A New Dutch Non-Word-Repetition Task to Test the Production of Consonant Clusters With and Without /s/ by TD Dutch Children

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“Een goed protocol vandaag is beter dan een perfect protocol morgen,

want een perfect protocol is een illusie” (G. Collée, 1991)

Abstract

The main aim of this thesis is to investigate the production of consonant clusters with and without /s/ by TD Dutch children. Sub aims are to determine the kind of errors children make while realising consonant clusters, and whether clusters are more accurately produced in initial or finial position. Elicited productions of 55 TD Dutch children of 3-5 year old were analysed. Productions were elicited via a new Dutch Non-Word Repetition Task (NWRT), which was adapted from French (Dos Santos & Ferré, 2016). In addition, the Digit Span test and the Peabody Picture Vocabulary Test (PVVT) were administered to see if correlations were present between the different scores. As expected, no correlation between NWRT and Digit Span scores was found, which showed that the NWRT did not test phonological short term-memory as a main component. No correlation was found between NWRT and PVVT scores for most children, which was also expected. Results showed that children of 3 and 5 made insertion and cluster reduction errors most often, while 4 year old children made cluster reduction most often. In addition, most children produced consonant clusters in final position more accurately than in initial position. The main results of this study were not in line with previous literature and showed that children performed better on initial structures with /s/ compared to initial structures without /s/ and that initial consonant clusters with /s/ were acquired before consonant clusters without /s/. These results can be explained in terms of different structures and frequencies between the two cluster groups. Results also showed that final consonant clusters including /s/ were acquired before initial clusters without /s/, which cannot be explained by frequency. In addition, performance was higher on initial and final clusters with /s/ compared to medial structures. The first can be explained in terms of frequency, while the second cannot. More research is needed on this subject, to understand why and which different patterns occur between the performance on consonant clusters with and without /s/. This study has clinical implications, since a new order of acquisition was found for consonant clusters.

Acknowledgments

I would like to thank my first supervisor, René Kager, for helping me in general, giving me critical remarks which made this thesis better and brainstorming about how to build a thesis around the NWRT. I am very grateful for his supervision, and also for the list of CELEX frequencies he provided near the end of this thesis. I would also like to thank by second supervisor, Jeannette Schaeffer. In particular I would like to thank her for helping me with the practicalities of conducting an experimental study at elementary schools. I am very grateful that both my supervisors agreed to work through summer, which gave me more time to finish this thesis.

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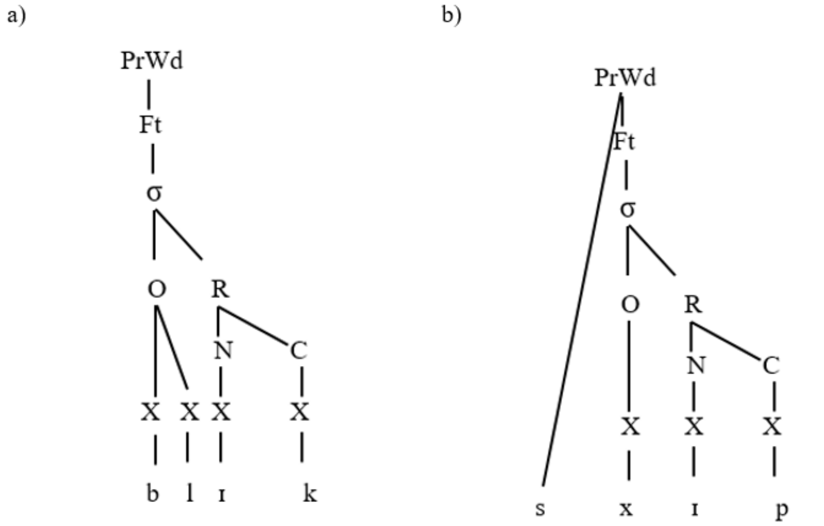
Content

1.Introduction

The current study is concerned with the production of consonant clusters. The main focus is on the contrast between consonant clusters including /s/ and obstruent-liquid clusters, which do not include /s/. The structures of some /s/clusters deviate from the structure of other clusters like obstruent-liquid clusters. Therefore, /s/ clusters are seen as special. Speakers of different languages and ages also treat structures with /s/ differently compared to other structures (Fikkert, 1994). Figure 1a illustrates the structure of a regular obstruent-liquid cluster. The onset of the syllable (σ) branches in two. This is in contrast with Figure 1b, which shows the structure of a consonant cluster including /s/. The /s/ is seen as an appendix (Halle & Vergnaud, 1980). The appendix is adjoined directly under the prosodic word; it is not part of the syllable structure.

