]), which could have contributed to the slightly slower mean DDR's in this study. It was also noticed that the subjects in the present study articulated the vowels in each CV-syllable distinctly, usually emphasizing the vowel in the first syllable, which could also have slowed their DDR's. Further, this study elicited the DDR-samples in a game (play elicitation mode), which succeeded in keeping the subjects interested in the tasks and encouraged co-operation especially from younger subjects, but could have interfered with the rate of execution. Although unlikely, since the examiner manipulated the toys involved, subjects still might have concentrated more on the actions of the toys than on their productions.

In addition, children in this study were encouraged to say the target words fast, but were urged not to go "too fast". Robbins and Klee (1987) for example, instructed their subjects to repeat the material as "quickly as possible" during a three-second-period. In the present study it was also noticed that children's fastest productions occurred very early in the eight-second-period of elicitation (DDR's were determined over the first five seconds), where after they maintained a steady rate of production. It can be speculated that if the DDR's in this study were determined over a period of three seconds only, faster mean DDR's would possibly have been obtained. Irwin and Becklund (1953) for example, also determined their DDR's over a five-second period and showed DDR's closer to those reported in this study (see Table 4.9).

Subsequently, when all these differences are considered, it should be emphasized that the normative information obtained in this study are most applicable for Afrikaans-speaking children, and should only be used in diagnostic settings where the DDR's were elicited exactly as described in this study (i.e. with a similar elicitation mode and instructions). The examiner would like to point out that this method of eliciting S-DDK-data is recommended for clinical use with children in this age range, due to its simplicity and the good amount of subject-co-operation it elicited.

4.4.1.3. <u>Description and discussion of individual and specific age group data</u>

Specific age group results indicated a general tendency for the four-year-old subjects to show slightly slower DDR's than the five and six-year-olds, although these differences were sometimes very small (See Tables 4.5 to 4.8). Occasionally a four-year-old also displayed slightly faster DDR's than some six and five-year-olds. The five-year-olds as a group generally displayed the fastest DDR's, but this was mostly caused by the very fast DDR's displayed by S7. A review of the individual data indicated that five and six year-olds performed quite similarly (see Tables 4.10 to 4.13 for individual DDR-data).

The general consensus in literature regarding DDR-information is that younger children can be expected to show slower DDR's than older children (e.g. Baken, 1987). However, variability in performance is also frequently cited and a review of the reported norms in Table 4.9 indicated very small differences between the DDR's of four, five and six-year-olds. From the distribution of performance reported by Irwin and Becklund (1953), it can be seen that a wide range of DDR's is possible, even for six-year-olds. Subjects in this study also displayed inter-subject variability in the number of syllables produced in the five-second time-period.

As previously explained, specific age group results should be considered very tentatively in the light of the small number of subjects used in this study. Larger subject groups in subsequent studies will throw more light on these identified, possibly age-related performance trends in Afrikaans children's speech diadochokinesis. Until more information has been obtained, it is again recommended that the *range* (lowest and highest DDR's, means etc.) obtained by the ten *subjects as a group* for particular material is used for evaluation purposes and *not specific age group data*.

4.4.1.4. <u>Description and discussion of DDR's for material of the same structure</u>

When the DDR-distributions for the different material in Tables 4.2 to 4.8 are considered for the subjects as a group, it can be seen that results for tongue and lip DDK in *CV-syllables* were more or less the same for all three target words (same means for [pə], [kə], and [tə]). Slightly slower DDR's were obtained for <u>glottal</u> (i.e. [pəbə]) than for <u>velar</u> DDK-tasks (i.e.[dənə]) (see Table 4.6). In addition, subjects also displayed very low PC-scores on the glottal DDK-task, further indicating that glottal DDK might be more difficult to accomplish than velar DDK (this will discussed more in depth in the next section).

The DDR's for the subjects as a group for two-place tongue and lip DDK-tasks (Table 4.7) indicated slightly faster DDR's for [pəkə] and [təkə] (front-to-back DDK) than for [kəpə] and [kətə] (back-to-front DDK). Results for three-place lip and tongue DDK-tasks indicated the fastest DDR's for front-middle-back DDK (i.e.[pətəkə]), second fastest DDR's for back-middle-front DDK (i.e.[kətəpə]) and slightly slower DDR's for mixed DDK (middle-front-back i.e. [təpəkə]).

However, DDR-differences between material of the same category were very small and only limited interpretations can be made regarding DDR's in different contexts from this study. Although these results do indicate some interesting trends in performance that may be explored in future studies, more extensive research is needed regarding the relationship between DDR's and context before conclusions can be reached.

4.4.2. DESCRIPTION AND DISCUSSION OF PERCEPTUAL ANALYSIS RESULTS FOR S-DDK

Performance was rated in terms of four categories on the compiled *Rating Scale for the Evaluation of Speech Diadochokinesis* (Table 3.11) named *I. Continuity, II. Associated Movements, III. Accuracy* and *IV. Sound Structure*. The results will be discussed in terms of the subjects' performance on these categories for the different material. In the following discussion, material corresponds with the material outlined in Table 3.5 and the *Test/Recording/Rating Sheet* compiled for sub-aim three (Appendix C). Roman numerals (e.g. II.) represent *categories* on the rating scale (Table 3.11) while lower case letters (e.g. b.) represent *ratings* in each category of the scale.

The overall, perceptual S-DDK data are summarized in Tables 4.10, 4.11, 4.12 and 4.13. In all categories an (a)-rating (indicated by an asterisk in the a-rating column) indicated that *no problems* were displayed for that category and that the subject thus produced *all* of the repetitions produced in the five-second time-period without any problems in that particular category. Numerical entries in columns other than (a) represent the number of times a particular error rating occurred across all of a subjects' repetitions in the five second time-period, except for continuity ratings (Category I.) which just consisted of an overall rating, and was thus only indicated by an asterisk in the applicable rating column. It is again emphasized that it was possible for a subject to score more than one error rating per repetition on categories III. (*Accuracy*) and IV. (*Sound Structure*). Multiple error ratings were also possible across categories for the same repetition (see Chapter 3 for clarification). In all the tables PC-scores (percentage correct) refer to the percentage of repetitions a subject produced with perfect accuracy, sound structure, continuity and without any associated movements. *Group PC-scores* will be discussed based on the data previously presented in Tables 4.5 to 4.8.

The perceptual S-DDK results will be described and discussed in terms of tongue and lip DDK in CV-syllables (i.e. [pə], [tə] and [kə]), followed by data for glottal DDK (i.e. [pəbə]), two-place lip, tongue and velar DDK in CVCV-syllables (i.e.[pəkə], [təkə], [kəpə] and [kətə]) and finally results for three-place DDK in CVCVCV-syllables (i.e. [pətəkə], [kətəpə] and [təpəkə]).

4.4.2.1. Description and discussion of perceptual S-DDK-results for [pə], [tə] and [kə]

The following results were obtained for tongue and lip DDK in CV-syllables [pə], [tə] and [kə] with regard to error ratings and PC-scores. Data from Table 4.5 indicated that the subjects as a group obtained a PC-score of 100 for [pə], 98 for [kə] and 97 for [tə], while data in Table 4.10 showed that error ratings (i.e. ratings other than (a) on the rating scale) were only displayed for [kə] and [tə].

Individual data in Table 4.10 indicated that only S7 and S1 scored PC-scores lower than 100 for these syllables. However, S7 also displayed the most repetitions in five seconds for all three CV-syllables, implying that too fast an execution rate might have resulted in his accuracy errors.

TABLE 4.10: SPEECH DIADOCHOKINESIS PERCEPTUAL RESULTS FOR [pə], [tə] AND [kə]

SUBJECT	PC-score	Nr. of R/5/s	I. Conti-Nuity	II. Associated Move-ments	III. Accuracy			IV. Sound Structure		General consistency of overall error pattern
			a.*	a.*	a.*	d.*	f.*	a.*	d.*	
[pə]										
S1	100	*18*	*	*	*			*		
S2	100	*15*	*	*	*			*		
S3	100	*16*	*	*	*			*		
S4	100	*18*	*	*	*			*		
S5	100	*16*	*	*	*			*		
S6	100	*22*	*	*	*			*		
S7	100	*24*	*	*	*			*		
S8	100	*20*	*	*	*			*		
S9	100	*16*	*	*	*			*		
S10	100	*22*	*	*	*			*		
[tə]										
S1	100	*17*	*	*	*			*		
S2	100	*16*	*	*	*			*		
S3	100	*18*	*	*	*			*		
S4	100	*18*	*	*	*			*		
S5	100	*15*	*	*	*			*		
S6	100	*22*	*	*	*			*		
S7	88	*25*	*	*		3		*	3	Consistent
S8	100	*21*	*	*	*			*		
S9	100	*14*	*	*	*			*		
S10	100	*22*	*	*	*			*		
[kə]										
S1	88	*17*	*	*			2	*		Consistent
S2	100	*17*	*	*	*			*		
S3	100	*18*	*	*	*			*		
S4	100	*15*	*	*	*			*		
S5	100	*14*	*	*	*			*		
S6	100	*22*	*	*	*			*		
S7	92	*26*	*	*			2	*		Consistent
S8	100	*20*	*	*	*			*		
S9	100	*18*	*	*	*			*		
S10	100	*20*	*	*	*			*		

**Please refer to the Rating Scale for Speech Diadochokinesis (TABLE 3.11) for definitions of these abbreviations*
** Nr. of r/5/s =Number of repetitions produced in 5 seconds*

S1 scored two (f)-ratings (i.e. *Mild phonetic inaccuracy of vowel*) on *Accuracy* (i.e. Category III.), due to slight distortion of [kə] to almost [kæ] on two repetitions, which could also have been caused by fast execution for that particular target. In summary, the subjects thus displayed very few errors with CV-syllable S-DDK-tasks.

4.4.2.2. Description and discussion of perceptual S-DDK-results for [pəbə]

Results in Table 4.6 indicated that with all S-DDK-material considered, the subjects as a group obtained the lowest PC-score (i.e. 37) for this two-place, glottal (i.e. [pəbə]) DDK-task. Data in Table 4.11 indicated that only two subjects (i.e. S10 and S4) managed to obtain a PC-score of 100 for this utterance, with two subjects (S7 and S8) even scoring PC-scores of 0. It was noted that both S10 and S4 reduced their execution rate considerably. S4 maintained a rhythmic but slow execution rate (i.e. Category I.(b)-rating), and scored a (b)-rating (i.e. *slow execution but accurate*) on Accuracy (Category III.). S10 *displayed successful self-correction without prompting* (i.e. Category IV.(b)-rating) also leading to a (d)-rating (i.e. *mildly intermittent/a-rhythmic due to self-correction or a syllable addition in the middle of the series*) in Category I. (Continuity), and further a (b)-rating (i.e. *slow execution but accurate*) in Category III. (Accuracy). The low PC-scores for this target were mostly caused by the fact that the majority of subjects produced the target sequence as "[bəbə]" or "[pəpə]", resulting in a *voicing error* (i.e. III.(d)-rating) and *substitution with a sound/syllable in the target utterance-error* (i.e. a IV(c)-rating, see Table 4.11).

The results for [pəbə] may indicate that normal children between 4;0 and 6;7 years find glottal S-DDK more difficult than other S-DDK-tasks in terms of *accuracy*. Production of this sequence requires that the glottis (vocal cords) is opened for the production of voiceless [p] and then closed for voiced [ə], [b] and [ə]. Presumably, some normal children this age still find repetitive execution of these alternating articulatory movements difficult. Even when the subjects were alerted to the fact that they should produce two distinctly different sounds, voicing errors continued to occur.

TABLE 4.11: SPEECH DIADOCHOKINESIS PERCEPTUAL RESULTS FOR [pəbə] AND [dənə]

Subject	PC-score	Nr. of r/5/s	I. Continuity				II. Ass. Movem.	III. Accuracy			IV. Sound Structure							General Consistency Of Overall Error Pattern
			a.*	b.*	c.*	d.*	a.*	a.*	b.*	d.*	a.*	b.*	c.*	g.*	h.*	j.*	k.*	
[pəbə]																		
S1	22	*9*	*				*			8			8			1		Inconsistent
S2	50	*6*		*			*			3			3					Inconsistent
S3	10	*10*	*				*			9			9					Consistent
S4	100	*8*		*			*		*		*							
S5	9	*11*	*				*			10			10					Consistent
S6	11	*9*			*		*			8			8		1			Inconsistent
S7	0	*12*	*				*			12			12					Consistent
S8	0	*11*	*				*			11			11					Inconsistent
S9	71	*7*				*	*			2			2					Consistent
S10	100	*5*				*	*		*			1						
[dənə]																		
S1	100	*9*	*				*	*			*							
S2	100	*9*	*				*	*			*							
S3	100	*9*	*				*	*			*							
S4	100	*11*	*				*	*			*							
S5	90	*10*			*		*	*									1	
S6	100	*12*	*				*	*			*							
S7	100	*12*	*				*	*			*							
S8	100	*10*	*				*	*			*							
S9	100	*8*	*				*	*			*							
S10	70	*10*	*				*	*			*			3	3		3	Consistent

** Nr.r/5/s= Number of repetitions per 5 seconds * Please refer to the Rating Scale for Speech Diadochokinesis (TABLE 3.11) for definitions of these abbreviations*

S7 for example, who displayed the fastest overall DDR's, did not manage to produce any correct productions of the this target sequence at all (although he did indicate awareness of the auditory difference between [b] and [p]).

It can be argued that auditory discrimination problems could also have contributed to the children's difficulty, since the [p] and [b]-sounds are perceptually very similar. However, in the pre-test elicitation of these targets, all the subjects (except S7, as discussed) could produce two distinct sounds, indicating that the auditory difference was recognized, which reduces this possibility. In addition, it is possible that in the S-DDK-task the subjects concentrated so hard on production of the repetitive movements that they did not pay attention to maintaining the perceptual distinction between the two sounds, or that their perception was distorted due to the fast rate of production. It is not certain whether the subjects were aware of their voicing errors, though, and any suggestions regarding the possible influence of perceptual factors on the data remains hypothetical and in need of further investigation.

It seemed that the children were more likely to manage this target sequence accurately when they reduced the rate of performance significantly (as displayed by S4 and S10, see Table 4.11). For this target utterance it thus may be more appropriate to use these two subjects' data for normative DDR-guidelines (previously discussed), since their results represent accurate productions. This would reduce the group-DDR for [pəbə] in Table 4.6 from 1 to 2.4 rep/sec to 1 to 1.6 rep/sec.

However, it was noted that reductions in performance rate did not result in increased accuracy in every case. (e.g. S2). Results showed that while some children in the study were thus inclined to be more accurate production when they had more time to execute the target utterance, others couldn't accomplish increased accuracy even when they did reduce their execution rate. In addition, results did not indicate this rate reduction to be a trend in general performance across the subject group. Most children did not show any adaptation in execution rate or did not indicate any awareness of inaccurate production. Very individual trends in performance thus occurred, due to possibly a variety of different influential factors (e.g. personality aspects such as perseverance, motivation to get the task right, perceptual factors, neurophysiological-maturational factors or other presently yet unknown factors).

However, these findings may indicate that a *reduction in execution rate* (evidenced in a decreased DDR) accompanied by *increased accuracy*, can be regarded as a positive trend in performance. It can be suggested that in such instances the child possibly reduces execution rate to allow more time for successful sensorimotor planning of the utterance, resulting in improved accuracy, sequencing, and continuity. This may further be taken as evidence to suggest that some normal children between the age of 4;0 and 6;7 years may apply a reduction in execution rate as a natural, *compensatory strategy* to accomplish more complex, articulatory movement sequences. Normal adult speakers for example, will also reduce speaking rate when an unfamiliar or long word is to be produced (Van der Merwe,1997).

These results further led to the conclusion that aspects of both rate (DDR) and accuracy should be considered when children's performances on more difficult S-DDK-tasks are evaluated. However, presently the exact relationship between DDR (rate) and aspects such as accuracy, sequencing, and continuity is unclear, which limits interpretations. Such a relationship can at best be assumed to be complex and certainly is an area in need of more extensive investigation.

4.4.2.3. Description and discussion of perceptual S-DDK-results for [dənə], [pəkə], [təkə], [kətə] and [kəpə]

Data in Table 4.6 showed that the subjects as a group obtained a high PC-score of 96 for two-place velar DDK (i.e. [dənə]), with only two subjects (S5 and S10) scoring any error ratings (see Table 4.11 for details). Results for two-place lip and tongue DDK-tasks also showed PC-scores above 90% for [pəkə], [təkə] and [kətə], with a group PC-score of 89% for [kəpə] (Table 4.7). The latter score was mostly due to a PC-score of 0 obtained by S1 (four-years-old), as can be seen from the results in Table 4.12.

Data thus showed that the subjects displayed very few error ratings for two-place S-DDK-tasks and that performance for two-place S-DDK-tasks was very similar (except for [pəbə], as discussed in the previous section). Subjects displayed no problems with either *Continuity* (Category I) or with *Associated movements* (Category II). *Accuracy (Category III)* error ratings only occurred for S7 and S8 in the form of (f) error-ratings (i.e *insertion*). The rest of the errors that occurred for these two-place S-DDK tasks were restricted to errors in terms of Sound Structure (Category IV) and ranged from occasional *syllable additions* (i.e. IV-e) and *substitutions* (i.e. IV-c), to *sound insertions* (i.e. IV-f) and *transpositionings* (i.e. IV-j), (see Table 4.12).

As with CV-syllable S-DDK-tasks, it was noticed that some subjects with very fast DDR's (i.e. produced many rep/sec) sometimes showed reduced accuracy, maybe as result of too fast an execution rate. S7 for example, maintained the fastest DDR for [pəkə] (DDR=2.8), but obtained the lowest PC-score (i.e. 57), although he did score a PC-score of 100 for the rest of the two-syllable S-DDK-tasks. In contrast, the youngest subject displayed a DDR of only 1.6 for [pəkə] but obtained a PC-score of 100 (Table 4.12), again suggesting that both accuracy and performance rate (DDR) should be considered in S-DDK-testing. Other subjects again, maintained fast execution rates without any accuracy problems (e.g. S5). Results thus indicated that these normal children were generally capable of accurate production of two-place S-DDK-tasks, although individual trends in performance occurred.

TABLE 4.12: SPEECH DIADOCHOKINESIS PERCEPTUAL RESULTS FOR [pəkə], [təkə], [kəpə] AND [kətə]

Subject	PC-score	Nr. of R/5/s	I. Conti-Nuity		II. Ass. Move-ments	III Accura-cy		IV. Sound Structure					General Consistency of Error Pattern
			a.*	d.*	a.*	a.*	f.*	a.*	c.*	e.*	f.*	j.*	
[pəkə]													
S1	100	8	*		*	*		*					
S2	100	9	*		*	*		*					
S3	100	10	*		*	*		*					
S4	100	9	*		*	*		*					
S5	91	11	*		*	*				1			
S6	100	12	*		*	*		*					
S7	57	14	*		*		6	*					Consistent
S8	91	11	*		*		1	*					
S9	100	10	*		*	*		*					
S10	100	11	*		*	*		*					
[təkə]													
S1	75	8	*		*	*			1	1			Inconsistent
S2	100	7	*		*	*		*					
S3	100	9	*		*	*		*					
S4	100	9	*		*	*		*					
S5	90	10	*		*	*					1		
S6	100	9	*		*	*		*					
S7	100	13	*		*	*		*					
S8	100	11	*		*	*		*					
S9	100	11	*		*	*		*					
S10	100	11	*		*	*		*					
[kəpə]													
S1	0	5	*		*	*				5			Consistent
S2	100	9	*		*	*		*					
S3	100	8	*		*	*		*					
S4	100	12	*		*	*		*					
S5	100	10	*		*	*		*					
S6	100	11	*		*	*		*					
S7	100	13	*		*	*		*					
S8	100	10	*		*	*		*					
S9	88	8	*		*	*					1		
S10	100	9	*		*	*		*					

**Please refer to the Rating Scale for Speech Diadochokinesis (TABLE 3.11) for definitions of these abbreviations*
** Nr. of R/5/s=Number of repetitions produced in 5 seconds*

TABLE 4.12 (-CONTINUED): SPEECH DIADOCHOKINESIS PERCEPTUAL RESULTS FOR [pəkə], [təkə], [kəpə] AND [kətə]

Subject	PC-score	Nr. of R/5/s	I. Conti-Nuity		II. Art. Move-ments	III Accura-cy		IV. Sound Structure					General Consistency of Error Pattern
			a.*	d.*	a.*	a.*	f.*	a.*	c.*	e.*	f.*	j.*	
[kətə]													
S1	86	7	*		*	*				1			
S2	100	7	*		*	*		*					
S3	100	8	*		*	*		*					
S4	78	9		*	*	*				1		1	Consistent
S5	100	10	*		*	*		*					
S6	100	10	*		*	*		*					
S7	100	9	*		*	*		*					
S8	100	10	*		*	*		*					
S9	100	8	*		*	*		*					
S10	100	9	*		*	*		*					

**Please refer to the Rating Scale for Speech Diadochokinesis (TABLE 3.11) for definitions of these abbreviations*
** Nr. of R/5/s=Number of repetitions produced in 5 seconds*

4.4.2.4. Description and discussion of perceptual S-DDK-results for [pətəkə], [kətəpə] and [təpəkə]

Results for three-place lip and tongue DDK indicated the highest group PC-score for front-middle-back DDK (i.e.[pətəkə]), second highest for back-middle-front DDK (i.e.[kətəpə]) and slightly lower PC-scores for mixed diadochokinesis (middle-front-back i.e. [təpəkə]) (see Table 4.8) This is exactly the same order as found in the previously discussed DDR-results for this material. The subjects as a group thus displayed the second slowest DDR's and PC-scores for three-place S-DDK-tasks (as discussed before, only data for [pəbə] had lower PC-scores and DDR's).

Investigation of individual data (Table 4.13) indicated that 50% of the subjects (S2, S3, S8, S9, S10) scored no error ratings in any category of the rating scale for [pətəkə], while 40% of the subjects (S3, S4, S5, S8) scored no error ratings in any category of the rating scale for [kətəpə]. Only two subjects (S6 and S9) scored no error ratings in any category of the rating scale for [təpəkə].

TABLE 4.13: SPEECH DIADOCHOKINESIS PERCEPTUAL RESULTS FOR [pətəkə],[kətəpə] AND [təpəkə]

Subject	PC-score	Nr. of R/S/s	I. Continuity				II. Ass. Movem.	III. Accuracy		IV. Sound Structure									General Consistency of Error Pattern
			a.*	b.*	c.*	d.*	a.*	a.*	d.*	a.*	b.*	c.*	d.*	e.*	f.*	g.*	j.*	k.*	
[pətəkə]																			
S1	60	5	*				*	*								1	1		Inconsistent
S2	100	5	*				*	*		*									
S3	100	5	*				*	*		*									
S4	86	7				*	*	*			1								
S5	33	6	*				*	*					4						Inconsistent
S6	89	9			*		*	*							1				
S7	63	8				*	*	*						4			1		Inconsistent
S8	100	6	*				*	*		*									
S9	100	6	*				*	*		*									
S10	100	6	*				*	*		*									
[kətəpə]																			
S1	0	5	*				*	*				5							Consistent
S2	50	4		*			*	*									2		Consistent
S3	100	5	*				*	*		*									
S4	100	6	*				*	*		*									
S5	100	5	*				*	*		*									
S6	83	6			*		*	*										1	
S7	71	7				*	*	*								1	1		Inconsistent
S8	100	6	*				*	*		*									
S9	60	5				*	*		1		1		1		1				
S10	75	4	*				*	*				1							

TABLE 4.13 (-CONTINUED): SPEECH DIADOCHOKINESIS PERCEPTUAL RESULTS FOR [pətəkə], [kətəpə] AND [təpəkə]

Subject	PC score	Nr. of R/5/s	I. Continuity				II. Ass. Movem.	III. Accuracy		IV. Sound Structure									General Consistency of Error Pattern
			a.*	b.*	c.*	d.*	a.*	a.*	d.*	a.*	b.*	c.*	d.*	e.*	f.*	g.*	j.*	k.*	
[təpəkə]																			
S1	80	5	*				*	*				1							
S2	0	4		*			*	*									4		Consistent
S3	100	5		*			*	*		*									
S4	83	6	*				*	*						1					
S5	100	3		*			*	*		*									
S6	100	6	*				*	*		*									
S7	25	4				*	*	*						1				2	Inconsistent
S8	67	6	*				*	*				1				1			Inconsistent
S9	100	5	*				*	*		*									
S10	17	6				*	*	*				4			1		1	1	Inconsistent

**Please refer to the Rating Scale for Speech Diadochokinesis (TABLE 3.11) for definitions of these abbreviations*

** Nr. of R/5/s= Number of repetitions produced in 5 seconds*

The type of perceptual errors that occurred can also be seen in Table 4.13. Category IV errors occurred the most (i.e. errors with *sound structure*) but the type of ratings differed among subjects. Not one error rating (i.e. ratings other than 'a' dominated the scoring, indicating very individual trends in error patterns. In summary, the results of three-place articulation possibly indicated that S-DDK in back-middle-front and mixed (middle-front-back) place-of-articulation sequences may be 'more difficult' than front-middle-back S-DDK for normal children in this age range.