Figure 1: The structures of *blik* ('can') and b) *schip* ('ship')



Turning to the acquisition of consonant clusters by children, Fikkert (1994) observed that consonant clusters with and without /s/ are not acquired at the same time. Clusters including /s/ seem to be acquired later than obstruent-liquid clusters by most of the children. However, this has not been systematically investigated. The main aim of this study is therefore to investigate the acquisition of consonant clusters with and without /s/ in a systematical way by looking at the production of Dutch typically developing children.

In order to do this, we collaborated with Dos Santos & Ferré (2016), from the University of Tours in France. They designed a new Non-Word Repetition Task including consonant clusters with and without /s/. In a Non-Word Repetition Task (NWRT), participants are asked to repeat non-words, which are not existing words in the specific language but according to the phonology of the language, they could be (i.e. they do not violate any phonological rules). This task was developed as part of the COST Action IS0804 project. This project aims to disentangle children with SLI from bilingual children. Children with SLI do not score well on Non-Word Repetition Tasks (Bishop et al., 1996), which is why it can be used as a clinical marker. The task by Dos Santos & Ferré (2016) was new in the sense that in contrast to older versions of the task, this task was not supposed to test phonological memory but segmental phonology as a main component. For this purpose, complex structures including consonant clusters were included. Since this task included /s/clusters and plosive-liquid clusters, it was decided to use this task to investigate how Dutch children perform on these two contrasting consonant cluster groups in the current study.

The current study is also related to the COST Action ISO804 project. However, the current study is concerned with typically developing children since a systematic investigation of their behaviour first needs to be done before bilingualism or language impairments can be investigated with this test. However, as a next step we would like to look at language impairments as well. One of the additional goals of this study is therefore concerned with future research on language impairments and specifically on language impairments in autism. A subset of children with Autism Spectrum Disorder (ASD) have structural language problems (Durrleman et al., 2017; Perovic et al., 2013). This is an under researched area; not much is known about these specific problems yet. Therefore, it would be useful if the Dutch version of the Non-Word Repetition Task can be used in later research to test children with ASD. This may give more insights in the specific phonological problems. Before this kind of research can be conducted, data needs to be collected from TD developing children in order to be able to create a control group to compare the (future) ASD data to. This is what the current study is also concerned with. It would be interesting to see whether children with ASD are mainly slower (i.e. that they make mistakes at a later age than TD children) or completely different (i.e. that they make different errors) in the development of phonology. Therefore, the current project also aims to look at the specific errors TD children make, in order for these errors to be compared to the kind of mistakes children with ASD make in future research. Ultimately, the results of an ASD study on phonological abilities may be used to advice on the development of more adequate intervention methods.

This paper has been organised in the following way. Chapter 2 and 3 provide background information on Dutch phonology and on the development of phonology in children. Subsequently, the specific research questions and hypotheses are presented in Chapter 4. The methodology of this study is described in Chapter 5. After this, the results are presented in Chapter 6 and discussed in Chapter 7. The conclusion is presented in Chapter 8.

2. The Phonology of Dutch

This section will focus on the Dutch phonology which is relevant for this study. First the phonemes and features of the Dutch language will be discussed briefly. After this, the structure of a syllables with and without /s/ will be discussed, focussing on the onset, nucleus and coda. A summary of structures with and without /s/ will be given after this. Lastly, stress patterns of Dutch will be discussed.

2.1. Dutch phonemes

The Dutch consonants are shown in Table 1 (Booij, 1995, p. 7). In addition, Dutch has 16 vowels, which are shown in Table 2 (Booij, 1995, p. 4). Vowels can be either short or long. The division between short and long is mainly based on phonological behaviour. A long vowel behaves as two units in the syllable structure, whereas a short vowel only has one unit (Moulton, 1962). /i/, /u/ and /y/ are named long vowels because they consist of two units phonologically. However, phonetically they are short and last about 100 milliseconds, which is also the average duration of short vowels. The other long vowels last for about 200 milliseconds (Nooteboom, 1972).

Table 1: Dutch Consonants

	Bilabial	Labio-dental	Alveolar	Palatal	Velar	Glottal
Plosives	p, b		t, d		k, g	
Fricatives		f, v	s, z		x, ɣ	h
Nasals	m		n		ŋ	
Liquids			l, r			
Glides	ʋ			j		

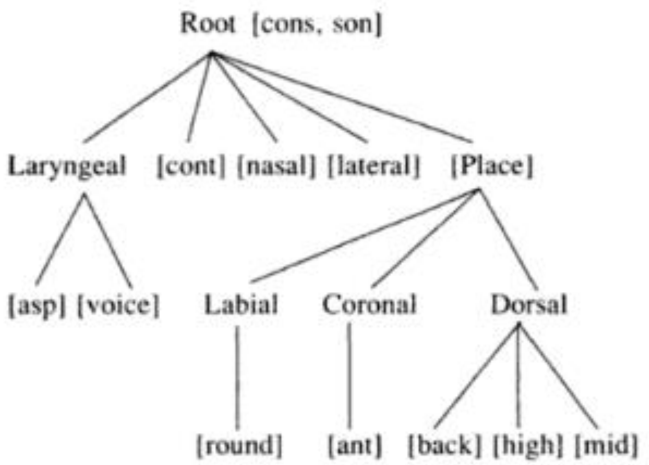
Table 2: Dutch Vowels

Long vowels	a, i, u, e, o, ø, y
Short vowels	ɑ, ɛ, ɪ, ɔ, ʏ
Schwa	ə
Diphthongs	ɛi, œy, ɑu

Phonemes can be broken down into groups of phonological features (Chomsky & Halle, 1968) and these features can be grouped together, as shown in Figure 2 (Booij, 1995). Figure 2 is called a feature hierarchy. The hierarchy in Figure 2 is based on Clements (1985), Sagey (1986), McCarthy (1988), Halle & Ladefoged (1988) and Halle (1992). The highest point in the feature hierarchy is called the root node. This node represents all the features combined in one phonological unit. When going down in the hierarchy, every presented word is called a node, and these nodes group the features further. [consonant] and [sonorant] are the two features associated with the root node. These features are called the major class features and they divide all phonemes in sonorants consonants [+con, +son] like /m, l/, vowels [-con, + son] like /a, i/ and obstruents [+con, -son] like /p, t, f/. A sonorant is produced with a relatively open passage of air flow. Vowels are also sonorants. On the other hand, obstruents are produced with an obstruction of the air flow. The next node is laryngeal. The most prominent laryngeal distinction in Dutch is between voiced and unvoiced phonemes. This contrast only exists for obstruents, since sonorants are always voiced. When producing voiced consonants, the vocal folds vibrate, as in /v/. They do not vibrate while producing voiceless consonants like /f/. Phonemes can also be characterised by manner features; continuant, nasal and lateral. Continuous phonemes are produced continuously. Examples are /s,x,h/. Nasals are defined by letting the air flow out through the nose instead of through the mouth. Examples of nasals are /m,n/. Lastly, laterals are produced by letting the air out along the sides of the tongue, like /l/.

Features of place are also distinctive. Phonemes can be labial, coronal or dorsal. Labials are produced by obstructing the airflow by the lips, like in /p,m/. Coronals are produced by raising the tong blade. Examples of coronal consonants are /n, t/. They can be [+anterior], which means the phoneme is produced in the front of the mouth. Lastly, phonemes can be dorsal. Dorsal phonemes are produced by changing the position of the tongue body, like /k, n/. The tongue body is also the main articulator when producing vowels. For example, vowels can be [+back] like /ɑ/, [+high] like /ɪ/ or [+round] like /o/.

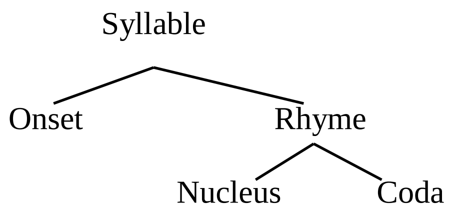
Figure 2: The feature tree for Dutch (Booij, 1995, p. 9).



2.2. Structure of the syllable

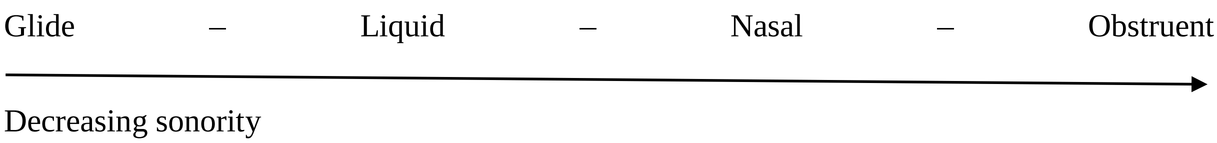
It is a assumed that the structure of a syllable (σ) contains an onset, nucleus and coda (Pike & Pike, 1947; Fudge, 1969; Selkirk 1982; Cairns & Feinstein, 1982) as illustrated in Figure 3 (Booij, 1995, p. 23). The onset contains zero to three consonants and the nucleus contains a vowel or a syllabic consonants. The nucleus is always present in a syllable. The coda can contain zero to a maximum two consonants, and up to three more consonants can be found in the appendix (see Section 2.2.4). The rhyme of the syllable is formed by the nucleus and coda together.