4.4.2.5. <u>Conclusive discussion of perceptual S-DDK-results</u>

Perceptual analysis of the S-DDK-data led to the conclusion that normal children aged 4;0 to 6;7 years displayed very few errors for CV-syllable and most CVCV-syllable S-DDK-tasks, and displayed no problems with associated movements in any of the S-DDK-tasks.(The latter observation is contrary to the findings for non-speech DDK tasks, where associated movements did occur).

However, many of these normal subjects displayed errors in terms *of accuracy, sound structure* and *continuity* for *glottal* and *three-place* S-DDK material, although these errors were few, individual and not severe. It can be hypothesized that glottal and three-place S-DDK tasks may place more demands on sensorimotor speech planning in terms of aspects of accuracy, continuity, and sound structure (sequencing).

Results suggested that some normal children between the age of 4;0 and 6;7 may apply a *reduction in execution* rate as a natural, compensatory strategy to accomplish more complex articulatory movement sequences. Results did not indicate this rate reduction to be a trend in general performance across the subject group though, since most subjects did not show any adaptation in execution rate, or did not indicate any awareness of inaccurate production. Very individual trends in performance thus occurred, due to possibly a variety of influential factors (e.g. personality aspects such as perseverance, motivation to get the task right, perceptual factors, neurophysiological-maturation or other currently unknown aspects).

Furthermore, results suggested that evaluation of S-DDK in terms of rate of execution (i.e. DDR, thus *quantitative* analysis) may yield limited information about children's overall S-DDK abilities. Rather, additional analysis of S-DDK in terms of *qualitative* aspects such as continuity, accuracy, sound structure (and associated movements) needs to be considered, since it may provide additional insight into symptom patterns. It is proposed that such analyses of S-DDK might be especially valuable in the case of diagnostic populations (e.g. children with DSD), providing more descriptive information in terms of symptom patterns.

The *Rating Scale for the Evaluation of Speech Diadochokinesis* (Table 3.11) compiled for use in this study may be helpful in such clinical analyses. The categories and ratings were found to be useful in describing and rating the behavior displayed by the normal children, providing valuable information about the characteristics of their performance in the different tasks. By applying this rating scale, the traditional assessment of S-DDK can be expanded beyond the mere calculation of diadochokinetic rates (DDR's) to a more in-depth analysis of symptom patterns. The tentative, normative information regarding the nature of S-DDK in children between 4;0 and 6;7 that has been collected in this study, may be used for comparison in assessment of Afrikaans-speaking children with DSD.

4.5. DESCRIPTION AND DISCUSSION OF RESULTS FOR SUB-AIM FOUR: CLUSTER PRODUCTION

The goal of this sub-aim was to investigate the ability of normal, Afrikaans-speaking children aged 4.0 to 7.0 years to *recall, plan, organize, and combine motor goals consecutively* during imitative productions of two (CC), and three-consonant (CCC) initial and final clusters in *isolation*. (Material can be viewed in Table 3.6 and Appendix D). Results will firstly be described and discussed in terms of percentage correct (PC)-scores displayed by the subjects for initial and final clusters, followed by a description and discussion of the individual error types that occurred.

4.5.1. PERCENTAGE CORRECT (PC)-SCORES FOR INITIAL AND FINAL CLUSTERS

The percentage correct (PC)-scores obtained by the individual subjects for initial cluster production (ICL) and final cluster production (FCL), are presented in Table 4.14. Mean, group standard deviation and total error percentages (EP's) for each cluster group are also reported.

TABLE 4.14: PERCENTAGE CORRECT SCORES FOR CLUSTERS

Subjects		Percentage Correct Scores for Initial Clusters	Percentage Correct Scores for Final Clusters
Subject	Age (years)		
S1	4;0	93	96
S2	4;1	72	67
S3	4;8	100	79
S4	5;0	79	79
S5	5;3	66	96
S6	5;4	90	67
S7	5;4	100	75
S8	5;6	76	79
S9	6;1	86	96
S10	6;7	76	54
Group Mean:		84%	79%
Group Standard Deviation:		11.8	14.1
Total Error Percentage:		16%	21%

It can be seen from the data in Table 4.14 that the subjects as a group obtained a higher PC-score for ICL than for FCL, although individual performance of the subjects did not indicate *consistent* lower PC-scores for FCL. Some subjects obtained higher PC-scores for FCL than for ICL (e.g. S1, S5 and S9). In the case of initial clusters only two subjects (S3 and S7) obtained a PC of 100, while no subjects managed to obtain a PC-score of 100 for final clusters. Results seem to suggest that normal children between 4;0 and 6;7 years can still show some problems with the production of consonant clusters in isolation and that some children may find the planning and sequencing of motor goals for final cluster combinations more complex than for initial clusters. No age-related trends in cluster production were identified, since very individual performance trends occurred.

4.5.2. ERROR PERCENTAGES AND ERROR TYPES FOR INITIAL CLUSTERS (ICL)

The subjects as a group showed an error percentage (EP) of 16% for ICL (see Table 4.14), indicating that normal children in this age range can still experience some difficulty with initial cluster production in isolation. Errors that occurred for initial clusters are summarized in Table 4.15, in terms of error types and frequency of occurrence for the subjects as a group.

TABLE 4.15: ERROR TYPES THAT OCCURRED FOR INITIAL CLUSTERS (CC-/CCC-)

ERROR TYPE	INITIAL CLUSTERS IN WHICH THE ERROR TYPE OCCURRED	NUMBER OF SUBJECTS WHO DISPLAYED THIS ERROR TYPE
INSERTION OF SCHWA VOWEL e.g. [fən]	[fn]	7
	[xl]	5
	[kn]	4
	[vr]	3
	[xr]	3
	[bl]	3
	[sl]	2
	[fl]	2
	[kl]	2
	[spl]	2
	[fr]	2
	[pl]	1
	[spr]	1
		Total: 37 (79%)
OTHER ERRORS:	[sn] produced as: [zn]= voicing/substitution [s-nə]=consonant lengthening/vowel addition [sp] produced as: [spə]= vowel addition [spl] produced as: [spi:l]= vowel insertion [xr] produced with voiceless [r]=voicing error [sm] produced as: [sm^{h}]/[n^{h}]=nasal distortion [smə]=vowel addition [smən]=syllable addition [spr] produced with voiceless [r]=voicing error [swə] produced with [s]-distortion	
		Total: 10 (21%)

A review of individual results and error patterns in Table 4.15 indicated that 79% of errors with initial clusters were the result of an insertion of the *schwa-vowel* between the first and second elements of CC-clusters, or between the second and third elements of CCC-clusters. The other 21% of errors were of a mixed type. Only 31% of the initial cluster material did not show any errors (i.e. [st/sk/kr/pr/tr/br/dr/skr/ and str]).

4.5.3. ERROR PERCENTAGES AND ERROR TYPES FOR FINAL CLUSTERS (FCL)

The subjects as a group showed an error percentage of 21% for FCL (see Table 4.14), indicating that normal children in this age range can still experience some difficulty with final cluster production in isolation. Errors that occurred for FCL clusters are summarized in Table 4.16, in terms of error types and frequency of occurrence for the subjects as a group.

TABLE 4.16: ERROR TYPES THAT OCCURRED FOR FINAL CLUSTERS (-CC/-CCC)

ERROR TYPE	FINAL CLUSTERS IN WHICH THE ERROR TYPE OCCURRED	NUMBER OF SUBJECTS WHO DISPLAYED THIS ERROR TYPE
INSERTION OF SCHWA VOWEL e.g. [rəf]	[rf]	4
	[rx]	3
	[rs]	3
	[rf]	3
	[xs]	2
	[rp]	2
	[lp]	1
	[lf]	1
	[lx]	1
	[lt]	1
	[ls]	1
	[rts]	1
		Total: 23 (45%)
ADDITION OF [ɦə] IN FRONT OF THE CLUSTER e.g. [ɦəlk]	[lk]	6
	[lx]	4
	[lt]	3
	[ls]	3
	[lf]	2
	[ŋks]	2
	[ŋk]	1
	[lp]	1
	[nt]	1
	[ns]	1
		Total: 24 (47%)
OTHER ERRORS:	[rf] produced with voiceless [r] [ks] produced as: [k-/st/ts]= sound deletion and substitutions [ns] produced as [nts]= sound insertion [nts] produced as [ŋks]: sound substitutions	
		Total: 4 (8%)

A review of individual results and error patterns in Table 4.16 indicated that 47% of these errors were due to an addition of syllable [ɦə] in front of the cluster.

45% of the errors were the result of an insertion of the schwa-vowel between the first and second elements of CC-clusters or between the second and third elements of CCC-clusters, while the other 8% of errors were of a mixed type. Only 29% of the final cluster material did not show any errors (i.e. [ləm/mp/ts/ps/rəm/rt/rk]).

4.5.4. DISCUSSION OF RESULTS FOR INITIAL AND FINAL CLUSTERS

The tendency for the subjects to insert a *schwa-vowel* between elements of a cluster (epenthesis), or to insert syllable [ɦə] in front of final clusters can be regarded as way of *simplifying the production* of the cluster in isolation (Khan,1985; Ohde & Sharf,1992). It can be suggested that the insertion of the schwa-vowel or syllables may allow more time for articulatory transitioning and sequencing of motor goals from one consonant to another. Hawkins (1984) stated that epenthesis implies a lack of coarticulation between the elements of a cluster. In English it has been found from phonetic observation that the closure for the first consonant in a cluster is generally not released until after the closure for the second is formed (Byrd & Tan,1996), further indicating that epenthesis may assist in the coordination of articulatory gestures.

Gilbert and Purves (1977) referred to the insertion of a schwa-vowel between clusters in real words as a splitting process and explained it as an attempt to overcome the demands of a time-dominant system. They argued that the child's timing control may not be developed enough to enable him/her to produce the required segments within the limited time allowed and consequently, "...the segmentation of clustered features is exaggerated in the split clusters, allowing target articulation of consonants to be achieved." (Gilbert & Purves,1977:431). From such a viewpoint schwa-vowel insertion may thus be regarded as a compensatory way of handling higher articulatory demands.

It is interesting to note that schwa-epenthesis is not regarded by some authors as being part of the four stages children are said to proceed through as they learn to produce clusters in real words i.e. 1) the entire cluster is omitted, 2) one of the consonants is omitted, 3) the previously deleted consonant is replaced by another, 4) the correct cluster is produced (Greenlee in Ohde & Sharf,1992). Other authors such as Shriberg and Kwiatkowski (1980) again, stated that vowel insertion occurs during stage three of cluster development, or at about two and a half years of age when it will alternate with correct articulation of the cluster.

Another explanation for the high occurrence of schwa-vowel insertion in initial and final clusters and the addition of syllable [ɦə] to final clusters, is that it might have been the result of *linguistically-related* or *syllable influences*. As noted in the method (Chapter 3), some subjects' reactions indicated that they perceived the targets as 'odd-sounding', in spite of preparation by the examiner. It should be considered that some subjects found this unfamiliar productions (i.e. devoid of meaning) strange, and that they might have attempted to produce it more familiarly (i.e. more syllable or word-like) by adding a schwa-vowel or [ɦə]-syllable. However, this is a mere hypothesis and extensive research is needed before any conclusions can be reached.

As described in Chapter 3, the clusters in this study were elicited in isolation and not in real, meaningful words. It may be argued that a short three-consonant sequence might be less complex to produce than a longer, real word, since less motor goals are involved. Yet, it is also possible that this isolated cluster context, which is devoid of meaning, may give a *clearer* indication of sensorimotor aspects of speech control, since it focuses on the consecutive articulation of two or three sounds *without* direct linguistic influences (as those present in real, meaningful words). In the sensorimotor speech planning phase of speech production hypothesized by Van der Merwe (1997), core motor plan recall of invariant motor plans for these sounds thus have to take place, followed by aspects such as planning of consecutive articulator-specific motor goals, sequencing and inter-articulator synchronization. Some subjects thus showed difficulty in planning and sequence motor goals for some clusters in isolation.

Yet, although not part of the aims of this study, informal review of the subjects' *spontaneous speech sample* (which was used for the next aim), showed that all the subjects produced a variety of consonant clusters with 100% accuracy and without any vowel epenthesis in words with clusters, in spite of difficulty with producing the same clusters in isolation. It is unlikely that factors such as imitative vs. spontaneous mode of elicitation could have contributed to the results since Bond and Korte (1983:b) for example found no differences between initial clusters in words produced in imitative vs. spontaneous speech condition.

From the results it thus appeared as if these normal children's *phonetic production repertoire for isolated clusters* differed from their ability to produce the same clusters in *meaningful, spontaneous* speech. Results suggested that even if normal children between 4;0 and 6;7 years are capable of producing clusters accurately in spontaneous speech, some may find it difficult to produce the same clusters in isolation. Results lead to the tentative suggestion that for some normal children, greater demands may be placed on sensorimotor speech control by the cluster-in-isolation context, but it is unclear why this might be the case. This observation is in need of much more future investigation before any conclusions can be made, since the two contexts were not statistically compared. To the knowledge of the examiner no research exists regarding normal children's production of clusters in isolation vs. cluster production in words.

It was very difficult to identify any patterns in cluster errors in terms of place and manner of production or to explain occurring problems. Results also indicated very individual production patterns between subjects. Initial cluster [fn],[xl] and [kn] showed the most errors. All three these clusters involved the progression from voiceless to a voiced sound and two involved a nasal consonant in the second position, possibly indicating some problems with the synchronization of voicing. Final clusters [lk], [lx] and [rf] displayed the highest errors, involving articulatory transitions from a voiced to a voiceless sound and from different places of articulation.

Researchers such as Gilbert and Purves (1977) have found in a segmental duration study of clusters (in Canadian English) that differences between age groups (5, 7, 9, 11-year-olds and adults) in terms of temporal organization of clusters were entirely restricted to clusters with [l] and Hawkins (1973) interpreted [l]-clusters to be more difficult for children than for adults (i.e. British English). Gilbert and Purves (1977) interpreted the lengthening of the [l]-sound in clusters as a further stage of the splitting process, "...an attempt by the child to achieve target articulation of [l] by relaxing the demands of the timing program." (Gilbert & Purves,1977:431). Three of the top six error clusters in the present study also included the [l]-sound. Gilbert and Purves (1977) opposed the view of researchers such as Hawkins (1973) that problems with [l]-clusters is an indication that the [l]-sound is 'more difficult' to produce. According to Gilbert and Purves (1977) the term 'articulatory difficulty' is ill-defined and there is no proof from information about the sequential acquisition of consonants to support the proposal that [l] is more difficult to produce in all contexts or that it is only more difficult to produce in clusters.

In summary, investigation of cluster production in isolation by normal four to six-year-olds raised some interesting questions regarding normal children's ability to plan and sequence speech motor goals for consonants in a *non-linguistic context*. It may be interesting to determine if children with DSD show the same trends in performance displayed by these normal subjects (e.g. the possible compensatory strategy of schwa-insertion etc.), when faced with this possibly 'more demanding' articulatory context. Further investigation regarding various aspects of cluster production (and in different contexts) may lead to interesting observations and deductions regarding sensorimotor speech control. Current suggestions should be regarded tentatively though, awaiting further investigation.

4 .6. DESCRIPTION AND DISCUSSION OF RESULTS FOR SUB-AIM FIVE: WORD SYLLABLE STRUCTURE

This goal aimed to investigate the ability of normal, Afrikaans-speaking children aged 4;0 to 7;0 years to *recall, plan, combine* and *produce* a variety of *motor* *goals consecutively for* different *word syllable structures, as* manifested in *spontaneous speech* production.

Percentage of occurrence (POO) calculations indicated that 18 different word syllable structure types occurred *at least once* in the spontaneous speech samples of all the children. These structures will be the focus of the description and discussion of results for this sub-aim, since it represents word syllable structures that may be most likely to occur in the speech of normal Afrikaans-speaking children. It thus provides some normative information for comparison with children with DSD. Table 4.17 displays the data for these structures, including the percentage of occurrence (POO) of each word syllable structure in the speech of each subject. The rest of the word syllable structures (that did not occur at least once in the sample of every subject) are displayed in Table 4.18, since it is evidence of normal speaking children's ability to plan and combine a great variety of motor goals consecutively. Figure 4.1 visually displays the top five occurring word syllable structure data for each subject.

TABLE 4.17: SYLLABLE STRUCTURES THAT OCCURRED AT LEAST ONCE IN THE SAMPLES OF ALL TEN SUBJECTS, WITH THEIR PERCENTAGES OF OCCURRENCE (POO's)

Syllable Structure	Total POO	POO for S1	POO for S2	POO for S3	POO For S4	POO for S5	POO for S6	POO for S7	POO for S8	POO for S9	POO for S10
CVC	22.1	23	23.3	22.6	27.1	20.7	19.1	18.9	20.4	27	20.6
CV	15.3	14.3	9.6	15.6	16.2	18.8	17.7	16.4	15.9	8.2	16.1
VC	12.4	13.9	11.6	10.6	8.6	13.6	11.9	11.6	13.6	13.5	15.4
CVV	9.8	7.8	10.6	11.6	9.1	8.7	9.8	9.6	10.8	7.7	12.7
CVCV	4.9	4.3	6.2	4.2	2.5	3.9	5.5	6.9	7	5.4	3.8
CVCVC	3.6	5.1	1.7	3.8	3.2	3.4	3.6	4.7	2.7	2.1	4.1
CCVC	3.6	2.7	2.7	3.2	4.1	5.5	3.2	4.8	1.8	3.0	3.8
V	2.9	3.9	4.1	2.6	2.5	2.5	2.3	3	3.6	4.3	1.1
VCV	2.7	4.5	2.4	2.8	3.6	2.7	1.8	2.7	2.5	2.6	2
CVCC	2.3	1.4	5.8	3.2	1.4	2.1	2.5	0.6	2.9	1.9	3.2
CVVC	2.1	3.7	2.1	1.8	1.6	2.1	2.5	2.1	1.6	0.6	2.3
VCC	1.3	0.6	2.1	1	1.1	0.9	1.2	1.1	1.1	3.2	1.1
CVCCVC	1.2	1.6	2.4	0.6	0.9	1.6	1.5	1.1	0.5	1.1	1.1
CVCCV	0.9	1.6	0.3	1	0.5	0.5	1.3	1	0.5	1.1	1.3
CCVVC	0.9	0.8	1	1.4	0.5	0.9	0.8	1	1.1	0.2	0.9
CCVV	0.6	0.2	0.3	0.4	1.2	1.1	1.3	0.5	0.4	0.6	0.2
VCVC	0.6	0.4	0.7	0.6	0.5	0.5	0.5	0.8	0.5	0.4	0.5
CVVCV	0.5	0.2	0.3	1.2	0.4	0.5	0.7	0.8	0.4	0.6	0.2
TOTAL NUMBER OF STRUCTURES: 18 (11%)											

** POO= Percentage of Occurrence * NOTE: VV refers to diphthongs*

TABLE 4.18: SYLLABLE STRUCTURES THAT DID NOT OCCUR AT LEAST ONCE IN THE SAMPLES OF ALL TEN SUBJECTS AND THEIR TOTAL PERCENTAGES OF OCCURRENCE (POO's)

STRUCTURES	TOTAL % OF OCCURRENCE	TOTAL NUMBER OF STRUCTURES WITH THIS %
VVC	0.6	1
CVCVCVC VCCVC CVCVCC CCVCV VVCV CVCVV CVCVVC CCVCVC	0.4	8
CVCVCV VCCV CCVCC CVVCVC CCVVCV	0.3	5
CCV CVCCVVC CVCCVCCV CVCCCVC C CCVCCVC CVCCVCC CVCCVV CVCCVCCVC VV CCCVC CVVCCV CVCVCCVC CCVCVCVC	0.2	14
CVCCVCVC CVCCVCV CVCVCCV VVCCVC CVVCCCVC VCCCVC CCVCVCV VCCVVC CCVCCV CVCVCVCC CVCVCVCVC CVVCVCVCC CVCCVVCVC VCVCC CVVCVCVC CCVCCCVC VCVCV VCVCVC VCCVCVC VCCVCCVC CVCVVCVC CC CVCCCVCV CVCVCCCV VCVCVCC VVCVCCVC CVCCCVCC	0.1	27
VCCCVV VCCVCCVCC VCCVCVV CVCCCVCCVC CVCCCVVC CVCVCVV CVVCVV CCVVCCVC VVCVC CVCVVCVCCV CVVCVCCVC VVCCVCVC VCCCCVC VCVCVCV CVVCCVC VCVCCVC CCVCCVCVC VCVV CCVCCVCC VCCVCVCC CCVCCVCV CCVCVCC VCVCCVCCV VCCVCCV CVCCVVCV	0.04	25
CCVVCC CVCVCCVVC VCCVCCCVC CVCVCCCVC CVCVCVCVV CCVVCCCCVC CCV CVCCVVCCVC CVCVCCVCC CVCVCVCCVVCV CCVCVCCVC CVCVCCVV CCVCCCVCCVC CCCVCCCVVCV CCVCVCVV CVCCVCCVCCVC CVCVCVVCCV CVCVCVVCV CVCVVCCVC CVVCVCCVCV CVVCVCVCCVC CCVCVCCCVC CVCVCVCCCVC VCVCCVCCVVCVC CVVCCVCCV CVVCVCC CCVCCVVC VCCV CVVCCVVCVC VCCVCVCCVCCCVC VCCVCC CVCCCVCCVCCV CVCCCVV CVCVCVCCCVVC CVCCC CVVCVCVCVC CVCVCCVCVCV CCVVCVVCVCVC CVCCCVCCCCVC CCCVVCV CVCVCVCCVCVCV CVCVCVCCVCVC CCVVCCVCC CVVCCVVC CVCVCCVCV VCCCV VVCCCV CVCCVCVCVC CVCCVCVCVCC CCVCCVCVCCV CVCVCCCVVCVC CCVVCCVCV CCVVCVC CVCCCVVCVCCV CVCCVCCCVC CVCVCVVC VCVCCV CVCCVCCVCC CVCVCVVCCCVCCCVC CVVCCVCV CVCCVCVVCCV VVCCVCCVC CVVCVCCV CCVCCCVCV CVCVCVCVCCV	0.02	65
		145 (89%)

From the data in Tables 4.17 and 4.18 it can be seen that the subjects displayed total of 163 different word syllable structures of which 18 (11%) occurred at least once in the spontaneous speech sample of all the subjects. Data showed that the syllable structures that occurred with the highest frequency were CVC, CV, VC, CVV and CVCV-utterances (from highest to lowest order of occurrence, see Table 4.17). Only 14 syllable structures had a POO of one percent and/or above, indicating that the majority of utterances in these normal Afrikaans-speaking children's speech were limited to these *basic* structures of combination. However, from Table 4.18 it can be seen that the normal children in this age range were able to recall, plan and combine a wide *variety* of motor goals consecutively and were capable to produce words of sometimes great length and complexity. Normal children between the ages of 4;0 and 6;7 years thus seem to be able to plan and program complex sequences of motor goals.