Figure 3: Syllable structure



Onsets and codas can contain multiple consonants. There are principles explaining which combinations of consonants are allowed. One of these principles is concerned with sonority (Pike, 1943). Sonority is related to how open the vocal tract is (Zsiga, 2012). In addition, it is also directly related to loudness. In the most sonorous sounds, there is no obstruction of the vocal folds and the produced sound is loud. An example is the vowel /a/ or glide /j/. The less sonorous phonemes are, the more obstruction of the air flow occurs and the quieter the sounds are. An example of a low sonority sound is the plosive /k/. Classes of phonemes can be ranked according to sonority and this is done in the sonority scale. The scale goes from glides, which have the highest sonority, to liquids, nasals and obstruents as illustrated in Figure 4 (Booij, 1995, p. 24, based on Zec, 1988; Clements, 1990).

Figure 4: The sonority scale.



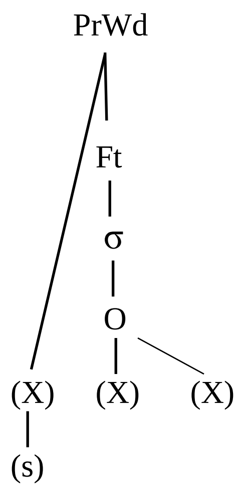
The principle which is concerned with sonority, is called the Sonority Sequencing Generalization (Selkirk, 1982). This generalisation states that the sonority of consonants must decrease towards the sides of the syllable. This means that a word like *melk* (‘milk’) is allowed, since the /l/ (liquid) occurs before the /k/ (obstruent) at the end of the syllable. On the other hand, is it not possible to have **mekl*, since the obstruent occurs before the liquid. A word like *klem* (‘grip’) is allowed, since the obstruent occurs at the edge of the syllable, and the liquid occurring next to it is higher in the sonority scale. Turning this around, **lkem* is not allowed. Words including consonant clusters with the same level of sonority will be discussed in Section 2.2.1.2.

There is an asymmetry in sonority sequencing between onsets and codas. The maximum sonority contrast is bigger in onsets compared to codas. For example, initial plosive-liquid clusters are allowed and common (e.g. /pl-,kl-,pr-,kr/), and the difference in sonority is quite big. However, if the difference in sonority becomes smaller, the allowed clusters are more limited. For example, the only allowed plosive-nasal combination in Dutch is /kn-/ as in *knie* (‘knee’). The sonority contrast is less strict in codas.

2.2.1. Onsets

The onset of a syllable can be filled with zero, one or two consonants. Three consonants are possible as well, however, the third phoneme is analysed as outside the syllable (see Section 2.2.1.2 and 2.2.1.3). The structure of an onset is shown in Figure 5. The following subsections will illustrate these four options. In Dutch, onsets need to be maximized. This means that if there are two adjacent syllables with consonants at the edges, as many consonants as allowed are assigned to the onset, resulting in fewer consonants in the coda of the previous syllable. This is called the Maximal Onset Principle (Goldsmith, 1990).

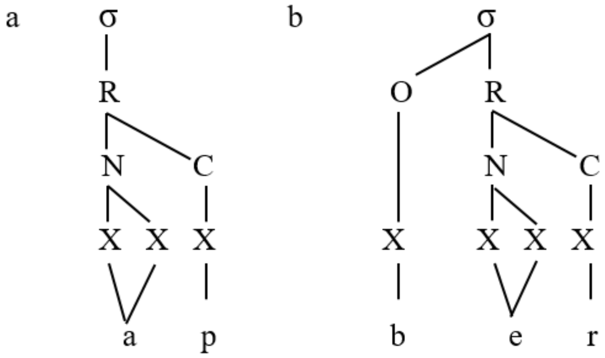
Figure 5: The onset of a syllable.