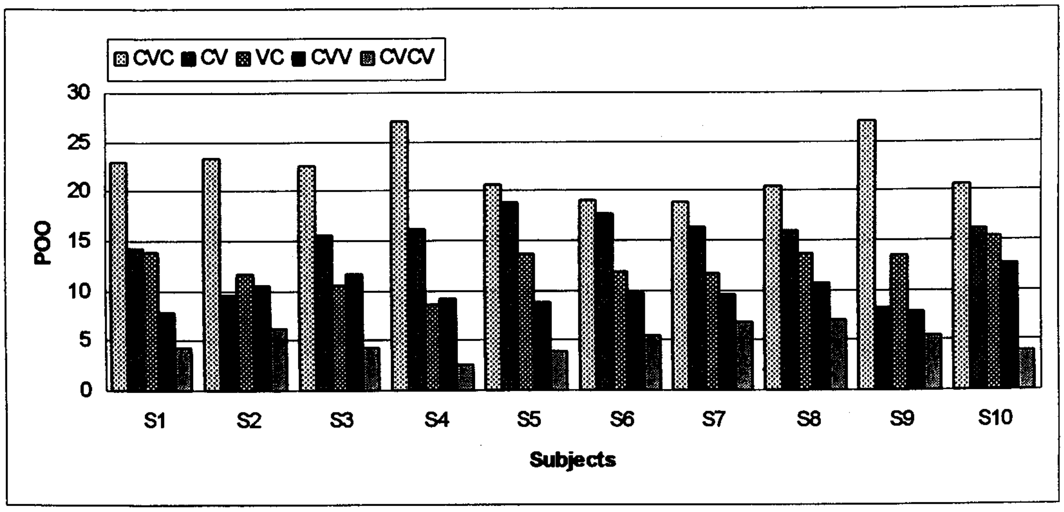


FIGURE 4.1: INDIVIDUAL PERCENTAGES OF OCCURRENCE (POO's) FOR THE TOP FIVE OCCURRING WORD SYLLABLE STRUCTURES

No related studies regarding word syllable structures in normal Afrikaans-speaking children could be identified. However, De Kock (1994) examined the syllable structures of 30 utterances each of four Afrikaans-speaking children between four and six years with suspected developmental apraxia of speech. Although a smaller sample that the present study were used, she found that the subjects only used a total of 18 different syllable structures (as opposed to the 163 in the present study), indicating a limited ability to combine motor plans consecutively and in complex fashion compared to these normal children.

The top five occurring word syllable structures in De Kock's study were CV, CVC, CVCV, VC, V and VCV-utterances, that compare well with those found in the present study (See Table 4.17 and Figure 4.1) Future investigation of the possible differences in the type and frequency of word syllable structures displayed by normal children and those with DSD may lead to interesting findings regarding their ability to combine a variety of motor goals consecutively.

4.7. DESCRIPTION AND DISCUSSION OF RESULTS FOR SUB-AIM SIX: A) FIRST-VOWEL DURATION (FVD) AND B) VARIABILITY OF FVD

The goal of sub-aim six was to investigate acoustically the following aspects of segmental duration in normal, Afrikaans-speaking children in the age range 4;0 to 7;0 years, in repeated utterances of the same word:

(a) To obtain *normative* indications of the length of *first-vowel duration (FVD)* in this age range and to determine if any differences exist in the vowel durations of the age groups (four, five, and six-year-olds).

(b) To investigate the nature of *variability* in first-vowel duration in this age range and to determine if any differences in vowel duration variability exist between the age groups (four, five, and six-year-olds).

The description and discussion of the results for this aim will begin with a presentation of the *individual* results obtained by the subjects in terms of *mean FVD* i.e. first-vowel duration in milliseconds (ms) as measured across the five repetitions, *STDEV* (standard deviation) and *CfV* (coefficient of variation) in Table 4.19. The data in Table 4.19 are thus the *individual* results for *both* parts of sub-aim six. Secondly, the specific age-group FVD and FVD-variability data will be presented in Table 4.20, in terms of *minimum and maximum duration, range, mean, STDEV* and the *CfV* for each age group (i.e. four, five, six-year-olds and 4;0 to 6;7 year-olds). The data in Table 4.20 are thus the specific *age group* results for *both* parts of sub-aim six. Tables 4.19 and 4.20 will be followed by a two-part description and discussion of their contents, together with other specific data concerning FVD and variability of FVD.

TABLE 4.19: INDIVIDUAL FIRST-VOWEL DURATION (FVD) AND FVD-VARIABILITY DATA

TAR-GET WORD	VALUE	S1 4;0	S2 4;1	S3 4;8	S4 5;0	S5 5;3	S6 5;4	S7 5;4	S8 5;6	S9 6;1	S10 6;7
[paki]	**Mean FVD (ms)**	87	93	139	123	97	61	60	172	123	112
	STDEV	21.1	5	3.7	21.1	6.9	12.9	9.5	14.9	8.5	9.5
	CfV	0.24	0.05	0.03	0.17	0.07	0.21	0.16	0.09	0.07	0.08
[baki]	**MeanFVD (ms)**	130	106	127	137	94	118	125	181	129	101
	STDEV	20	7.6	28.1	14.9	9.4	27.1	14.6	7.6	3.2	12.3
	CfV	0.15	0.07	0.22	0.11	0.10	0.23	0.12	0.04	0.02	0.12
[tasə]	**Mean FVD (ms)**	202	143	153	169	118	154	154	193	154	117
	STDEV	18.9	34.9	33.1	12.7	22	13.6	7.7	13	11.9	20.8
	CfV	0.09	0.24	0.22	0.08	0.19	0.09	0.05	0.07	0.08	0.18
[dasə]	**Mean FVD (ms)**	175	169	179	184	139	156	149	241	161	152
	STDEV	8.1	12.5	22.9	8.8	13	10.3	15.2	12.6	11	27.7
	CfV	0.05	0.07	0.13	0.05	0.09	0.07	0.10	0.05	0.07	0.18
[tɔpi]	**Mean FVD (ms)**	117	115	117	177	83	108	88	159	122	98
	STDEV	29.4	6.5	15.7	15.6	5.3	11.2	19.1	12.4	12.4	7.5
	CfV	0.25	0.06	0.13	0.09	0.06	0.1	0.22	0.08	0.1	0.08
[dɔpi]	**Mean FVD (ms)**	113	139	129	184	81	105	90	149	123	108
	STDEV	24.2	25.3	19.3	16.1	14.4	15.3	12.3	7.5	15.6	7.1
	CfV	0.22	0.18	0.15	0.09	0.18	0.15	0.14	0.05	0.13	0.07
[tək]	**Mean FVD (ms)**	63	93	101	147	112	67	66	163	103	83
	STDEV	8.3	14.3	10	8.2	15.9	9.4	22	17.9	6.1	7.7
	CfV	0.13	0.15	0.1	0.06	0.14	0.14	0.34	0.11	0.06	0.09
[dək]	**Mean FVD (ms)**	124	120	153	234	118	92	69	201	144	108
	STDEV	26.4	10.7	14.9	12.3	20.5	17.9	22.4	16.4	26.7	16.5
	CfV	0.21	0.09	0.1	0.05	0.17	0.19	0.33	0.08	0.18	0.15

ABBREVIATIONS: S=Subject ms=Milliseconds STDEV=Standard deviation CfV=Coefficient of variation

TABLE 4.19 (-CONTINUED): INDIVIDUAL FIRST-VOWEL DURATION (FVD) AND FVD-VARIABILITY DATA

TAR-GET WORD	VALUE	S1 4;0	S2 4;1	S3 4;8	S4 5;0	S5 5;3	S6 5;4	S7 5;4	S8 5;6	S9 6;1	S10 6;7
[kat̠ə]	**Mean FVD (ms)**	109	131	134	113	105	108	118	181	150	113
	STDEV	14.1	22.2	17.5	24	12.9	13.8	12.5	10.8	13.4	14
	CfV	0.13	0.17	0.13	0.21	0.12	0.13	0.11	0.06	0.09	0.12
[fənəx]	**MeanFVD (ms)**	126	114	121	197	133	84	69	216	113	59
	STDEV	14.2	28	23.5	52.3	10.8	10.2	13.6	30.5	13.2	7.6
	CfV	0.11	0.24	0.19	0.27	0.08	0.12	0.2	0.14	0.12	0.13
[knəbəl]	**Mean FVD (ms)**	116	128	130	164	100	116	123	126	103	100
	STDEV	27.9	26.1	25	38	24.3	17.4	14.9	9.7	9.3	21.9
	CfV	0.24	0.2	0.2	0.23	0.24	0.15	0.12	0.08	0.09	0.22
[klɔki]	**Mean FVD (ms)**	88	100	91	149	70	86	68	103	105	88
	STDEV	19.5	10.7	13.5	11.9	11.2	16.4	7.3	6.6	11.7	19.1
	CfV	0.22	0.11	0.15	0.08	0.16	0.19	0.11	0.06	0.11	0.22
[blɔki]	**Mean FVD (ms)**	103	105	104	173	94	85	93	111	118	67
	STDEV	25.4	13.2	19.1	11.4	19.2	10	17.2	9.4	14.9	11.4
	CfV	0.25	0.13	0.18	0.07	0.2	0.12	0.18	0.08	0.13	0.17

ABBREVIATIONS: S=Subject ms=Milliseconds STDEV=Standard deviation CfV=Coefficient of variation

TABLE 4.20: SPECIFIC AGE GROUP STATISTICS FOR FVD AND VARIABILITY OF FVD

TARGET WORD	MEASURE	AGE GROUP 4;0 to 4;8 yrs n=3	5;0 to 5;6 yrs n=5	6;1 to 6;7 yrs n=2	4;0 to 6;7 yrs n=10
[paki]	*Min. & Max. Dur.*	52 to 145ms	39 to 195ms	100 to 133ms	39 to 195ms
	Range (Max.- Min.)	93ms	156ms	33ms	156ms
	Mean	106ms	103ms	117ms	107ms
	STDEV	27.1	44.4	10.3	35.1
	CfV	0.26	0.43	0.09	0.33
[baki]	*Min. & Max. Dur.*	92 to 169ms	78 to 191ms	83 to 133ms	78 to 191ms
	Range (Max.- Min.)	77ms	113ms	50ms	113ms
	Mean	121ms	131ms	115ms	125ms
	STDEV	21.9	32.8	17.1	27.6
	CfV	0.18	0.25	0.15	0.22
[tasə]	*Min. & Max. Dur.*	102 to 219ms	88 to 214ms	88 to 164ms	88 to 214ms
	Range (Max.- Min.)	117ms	126ms	76ms	126ms
	Mean	166ms	158ms	135ms	156ms
	STDEV	38.3	28.2	24.9	32.3ms
	CfV	0.23	0.18	0.18	0.21
[dasə]	*Min. & Max. Dur.*	145 to 209ms	125 to 261ms	128 to 197ms	125 to 261ms
	Range (Max.- Min.)	64ms	136ms	69ms	136ms
	Mean	174ms	174ms	156ms	171ms
	STDEV	15.2	39	20.4	30.6
	CfV	0.09	0.22	0.13	0.18
[tɔpi]	*Min. & Max. Dur.*	84 to 164ms	63 to 194ms	88 to 138ms	63 to 194ms
	Range (Max.- Min.)	80ms	131ms	50ms	131ms
	Mean	116ms	123ms	110ms	118ms
	STDEV	18.2	40.8	16.1	31.4
	CfV	0.16	0.33	0.15	0.27
[dɔpi]	*Min. & Max. Dur.*	88 to 183ms	63 to 200ms	100 to 148ms	63 to 200ms
	Range (Max.- Min.)	95ms	137ms	48ms	137ms
	Mean	127ms	122ms	115ms	122ms
	STDEV	24.2	41.7	14	32.7
	CfV	0.19	0.34	0.12	0.27
[tɔk]	*Min. & Max. Dur.*	55 to 114ms	47 to 181ms	73 to 109ms	47 to 181ms
	Range (Max.- Min.)	59ms	134ms	36ms	134ns
	Mean	86ms	111ms	93ms	100ns
	STDEV	19.6	43	12.3	34.3s
	CfV	0.23	0.39	0.13	0.34
[dɔk]	*Min. & Max. Dur.*	94 to 170ms	42 to 253ms	92 to 184ms	42 to 253ms
	Range (Max.- Min.)	76ms	211ms	92ms	211ms
	Mean	132ms	143ms	126ms	136ms
	STDEV	23	67.3	28.3	50.6
	CfV	0.17	0.47	0.22	0.37

ABBREVIATIONS: Min.=Minimum Max.=Maximum STDEV=Standard deviation CfV=Coefficient of variation yrs=Years n=Number ms=Milliseconds Dur=Duration

TABLE 4.20 (-CONTINUED): SPECIFIC AGE GROUP STATISTICS FOR FVD AND VARIABILITY OF FVD

TARGET WORD	MEASURE	AGE GROUP			
		4;0 to 4;8 yrs n=3	5;0 to 5;6 yrs n=5	6;1 to 6;7 yrs n=2	4;0 to 6;7 yrs n=10
[katə]	*Min. & Max. Dur.*	94 to 153ms	86 to 198ms	91 to 161ms	86 to 198ms
	Range (Max.- Min.)	59ms	112ms	70ms	112ms
	Mean	125ms	125ms	132ms	126ms
	STDEV	20.5	32.3	23.6	27.2
	CfV	0.16	0.16	0.26	0.22
[fənəx]	*Min. & Max. Dur.*	70 to 141ms	53 to 263ms	52 to 128ms	52 to 263ms
	Range (Max.- Min.)	71ms	210ms	76ms	211ms
	Mean	120ms	140ms	86ms	123ms
	STDEV	21.5	65.5	30.1	53.1
	CfV	0.18	0.47	0.35	0.43
[knəbəl]	*Min. & Max. Dur.*	78 to 167ms	78 to 206ms	72 to 133ms	72 to 206ms
	Range (Max.- Min.)	89ms	128ms	61ms	134ms
	Mean	123ms	126ms	102ms	120ms
	STDEV	25	30	16	27.7
	CfV	0.2	0.24	0.16	0.21
[klɔki]	*Min. & Max. Dur.*	56 to 114ms	58 to 163ms	58 to 120ms	56 to 163ms
	Range (Max.- Min.)	58ms	105ms	62ms	107ms
	Mean	93ms	95ms	96ms	95ms
	STDEV	14.9	31.9	17.3	24.9
	CfV	0.16	0.34	0.18	0.26
[blɔki]	*Min. & Max. Dur.*	75 to 133ms	70 to 192ms	48 to 134ms	48 to 192ms
	Range (Max.- Min.)	58ms	122ms	86ms	144ms
	Mean	104ms	111ms	92ms	105ms
	STDEV	19.1	34.9	29.5	31.1
	CfV	0.18	0.31	0.32	0.3

ABBREVIATIONS: Min.=Minimum Max.=Maximum STDEV=Standard deviation CfV=Coefficient of variation yrs=Years n=Number ms=Milliseconds Dur=Duration

4.7.1. DESCRIPTION AND DISCUSSION OF FIRST-VOWEL DURATION (FVD) RESULTS

4.7.1.1. Description of age-related trends in performance for FVD

From the data in Table 4.20 it can be seen that in two of the thirteen target words, namely [tasə] and [dɔpi], the four-year-olds displayed the longest mean FVD duration, followed by the five-year-olds (second longest) and the six-year-olds with the shortest mean FVD. This finding indicated an *increase in mean duration*

with an increase in age, which is a tendency frequently observed in previous studies of segmental duration in children.

Data for [klɔki] however, indicated an *increase in mean FVD with an increase in age*, which is in contrast with most previous research findings. The average statistics for the age groups (for all the target words combined) are presented in Table 4.21, and it can be seen that the difference between the mean FVD of the age groups was as follows: difference between mean FVD of four and five-year-olds: *5ms*, difference between mean FVD of four and six-year-olds: *9ms*, difference between mean FVD of six and five-year-olds: *14ms*. Data in Table 4.20 for [klɔki] showed that the difference between the means of the age groups only differed between one and three milliseconds, which is much smaller than the average differences in means between the age groups across target words. It can thus be argued that since the difference in mean FVD's between the age groups was so small, this can be regarded as a case of *similarity* in performance by the three age groups, rather than a case of increase in mean FVD with an increase in age.

TABLE 4.21: SUMMARY OF AGE GROUP PERFORMANCE WITH REGARD TO MEAN FVD AND VARIABILITY (CALCULATED ACROSS ALL THE TARGET WORDS)

MEASURE	GROUP			
	Subjects as a Group (n=10)	4-year -olds n=3	5-year-olds n=5	6-year-olds n=2
Min. and Max. Duration	39 to 263ms	52 to 219ms	39 to 263ms	48 to 197ms
Range (Max - Min)	224ms	167ms	224ms	149ms
Mean Duration (ms)	123ms	123ms	128ms	114ms
STDEV	40.2	33.2	46.8	27.9
CfV	0.33	0.27	0.37	0.25

ABBREVIATIONS: Min.=Minimum Max.=Maximum STDEV=Standard deviation CfV=Coefficient of variation yrs=Years n=Number

In spite of the absence of consistent age-related trends in FVD throughout the material, further analysis of the data in Table 4.20 did indicate a general trend for the <u>oldest</u> age group to show the <u>shortest</u> mean FVD's most often. Table 4.22 presents a summary of age group performance concerning mean duration position (i.e. longest or shortest FVD) for the material. It indicated that the age group that displayed the *longest* mean FVD-position most often (thus in most target words), was the five-year-old group (7.5 times), followed by the six-year-olds group (3 times) and the four-year-olds (2.5 times). In contrast with most previous research findings, the youngest age group thus did *not* obtain the overall longest mean FVD. However, in accordance with previous findings, the *oldest age* group did obtain the *shortest* mean FVD-position most often (9 times), compared to the 2.5 times of the four-year-olds and the 1.5 times of the five-year-olds.

TABLE 4.22: SUMMARY OF AGE GROUP PERFORMANCE IN TERMS OF MEAN DURATION POSITION OBTAINED ACROSS TARGET WORDS

Position *	*Longest* Mean Duration Position	*Middle* Mean Duration Position	*Shortest* Mean Duration Position
Age group that obtained this position the <u>most</u>:	5 year-olds (7.5 times)	4 year-olds (7 times)	6 year-olds (9 times)
Age group that obtained this position <u>second most</u>:	6 year-olds (3 times)	5 year-olds (3 times)	4 year-olds (2.5 times)
Age group that obtained this position the <u>least</u>:	4 year-olds (2.5 times)	6 year-olds (once)	5 year olds (1.5 times)

* *<u>NOTE</u>: a 0.5 score was assigned when the position was shared with another age group)*

The same tendency was also observed when the mean FVD's of the different age groups for all the target words combined were summarized (Table 4.21). The six-year-olds showed a shorter mean FVD-value than the four and five-year-olds. Further, the means for the four and five-year-olds differed only slightly (i.e. 5ms), while a bigger difference existed between the means of the six and five-year-olds (i.e. 14ms), and the six and four-year-olds (i.e. 9ms) respectively.

FVD-results for the rest of the target words indicated <u>mixed</u> individual and group performance, with *no clear age-related trends* in performance. Mean FVD-results for the different subjects (calculated from the durations of all the target words combined) generally also did not show clear age-related trends (See Tables 4.19 and 4.23). Although the two *longest* mean FVD's across words for example, were displayed by five-year-olds (S8 and S4), the *shortest* mean FVD was also displayed by a five-year-old (i.e. S7). A strong tendency for *individual* performance rather than age-related performance was thus indicated by these data. The mean FVD's of the two five-year-olds, S8 (longest mean vowel duration) and S7 (shortest mean vowel duration) differed as much as 71ms, indicating a big difference in performance. The two *shortest* individual mean FVD's however, were obtained by two of the *oldest* subjects i.e. S10 (6;7 yrs) and S7 (5;4yrs), which corresponds with the previous described tendency for older subjects to generally show shorter FVD's.

TABLE 4.23: MEAN FVD-DATA FOR THE TEN SUBJECTS (CALCULATED ACROSS TARGET WORDS)

Subjects	Mean First-vowel Duration (FVD) Across Words
S8 (5;6 years)	169ms
S4 (5;0 years)	165ms
S3 (4;8 years)	131ms
S9 (6;1 years)	127ms
S2 (4;1 years)	120ms
S1 (4;0 years)	119ms
S5 (5;3 years)	103ms
S6 (5;4 years)	103ms
S10 (6;7 years)	100ms
S7 (5;4 years)	98ms

4.7.1.2. Summary and discussion of general FVD-results

The *main normative indications* that emerged from the FVD-data can be summarized as follows. Firstly, a tendency existed for the *older* subjects (mostly six-year-olds) to display *shorter* FVD's than younger subjects, but in contrast the youngest subjects did not always show the longest FVD's. Secondly, the effect of an increase in mean FVD with increased age was observed, but it occurred only twice (in two target words out of thirteen). Afrikaans-speaking children in the age range 4;0 to 6;7 years thus did not show clear age-related trends (i.e. decrease in duration with increased age) in performance with regard to FVD throughout the material. Thirdly, results indicated very *individual* trends in performance.

In correspondence with the general observations of this study, previous findings regarding sensorimotor speech timing control cumulatively indicated that children generally display longer segmental and speech gestural durations than adults, and that older children tend to display shorter segmental or speech gestural durations than younger children (DiSimoni,1974:a;b; Tingley & Allen,1975; Kent & Forner,1980; Smith et al.,1983; Rimac & Smith,1983; Chermak & Schneiderman,1986; Walker et al.,1992; Nittrouer,1993; Robb & Tyler,1995; Smith & Kenney,1998). It should be noted that this conclusion is based on a wide variety of data characterized by more methodical differences than similarities in terms of instrumentation used (acoustic vs. kinematic studies), ages of subjects, material used (spontaneous speech, sentences, nonsense syllables, non-words vs. meaningful words, consonants/vowels in different word positions, clusters), and the aspects of sensorimotor control that were investigated. Only limited comparison and cautiously offered explanations are thus possible. Some of the few studies comparable to this study (i.e. DiSimoni,1974:a;b; Smith,1978; Kent & Forner,1980) generally found a more profound decrease in segmental duration with an increase in age than was observed in this study, but did not report on individual trends in their results, which again limits comparison.

Some explanations can be considered for the fact that the results of this study did not show FVD to decrease more profoundly with increased age. It can be suggested that the segmental duration differences in normal children in the clinically relevant age range of 4;0 to 6;7 years may be less intense, since only one-year differences between age groups occur. Information is not yet available regarding the specific performance of four, five, and six-year-olds on segmental duration tasks. Existing comparable studies that reported more profound segmental duration decreases with increased age, studied age groups which differed mostly two to three years and reported on a wide variety of age groups e.g. Tingley and Allen (1975): five, seven, nine-year-olds and adults, Smith (1978) two to four-year-olds and adults, DiSimoni (1974:a;b): three, six, nine-year-olds and adults), Kent and Forner (1980): four, six, twelve-year-olds and adults, Walker et al. (1992): three to five-year-olds, Smith (1994): five, eight and 11-year-olds. Comparable information regarding segmental duration in normal children in the clinically important age range of 4;0 to 7;0 years is thus limited. This is mostly the result of the fact that the aims of previous research were to determine *general trends* in normal sensorimotor speech development through childhood, and not necessarily to concentrate on specific clinical-relevant age ranges. This study's aim was different, since it intentionally investigated sensorimotor speech control skills in the age range 4;0 to 7;0 years, in order to establish a general normative database to which the sensorimotor speech control skills of children with DSD can eventually be compared with.

Research findings regarding the development of speaking rate highlight the possibility that developmental rate changes may not necessarily proceed on a yearly basis (although again no results are available specifically for four, five and six-year-olds). Pindzola, Jenkins and Lokken (1989) for example, did not find significant differences in the speaking rates of three, four and five-year-olds (conversational speech) and suggested that speaking rate might rather increase sporadically at certain age intervals. Kowal, O'Connel and Sabin (1975) found a developmental increase in conversational rates at two-year intervals, when studying children in kindergarten trough high school, while Amster and Starkweather (1985) found significant rate differences between two year-olds and preschoolers, but non-significant rate differences among three, four, and five-year-olds. Smith (1978) also found that although his data showed a general decrease in segmental duration with decreased age, the adults vs. two-year-old comparisons constituted the primary age-related differences (rather than the two- and four-year-olds). Although the general assumption is that children are able to increasingly produce faster segmental durations as they grow older, results are still inconclusive in indicating possible *stages* of sensorimotor speech development in children (Netsell,1986; Smith et al.,1995). It is thus still uncertain when major developmental changes in segmental duration exactly occur. Results of this study may suggest that the 4;0 to 6;7 year age-period is not be characterized by *major* developmental changes in first-vowel duration (FVD) in Afrikaans-speaking children, although minor differences may be present between individuals.

It is also possible that more individual and age-unrelated differences than previously found may be observed in children's sensorimotor speech timing control, if data are not necessarily pooled according to *age*, if data are more purposefully examined for *individual trends* and if more *longitudinal* studies are performed. In a recent longitudinal study Smith and Kenney (1998) reported on individual trends in development of several acoustic parameters in seven subjects. Syllable duration measured at ages eight, ten and eleven did not show a *consistent* decrease in segmental duration across time for all seven subjects. Most of them however, did show *shorter* durations when comparing the first and last measurement. Smith and Kenney (1998) found that the individual developmental patterns observed were not linear in nature and further, subjects did not 'mature' on the same schedule regarding different aspects of sensorimotor speech control. They also concluded that the various structures and systems associated with speech production do not necessarily develop in comparable ways or at similar rates. In most existing acoustic studies findings are based on *averages* across a number of children belonging to different age groups, which makes it difficult to know what the various *courses of development* for different individuals will be (Smith & Kenney,1998). Since most previous acoustic studies on speech production development involved cross-sectional or group studies, existing results "... represents a somewhat generalized or idealized description of changes found to occur across groups of children of different ages." (Smith & Kenney:1998:96).Von Hofsten (1989:952-953) also commented that "...the rate of development is different for different subjects. Some develop quickly, whereas others develop slowly. One and the same child may develop quickly at certain ages and slowly at others...Therefore pooling data for groups of individuals of the same age will 'smear' the developmental function, hide important transitions, and make it look smooth and uneventful.".

Individual trends in performance regarding sensorimotor speech timing control may thus be expected rather than considered exceptional. As was the case with diadochokinetic rate data in this study, it may thus be more appropriate to use the *range* of FVD-values exhibited by the subjects as a group for normative comparison than specific age group data. This issue will be more extensively discussed under the heading of variability in segmental duration and in Chapter 5 where the results of the different aims will be considered together.

4.7.1.3. Description and discussion of FVD-data for voiced/voiceless word pairs

Although the investigation of *contextual influences* on FVD was not a main focus of this study (i.e. not statistically compared), the material was varied to some extent to allow for the possible emergence of contextual differences (See Chapter 3). One contextual effect emerged from the FVD-data. When the mean FVD obtained by the subjects as a group for the different words were examined, it was observed that in the case of all the voiced/voiceless initial stop word pairs, the duration of a *vowel preceded by a voiced plosive* (e.g. [a] in [baci]) were longer than the duration of the same vowel *preceded by a voiceless plosive* (e.g. [a] in [paci] (see Table 4.24).

TABLE 4.24: MEAN FVD'S OF THE SUBJECTS AS A GROUP FOR VOICED/VOICELESS TARGET WORD PAIRS

TARGET WORDS	Mean FVD for the Subjects as a Group	Difference in Mean FVD
[paci] [baci]	107ms 125ms	18ms
[tasə] [dasə]	156ms 171ms	15ms
[tɔpi] [dɔpi]	118ms 122ms	4ms
[tək] [dək]	100ms 136ms	36ms
[klɔki] [blɔki]	95ms 105ms	10ms

Although no direct comparable studies to this study could be identified, adults (e.g. Peterson & Lehiste,1960; Klatt,1975) and children (e.g. DiSimoni,1972 in Smith,1978; Krause,1982; Beardsley & Cullinan,1987) had been shown to produce longer (about 100ms) English vowels before voiced than before voiceless *word-final* English consonants. The results of this study thus correspond to some extent to these findings, although different languages and consonant word positions are applicable. The difference between the overall mean FVD for all ten subjects of *vowels preceded by a voiced* consonant *and* *vowels preceded by a voiceless consonant* ranged from four to 36ms. These values are much smaller than the values reported for English and more like those reported for Russian and Korean (Smith,1978). One explanation for the durational differences in the case of bilabial stops, is that the closing gestures for voiceless bilabial stops (in terms of jaw and lip closure/velocities) had been found to be accomplished more rapidly than for voiced stops (Chen in Smith,1978; MacNeilage & Hanson in Smith,1978). Further investigation regarding contextual effects on vowel duration in Afrikaans is needed before any conclusions can be reached regarding the influence of *pre-ceding consonantal voicing* on first-vowel duration, since so many linguistic and phonetic factors may be influential in segmental duration (Kent & Forner,1980).

4.7.2. DESCRIPTION AND DISCUSSION OF VARIABILITY OF FIRST-VOWEL DURATION (FVD) RESULTS

4.7.2.1. Description of variability of FVD-results

In terms of *intra-individual variability* in vowel duration, (i.e. the performance of the individual subjects for the different target words), the subjects displayed different standard deviations and CfV-values (i.e. coefficient of variation which is the standard deviation divided by the mean, see Chapter 3) for every target word (see Table 4.19). Irregular individual performance patterns and a wide range of FVD occurred across the material for all the subjects.

The CfV-values obtained by the subjects, based on FVD obtained for all the words together (65 utterances each), are illustrated in Figure 4.2 and give some indication of *inter-subject* (or inter-individual) variability in FVD. The lowest CfV (thus the least variability) was displayed by S9 (6;1 years) and the highest CfV (greatest variability) by S7 (5;4 years). Based on earlier hypotheses regarding the nature of the relationship between duration and variability (e.g. Kent & Forner,1980; Chermak & Schneiderman,1986; Crystal & House,1988), it may be considered surprising that the subject who scored the shortest mean FVD across words (see previous section) demonstrated the most variability in FVD.

According to these hypotheses, S9 would rather have been expected to show very little variability in terms of FVD. However, more recent research indicated a different relationship between variability and duration than previously expected (e.g. Smith,1994), as will be illustrated and discussed in-depth later in this section.

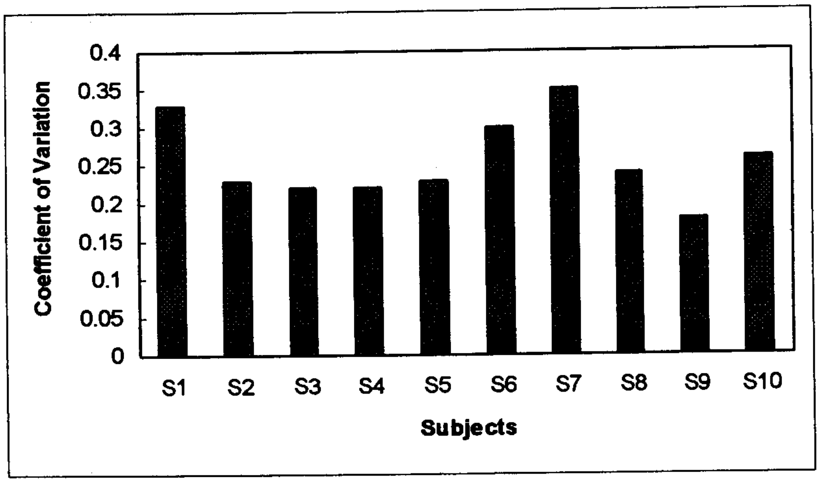


FIGURE 4.2: COEFFICIENTS OF VARIATION (CfV'S) FOR EACH SUBJECT, AS CALCULATED FROM THEIR FIRST VOWEL DURATIONS FOR ALL THE MATERIAL (i.e. 65 UTTERANCES EACH)

Age group performance concerning mean FVD and variability across age groups are presented in Table 4.21. These data indicated that the subjects as a group (mean age=5;2 years) obtained a wide distribution (from 39ms to 263ms across the thirteen target words, mean=123ms, STDEV=40ms. Results thus indicated a wide range (range=224) of FVD for Afrikaans-speaking children aged 4;0 to 6;7 years.

In terms of *inter-subject variability* of FVD, no clear *age-related trends* could be identified from the data. The youngest subject (S1) did show a very high CfV-value (indicating great variability) compared to eight other subjects, but the general finding in research relating to variability in segmental duration, which is that variability tends to decline with an increase in children's age, was not clearly present in this individual data. Results rather indicated very individual trends in performance (see Figure 4.2 and Table 4.19).

Age group results (Table 4.21) further indicated that the five-year-olds had the largest CfV-value (i.e. 0.37, displaying the greatest variability) and the six-year-olds the smallest (i.e. 0.25, displaying least variability in vowel duration). These observations were confirmed by the summary analysis of the CfV-position scored by the age groups (displayed in Table 4.25). The six-year-olds obtained the lowest CfV-value the most (across the thirteen target words) and the five-year-olds scored the highest CfV-value the most. Based on previously reported age trend results, the youngest age group would have been expected to show the least variability in FVD. It should be noted that a contributing factor to the five-year-olds showing the greatest variability in FVD and not the four year-olds, could be the fact that this age group had two more subjects than the four-year-olds, which increased the chance for a wider range of performance. Other possible contributing factors will be discussed further on.

TABLE 4.25: SUMMARY OF AGE GROUP PERFORMANCE IN TERMS OF COEFFICIENT OF VARIATION (CfV) POSITION OBTAINED ACROSS TARGET WORDS

Position	Highest CfV (most variability)	Middle CfV	Lowest CfV (least variability)
Age group that obtained this position the <u>most</u>:	5 year-olds (11 times)	4 year-olds (6 times)	6 year-olds (6.5 times)
Age group that obtained this position <u>second most</u>:	-	6 year-olds (5 times)	4 year-olds (5.5 times)
Age group that obtained this position the <u>least</u>:	6 year-olds (once) 4 year-olds (once)	5 year-olds (never)	5 year-olds (once)

** NOTE: a 0.5 score was assigned when the position was shared with another age group*

4.7.2.2. Summary and discussion of variability of FVD-results

In summary, results regarding variability in FVD firstly indicated very individual trends in performance, with children in the same age group sometimes displaying contrasting results. Secondly, an interesting finding in the individual data was that S7, who scored the lowest mean FVD across words (see previous section), displayed the greatest variability in FVD, while S9 who ranked fourth highest on mean FVD, displayed the least variability. Generally speaking, subjects with shorter segmental durations will be expected to show less variability, based on the traditional view (e.g. Bruner,1973) that skilled motor performance is marked by a faster execution rate and less variability (i.e. greater consistency in performance).

Thirdly, age groups results indicated a tendency for the <u>oldest</u> age group (six-year-olds) to show the <u>least</u> variability in vowel duration, which is in agreement with findings from previous acoustic studies (e.g. DiSimoni,1974:a;b; Tingley & Allen, 1975; Kent & Forner,1980; Smith et al.,1983). However, the most variability in FVD was displayed by the five-year-olds and not as would have been expected from generally observed trends in previous research, by the youngest age group in the study.

The following explanations can be considered for the observed contrasting performance by subjects of the same age, and the fact that the effect of a decrease in variability with increased age was not consistently observed. First, it has to be pointed out that although the finding that variability in sensorimotor speech timing control tends to decrease with age was a fairly consistent result in previous studies, *exceptions* in individual and group performance have been simultaneously reported. Tingley and Allen (1975) noted a wide variation within age groups (five, seven, nine and 11-year-olds), suggesting that there appears to be clear individual differences in children's timing control. Smith (1978) mentioned that in several instances the four-year-olds in his study revealed less variability than even adults. Kent and Forner (1980) also found considerable inter-subject differences in phrase repetition tasks in four-year-old children and a weak developmental trend in terms of individual variability. They noted that although the four-year-old group generally showed large inter-subject variability, some of them displayed standard deviations within the adult range. They concluded that "...some of these young children are capable of much more reliable control over speech production than the others." (Kent & Forner,1980:161). Stathopoulos (1995) also argued that children (four, six, eight, ten, twelve years) are not consistently more variable than adults. She found that there were significant variability differences for some measures between children and adults, and that it was primarily four-year-olds that accounted for the increased variability. "Of the 15 measures made, 4 year-olds were significantly more variable than adults on only eight. And on one measure, lung volume termination, 4-, 6- and 8- year-olds were significantly less variable than the adults. There did not appear to be any pattern to the variability across age." (Stathopoulos,1995:75).

Such findings would be in line with recent research suggesting the possible very *individual* nature of children's sensorimotor speech skills (Goodell & Studdert-Kennedy,1993; Nittrouer,1993;1995; Smith & Goffman,1998; Smith & Kenney,1998). Smith and Kenney (1998:105) stated that "....the rate and pattern of change for individual parameters and/or the periods during which such changes occur may differ considerably among subjects and across ages.". Smith (1994:173) hypothesized that "...two children of the same age and with comparable developed nervous systems could manifest different amounts of variability if one were more inclined than the other to explore the capabilities of his or her vocal tract.". A great amount of data is still needed to clarify the issue of *individuality* in sensorimotor speech timing control and explanations remain for the most part hypothetical. What seems to be needed is less of a focus on averaged group results and more focus on *individual trends* in performance and longitudinal data on how individual children's sensorimotor speech control changes over time. The issue of individuality in sensorimotor speech control development will be further discussed in Chapter 5.

Based on earlier hypotheses of the relationship between speech timing variability and segmental duration, some of the individual results on FVD variability may be considered somewhat surprising, since some researchers were of opinion that variability might essentially be a consequence of duration and that the two concepts are highly correlated with one another (i.e. mathematical hypothesis e.g. Chermak & Schneiderman,1986; Crystal & House,1988). First, the subject who scored the shortest mean FVD displayed the greatest variability, and secondly, the subject who displayed the least variability, ranked fourth highest on mean FVD. Based on the view that duration and variability are related, subjects who display shorter segmental durations will be expected to show less variability, and vice versa.

However, conflicting opinions exist regarding the matter, since it has also been theorized that variability is relatively *independent* of duration (neuromotor hypotheses e.g. Smith,1992). Smith (1992) argued that variability and duration may each provide somewhat *different* information about sensorimotor speech development. This would imply that a subject can indeed perform very differently on these two aspects. Smith (1994) conducted one of the most extensive studies up to date regarding the nature of the relationship between segmental duration and variability, which confirmed his earlier hypothesis. On closer examination of individual results Smith (1994) observed that two to three subjects in each of his subject groups (a total of five subjects per age group), did not comply with the prediction that shorter segment durations result in reduced variability. Smith (1994:171) concluded that his "..assortment of findings from a number of different perspectives.." indicated that variability and duration in acoustic segmental measurements may not be very closely related (although some degree of relationship may exist).

Smith's (1994) findings also showed that variability may reach adult-levels *later* in the process of development than duration does, thus that the two may not develop in tandem. This implies that a child can reach maturity in one aspect of sensorimotor speech control but not in another. Recently Stathopoulos (1995) and Smith and Kenney (1998) have both proposed that sensorimotor speech development may be non-linear and multi-modal, thus that different speech parameters/components develop at different rates. According to this point of view, the contrasting performance of S7 and S9 on FVD and variability respectively, may not be so surprising at all. It may simply reflect different components (i.e. aspects) of sensorimotor speech development. Yet, to presently explain these findings satisfactorily and conclusively remains very difficult in the light of the controversy and great amount of speculation still involved regarding the nature of the relationship between variability and duration in sensorimotor speech control.

4.8. DESCRIPTION AND DISCUSSION OF RESULTS FOR SUB-AIM SEVEN: VOICE ONSET TIME (VOT)

The goal of this sub-aim was to obtain normative, acoustic indications of the nature of *voice onset time (VOT)-values* of voiced and voiceless Afrikaans stops in normal, Afrikaans-speaking children in the age range 4;0 to 7;0 years, as measured in repeated utterances of the same word.

The results of this aim will be described and discussed with reference to the *mean individual* VOT-data summarized in Table 4.26 and the *group* VOT-data presented in Table 4.27, where data for the different material were pooled together based on voicing. Data will be described and discussed in the same order as the data groupings in Table 4.27 i.e. data *for word-initial voiced stops* [b] and [d], followed by data for *word-initial voiceless stops* [p], [t], and [k], data for *voiced stop [b] in cluster [bl],* and data for *voiceless stop [k] in clusters [kl] and [kn].* Finally, VOT-results for the *combined voiced* stop contexts (i.e. word-initial and cluster contexts) and *combined voiceless* stop contexts (word-initial and cluster contexts) will be described.

TABLE 4.26: INDIVIDUAL VOICE ONSET TIME (VOT) DATA (MEANS AND STDEV'S)

TARGET WORD	VALUE	S1 4;0	S2 4;1	S3 4;8	S4 5;0	S5 5;3	S6 5;4	S7 5;4	S8 5;6	S9 6;1	S10 6;7
[paki]	**Mean VOT(ms)**	+11	+9	+5	+12	+8	+18	+7	+5	-4	+11
	STDEV	3.7	3.9	1.9	3.2	1.3	5	2.4	3.6	6.9	1.6
[baki]	**Mean VOT (ms)**	+11	+11	-16	+6	+7	+7	0	+3	-185	-42
	STDEV	7.2	4.7	26.2	1.1	1.4	2.4	4.4	2.6	136.9	36.8
[tasə]	**Mean VOT (ms)**	+12	+10	+9	+9	+10	+13	+7	+12	+12	+21
	STDEV	3.9	3.2	1.8	3.2	3	5.7	3.4	1.8	2.4	6.4
[dasə]	**Mean VOT (ms)**	+13	+13	-6	+7	+13	+10	+10	+6	-44	-7
	STDEV	3.3	4.6	25.5	3.4	1.8	4.1	1.8	3.8	74.6	53.9
[tɔpi]	**Mean VOT (ms)**	+8	+14	+9	+6	+10	+11	+7	+7	+11	+12
	STDEV	1.3	1.7	1.9	2.8	2	5.1	3	1.3	0.7	1.8
[dɔpi]	**Mean VOT (ms)**	+13	+12	-37	+8	+10	+4	+7	+5	-253	0
	STDEV	6.2	2.8	64.8	1.1	2	19.8	2	5.1	93.6	34.6
[tək]	**Mean VOT (ms)**	+9	+11	+13	+14	+11	+12	+8	+16	+23	+39
	STDEV	1.4	2.3	3.9	3.7	1.3	5.3	4.6	6.5	6.3	42.7
[dək]	**Mean VOT (ms)**	+17	+12	+8	+10	+14	+9	+12	+16	-170	-79
	STDEV	4.8	2.4	5.3	1.3	3.4	9.6	2.9	3	94.6	26
[katə]	**Mean VOT (ms)**	+12	+22	+23	+14	+22	+20	+13	+17	+23	+24
	STDEV	4.2	4	14.8	4.9	4.3	7.6	1.4	3.7	6.3	7.7
[knəbəl]	**Mean VOT (ms)**	+26	+12	+55	+67	+27	+76	+23	+24	+35	+58
	STDEV	14.5	3.9	56	25.5	6.8	35.6	6.5	8.6	10.7	48.9
[klɔki]	**Mean VOT (ms)**	+23	+26	+32	+31	+23	+48	+20	+35	+33	+19
	STDEV	6.9	13.9	12.4	7.1	5.5	12.6	11.3	12.9	11.7	6.3
[blɔki]	**Mean VOT (ms)**	+26	+17	-7	+32	+12	+3	+11	-4	-1	0
	STDEV	25.8	10.1	48.7	12.9	5	15.8	5.9	25.3	3.2	23.2

ABBREVIATIONS: S=Subject ms=Milliseconds STDEV=Standard deviation VOT=Voice onset time

TABLE 4.27: GROUP DATA FOR VOICE ONSET TIME (VOT) POOLED ACCORDING TO VOICING, WITH CLUSTERS PRESENTED SEPARATELY

WORDS FOR WHICH VOT-RESULTS WERE POOLED TOGETHER	MEASURE	AGE GROUPS 4;0 to 4;8 yrs n=3	5;0 to 5;6 yrs n=5	6;1 to 6;7yrs n=2	Subjects as a Group n=10
Words with initial VOICED stops: [baki] [dasə] [dɔpi] [dək]	*Min. & Max.VOT*	-120 to +23ms	-31 to +25ms	-384 to +30ms	-384 to +30ms
	Range:	143ms	56ms	414ms	414ms
	Mean:	+4ms	+8ms	-97ms	-14ms
	STDEV:	25	6	113	67
Words with initial VOICELESS stops: [paki] [tasə] [tɔpi] [tək] [katə]	*Min. & Max. VOT*	+2 to +47ms	+2 to +27ms	-10 to +114ms	-10 to +114ms
	Range:	45ms	25ms	124ms	124ms
	Mean:	+12ms	+11ms	+17ms	+13ms
	STDEV:	6	6	17	10
Clusters with initial VOICED stops: [blɔki].	*Min. & Max VOT*	-94 to +55ms	-41 to +50ms	-30 to +23ms	-94 to +55ms
	Range:	149ms	91ms	53ms	149ms
	Mean:	+12ms	+11ms	0ms	+9ms
	STDEV:	33	18	16	23
Clusters with initial VOICE-LESS stops: [knəbəl] [klɔki]	*Min. & Max VOT*	+8 to +152ms	+8 to +108ms	+11 to +142ms	+8 to +152ms
	Range:	144ms	100ms	131ms	144ms
	Mean:	+29ms	+37ms	+36ms	+35ms
	STDEV:	26	24	28	25

ABBREVIATIONS: Min.=Minimum Max.=Maximum VOT=Voice onset time STDEV=Standard deviation ms=Milliseconds yrs=Years

4.8.1. DESCRIPTION AND DISCUSSION OF VOT-RESULTS OF WORDS STARTING WITH VOICED STOPS [b] AND [d] (i.e. [baki], [dasə], [dɔpi] AND [dək])

The VOT-results obtained for voiced plosives [b] and [d] will be discussed with reference to the data in Table 4.27 (where VOT-values for words starting with these sounds were pooled together), and Figure 4.3 which visually illustrates the minimum and maximum VOT-values for the different age groups and material.