2.2.1.1. Onset with zero and one position

The onset of a syllable can contain zero or one consonant (or more, as discussed later). Figure 6a shows an example of an onset with no consonant; *aap* ('monkey') and Figure 6b of an onset with one consonant *beer* ('bear'). There are only two combinations of phonemes which are not allowed in the onset and the following nucleus position. The first one is that /j/ cannot be followed by /i/. The second is that /w/ cannot be followed by /ø y/. All other combinations are allowed (Booij, 1995).

Figure 6: a) the word *aap* ('monkey') without an onset, b) the word *beer* ('bear') with an one consonant onset.



2.2.1.2. Onset with two positions

Figure 7 shows the possible consonant clusters in onset position (Trapman & Kager, 2009) based on the CELEX databse (Baayen, Piepenbrock & Gulikers, 1995) The clusters in italics are not frequent (the frequency is < 25). When a consonant cluster of two consonants occurs at the start of a syllable and obeys the sonority principle, this is called a branching onset. The structure of a branching onset is illustrated in Figure 8. A list of examples of branching onsets is shown in Figure 9 (Cohen et al., 1969).

Figure 7: The possible consonant clusters in onset position

		plosives						fricatives							nasals		liquids		glides	
		p	t	k	b	d	g	f	s	ʃ	x	v	z	ʒ	m	n	r	l	w	j
plosives	p							*pf*	ps							*pn*	pr	pl	*pw*	*pj*
	t								*ts*	tʃ							tr		tw	tj
	k								*ks*							kn	kr	kl	kw	*kj*
	b																br	bl		*bj*
	d													*dʒ*			dr		dw	*dj*
	g																*gr*	*gl*	*gw*	
fricatives	f															*fn*	fr	fl	*fw*	*fj*
	s	sp	st	sk				*sf*			sx				sm	sn		sl	*sw*	sj
	ʃ	*ʃp*	*ʃt*												*ʃm*	*ʃn*		*ʃl*	*ʃw*	
	x															*xn*	xr	xl		
	v																vr	vl	*vw*	*vj*
	z																		zw	
	ʒ																			
nasals	m																		*mw*	*mj*
	n																		*nw*	*nj*
liquids	r																		*rw*	
	l																		*lw*	*lj*
glides	w																			
	j																			

Figure 8: Syllable structure including branching onset of the noun *blik* (‘can’).

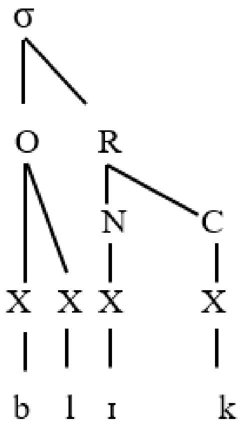
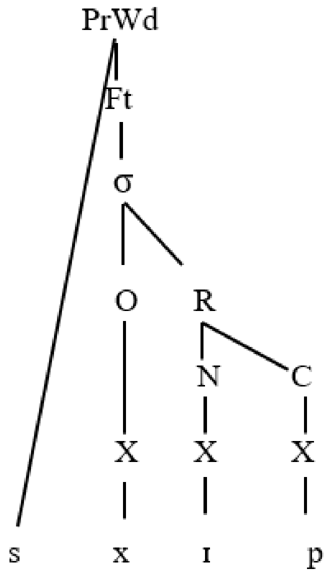


Figure 9: Examples of possible branching onsets in Dutch (Cohen et al., 1969).

zw-	zwak	‘weak’	tr-	*traan*	‘tear’	vl-	*vlek*	‘stain’
pl-	*plat*	‘flat’	tw-	*twee*	‘two’	vr-	*vraag*	‘question’
pr-	*pret*	‘fun’	tj-	*tjalk*	‘barge’	xn-	*gniffel*	‘chuckle’
bl-	*bloed*	‘blood’	dr-	*droog*	‘dry’	xl-	*glad*	‘smooth’
br-	*broek*	‘trousers’	dw-	*dwars*	‘crosswise’	xr-	*griet*	‘chick’
fn-	*fnuikend*	‘disastrous’	kl-	*klap*	‘blow’			
fl-	*flap*	‘flap’	kr-	*kroeg*	‘pub’			
fr-	*fraai*	‘pretty’	kw-	*kwaad*	‘evil’			