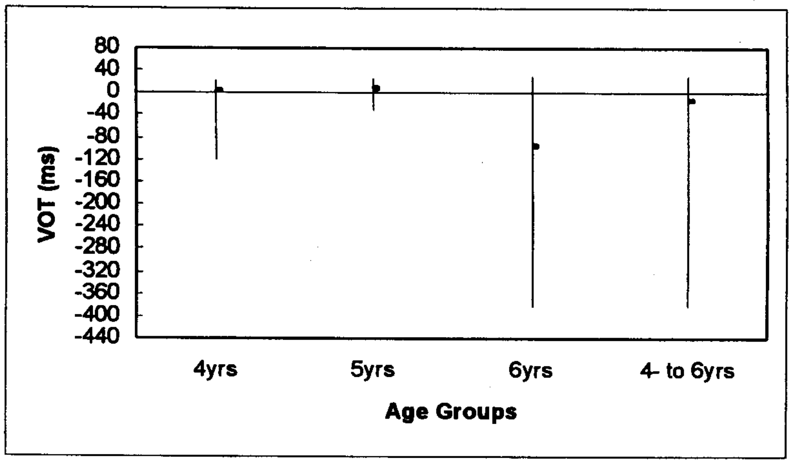


FIGURE 4.3: AGE GROUP VOT-DATA (i.e. MINIMUM, MEAN, MAXIMUM) FOR VOICED INITIAL STOPS [b] AND [d]

From the results for words starting with *voiced stops* [b] and [d] it can be seen that the subjects as a group showed a wide range of VOT-values (-384ms to +30ms), although the individual means only ranged from –97ms to +8ms (Table 4.27). The wide range of overall VOT-values was mostly the result of the very negative VOT's displayed by the six-year-olds (mean of -97ms, see Table 4.27 and Figure 4.3). Individual mean VOT-data (Table 4.26) showed that unlike any of the younger subjects, S9 and S10 displayed long voicing *leads* in almost all of their productions of words starting with voiced stops. A summary of subject and age group percentages for the occurrence of *mean voicing lead* are presented in Table 4.28 (calculated from data in Table 4.26).

It can be seen from the data in Table 4.28 that S9 displayed only negative mean VOT's or voicing lead (i.e. 100%) for voiced stop productions, while S10 showed voicing lead in 75% of his mean VOT's. In contrast, results for the younger subjects indicated that S3 (75% of his mean VOT's for voiced stops) was the only other subject who displayed any mean VOT voicing leads for voiced stops. However, his VOT's were not as negative as those of S9 and S10 (see Table 4.26).

TABLE 4.28: SUBJECT AND GROUP PERCENTAGES FOR MEAN VOICING LEAD IN WORDS WITH VOICED INITIAL STOPS

SUB-JECT	Number of negative VOT-means (voicing lead) in words with initial voiced stops	Percentage	PERCENTAGE OF MEAN VOICING LEAD FOR THE AGE GROUPS	PERCENTAGE OF MEAN VOICING LEAD FOR THE SUBJECTS AS A GROUP
S1	0	0	Four-year-olds: 25%	4;0 to 6;7-years-old: 25%
S2	0	0		
S3	3	75		
S4	0	0	Five-year-olds: 0%	
S5	0	0		
S6	0	0		
S7	0	0		
S8	0	0		
S9	4	100	Six-year-olds: 88%	
S10	3	75		

The four-year-olds displayed mean voicing lead in 25% of their productions of word-initial stops, the five-year-olds displayed no negative mean voicing leads and the six-year-olds in contrast, displayed 88% voicing lead for this context. The subjects as a group displayed mean voicing lead in 25% of word-initial voiced stops.

These findings are in agreement with those of previous English studies. Zlatin and Koenigsknecht (1976) for example found that English adults showed more frequent voicing lead productions than children and that six-year-olds showed more frequent voicing leads than two-year-olds. The infrequent lead exhibited by two-year-old children resulted in a consistently narrower range of production for voiced stops than older children and adults (Zlatin & Koenigsknecht,1976). In correspondence with these findings, data showed that the range displayed by the four and five-year-olds in this study was smaller than that of the six-year-olds (See Table 4.27 and Figure 4.3.). Results from this study thus indicated a tendency for Afrikaans-speaking subjects younger than six years, to show voicing *lag* (positive VOT's) rather than voicing *lead* (negative VOT's) in their VOT's for word-initial *voiced stops.*

VOT-values for *English* voiced stops are usually reported to fall anywhere in the range of -20 to +20ms (Kent & Read,1992). Lisker and Abramson (1964) reported adult values for *Dutch* voiced stops ranging from -145ms to -45ms.

Dutch more closely resembles the Afrikaans-language, since both Dutch and Afrikaans have the same contrasts of voiced and voiceless unaspirated stops [p/b/d/t] and only [k] in the velar position. Lisker and Abramson (1964) reported that other than English, which displayed three sets of VOT-values for stops in their study, Dutch had mostly two, namely one set of stops with negative values and the other with zero or small positive values of VOT. In this study the mean VOT-values of four and five-year-olds were closer to the reported voiced stop VOT-values for English than those reported for Dutch, while the six-year-olds' mean VOT-value for voiced stops, appears to be more closely related to the values reported for Dutch (Table 4.27).

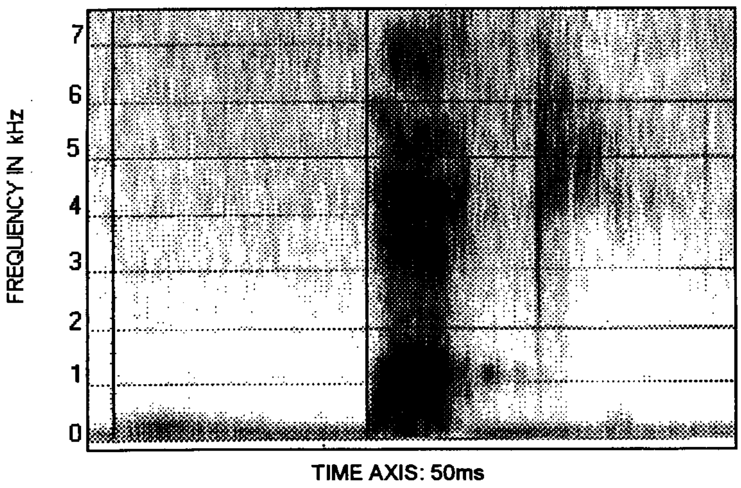
Consensus exists about the fact that English children's VOT-values proceed from *unimodal* to *bimodal* distributions in terms of development, first showing VOT's mostly concentrated in the *short* voicing-lag range (i.e. 0 to +39ms) and over time adding more VOT's in the *long* voicing-lag range (i.e. values of +40ms and above) (Kewley-Port & Preston,1974; Zlatin & Koenigsknecht,1976; Gilbert, 1977; Macken & Barton, 1980). It has been reported that utterance-initial voiced stops generally are not pre-voiced in English, indicating that English speakers habitually effect an oral closure when beginning an utterance with a stop (Lisker & Abramson,1964; Klatt,1975).

Results from this study indicated a possibly different developmental pattern for Afrikaans-speaking children's VOT-control. Similar to English, results from this study may indicate that VOT's for Afrikaans-speaking children's voiced stops also first show a *unimodal* distribution with VOT's concentrated in the short-lag voicing range (i.e. 0 to +39ms). However, where the English VOT bimodal distribution is characterized by an increase in *long* voicing-lag values, (i.e. VOT's of +40ms and above), results seem to indicate the opposite for Afrikaans-speaking children. Their bimodal distribution may rather be characterized by the occurrence of more VOT's in the voicing *lead* range (negative VOT's) by six years. Extensive research with larger subject groups (and both younger and older children) is needed to expand on the present findings regarding VOT-development for normal Afrikaans-speaking children though. Due to the small number of subjects per age group, age-related observations have to be considered tentatively.

Some explanation for the fact that negative voicing leads were mostly displayed by the *older* children in this study, may be gained from the physiology of stop consonant production in adults. Researchers have frequently hypothesized that articulatory movements which result in stops with *short* VOT-intervals (i.e. 0 to +39ms) might be easiest for children to accomplish. On the other hand, to produce stops with either voicing *lead* or *long* voicing-lag (i.e. above +39ms), requires more careful timing between supra-glottal and glottal articulators (Kewley,Port & Preston,1974; Gilbert,1977). Allen (1985) in a study of VOT in French children had theorized that VOT's in the voicing lead region may even be motorically more difficult for children to produce than VOT's in either the short or long-lag voicing regions. At least three separate articulatory gestures with separate innervations are needed to produce a stop consonant. These include the articulations to permit stop closure and release (labial, alveolar or velar positions), to isolate the nasal cavities at the velum and to initiate vocal fold vibration (Rothenberg,1968; Kewley-Port & Preston,1974). Other articulatory gestures in the vocal tract may also be used by adults to produce stops (Kewley-Port & Preston,1974). The nasal cavities must be isolated from the rest of the vocal tract in order to create the intraoral pressure needed to produce the stop. "Articulatory gestures required to produce *short lag stops* are velopharyngeal closure followed by the complete adduction of the vocal folds at the time of release of the supraglottal articulators, such that vocal fold oscillation begins within 20ms of release. In order to initiate vocal fold oscillation, another factor must be coincident. Oscillation of adducted folds is the result of airflow through the glottis, which in turn occurs when there is a sustained pressure drop across the glottis. When the vocal tract is unobstructed and the vocal cords are adducted, a wide range of transglottal pressure differentials and tensions in the vocal folds will result in some sort of vocal fold oscillation." (Kewley-Port & Preston,1974:203-204). However, when the vocal tract is obstructed, as during stop closure, and the vocal folds adducted, Rothenberg (1968) had theorized that oscillation will not occur or be maintained unless special articulatory mechanisms are utilized to sustain transglottal pressure drop. Special mechanisms might include passive enlargement of the supraglottal cavity, heightened subglottal pressure, and some nasal airflow which may comprise velopharyngeal adjustments other than simple velopharyngeal closure (Kewley-Port & Preston,1974).

Thus, for a child to successfully produce short-lag alveolar stops (i.e. VOT's between 0 and +39ms) in the initial position, the glottis may be fully closed any time during alveolar closure, providing that the velopharyngeal closure merely isolates the nasal cavities. However, to produce voicing *lead* stops (negative VOT's), the child must complete glottal closure considerably before oral release and then initiate and sustain vocal fold oscillation by the addition of other articulatory mechanisms (Kewley-Port & Preston,1974). Voicing lead stops may thus require muscle gestures in *addition* to those needed for short voicing-lag stops, which support the hypothesis that *short* voicing-lag stops may have less complex articulations than *voicing lead* productions (Kewley-Port & Preston, 1974). Based on maturity aspects, it may thus be easier for older children to produce the complex articulations resulting in voicing lead, than for younger children.

In addition, it was occasionally observed in the present study that long intervals of pre-voicing were marked by nasal sounding voicing, almost as if the child added a nasal sound to the production e.g. [mbaki] instead of [baki] or [ndək] instead of [dək]. Figure 4.4 is an example of such an instance, where S9 displayed a very negative VOT of -384ms for [baki]. It should be mentioned that this did not occur consistently in all instances of negative VOT-values, and was not so explicit that it could be considered a true addition of a distinct nasal consonant. One reason for the occurrence of this perceptually discernable nasal quality during the pre-voicing interval, could be that the subjects were merely a little late with velopharyngeal closure in those cases. However, based on the previously described theory of Rothenberg (1968), it can also be argued that these, being instances of nasal airflow, could have been one of his proposed 'special' articulatory mechanisms, with the goal of sustaining transglottal air pressure drop so that vocal fold oscillation (initiation and maintenance of voicing) could occur. Although much younger children and a different language were studied, Allen (1985) in a VOT-study of French children aged 1;9 to 2;8 years, interestingly also found that voiced targets were sometimes preceded by a nasal or vowel segment. Allen (1985) believed that this was a strategy of the children to avoid producing pre-voiced stops, which he postulated was articulatory more difficult to produce. Again, the proposed possibilities are merely hypothetical. Discussion of this issue is limited by the lack of comparable data, and the small amount of subjects used in this study.



Nasal quality b a ki

FIGURE 4.4: PRODUCTION OF [baki] BY S9, INDICATING NASAL QUALITY RESULTING IN A VERY NEGATIVE VOT (-384ms)

4.8.2. DESCRIPTION AND DISCUSSION OF VOT-RESULTS OF WORDS STARTING WITH VOICELESS STOPS [p], [t] AND [k] (i.e. [paki], [tasə], [tɔpi], [tək] AND [katə])

The VOT-results obtained for voiceless stops [p], [t] and [k] will be discussed with reference to the data in Table 4.27 (where VOT-values for words starting with these sounds were pooled together) and Figure 4.5, which visually illustrates the minimum, mean and maximum VOT-values for the different age groups and material (data from Table 4.27).

Results from Table 4.27 and Figure 4.5 indicated that all the age groups obtained *mean VOT's* for voiceless stops between +11ms and +17ms. These VOT-values obtained by the age groups for voiceless stops were significantly lower than those usually reported for English. Zlatin and Koenigsknecht (1976) found that for the English language, a greater concentration of VOT's for labial voiceless stops occurred between +50ms and +100ms, with VOT's for alveolar and velar voiceless stops occurring between +60 and +100ms.

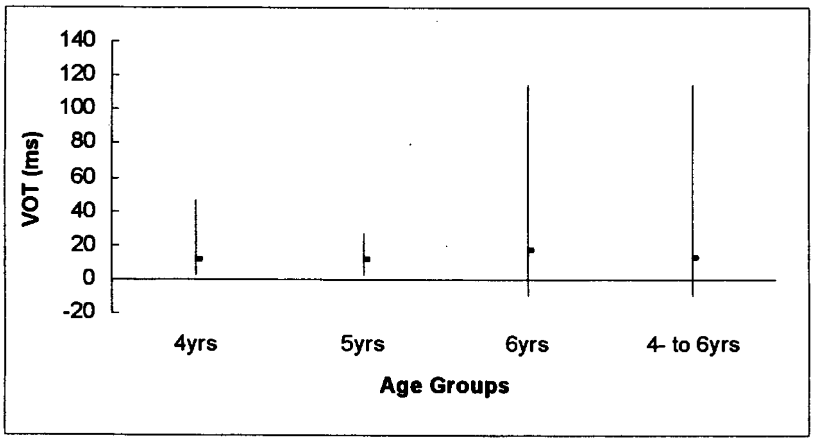


FIGURE 4.5: AGE GROUP VOT-DATA (i.e. MINIMUM, MEAN, MAXIMUM) FOR VOICELESS INITIAL STOPS [p], [t] AND [k]

In the present study *mean VOT-values* of +40ms or above never occurred for voiceless initial stops (see Table 4.26), indicating that Afrikaans-speaking children's mean VOT's for *voiceless stops* thus seem to fall into what is generally referred to in VOT-research as the *short voicing-lag range* (i.e. 0 to +39ms), as opposed to English VOT-values which generally extend into the *long voicing-lag range* (Kewley-Port & Preston,1974; Zlatin & Koenigsknecht, 1976). (More detailed definitions of terminology can be found in Table 2.5).

This big difference in results can be a direct effect of language differences, since voiceless stops in English are aspirated while Afrikaans stops generally are not. Indeed, the values obtained by the subjects in this study for voiceless stops compare much better with the range reported for Dutch adults by Lisker and Abramson (1964) namely 0 to +35ms. Results thus indicated that VOT-values for voiceless stops in Afrikaans-speaking children aged 4;0 to 6;7 years differed considerably from those of English children, most probably due to the absence of aspiration in the Afrikaans-language, with Afrikaans mean VOT-values being concentrated in the short-lag voicing range (i.e. 0 to +39ms). (It is emphasized that all the subjects produced perceptually distinct voiceless stops).

The VOT-data for voiceless stops further indicated that the subjects produced longer VOT-values for velar stop [k] than for labial and alveolar stops [p] and [t] (Table 4.26). The subjects as a group obtained the following percentages of *mean VOT-values* above +20ms for the different stops: [p]= 0%, [t]=10%, and [k]=50% (calculated from data in Table 4.26). Results thus indicated that Afrikaans children aged 4;0 to 6;7 years showed a progression of later mean voicing-lag times from the most *anterior* point of constriction in the vocal tract (labial), to the *velar* position, which is in agreement with findings for English adults (Lisker & Abramson,1964; Zlatin,1974; Baken, 1987) and children (Zlatin & Koenigs-knecht,1976).

Further, all the age groups displayed slightly higher (i.e. more positive) *mean* VOT values for *voiceless* stops than for *voiced* stops (Table 4.27). Data in Table 4.26 indicated that only one subject (S9, a six-year-old) showed one small negative mean VOT-value (i.e. –4ms) for voiceless stops.

4.8.3. DESCRIPTION AND DISCUSSION OF VOT-RESULTS FOR VOICED STOP [b] IN CLUSTER [bl] (i.e. [blɔki])

The VOT-results obtained for voiced stop [b] in cluster [bl] will be discussed with reference to the data in Table 4.27 and in Figure 4.6 which visually illustrates the minimum, mean and maximum VOT-values for the different age groups and material (data from Table 4.27).

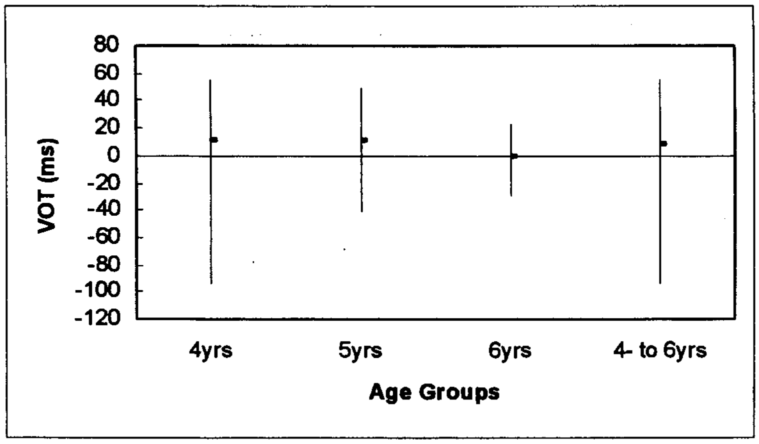


FIGURE 4.6: AGE GROUP VOT-DATA (i.e. MINIMUM, MEAN, MAXIMUM) FOR VOICED STOP [b] IN CLUSTER [bl])

Results indicated more or less similar performance across age groups, although the six-year-olds again tended to produce more negative mean VOT's than the other age groups, similar as to what was observed with the previous results for voiced word-initial stops. Analysis of the ***mean*** VOT-data in Table 4.26 indicated that voicing lead occurred in 70% of the mean VOT's of the subjects for voiced stop [b] in cluster [bl], and 70% of the mean VOT's for voiced word-initial stop [b] (Table 4.28). However, when the data in Table 4.27 are considered, it is evident that the mean VOT's for [b] in [bl] were slightly higher (more positive values) than for word-initial [b].

Klatt (1975) also reported VOT-values slightly higher for the [b] in [bl] (cluster context) than in a word-initial context, but offered no explanations for this finding. Baken (1987:377) noted that "...in stressed single-word utterances a VOT less than +25ms or so can be said to signal an English voiced plosive. Longer VOT's indicate a voiceless phoneme." 20% of the mean VOT-values reported for [b] in [bl] in this study (Table 4.26) were found to be +25ms or above (as opposed to 0% in the case of [b] in the word-initial context), but these values were displayed by only S1 (mean: +26ms) and S4 (mean: +32ms). The stops in all these cluster productions were clearly perceived as voiced though. It is possible that these few instances of higher positive VOT-values could have been the result of more profound instances of *aspiration* which were observed in these subjects' spectrograms. Aspiration could thus have extended the voicing lag.

4.8.4. DESCRIPTION AND DISCUSSION OF VOT-RESULTS FOR VOICELESS STOP [k] IN CLUSTERS [kl] AND [kn] (i.e. [klɔki] AND [knəbəl])

The VOT-results obtained for voiceless [k] in clusters [kl] and [kn] will be discussed with reference to the data in Table 4.27 (results for these two words were pooled together) and Figure 4.7, which visually illustrates the minimum and maximum VOT-values for the different age groups and material (data from Table 4.27).

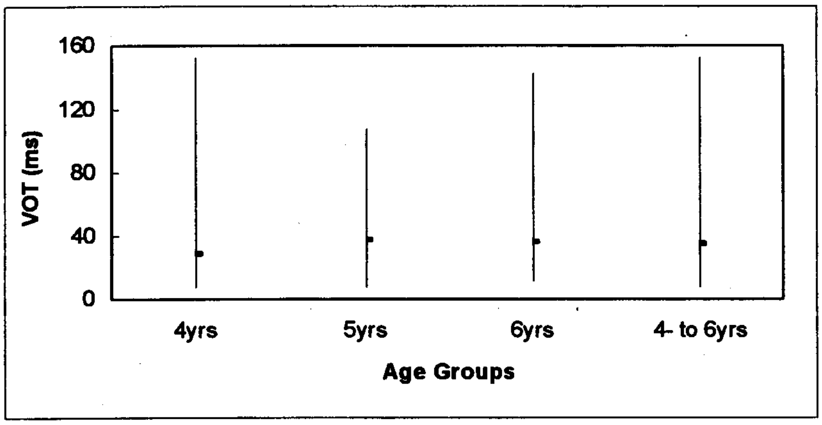


FIGURE 4.7: AGE GROUP VOT-DATA (i.e. MINIMUM, MEAN, MAXIMUM) FOR VOICELESS STOP [k] IN CLUSTERS [kl] AND [kn]

VOT-results obtained for voiceless stop [k] in clusters [kl] and [kn] indicated that all age groups displayed much higher *mean VOT's* for these sound in clusters than in word initial position (Table 4.27). Mean VOT-values of +40ms and above (thus ranging into what is theoretically referred to as the *long* voicing-lag range) occurred in 25% of the means for the clustered context, as opposed to 0% of the means of the word-initial context (Table 4.26). Klatt (1975) also reported VOT-values slightly higher for the [k] in clustered context [kl] than for [k] in a word-initial contexts. Aspiration was heard and noticed on the spectrogram in most of the higher (i.e. more positive) VOT's in this study, which could have caused these instances of high positive VOT's, but it is unclear why it occurred.

An interesting observation concerning cluster production was that the subjects as a group produced [knəbəl] as [kənəbəl] in 29% of all their productions. This vowel could be perceived and occasionally also be observed on the spectrogram (in terms of vowel formants). The insertion of this epenthetic vowel did not occur in any of the other clusters (or spontaneous speech samples), but was also observed in cluster production, as previously discussed. According to Hawkins (1984) this type of modification of adult clusters implies a lack of coarticulation between the two consonants. It can be argued that the [kn]-cluster, which involves moving the tongue from a *velar* position to an *alveolar* position, and simultaneously opening the velopharyngeal port to create a nasal air stream, may be articulatory speaking more complex to coordinate than [bl] and [kl], where oral airstream and velopharyngeal closure are maintained in the transition. It can be hypothesized that general timing for cluster-[kn] may not yet be so mature or adult-like in some normal children aged 4;0 to 6;7 years of age. When the VOT-data were compared it was found that the [k] in [knəbəl] showed the longest overall mean VOT of all three clusters (Table 4.26).

Unfortunately all of the cluster results are very difficult to interpret due to the lack of comparable acoustic VOT-data. Byrd (1996) has recently emphasized the complexity of cluster production by stating that "...consonant sequences are of special interest in creating models of speech production, as often many demands are concurrently placed on an individual articulatory structure, the tongue. The tongue must execute these demands in a short period of time, and the consonants are not discretely articulated Consonant cluster timing is likely to be variable and subject to myriad influences interacting in complex ways." Extensive data is needed before any further interpretations can be made.

4.8.5. DESCRIPTION OF VOT-RESULTS FOR COMBINED VOICED STOP CONTEXTS (i.e. WORD-INITIAL AND CLUSTER) AND COMBINED VOICELESS STOP CONTEXTS (i.e. WORD-INITIAL AND CLUSTERS)

The VOT-data for *voiced stop material* (i.e. data for word-initial and cluster voiced contexts combined) indicated that the subjects as a group displayed mean VOT's for all voiced stops ranging from -97ms to +12ms and voicing lead in 26% of the mean VOT-values reported for voiced stops (Table 4.29). The *six-year-olds* showed the overall most instances of mean voicing lead for voiced stop contexts (i.e. 80%) and the five-year-olds the least (i.e. 4%.).

TABLE 4.29: SUMMARY OF VOT-DATA FOR COMBINED VOICED STOP CONTEXTS AND COMBINED VOICELESS STOP CONTEXTS

COMBINED VOT-DATA FOR VOICED STOPS *(i.e. data for word-initial [b], [d] and cluster context [bl] combined)*		
Overall range of individual VOT's for the group (4;0 to 6;7 year-olds):	-384ms to +55ms	
Mean VOT-range for the group (4;0 to 6;7 year-olds:	-97ms to +12ms	
Overall percentages of *mean voicing lead* in voiced stops:	***Subjects as a group (4;0 to 6;7 year-olds)***	26%
	4-year-olds:	27%
	5-year-olds	4%
	6-year-olds	80%
COMBINED VOT-DATA FOR VOICELESS STOPS *(i.e. data for word-initial [p], [t], [k] and cluster contexts [kn] and [kl] combined)*		
Overall range of individual VOT's for the group (4;0 to 6;7 year-olds):	-10ms to +152ms	
Mean VOT-range for the group (4;0 to 6;7 year-olds:	+11ms to +37ms	
Overall percentages of *mean long-voicing lag* (i.e. VOT's of +40ms and above) for voiceless stops:	***Subjects as a group (4;0 to 6;7 year-olds)***	7%
	4-year-olds:	5%
	5-year-olds	9%
	6-year-olds	7%

The VOT-data for *voiceless stop material* (i.e. data for word-initial and cluster voiceless contexts combined) indicated that the subjects as a group displayed mean VOT's for all voiceless stops ranging from +11ms to +37ms (Table 4.29). The subjects as a group displayed overall instances of *mean long voicing-lag* (i.e. VOT's of +40ms and above) for 7% of the voiceless stop material and the age groups performed very similarly (Table 4.29).

4.8.6. SUMMARY OF VOT-RESULTS

Voicing lead occurred more frequently in the mean VOT-values of six-year-olds. Six-year-olds thus evidenced more of an ability to produce the complex articulatory movements and inter-articulator synchronization associated with the production of negative VOT's than five and four-year-olds. Results seem to confirm the hypothesis that the production of short voicing-lag VOT's may be easier to accomplish than articulatory movements of either stops with voicing lead or long voicing-lag. The subjects' mean VOT-values for *voiced stops* fell into either the *voicing lead* or *short-voicing lag* category (i.e. 0 to +39ms) for English.

Mean VOT-values for *voiceless stops* fell mostly in the short voicing-lag category (i.e. 0 to +39ms) while values in the long voicing-lag range (i.e. +40ms and above) seldom occurred (only in some cluster contexts). Results further showed a progression of later mean voicing-lag times from the most *anterior* point of constriction in the vocal tract (labial), to the most posterior (velar) position. Subjects occasionally inserted a schwa-vowel in productions of the word [knəbəl], which may indicate that production of this cluster in terms of inter-articulator synchronization may be more difficult for some normal children to accomplish than for others. It can be hypothesized that schwa-insertion may allow more time for inter-articulator synchronization and coordination.

Due to the lack of comparable normative data about the development of VOT in voiced and voiceless stops in Afrikaans and the small number of subjects used in this study, all interpretations must be considered tentatively. Extensive longitudinal and cross-sectional research of both younger and older children, as well as adults are needed to expand on this preliminary observations regarding VOT-development of Afrikaans stops. However, basic normative information regarding VOT-characteristics (i.e. inter-articulator synchronization) of normal children between 4;0 and 6;7 years were obtained, to which speech motor control skills such as inter-articulator synchronization and coordination of children with developmental speech disorders can be compared with.

4.9. DESCRIPTION AND DISCUSSION OF RESULTS FOR SUB-AIM EIGHT: FIRST SYLLABLE DURATION (FSD) IN WORDS OF INCREASING LENGTH

The goal of this sub-aim was to investigate acoustically if normal, Afrikaans-speaking children in the age range 4;0 to 7;0 years make any adaptations in first-syllable duration (FSD) in imitated words of *increasing length* and if so, what the nature of these adaptations are.

The following terms will be used for the subsequent description and discussion of the results for sub-aim eight. W*ord group* will refer to the three words of increasing length that were grouped together (see Table 3.8) e.g. word group one (Wg1) consists of [pan], [panə] and [panəkuk]. *Length A* will be used to refer to the shortest word in every Wg (word group) e.g. [pan], *Length B* will refer to the second longest word e.g. [panə] and *Length C* will refer to the longest word in every word group e.g. [panəkuk].

Figure 4.8 visually illustrates the FSD-results of the subjects as a group for the three word lengths. FSD-data of words of the same length were pooled together. Figure 4.9 depicts the same pooling of data but for the other three age groups (four, five and six-year-olds). Figures 4.10 and 4.11 depict the mean FSD and FSD-standard deviation data for the subjects as a group for each word group.

4.9.1. GENERAL DESCRIPTION AND DISCUSSION OF FSD-RESULTS

The data from Figures 4.8 and 4.9 indicated that for all the age groups the longest mean FSD (first syllable duration) occurred in the <u>*shortest*</u> words, and that the shortest mean FSD occurred in the <u>*longest*</u> words (observed in 70% of all the word groups). Results thus indicated a *general trend of a decrease in FSD with increased word length.*

This is surprising when taking into account that the words in the different word groups were elicited randomly and not successively (in which instance learning could have played a role in decreased duration).

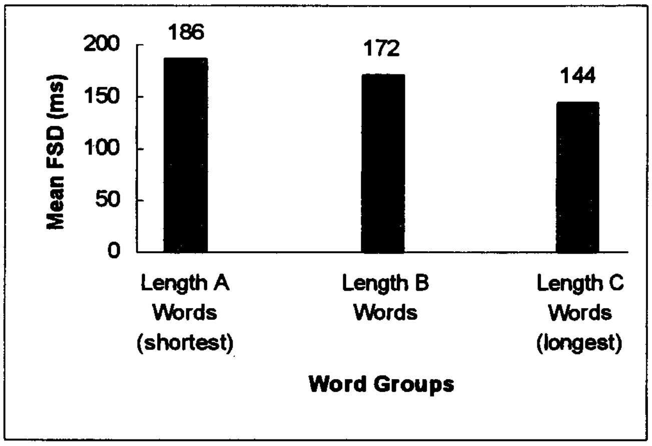
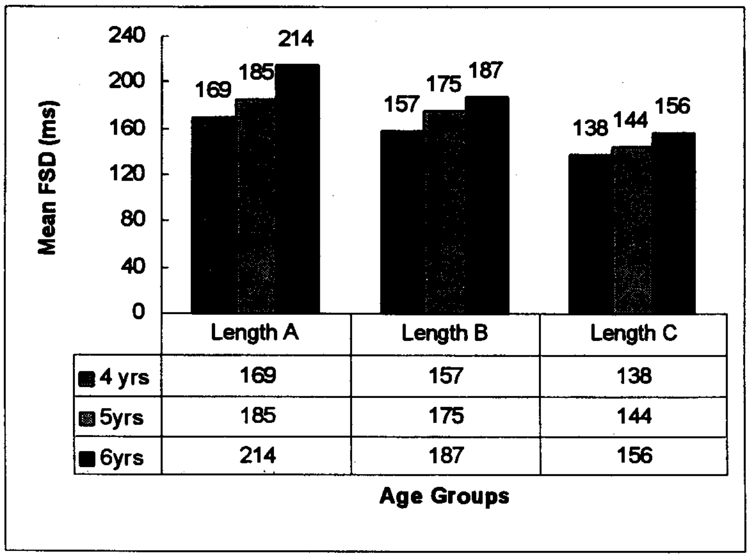


FIGURE 4.8: MEAN FIRST-SYLLABLE DURATION (FSD) OBTAINED FOR THE SUBJECTS AS A GROUP FOR THE DIFFERENT WORD LENGTHS

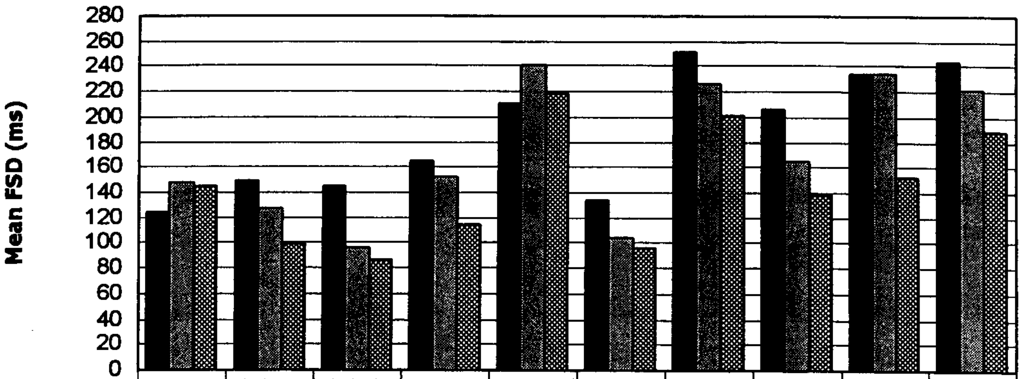


	Length A	Length B	Length C
4 yrs	169	157	138
5yrs	185	175	144
6yrs	214	187	156

FIGURE 4.9: MEAN FIRST-SYLLABLE DURATION (FSD) OBTAINED BY THE AGE GROUPS FOR THE DIFFERENT WORD LENGTHS

Results thus indicated that Afrikaans-speaking children aged 4;0 to 6;7 years adapted FSD to word length by *decreasing* FSD as word length of the material increased. The results for the subjects as a group showed that only 30% of the word groups did not show this general trend (Figure 4.10). Individual subject results also indicated that this effect was not consistently present in every word group for all the subjects. Individual trends in performance occurred frequently and it was very difficult to identify any age-related trends (except for the mean FSD-values, which will be discussed later).

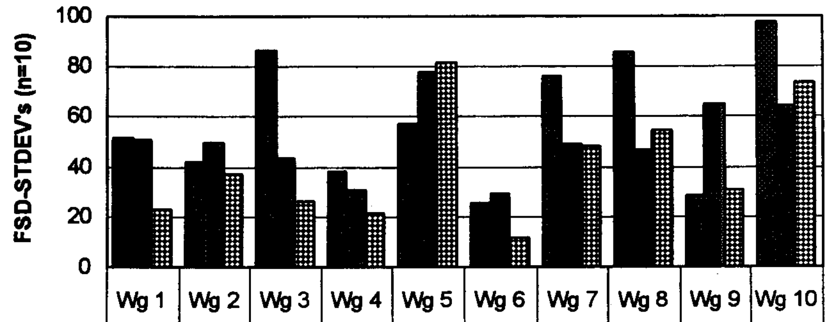
The general decrease in FSD that was observed with an increase in word length was not present in Wg1 (tel/telling/telefoon), Wg5 (blom/blomme/blombakke), and Wg9 (man/manne/mannetjie) (Figure 4.10). It was noticed that in these words, (as well as in other individual cases where subjects did not display the overall trend), word length *B* frequently had the longest duration. Figures 4.12, 4.13 and 4.14 display the individual FSD-results for these three word groups.



	Wg 1	Wg 2	Wg 3	Wg 4	Wg 5	Wg 6	Wg 7	Wg 8	Wg 9	Wg 10
Length A	123.6	149.2	144.3	164.4	210.5	133.6	251.9	205.6	234.4	243.9
Length B	148.6	127.2	96.3	152.5	240.9	103.8	226.6	164.7	233.8	221.2
Length C	145.5	98.9	87.2	115.6	219.2	96.2	200.8	137.7	153.3	189.1

Word Groups

FIGURE 4.10: MEAN FIRST-SYLLABLE DURATION (FSD) DISPLAYED BY THE SUBJECTS AS A GROUP FOR THE DIFFERENT WORD GROUPS



	Wg 1	Wg 2	Wg 3	Wg 4	Wg 5	Wg 6	Wg 7	Wg 8	Wg 9	Wg 10
tel bak doek pan blom kop knop lip man vin	51.4	41.7	86.8	38.4	56.8	25.4	76	86.1	28.3	97.7
telling bakkie doeke panne blomme koppies knoppe lippe manne vinne	50.8	49.7	44	30.7	77.5	29.5	49	46.7	65	64.3
telefoon bakkery doeksakke pannekoek blombakke koppietjie	22.9	37.3	26.5	21.7	81.7	12	48.4	54.5	31.3	73.7

Word Groups

FIGURE 4.11: FIRST-SYLLABLE DURATION (FSD) STANDARD DEVIATIONS FOR THE SUBJECTS AS A GROUP (CALCULATED FOR THE DIFFERENT WORD GROUPS)

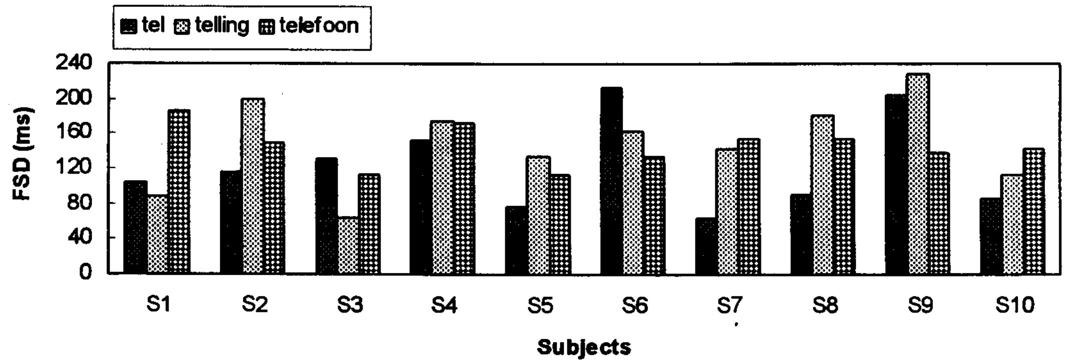


FIGURE 4.12: INDIVIDUAL FSD-RESULTS FOR WORD GROUP ONE

It is very difficult to explain why these words did not show the generally observed effect, and why word length B occasionally was the longest in those cases. The manner in which these words' length increased from length A to length B to length C did not appear to differ linguistically much from the pattern of increasing length in the other words. In fact, in several other cases where word length was increased by addition of a sound like [ə] or [i] (similar to Wg5 and 9), FSD generally did decrease when length increased (e.g. doek/doeke/doeksakke). The only observable difference was in the case of Wg1 (i.e. tel/telling/telefoon). This was the only word group where word length was increased by adding the Afrikaans suffix '-ing' (which changes the word "tel" from 'n verb to a noun) and not the plural suffix [ə]/[s] or the diminutive suffix [i]. It can be proposed that some phonological or semantic variable could have played a role. However, it is not clear exactly how, since one subject (S6) still showed the effect of a decrease in FSD with increasing word length for this word group.

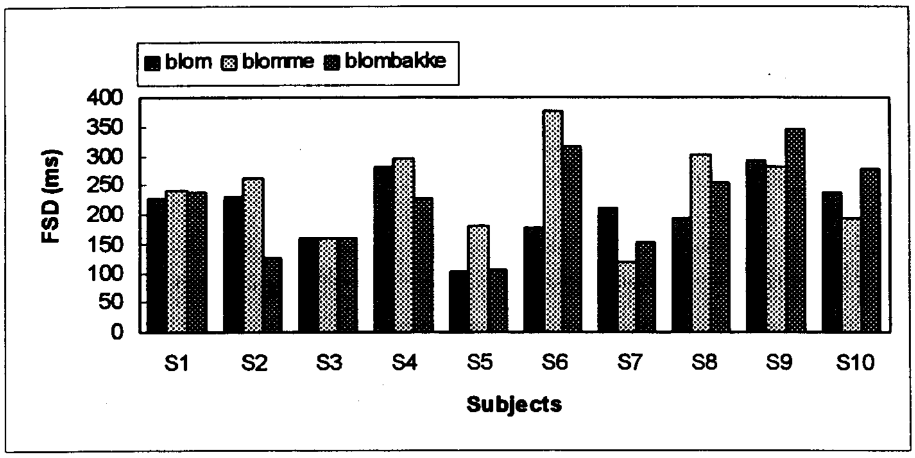


FIGURE 4.13: INDIVIDUAL FSD-RESULTS FOR WORD GROUP FIVE

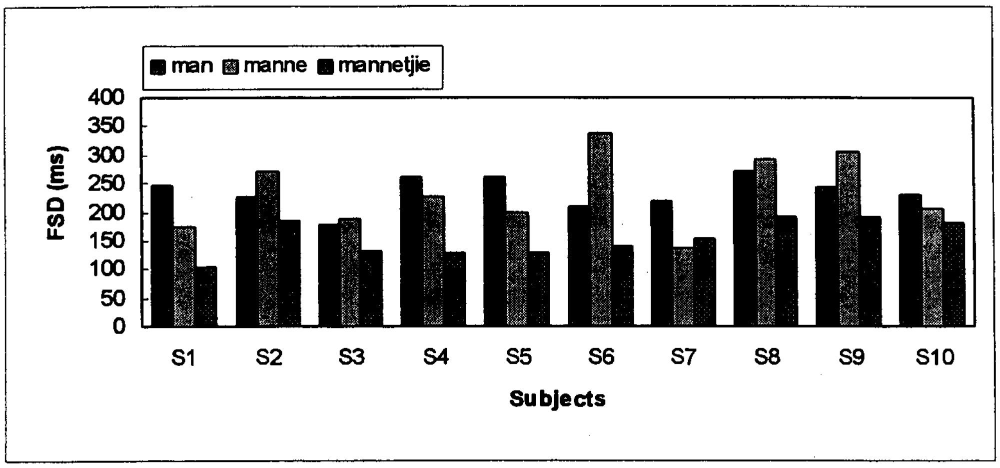


FIGURE 4.14: INDIVIDUAL FSD-RESULTS FOR WORD GROUP NINE

In addition, no pattern that could help explain the results was identified in the sequence or manner of presentation of the material. The same random order and manner of presentation were maintained for all the subjects.

Due to the limited number of research in this area for both the English and Afrikaans languages, it can only be concluded at this stage that a combination of unknown linguistic/phonologic, phonetic or other unidentified factors may have contributed to the observed effects. These results indicate the need for more research in this area.

Results further indicated that for Wg1 (tel/telling/telefoon), S7 and S10 even showed an *increase in FSD with increased word length,* which was opposite to the general trend. S3 also displayed this slightly in Wg3 (doek/doeke/doeksakke) but no other subjects showed it in any other word groups. A contributing factor to the occurrence of this effect in S3's results, was the fact that he produced [duk] with such a fast transition from [d] to [k], that almost no vowel formants were seen on the spectrogram. Again it is uncertain why S7 and S10 showed this effect in their FSD's. The low frequency of occurrence of an *increase* in *FSD* with *increased word length* may indicate it to be an exception to the rule, or just very individual trends in performance.

An unexpected result in FSD was the fact that the *oldest* children (six-year-olds) had the *longest* mean FSD followed by the five-year-olds and finally the four-year-olds with the shortest mean FSD (see Figure 4.9). These results thus indicated an *increase* in FSD with *increased age*. This occurred for all three word lengths and is unexpected in the light of the fact that researched conclusively indicated that segmental duration usually tend to decrease with increased age. In this study too for example, in spite of some individual exceptions, the six-year-olds showed a tendency to show the shortest mean FVD-. A possible explanation for this unexpected tendency may be the fact that S9 and S10's spectrograms frequently displayed instances of pre-voicing in material starting with stops, in contrast with the younger subjects who seldom did. As a result of the measurement procedure (which included these instances of pre-voicing in the FSD-value), S9 and S10's first-syllable duration values were thus automatically longer in duration that those of the other subjects. Figure 4.15 illustrates one such instance (i.e. S10 producing [duk] with pre-voicing).

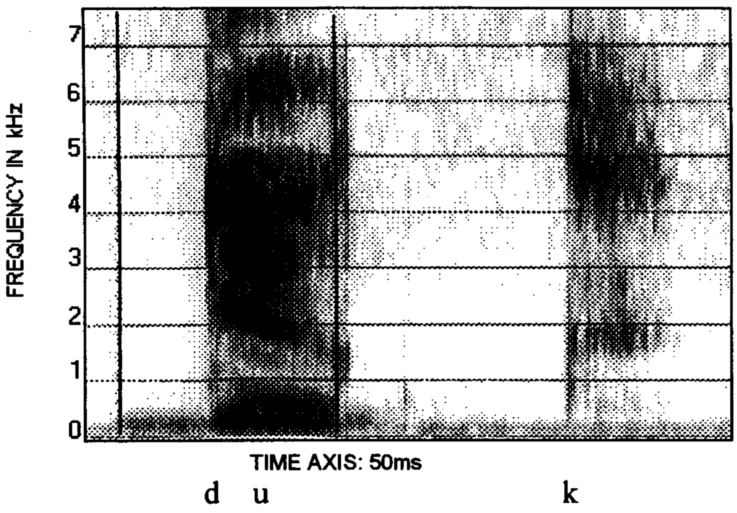


FIGURE 4.15: EXAMPLE OF PRE-VOICING DISPLAYED BY S10, RESULTING IN A LONG FSD-VALUE OF 190ms FOR FIRST SYLLABLE [du] in THE TARGET WORD [duk]

4.9.2. DESCRIPTION AND DISCUSSION OF INDIVIDUAL TRENDS IN FSD

In addition to the discussed group trends, the following observations were made spectrographically and perceptually regarding occasional individual productions of the material. These observations may contribute to a better understanding of at least some of the results (e.g. longer FSD in some words) and in general of aspects present in normal children's sensorimotor control of FSD. First, longer FSD-values were sometimes the result of *lengthening of a consonant or vowel* e.g. [tæl] was sometimes characterized by a vocalic transition e.g. [tihæl]. Words starting with sound combinations were frequently produced by the lengthening of one sound in the cluster e.g. [l] in [bl......ɔki], lengthening of the whole first syllable e.g. [blɔ....mə]. This also occasionally occurred in words starting with continuants e.g. [l] in [ləp] and fricatives [f] in [f...ən] or [f...ənəx]. *Aspiration* was another factor that was observed spectrographically and contributed to longer FSD e.g. [kʰnɔp] (knop). Interestingly, Hawkins (1973:208) regarded increased aspiration of fricatives in a cluster as the result of an "...effort to reduce the articulatory load...". It's uncertain if the same speculation can be made of results in this study. *Epenthesis* of schwa vowel [ə] occurred in two word groups namely

Wg5 and Wg7, with the clusters [bl] and [kn] which also caused increased FSD e.g. [kənɔp] (a spectrographic example of this can be seen in Figures 3.6). A final contribution to increased FSD was *negative voice onset time* (pre-voicing) in words starting with voiced plosives, which was especially evident in the older children's data (i.e. S8, S9 and S10) and has already been discussed previously (see Figure 4.15).

4.9.3. GENERAL DISCUSSION OF FSD-RESULTS

Although no studies directly related to all these results could be identified, results of Lindblom (1968) indicated that in the utterances of mature speakers, both consonant duration and vowel duration are decreased as the overall length of an utterance is increased. Schwartz (1972) found a similar phenomenon and interpreted it as evidence that a speaker scans ahead to appraise the length of the utterance and uses this information to determine the amount of time he may devote to the articulation of individual sounds. DiSimoni (1974:b) repeated Schwartz (1972)'s experiment with children aged three, six, and nine-years-old and found the phoneme duration conditioning effects to be present in the speech of six and nine-year-old children but not in three-year-olds. He concluded that his experiment showed "...aspects of the chronologic sequence of development of durational control systems in children..." and suggested the possibility of a "...hierarchy of coarticulatory functions..." (DiSimoni,1974:b: 1354). House (1961) found that the duration of a stem word decreases as the length of the utterance increases, which Lehiste (1970) explained as rule-governed phonological behavior. Unfortunately not much is presently known about rule-governed variables involved in segmental duration in the Afrikaans language.