Some consonant clusters with /s/ obey the sonority principle. For example, the word *snoep* (‘sweets’) consists of an obstruent and nasal, so the sonority decreases towards the edge of the syllable. In this case, the structure is similar to the one shown in Figure 8. However, some clusters with /s/ are special. Some clusters with /s/ consist of two obstruents. Examples are *schip* (‘ship’), *spel* (‘game’), *sfeer* (‘atmosphere’), *ski* (‘ski’) and *steen* (‘rock’). According to the Sonority Principle, the sonority should decrease towards the edge of a syllable. In this case, the sonority is the same in both phonemes. This should not be allowed according to the principle. However, this is possible since /s/ is seen as outside the onset and even as outside the syllable. This is called an appendix (Halle & Vergnaud, 1980; Trommelen, 1983; Goad & Rose, 2004), an adjunct (Gierut, 1999) or an extrasyllabic segment (Fikkert, 1994). In this thesis it is assumed that a word initial /s/ is an appendix. Figure 10 shows the syllable structure of the word *schip* (‘ship’) with /s/ in the appendix. The appendix is not part of the syllable, but is adjoined directly under the prosodic word. Since /s/ is seen separately from the syllable and the onset, the sonority principle within the onset is not violated (Halle & Vergnaud, 1980; Trommelen, 1983;Pan & Snyder, 2004). This also explains why combinations like /st,sf, sp/ are allowed in Dutch; the sonority principle is not violated because /s/ is not part of the onset.

Figure 10: The syllable structure of the word *schip* ('ship') including a word initial appendix.



2.2.1.3. 'Onset' with three positions

Onsets of words can contain three consonants in Dutch. However, this is only allowed if the first phoneme is /s/. Again, this is only possible because /s/ is placed outside the syllable. The two segments following /s/ are structured as a branching onset. Possible combinations of three consonants can be seen in Figure 11, which are taken and adjusted from Booij (1995).

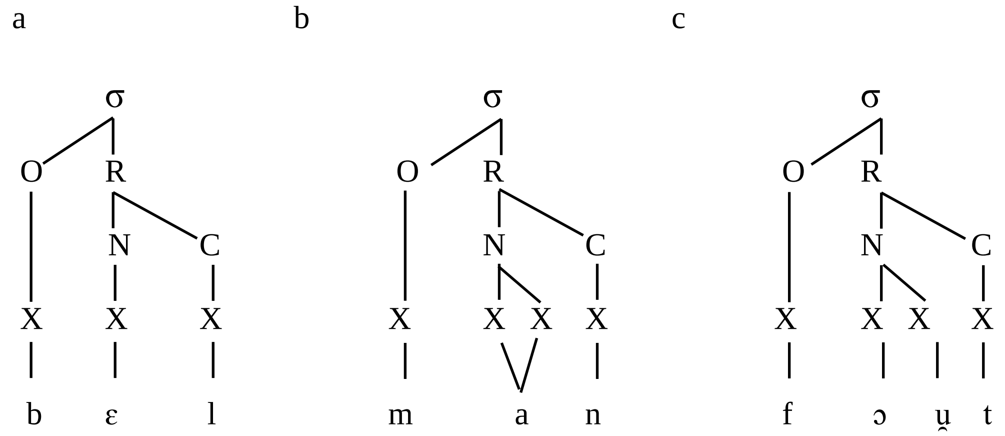
Figure 11: Examples of /s/ + two consonants (onset).

spl-	*split*	'split'
spr-	*spreeuw*	'starling'
str-	*stroom*	'stream'
skr-	*skriba*	'scribe'
skl-	*sklerose*	'sclerosis'
sxr-	*schreeuw*	'scream'

2.2.2. Nucleus

The nucleus of a syllable must always be filled, and across languages there is either a vowel or a syllabic consonant occupying this position. However, Standard Dutch only allows vowels in this position. A few non-standard varieties of Dutch also allow syllabic nasals in the nucleus (Booij, 1995). Either one or two positions can be filled in the nucleus. When one position is filled, it is filled with a short vowel (/ɑ, ɛ, ɪ, ɔ, ʏ/). Figure 12a shows the word *bel* (bubble), which is an example of structure with a nucleus with one filled position. When both positions in the nucleus are filled, the positions are either filled with a long vowel (/a, e, i o, y, u, ø/), as in Figure 12b, or with two short vowels forming a complex nucleus (Figure 12c). In this case a diphthong (/ɛi̯, œŷ, ɔu̯/) is formed.