It is known that several factors can influence sensorimotor speech timing control, although details regarding these processes are not yet completely determined. Picket in Glasson (1984:87) summarized general lengthening and shortening effects as follows: "(1) the greater the number of sub-units in speech, the shorter is each sub-unit (2) each sub-unit is shorter up to a minimum duration of compressibility; and (3) successive sub-units have a greater effect than antecedent sub-units". However, specific details of such effects on children's sensorimotor timing control patterns are too few to represent a standard (Glasson,1984).

Due to the lack of related research findings in this area for both English and Afrikaans-speaking children, it can only be concluded at this stage that a combination of linguistic, segmental and suprasegmental variables may have contributed to the observed FSD results. This may range from factors such as the characteristics of the phonetic environment of the words and the sound following the first syllable, and stress patterns (although unlikely, since stress was on the first syllable of all the words), to a range of unknown and possibly yet unidentified phonetic, linguistic and other factors. These findings can be regarded as further indication of the very complex nature of sensorimotor speech control.

4.10. CONCLUSION

In this chapter the results for the different sub-aims were described and discussed with reference to existing research findings. General normative data for speech motor development were presented in the areas of non-speech oral movements, non-speech oral diadochokinesis, speech diadochokinesis, cluster production, word syllable structure, aspects of first-vowel duration, variability of first-vowel duration, voice onset time in stops, and first-syllable duration in words of increasing length. A basic, normative database for a variety of speech motor developmental parameters in normal, Afrikaans-speaking children in the clinically important age range of 4;0 to 6;7 years, has thus been established, to which the same speech motor skills in children with developmental speech disorders can be compared with.

CHAPTER 5

EVALUATION OF THE STUDY, SUMMARY OF RESULTS AND CONCLUSIVE DISCUSSION

5.1. INTRODUCTION

In this chapter the research method of the study will firstly be evaluated in terms of strengths and weaknesses. A summary of the main findings for each sub-aim will then be provided, together with a discussion of its major clinical and theoretical implications. General aspects of speech motor development that emerged from the findings of this and previous studies that need to be considered in future research and clinical assessment, will then be discussed. This will be followed by recommendations for future research.

5.2. EVALUATION OF THE RESEARCH METHOD

The research method has strengths in the following areas:

-The study's method was theoretically based on the characteristics of speech as a fine-sensorimotor skill and a theoretical framework of sensorimotor speech control (i.e. Van der Merwe,1997). These clear theoretical underpinnings are considered to be a strength of the study, since it laid the foundation for a clear focus on sensorimotor (non-linguistic) processes of speech production, served to define terminology, to identify, formulate and motivate sub-aims, and to direct the construction of an assessment battery that addressed a variety of parameters of sensorimotor speech control development. It also provided a framework of interpretation of results.

-Since the test battery focused on basic aspects of sensorimotor speech control, with all material compilation and data elicitation procedures described in detail, it will be relatively easy to adapt and translate it to other South African languages.

-The multi-subject case-study research design, together with the implementation of 'methodological triangulation' (i.e. using both quantitative and qualitative description of data) were effective in establishing a normative information basis regarding the 'normal range of performance' possible for normal children aged 4;0 to 6;7 years (mean age: 5;2 years) on these assessment tasks, and also to identify individual trends in performance.

-The data elicitation and recording procedures were found to be efficient in eliciting good co-operation from the subjects and to ensure reliable samples. These procedures are expected to have good clinical assessment potential.

-The rating scales compiled for data-analysis for sub-aims one, two and three were effective in rating and describing performance and can be clinically used to expand traditional assessments of these areas.

The following <u>limitations</u> can be identified in the method:

-The absence of an Afrikaans-speaking adult control group is a limitation, since its inclusion might have led to more direct comparison of adult and child performance on sensorimotor speech control tasks, and thus possibly to more extensive explanation and interpretation of the children's results. Overall it might also have provided additional information regarding the performance of normal Afrikaans-speaking adults on these tasks.

-More subjects per age group and an equal number of subjects per age group (i.e. four-year-olds, five-year-olds, six-year-olds) may have provided more extensive normative information and may have allowed for more complex statistical analysis procedures (e.g. direct age group comparisons).

-It may be difficult to perform the assessment battery on children younger than four years, or on children with developmental speech disorders (DSD) with concomitant language, attention, or auditory processing problems, due to the fact that a certain amount of co-operation and concentration is required.

-Clinically, it may be difficult for therapists to obtain access to instrumentation such as spectrographic analysis, implying that the results of sub-aims seven, eight and nine presently have more application value for future research (e.g.

comparative studies of sensorimotor speech control characteristics of normal children and those with suspected DSD's), than for clinical usage.

-On the other hand, implementation of more sophisticated instrumental analysis procedures such as kinematic or electromyographic measurements might have enabled the assessment of additional and possibly more detailed aspects of sensorimotor speech control and its development, although this would have decreased clinical applicability even more.

5.3. SUMMARY OF FINDINGS

The main aim of this study was to collect general, normative information regarding certain sensorimotor speech control abilities of normal, Afrikaans-speaking children. This aim was reached since a variety of basic, previously non-existing information for Afrikaans-speaking children were gathered regarding different aspects of sensorimotor speech control for normal children aged 4;0 to 6;7 years (mean age: 5;2 years). In addition, basic qualitative assessment of non-speech oral movements (NSOM), non-speech diadchokinesis (NSO-DDK) and speech diadochokinesis (S-DDK), were expanded in the form of compiled Rating Scales (used to perceptually rate performance). A basic sensorimotor speech assessment battery, together with basic normative information were thus established, to which the performance of Afrikaans-speaking children with (DSD) in the age range 4;0 to 6;7 years can be compared with in the future. A summary of the findings for each sub-aim, together with clinical and theoretical implications of these results are presented in Table 5.1.

TABLE 5.1: SUMMARY AND IMPLICATIONS OF RESULTS

SUB-AIMS	SUMMARY OF RESULTS FOR NORMAL CHILDREN AGED 4;0 to 6;7 years	THEORETICAL AND CLINICAL IMPLICATIONS OF RESULTS
<u>Sub-Aim One:</u> **Voluntary non-speech oral movements (NSOM):** *Isolated oral movements (I-OM), *Two-sequence oral movements (2S-OM) *Three-sequence oral movements (3S-OM)	*All subjects were capable of voluntary execution of all the individual components of all target movements in all three sections (indicating the absence of oral apraxia in these normal subjects as expected). *However, most of the subjects' performance on these tasks were not completely adult-like, since: -Only four (40%) subjects (S6,S7,S8,S9) scored perfect ratings for I-OM -Only three (30%) subjects (S3,S6,S8) scored perfect ratings for 2S-OM -Only two (20%) subjects (S4,S6) scored perfect ratings for 3S-OM -Only one subject (10%) (S6:5;4 yrs) scored perfect ratings in all three sections *The *<u>types</u>* of errors that occurred however, were only minor in nature and restricted to: *<u>Associated movements</u>*: (Only a., b. and c.-ratings occurred for this rating scale Category I) I-OM: lifting chin and tilting head with target movement (TM) 1.3. (*lick an ice cream*) were displayed by five (50%) of the subjects. 2S-OM: mandible movements in tongue lateralization tasks (TM 2.2. and 2.3) displayed by five (50%) of the subjects 3S-OM: five (50%) of the subjects displayed backwards head-tilting when trying to touch their noses with their tongue (TM 3.2.), which may be considered a result of effort rather than being a true associated movement. *<u>Accuracy errors</u>*: (Only a., c., d., and f.-ratings occurred for this rating scale Category II) I-OM: five (50%) subjects displayed either inaccurate or incorrect movements with upward tongue licking movements. This was characterized by circular/in-out-movements, or by resting the tongue on the lower lip during execution.	*The fact that the majority of these normal children did not show perfect execution in all three these sections, implies that the execution of NSOM may *not yet be completely adult-like* for all normal children in this age range, and may continue to develop after 6;7 years of age. *The fact that one subject did manage to get perfect ratings for all the sections, implies that some normal children can show adult-like performance at this age, indicating possible *individual trends* in performance. * Children in this age range can still be expected to show minor *<u>associated movements</u>* when performing tongue *lateralization* tasks and upward tongue licking movements. * The second part of TM 3.2. (i.e. "then touch your nose with your tongue") should be changed to a more achievable task such as "touch your upper lip with your tongue" in future assessments, due to the relative impossibility of this task. * Children in this age range can still display minor *<u>accuracy errors</u>* when performing upward tongue licking movements, but the majority of children can be expected to perform these non-speech tasks with good accuracy. * Normal children in this age range can be expected to *<u>sequence</u>* these two and three-sequence oral movements well. However, four-year-olds may need key words for 2S-OM, and four to six-year-olds may need key words for 3S-OM, in order to aid the auditory recall of commands.

TABLE 5.1 (-CONTINUED): SUMMARY AND IMPLICATIONS OF RESULTS

SUB-AIMS	SUMMARY OF RESULTS FOR NORMAL CHILDREN AGED 4;0 to 6;7 years	THEORETICAL AND CLINICAL IMPLICATIONS OF RESULTS
Sub-Aim One **Voluntary non-speech oral movements (NSOM):** *(-continued)*	2S-OM: three (30%) subjects displayed either inaccurate (i.e. inadequate touching of lip corners/sweeping tongue over bottom lip) or incorrect movements (i.e. in-out, or inside instead of outside mouth) for tongue lateralization tasks (TM.2.2 and 2.3), indicating that the majority of subjects did not experience accuracy problems for 2S-OM. 3S-OM: only two (20%) subjects displayed error ratings, indicating that the majority of subjects did not experience accuracy problems for 3-SOM Sequencing errors: (Only a., c., d., and f.-error ratings occurred for this rating scale Category III) 2S-OM: only the two (20%) youngest subjects (four-year-olds) displayed problems. 3S-OM: only three subjects (30%) obtained correct sequencing without any key words provided, while only one subject's performance did not improve with the provision of key words, indicating that auditory memory problems may have contributed to sequencing errors. * No general age-related trends were observed, except for the fact that the two youngest subjects display auditory-memory problems with 2S-OM in addition to 3S-OM, while the older children managed correct sequencing without key words for 2S-OM.	*It may be appropriate to incorporate key words when using these tasks for assessment purposes in clinical settings, since children with DSD may also have accompanying auditory processing problems, which can further hamper auditory recall. *A traditional pass/fail system or the mere reporting of diadochokinetic rates (i.e. quantitative analysis) when assessing children's performance on NSO-DDK tasks may not be adequate, and need to be expanded by *qualitative* descriptions and analysis of occurring error types. This may lead to more information regarding symptom patterns in DSD.

TABLE 5.1 (-CONTINUED): SUMMARY AND IMPLICATIONS OF RESULTS

SUB-AIMS	SUMMARY OF RESULTS FOR NORMAL CHILDREN AGED 4;0 to 6;7 years	THEORETICAL AND CLINICAL IMPLICATIONS OF RESULTS
Sub-Aim Two: **Non-speech oral diadochokinesis (NSO-DDK):** -Tongue lateralization -Tongue in-and-out -Lips pout-stretch -Jaw open-close	* Only one subject (S7:5;4 yrs) scored perfect ratings on all four target movements. The type of errors that occurred though were only minor in nature and restricted to the following: *Associated Movements:* (Only a., b., c., and d.-ratings occurred for this rating scale Category I). Five (50%) subjects displayed associated movements of body and/or articulators for TM (target movement) 1 (*tongue lateralization outside mouth*) and TM 2 (*tongue in and out the mouth*), with only two (20%) displaying some associated movements for TM 3 (*lips pout-stretch*) and TM 4 (*jaw open-close*). A too fast execution rate led to an increase in associated movements *Accuracy Errors*: (Only a., d. and f-ratings occurred for this rating scale Category I.). Four (40%) subjects scored perfect ratings on accuracy while the rest of the subjects only displayed occasional error ratings indicating that the subjects generally were capable to execute these tasks with good accuracy. It was observed that a too fast execution rate decreased accuracy *Sequencing Errors*: (Only a., c, and f.-ratings occurred for this rating scale Category III.) Five (50%) subjects scored perfect ratings on sequencing, while the rest of the subjects only displayed occasional error ratings, indicating that the subjects generally were capable of executing these tasks with good sequencing. *Continuity:* (Only a, b, and d-ratings occurred for this rating scale category IV.). Five (50%) subjects scored perfect ratings on continuity, while the rest of the subjects only displayed occasional error ratings, indicating that the subjects generally were capable of executing these tasks with good continuity.	*The fact that the majority of these normal children did not show perfect execution for all four target movements, implies that NSO-DDK may *not yet be completely adult-like* for all children in this age range. *Since one subject did manage to obtain perfect ratings for all the sections, it can be deducted that some normal children can show more adult-like performance at this age. This indicates possible *individual trends* in speech motor development in this area. *Children in this age range can be expected to exhibit associated movements in *tongue lateralization* and tongue *in-out* movement tasks, but generally seem able to execute these tasks with only *occasional* and minor errors of accuracy, sequencing and continuity. *The mere reporting of diadochokinetic rates (i.e. quantitative analysis) when assessing children's performance on S-DDK tasks, needs to be expanded by *qualitative* descriptions and analysis of occurring error types in order to expand the applicability of such testing. This may for example, lead to expanded information regarding symptom patterns in DSD.

TABLE 5.1 (-CONTINUED): SUMMARY AND IMPLICATIONS OF RESULTS

SUB-AIMS	SUMMARY OF RESULTS FOR NORMAL CHILDREN AGED 4;0 to 6;7 years	THEORETICAL AND CLINICAL IMPLICATIONS OF RESULTS
Sub-Aim Three: **Speech Diadochokinesis (S-DDK):** -velar DDK: [dənə] -glottal DDK: [pəbə] -tongue DDK: [tə] & [kə] -lip DDK: [pə] -combined DDK in two-place articulation syllable strings: [pəkə], [təkə], [kəpə] and [kətə]) -combined DDK in three-place articulation syllable strings: [pətəkə], [kətəpə] and [təpəkə]	**Normative Diadochokinetic Rate (DDR) Data*: *(See Tables 4.5, 4.6, 4.7 and 4.8 for detailed normative data)* .The elicitation procedure described in the method (Chapter 3) was effective for children this age. DDR's increased as the syllable length of the material increased. - Range of DDR's for the subjects as a *group* *(measured in number of repetitions per second)*: [tə]: 2.8 to 5 [pə]: 3 to 4.8 [kə]: 2.8 to 5.2 [pəbə]: 1 to 1.6 *(based on accurate productions)* [dənə]: 1.6 to 2.4 [pəkə]: 1.6 to 2.8 [təkə]: 1.4 to 2.6 [kəpə]: 1 to 2.6 [kətə]: 1.4 to 2 [pətəkə]: 1 to 1.8 [kətəpə]: 0.8 to 1.4 [təpəkə]: 0.8 to 1.2 -No age-related trends could be identified for four, five and six-year-olds and very individual trends in performance occurred. DDR-differences between material of the same structure category were small. * *Perceptual Results:* *(Based on percentage correct-PC-scores and rating scale analysis)*. -Very few errors occurred with tongue and lip-DDK-tasks (CV-syllables). The lowest overall PC-score was obtained for glottal DDK-task [pəbə] with many voicing (II.d) and substitution errors (IV.c) occurring. Some subjects reduced their execution rate in a possible attempt to increase accuracy, but not all subjects displayed this tendency. It also did not always result in increased accuracy. Very few errors occurred for the other two-place DDK-tasks (CVCV-syllables). In some children fast execution rates resulted in reduced accuracy, while others maintained good accuracy in spite of fast execution rates. -For three-place DDK-tasks the subjects displayed the highest PC-scores for [pətəkə], followed by [kətəpə] and the lowest PC-score for [təpəkə]. Error patterns for all DDK-task were very individualized and no error rating dominated the results *(see Tables 4.10, 4.11, 4.12, 4.13, and 4.14 for error type details)*. No associated movements occurred in any of the S-DDK tasks (in contrast with the subjects' performance on NSO-DDK tasks).	*The fact that no clear *age-related trends* were identified and that individual trends in performance occurred, implies that it may be more appropriate to use DDR-results of the subjects as a *group* for normative, assessment purposes in a clinical setting. For example, when a five-year-old child's DDR's are assessed, it should be determined whether they fall outside the normal *range* reported for 4;0 to 6;7 year-old normal children as a group, rather than to compare the child's performance to norms for his/her *specific* age group (i.e. five-year-olds) or to mean *DDR's*. *Glottal DDK-tasks seem to be difficult to accomplish for some normal children in this age range and voicing and substitution errors can occur. It's possible that glottal and three-place syllable sequences place more demands on sensorimotor speech planning in terms of rate, accuracy, continuity and sound structure. *Some normal children in this age range may apply a *reduction in rate of execution* as a natural, *compensatory strategy* to accomplish more complex articulatory movement sequences, although not all such attempts may result in increased accuracy. It will be interesting to determine how children with DSD handle these tasks (e.g. if they employ the same strategies as normal children and how 'successful' it is). *Both *rate* and *accuracy* should be considered when children's performance on more difficult S-DDK-tasks are evaluated, although the exact relationship between these two concepts is not yet established and appears to be complex. It can be deducted that the traditional practice of reporting DDR-values only in assessments *(i.e. quantitative analysis)* without reference to *accuracy* or occurring *error types (i.e.qualitative analysis)*, yields limited information about speech motor abilities. For example, it is possible that a child with fast DDR's but with little accuracy in production, has 'poorer' speech motor performance than a child with slower DDR's but who displays more accuracy.

TABLE 5.1 (-CONTINUED): SUMMARY AND IMPLICATIONS OF RESULTS

SUB-AIMS	SUMMARY OF RESULTS FOR NORMAL CHILDREN AGED 4;0 to 6;7 years	THEORETICAL AND CLINICAL IMPLICATIONS OF RESULTS
Sub-Aim Four: **Cluster production:** Initial and final consonant clusters in isolation	*Subjects generally obtained higher PC-scores for initial (i.e. 84%) than for final clusters (i.e. 79%). * 79% of errors with initial clusters were the result of schwa-vowel insertion and the other 21% errors were of a mixed type. *For final clusters 47% of the errors were the result of an addition of the syllable [hə] in front of the cluster, 45% were the result of a schwa-vowel insertion and 8% of errors were of a mixed type. *None of these error types occurred in the subjects' spontaneous speech sample.	*Some normal children in this age range may still find it difficult to produce some clusters in isolation. The planning and sequencing of consecutive motor goals for *final* cluster combinations appear to be more complex for the majority of children than for *initial* clusters. *Results may indicate that the occurrence of *schwa-vowel insertion* and addition of the syllable [hə] in clusters produced in isolation, can be expec-ted from normal children in this age range. It possibly is a compensato-ry strategy to allow more time for articulatory transitioning and sequencing of motor goals from one consonant to another, thus a way of handling higher articulatory demands. *The fact that the subjects were able to produce words starting and en-ding with clusters accurately in spontaneous speech, may indicate that the production of a cluster in isolation (which can be argued to be a "non-linguistic' context), places different *demands* (i.e. maybe greater) on speech motor planning than the production of a cluster in spontaneously produced words. *The results raise some interesting questions regarding contextual effects on sensorimotor speech planning of clusters, which are yet unanswered. It also provides some additional *motivation* for determining a child's productive repertoire for producing initial and final clusters in isolation. Such assessment may yield some information regarding aspects of sensorimotor planning, programming and execution such as *coordination* and *sequencing* of speech movements, without having added linguistic and phonological factors influencing performance. Byrd (1996:209) has argued that the study of consonant sequence production is of special importance in understanding "articulatory organization" and thus in creating models of speech production.

TABLE 5.1 (-CONTINUED): SUMMARY AND IMPLICATIONS OF RESULTS

SUB-AIMS	SUMMARY OF RESULTS FOR NORMAL CHILDREN AGED 4;0 to 6;7 years	THEORETICAL AND CLINICAL IMPLICATIONS OF RESULTS
Sub-Aim Four: **Cluster production:** *(-continued)*	*(See previous page)*	*It will further be interesting to determine if children with DSD use the same 'strategies' (e.g. schwa-vowel and syllable [hə] insertion) to possibly assist the production of these sequences, and/or if they show errors different from these normal children. Until more research has been conducted in terms of cluster production in isolation, it seems warranted to include such testing in a speech motor control assessment battery.
Sub-Aim Five: **Word syllable structure:**	*The subjects produced a total of *163* different word syllable structure combinations. Of these structures *18* (11%) occurred at least once in the spontaneous speech samples of each subject, while 145 (89%) occurred at least once in some subject's sample.	*Normal children of this age display sensorimotor speech skills that are developed to such an extent that they can plan, program and execute a wide variety and intricate sequence of *consecutive motor goals* in spontaneous speech, resulting in sometimes very lengthy and creative word structures. *It can be hypothesized that normal-speaking children's sensorimotor speech control systems are capable to convert complex phonological sequences, which were linguistically planned (selected and sequenced) during the linguistic-symbolic phase of speech production, to a code that can be handled by the speech motor system (Van der Merwe, 1997). They can thus be said to be able to "...plan the consecutive movements necessary to fulfill the spatial and temporal goals..." by "...identifying the different motor goals for each phoneme..." and by sequentially organizing the "...movements that are necessary to produce the different sounds in the planned unit..." (Van der Merwe, 1997:11). *Further, they can specify articulator-specific motor goals such as lip rounding, jaw depression, glottal closure, or lifting of the tongue tip, and plan inter-articulator synchronization for each phoneme in the utterance (Van der Merwe, 1997).

TABLE 5.1 (-CONTINUED): SUMMARY AND IMPLICATIONS OF RESULTS

SUB-AIMS	SUMMARY OF RESULTS FOR NORMAL CHILDREN AGED 4;0 to 6;7 years	THEORETICAL AND CLINICAL IMPLICATIONS OF RESULTS
<u>Sub-Aim Five:</u> **Word syllable structure:** *(-continued)*	*(See previous page)*	* Using word structure analysis in the assessment of sensorimotor speech control is still in need of more development. It is recognized that at this level of assessment, language and sensorimotor aspects of speech production are complex and interrelated, and that it can be very difficult, and possibly artificial, to separate the two concepts. As Hawkins (1984:355) put it: "As a motor skill, speech is learned in accordance with laws governing the acquisition of any other motor skill, although the unique relationship between speech and other linguistic and non-linguistic systems means that its acquisition may also have unique aspects.". It is for example clear that *linguistic factors* such as a child's vocabulary, syntactic, morphological and phonological skills also play a role in the type and length of word structures displayed. Yet, it's hypothesized that word syllable structure analysis also has the potential to give at least *some* indication of *the level of sensorimotor control* a child has mastered, in addition to being a reflection of linguistic skills. This may be especially be the case when additional *qualitative* analysis of word syllable structure takes place (e.g. in terms of possible error types or preferences), and when results are interpreted within the context of a variety of data obtained from a test battery combining the assessment of linguistic-symbolic planning skills and sensorimotor speech control (i.e. non-linguistic skills).
<u>Sub-Aim Six:</u> **Segmental duration in repeated utterances** a) First-vowel Duration (FVD):	*The *mean FVD* of the subjects ranged from 98ms to 169ms (thus a wide range) as calculated across target words. * A direct *increase* in mean FVD with *increased age* was only observed in two target words (out of a possible thirteen).	*Although results imply that a tendency may exist for six-year-olds to generally show faster FVD's than five and four-year-olds, it appears as if developmental FVD-changes do <u>*not*</u> necessarily occur on a <u>*yearly*</u> basis for four, five and six-year-old normal children. It is possible that the 4;0 to 6;7 year period is not characterized by major developmental changes in FVD. Rather, based on the <u>*wide range*</u> of values that these normal children have displayed, very individual FVD-performance may be prevalent for this age range.

TABLE 5.1 (-CONTINUED): SUMMARY AND IMPLICATIONS OF RESULTS

SUB-AIMS	SUMMARY OF RESULTS FOR NORMAL CHILDREN AGED 4;0 to 6;7 years	THEORETICAL AND CLINICAL IMPLICATIONS OF RESULTS
<u>Sub-Aim Six:</u> **Segmental duration in repeated utterances** a) First-vowel Duration (FVD): *(-continued)*	*In spite of no consistent age-related differences for the rest of the material, a tendency did exist for the *oldest* age group (six-year-olds) to show the *shortest* mean FVD most often. However, the youngest age group (four-year-olds) did not obtain the longest mean FVD most often. * A tendency for individual rather than age-related performance was thus present. For example, the shortest overall mean FVD was displayed by a five-year-old (S7:5;4 yrs) but the two longest overall FVD's were also displayed by two five-year-olds (S8 and S4). *A contextual effect that emerged from the data was that duration of a vowel preceded by a *voiced plosive* were longer than the duration of the same vowel preceded by a *voiceless* plosive (difference ranged from 4ms to 36ms, depending on material).	*Due to the wide range of FVD-values that may occur for this age range, it is important in future research and/or clinical assessments that *clustering* of results for subjects in this age range according to age in years is carefully approached. Secondly, a child with suspected DSD's performance should be compared with the *<u>range</u> of FVD-values* displayed by these normal subjects as a group, rather than with subjects of exactly the same age. *Results seem to provide some evidence for theories suggesting that normal children do not necessarily 'mature' on the *same schedule* with regard to the same aspects of sensorimotor speech control (Smith and Kenney, 1998), and that different children may develop at different *rates* (Von Hofsten,1989). **Preceding consonantal voicing* appears to affect FVD, implying that it may be a contextual influence worth studying in future studies of linguistic and phonetic influences on FVD.
<u>Sub-Aim Six:</u> **Segmental duration in repeated utterances** *(-continued)* b) Variability of FVD	*Subjects displayed FVD-values ranging from 39ms to 263ms across all utterances and target words (a range of 224), indicating great inter- and intra-subject variability in FVD. *Age-related decreases in variability with increased age did not occur. However, a tendency was found for the oldest subjects (six-year-olds) to obtain the *least* variability (i.e. smallest CfV) the most, and for the five-year-olds to display the *highest CfV* (i.e. most variability) the most. *Very individual trends in performance occurred, with children of the same age sometimes showing contrasting results. High intra-individual variability also occurred. *The *most* variability in FVD (i.e. the highest CfV) was displayed by the subject who had the *shortest* mean FVD across target words (S7-5;4yrs) and the *least* variability by S9 (6;1yrs) who had the fourth highest mean FVD.	* Inter- and intra-subject variability for FVD seem to be high for children in this age range. Normal children can thus be expected to show very individual FVD-values, which can vary over a large range for different repetitions and different target words. *Clear age-related differences do *not* seem to be present for FVD in this age range and children of the same age may perform differently. * Results imply that in assessment, a child with a suspected developmental speech disorder's performance should be compared with the <u>*range*</u> of FVD-values displayed by the subjects as a group, rather than with subjects of exactly the same age, since this may allow for 'normal' individual variation.

TABLE 5.1 (-CONTINUED): SUMMARY AND IMPLICATIONS OF RESULTS

SUB-AIMS	SUMMARY OF RESULTS FOR NORMAL CHILDREN AGED 4;0 to 6;7 years	THEORETICAL AND CLINICAL IMPLICATIONS OF RESULTS
<u>Sub-Aim Six:</u> **Segmental duration in repeated utterances** b) Variability of FVD *(-continued)*	*(See previous page)*	*Based on the theory that skilled motor performance is marked by a faster execution rate and less variability (e.g. Bruner,1973), subjects with shorter FVD's will be expected to show less variability in FVD than subjects with longer FVD's. However, the fact that the subject in this study with the *shortest* FVD displayed the *most* variability, may rather be evidence in favor of hypotheses that segmental duration and variability are not closely related, that these concepts possibly reflect *<u>different</u>* aspects of sensorimotor speech development and further, may *<u>not</u>* develop *<u>in</u>* *<u>tandem</u>* (e.g. Smith, 1992; Smith,1994).
<u>Sub-Aim Seven:</u> **Voice onset time (VOT)**	*<u>*Minimum, maximum and mean VOT-values for the subjects as a group:</u>* -*word-initial* voiced stops: -384ms to +30ms (*mean*: -14ms) -voiced stops in *clusters*: -94ms to +55ms (*mean*:+9ms) -*<u>combined</u> voiced contexts <u>mean</u> VOT range:* -97ms to +12ms -*word-initial* voiceless stops: -10 to +114ms (*mean*: +13ms) -voiceless stops in *clusters*: +8ms to +152ms (*mean*: +35ms) -<u>combined</u> voiceless contexts <u>mean</u> *VOT-range:* +11ms to +37ms * *<u>Normative results for voiced stops:</u>* -S9 and S10 (six-year-olds) displayed *voicing leads* in almost all of their productions of words starting with voiced stops, unlike any of the younger subjects. *Mean voicing leads* occurred in 88% of the six-year-olds', in 0% of the five-year-olds', and in 25% of the four-year-olds' productions. The subjects as a group displayed 25% mean voicing leads. -Long intervals of pre-voicing displayed by the six-year-olds were sometimes marked by a perceptually discernable nasal quality which can be interpreted as either the result of a late velopharyngeal closure, or as a 'special' articulatory mechanism with the goal of sustaining transglottal air pressure drop so that vocal fold initiation can occur. -The subjects displayed slightly more positive (i.e. higher) mean VOT's for voiced stops in *clusters* than for word-initial voiced stops.	*Normal children younger than six years have a tendency to display a greater percentage of *positive* VOT's (i.e. voicing-lag) than negative VOT's (i.e. voicing lead) in initial *voiced stop productions*. They may be expected to seldom exhibit negative VOT's. Six-year-olds on the other hand may produce negative VOT's more often. *Based on the physiology of stop consonant production, it can be hypothesized that the production of a *voicing lead* (i.e. negative VOT's) may require more careful timing between glottal and supra-glottal articulators and thus more *complex inter-articulator synchronization* than the production of positive VOT's between 0 and +39ms (short voicing-lag). This implies that normal Afrikaans-speaking six-year-olds display the possibly more complex interarticulator-synchronization associated with the production of *voicing lead* VOT's, with greater frequency than four and five-year-olds. This possibly indicates more *mature* sensorimotor voice onset time control abilities for six-year-olds.

TABLE 5.1 (-CONTINUED): SUMMARY AND IMPLICATIONS OF RESULTS

SUB-AIMS	SUMMARY OF RESULTS FOR NORMAL CHILDREN AGED 4;0 to 6;7 years	THEORETICAL AND CLINICAL IMPLICATIONS OF RESULTS
Sub-Aim Seven: **Voice onset time (VOT):** *(-continued)*	* *Normative results for voiceless stops:* -*Mean* VOT's of all age groups for voiceless *word-initial* stops fell between +11ms and +17ms (i.e. short-lag voicing lag range), probably due to the small amount of aspiration involved in Afrikaans voiceless plosive production. Mean VOT-values displayed by these subjects for voiceless stops corresponded with the range reported for Dutch rather than for English. A progression of later mean VOT-lag times from the most anterior point of constriction in the vocal tract (labial) to the most posterior (velar) position was present. *The subjects displayed slightly higher mean VOT-values for [k] in a cluster than in word-initial context. * *Normative results for combined contexts:* -Overall percentage of *mean voicing lead* displayed in voiced stop contexts (word-initial and cluster context combined) by the subjects as a group: 26% -Overall percentage of *mean long voicing-lag* displayed for voiceless stop contexts (word-initial and cluster contexts combined) by the subjects as a group: 7% * Epenthesis of vowel [ə] in the word [knəbəl] occurred in 29% of all the subjects' productions, possibly indicating a lack of coarticulation between the two elements of the cluster. No problems with words contai-ning this cluster were found in the subjects' spontaneous speech samples, but was also observed in isolated cluster production.	*Unlike English-speaking children, Afrikaans-speaking children do not show VOT-values for *voiceless word-initial stops* in the long-lag voicing range (i.e. +40ms and above), although higher VOT's may occur for voiceless stops in *cluster* contexts. This is a linguistic difference in VOT between these languages. *Some normal children may show schwa-vowel epenthesis in repeated utterances of the Afrikaans-word [knəbəl], possibly indicating that this cluster is articulatory speaking more *complex to coordinate* than the other clusters. It is possible that schwa-insertion may allow more time for inter-articulator synchronization and coordination. * It still has to be determined why schwa-epenthesis for [kn] occurred in cluster production in isolation, and also occasionally in repeated utterances of the word [knəbəl], but was not present in the subjects' spontaneous speech samples. Several questions regarding contextual influences on VOT were raised by the findings of this study. *It will be interesting to compare inter-articulator synchronization abilities of children with DSD in the same age range, with the performance of these normal children, in order to determine if they exhibit the same performance trends in VOT-control.
Sub-Aim Eight: **First-syllable duration (FSD) in words of increasing length:**	* For all age groups the *longest* mean FSD occurred in the *shortest* word length context, while the *shortest* mean FSD occurred in the *longest* word length context, indicating a general *decrease in FSD* with *increased* word length. *Only 30% of the word groups did not show a direct decline in FSD with increased length (i.e. Wg1, Wg5 and Wg9).	*Normal children can be expected to generally adapt FSD to word length by *decreasing FSD* as *word length increased*, except for the three word groups mentioned. *It is possible that some yet unidentified linguistic or phonetic variable/s could have played a role in the fact that three words in the material did not show this effect, implying that the *nature* of the material have to be considered a contextual variable in studies of FSD.

TABLE 5.1 (-CONTINUED): SUMMARY AND IMPLICATIONS OF RESULTS

SUB-AIMS	SUMMARY OF RESULTS FOR NORMAL CHILDREN AGED 4;0 to 6;7 years	THEORETICAL AND CLINICAL IMPLICATIONS OF RESULTS
Sub-Aim Eight: **First-syllable duration (FSD) in words of increasing length:** *(-continued)*	* Longer FSD-values in some instances were the result of consonant, vowel or whole first-syllable lengthening, vowel addition, epenthesis of schwa vowel [ə] between two cluster elements, lengthening of one cluster element, aspiration and/or pre-voicing (i.e. negative VOT's, only noticed for the six-year-olds). *An unexpected finding was that the oldest subjects (six-year-olds) had the *longest* mean FSD for all three word groups, followed by the five-year-olds and finally the four-year-olds with the shortest mean FSD. This indicated an increase in FSD with increased age. However, this could have been mostly the result of occasional, individual instances of pre-voicing (as those described in VOT-results), and instances of aspiration that was evident in the spectrograms of productions of S9 and S10.	*The fact that normal children in this age range generally do adapt FSD to the length of the utterance, may indicate that they are capable of some degree of speech motor planning such *as scanning ahead* to appraise the length of the utterance, and then to use the information to determine the time that can be devoted to articulation of sounds and syllables (Schwartz,1972). *It is thus possible that children in this age range exhibit *context sensitivity* (Van der Merwe, 1997) in terms of FSD. It will be interesting to determine if younger children and children with DSD of the same age, display the same tendencies. *FSD-results need to be analyzed both *quantitatively* (i.e. mean durational aspects) and *qualitatively* (i.e. perceptual errors such as epenthesis or spectrographically discernable processes such as pre-voicing/aspiration), in order to determine all possible variables contributing to results.

5.4. CONCLUSIVE DISCUSSION OF SPEECH MOTOR DEVELOPMENT

Collectively, the body of information regarding normal children's speech motor development indicates a *gradual increase* in various aspects of sensorimotor speech control from birth to puberty. However, specific details regarding this developmental process are only beginning to be uncovered. Currently we lack descriptions of general *stages* of speech motor development from birth to puberty. The *range* of normal speech motor performance that can be expected from normal children at different ages for different *parameters* of sensorimotor control also has not yet been fully documented. Further, the exact influence of a variety of *factors* (i.e. linguistic aspects, auditory perceptual skills, neuro-physiological maturational factors) on sensorimotor speech control development is undetermined. In addition to being limited, current normative data regarding speech motor development are also very *diverse* in terms of methodical aspects such as parameters studied, ages of subjects and instrumentation used.

As result of all these factors a standard *set of parameters* for clinical assessment of sensorimotor speech control development has not been established. This has a negative effect on assessment of speech motor skills of children in the clinically important age range of four to seven years, ages when children are frequently referred for speech-language assessments due to suspected developmental speech disorders (DSD's). Presently, it is difficult to clinically identify and specify potential isolated or accompanying problems with *non-linguistic* processes of speech production such as sensorimotor speech planning, programming and execution that may contribute to the symptom patterns of children with DSD. The *complex* nature of the speech production process and the resulting *hypothetical status* of most current theories of normal speech production and its sensorimotor control and development, further contribute to the problem with the identification of assessment parameters.

In spite of the current lack of specific details regarding speech motor development, the diverse nature of research in this field, and the hypothetical nature of theories and models of speech production and speech motor control, certain conclusive principles regarding the general development of sensorimotor speech control are indicated by the results of this and previous studies. By considering these general aspects in future research and clinical assessments, the effectiveness of assessment and treatment of possible sensorimotor speech problems in the pre-school years and other ages will ultimately be expanded.

Firstly, it appears as if a *wide range* of what can be considered 'normal' performance is possible regarding sensorimotor speech control aspects for children of the same age (i.e. the trend of high inter-subject variability). This implies that researchers have to be sensitive for *individual* trends in normal performance, and further, should *document and describe* such trends extensively rather than to consider it exceptional and not worth further investigation. The traditional focus in research regarding speech motor development on *group* findings and tendencies thus has to shift to also include more documentation and descriptions of *individual* performance. Smith and Kenney (1998:96) recently cautioned that our basic understanding of speech motor development represents a somewhat "...generalized or idealized descriptions of changes found to occur across groups of children of different ages...", since "...group data reveal 'average' performance across many subjects, but they do not reflect the developmental patterns of individual children". Von Hofsten (1989:952-953) similarly warned that "...pooling data for groups of individuals of the same age will 'smear' the developmental function, hide important transitions, and make it look smooth and uneventful.".

Descriptions of normal *individual variation* and *individual characteristics* of speech motor performance, in addition to general group tendencies, will lead to the establishment of a more reliable normative database in terms of the normal range of performance possible for a certain speech parameter. With the normal range of performance for a specific parameter available, the speech motor skills of children with DSD can be assessed more adequately and reliably. In addition, longitudinal studies of individual children's performance across time which is presently very scarce, will also supplement and enhance the overall understanding of speech motor development (Smith & Kenney,1998). Such combined and complementary approaches to the study of sensorimotor speech development will lead to more comprehensive knowledge of this phenomenon.

In addition, the need for more extensive descriptions of individual trends in performance implies that *quantitative* analysis of performance on different speech motor tasks, need to be supplemented with *qualitative* analysis of performance on the same tasks (e.g. description of error patterns by the application of rating scales). Hawkins (1984:367) wrote in terms of speech motor development that "...a reasonable first step in understanding underlying processes is to describe what is observed.". Qualitative analysis allows for such description. Although it may be a lengthy process to compile such extensive and specific information, eventually such data may assist in determining for example, whether a given child displays a mere *delay* in aspects of speech motor development (e.g. by displaying behavior of a normal but much *younger* child), or whether the displayed behavior is an indication of some *impairment* in sensorimotor speech control (e.g. by displaying *different* behavior not usually exhibited by normal children of the same age, neither by normal younger children). Differential diagnosis of DSD will also be ultimately enhanced.

A third aspect that needs to be considered in sensorimotor control development is that *different parameters* yield different perspectives on the processes of normal sensorimotor speech control. Integrated assessment of several different measures of speech production may thus lead to better interpretations of results, and ultimately to the identification of the most appropriate set of parameters for clinical assessment of speech motor development. Further, researchers and clinicians have to be sensitive to the possibility that results from recent studies have suggested that different sensorimotor speech parameters may not necessarily change at the same rate or within the same time frame as a child develops (e.g. Nittrouer,1993;1995; Smith & Goffman,1998; Smith & Kenney,1998). This is in line with trends in general motor development. Nittrouer (1993) for example, inferred that jaw and tongue speech gestures have distinctive developmental time courses, with jaw movements maturing earlier than tongue movements. Von Hofsten (1989) emphasized an important principle of general motor development which is that the general rate of development is different for different children and that one child may develop quickly at certain ages and slower at others. Smith and Kenney (1998:104) for example found that a "...child who demonstrates quite adult-like values in certain parameters may still be considered quite non-adult-like in other aspects of speech production.", implying that not all sensorimotor speech skills mature on the same schedule for a given child. The rate and change for individual parameters and/or the periods during which such changes may occur, may differ considerably among subjects and across ages. This emphasizes the complex nature of speech motor development and the necessity for many investigations of the development of a variety of parameters of sensorimotor speech control in children of all ages. Such an approach will serve to establish a body of information regarding the normal *range* of performance children can show for different parameters at different ages.

The issue regarding the possible diverse development of different parameters and in different children, further implies that a child's speech motor developmental status should not be assessed or judged based on one measurement only. A child may have no problems with one particular parameter, while still exhibiting sensorimotor control problems of a different nature than the parameter measured. Hawkins (1984:343) cautioned that "...there may be no changes in the parameter being measured, but some other relevant parameter may be changing.". A variety of sensorimotor speech control aspects thus need to be assessed in order to identify all possible problems in a specific child.

5.5. RECOMMENDATIONS FOR FUTURE RESEARCH

The following specific recommendations for future research are made:

-The test battery can be translated to assess populations of *other* normal, South African children speaking *languages* such as English, Zulu and Northern-Sotho. Comparison of differences and similarities in performance may throw more light on linguistic influences on timing aspects of sensorimotor speech control (e.g. VOT and first-vowel duration).

-More *advanced* methods of assessment can be considered for future studies of non-speech voluntary oral movements and non-speech diadochokinesis such as visuomotor tracking, measurements of strength and fatigability, or control of static position and isometric force, as to expand assessment of possible dysarthric involvement and sensorimotor control processes such as programming and execution of speech movements. Speech motor tasks can also be assessed with more sophisticated instruments such as kinematic, electromyographic and areodynamic measurements.

-Overall similarities and differences in performance aspects of *speech and non-speech tasks* can be compared in order to explore the nature of the relationship between sensorimotor speech and non-speech sensorimotor control.

-The relationship between *rate* and *accuracy* of performance in speech diadochokinesis tasks (especially in more demanding tasks such as glottal and three-place syllable sequences), can be further and more directly explored, in order to investigate how normal children and children with DSD's plan more demanding speech motor contexts (e.g. the nature of compensatory strategies).

-Cluster production in *different contexts* can be investigated further in normal and diagnostic populations. Contexts such as isolation, words and spontaneous speech or contexts of meaningfulness (i.e. a linguistic context) versus meaninglessness (i.e. more of a non-linguistic context) can be examined for differentially diagnostic purposes. Differences between initial and final cluster production and general phonetic influences involved in cluster production and error types (e.g. schwa-vowel insertion as a possible compensatory strategy), can be further examined to determine the influence of linguistic factors on speech motor development.

-The effect of *linguistic* aspects on first-vowel duration can be investigated more extensively (e.g. preceding consonantal voicing) in normal and diagnostic populations, by using different and more complex contexts.

-The effect of *increasing task demands* (i.e. longer and more complex material, increased speaking rate) on these different parameters of speech motor control can be studied, since it has been hypothesized that increasing task demands may have a greater impact on the speech motor processes of children than on those of adults (Smith & Goffman (1998).

-The whole test battery can be applied to children *with developmental speech disorders*. It is possible that when this speech motor development assessment battery is incorporated in a *complete test battery* that addresses all four stages of speech production (i.e. linguistic-symbolic planning aspects, speech motor planning, programming and execution), in addition to aspects such as hearing, auditory processing, and oro-facial and pharyngeal structure and functioning, it may assist with *differential diagnosis* in DSD. Although still hypothetical, performance characteristics may yield some indication of the *affected level* of speech production (e.g. linguistic-symbolic planning, sensorimotor planning, sensorimotor programming and sensorimotor execution), since different types of disorders may display dissimilar impairments on the variety of parameters. The *nature* of specific disorders may thus be more clearly indicated. Performance on the test battery may also have the potential to indicate whether a child's sensorimotor speech skills are *delayed* (immature) or *deviant* when compared with the performance of normal children of different ages. Similarly, comparison with normative data can also serve to identify different *degrees of impairment* or *delay* (i.e. severity). The following are hypothetical examples of how performance on the test battery may reflect *differentially diagnostic aspects* of sensorimotor speech control problems, which can be considered in future investigations:

- Theoretically, children with *phonological* planning problems but no *sensorimotor* planning problems may exhibit FVD-values in the range reported for their normal-speaking peers. Children with sensorimotor speech control problems (i.e. such as dysarthria or DAS) may show *longer* FVD-values than normal-speaking peers and children with phonological planning problems, due to impairments in the planning, programming and/or execution of motor goals, plans and programs. Further, performance such as FVD-lengthening in the absence of any dysarthric indications or generalized neurological pathology for example, may be differentially diagnostic of a speech motor planning impairment or delay. In addition, age-inappropriate token-to-token variability in FVD may be expected in children with speech planning problems, due to inconsistent temporal specifications of segmental duration and interarticulator-synchronization. Children with dysarthric impairment may tend to show more consistently lengthened FVD's (depending on the type of dysarthria).

- Children with *sensorimotor speech planning* problems may show different VOT-characteristics than children with phonological planning problems or normal children, since they may have major problems with *interarticulator-synchronization*. This may result in a greater frequency of voicing errors (i.e. distortions). Children with normal speech motor planning abilities but possible phonological planning impairments, may be capable of producing VOT-values similar to those of normal peers, while their voicing errors may be true voiced/voiceless substitutions (indicating a phonological selection error).
- Children with *sensorimotor speech planning* problems may show opposite performance trends than normal children in terms of the *adaptation* of first-syllable duration to words of increasing length. Based on the premise that longer words may place more *demands* on all aspects of speech motor planning (i.e. more core motor plan recall, increased coarticulation, interarticulator-synchronization etc.) and that contextual adaptations of FSD have to take place when word length increases, FSD's of these children may be expected to increase as word length increases. They may thus need more time to adjust temporal and spatial aspects of speech movements to the changing contexts than normal-speaking children. Children with phonological planning problems on the other hand, can possibly be expected to display FSD-trends very *similar* to their normal-speaking peers, since they may not have difficulty to adapt temporal aspects to the changing context.

5.6. CONCLUSION

Researchers and clinicians need to be sensitive to the immense *complexity* of the speech production process and processes central to its control and development. It is crucial that findings are related to theories of speech production, in order to infer what children's behavior on different sensorimotor speech tasks imply about their sensorimotor speech control development and the normal speech production process in general. Further, the contributing influences of various factors need to be carefully considered when speech motor performance is assessed and interpreted and test batteries compiled. These include the complex interaction of a variety of factors such as linguistic aspects (e.g. phonological influences, suprasegmental aspects), personal-social factors (e.g. motivational aspects and personality traits which may affect performance), auditory-perceptual factors, neural factors (e.g. brain maturation), musculoskeletal factors (e.g. structural growth and tissue changes) and even cognitive aspects.

Our ultimate goal should be to develop cost-effective and clinically effective assessment tools by which speech motor development can be assessed and problems efficiently identified and treated. Only through continuing research of both normal and deviant speech production, can the most appropriate assessment variables be identified and assessment tasks and analysis guidelines be developed and refined. We are only standing on the brink of uncovering the mysteries of sensorimotor speech control and to reach our goal will require continuous and persistent research. But as Crary (1993:xiv) said: "If we do not experiment, criticize and change, the ultimate losers will be the children.".

5.7. SUMMARY

In this chapter the method of this study was evaluated. This was followed by a summary of the results and a discussion of their theoretical and clinical implications. Speech motor development was conclusively discussed in terms of aspects that need to be considered in future research and assessment. Finally, specific recommendations for future research were made.