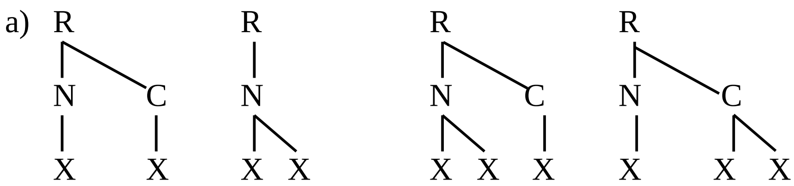
Figure 12: Syllable structure of a) *bel* (‘bubble’), b) *maan* (‘moon’), c) *fout* (‘mistake’).



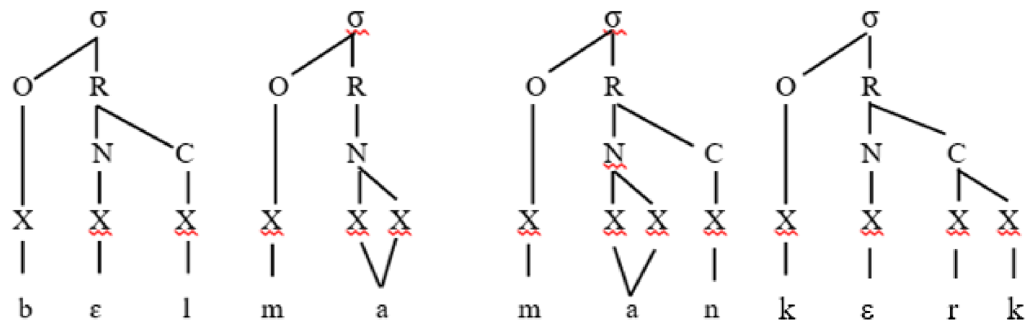
2.2.3. Rhyme

A syllable cannot end in a short vowel. When there is only one short vowel in the nucleus (as in Figure 12a), the coda must contain at least one consonant. The Minimal Rhyme Constraint (Trommelen 1983, Kager & Zonneveld 1986, Kager 1989) describes this; the rhyme, consisting of the nucleus and coda together, minimally needs two X-positions. In addition, no more than three X-positions can occur in the rhyme (Trommelen, 1983). Figure 13a illustrates the options for the rhyme (taken from Booij, 1995). Examples of the different rhyme structures can be found in Figure 13b. The Minimal Rhyme Constraint overrules the previously mentioned Maximal Onset Principle. An example is the word aspect, /ɑs.ˈpɛkt/ (‘aspect’) taken from Booij (1975). The dot indicates the syllable boundary. Since the short vowel /ɑ/ only occupies one X-position in the nucleus, the consonant /s/ needs to be assigned to the coda of the first syllable to be in line with the Minimal Rhyme Constraint, even though according to the Maximal Onset Principle the /s/ should be part of the next onset.

Figure 13: Rhyme structures : a) the structures, b) examples of the structures : *bel* (‘buble’), *ma* (‘mum’), *maan* (‘moon’) and *kerk* (‘chruch’).



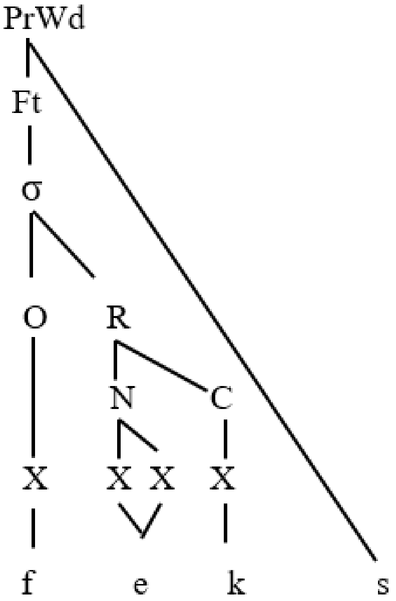
b)



2.2.4. Codas

The coda can consist of zero, one or two consonants as illustrated in Figure 13 above. When a consonant cluster including /s/ occurs in coda position, and obeys the sonority principle, the structure is not deviant from other consonant cluster combinations in coda positions. If the consonant cluster including /s/ does not obey the sonority principle, for example in words like *feeks* ('bitch') in which both consonants are of the same sonority, Trommelen (1983) proposes that the /s/ is analysed as a word final appendix (for previous discussion about appendices see Section 2.2.1.2) (Halle & Vergnaud, 1980). This is illustrated in Figure 14 (based and adjusted on Trommelen, 1983, p. 89). As discussed previously, the appendix is not part of the syllable, but falls directly under the prosodic word.

Figure 14: Structure of word final consonant clusters which do not obey the sonority principle



Word final appendices of two and three consonants are also allowed in Dutch. These consonants are always coronal obstruents. Examples of appendices taken from Trommelen (1983) are shown in Figure 15 below. The hyphens shows the boundary between coda and appendix. The first example (Figure 15a) containing an two consonant appendix, is *herfst* ('autumn'). /ɛrf/ takes up the three positions of the rhyme and /st/ is the appendix. In Figure 15b an appendix with three consonants is shown. Appendices of three consonants are always of the kind /tst/ and usually the first /t/ is not pronounced. It must be noted that not necessarily all positions of the rhyme need to be filled in order for an appendix to occur. Trommelen (1983) illustrates this with the word *heks* ('witch'), which is shown in Figure 15c. The short vowel /ɛ/ and the obstruent /k/ take up only two positions in the rhyme and the /s/ is seen as an appendix. Note that the reason /s/ cannot fill up the third X in the rhyme in this case is because the sequence /ks/ does not obey the sonority principle, which is why /s/ is seen as the appendix.

Figure 15: Examples of 1,2,3 consonant appendices.

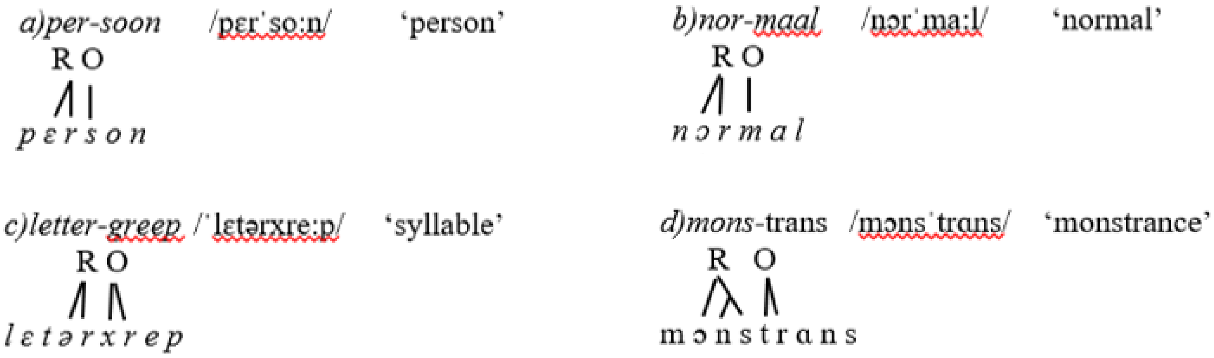
a)	*herf-st*	/hɛrfst/	'autumn'
b)	*vermoei-dst*	/vɛrˈmujtst/	'most tired'
c)	*hek-s*	/hɛks/	'witch'

2.2.4.1. Internal codas

Internal codas are allowed in Dutch. This means that when two syllables are next to each other, the first syllable has a consonant in the coda and the onset of the next syllable also contains (a) consonant(s). Figure 16 gives examples of internal codas, in which the hyphen marks the boundary between the coda and following onset. Simplified structures are shown in Figure 16 to illustrate the internal structure of the most relevant parts of the word for this section: the rhyme and following onset. It is possible to have medial consonant clusters of two consonants, as shown in Figure 16a and b. The first consonant is part of the coda and the second consonant is part of the following onset. It is also possible to have medial consonant clusters of three syllables as shown in Figure 16c. The first consonant is analysed as the coda, while the two next consonants occupy the branching onset of the following syllable (Trommelen, 1983). Moreover, medial consonant clusters of four consonants are also allowed, but these are very rare (Trommelen, 1983). An example taken from Trommelen (1983) is shown in Figure 16d. These examples show that the Minimal Rhyme Constraint (Trommelen 1983, Kager & Zonneveld 1986, Kager 1989) also holds for internal rhymes: minimal two X-positions need to be filled, as illustrated by /ɛr/ in Figure 16a, and maximally three X-positions can be filled, as illustrated by /ɔns/ in Figure 16d (it must be noted that of course internal codas are not obligatory. If there is no internal coda, the rhyme must consist of a long vowel in which case two X-positions are still filled). Appendix consonants are not allowed in medial position

(Trommelen, 1983). As mentioned before, medial structure obey the Maximal Onset Principle (Goldsmith, 1990); as many consonants as possible are part of the onset, which is the case in Figure 16c where /xr/ are part of the following onset, while only /r/ is part of the coda. In addition, the sonority must also decrease towards the edge of a syllable, which is in line with the Sonority Principle.

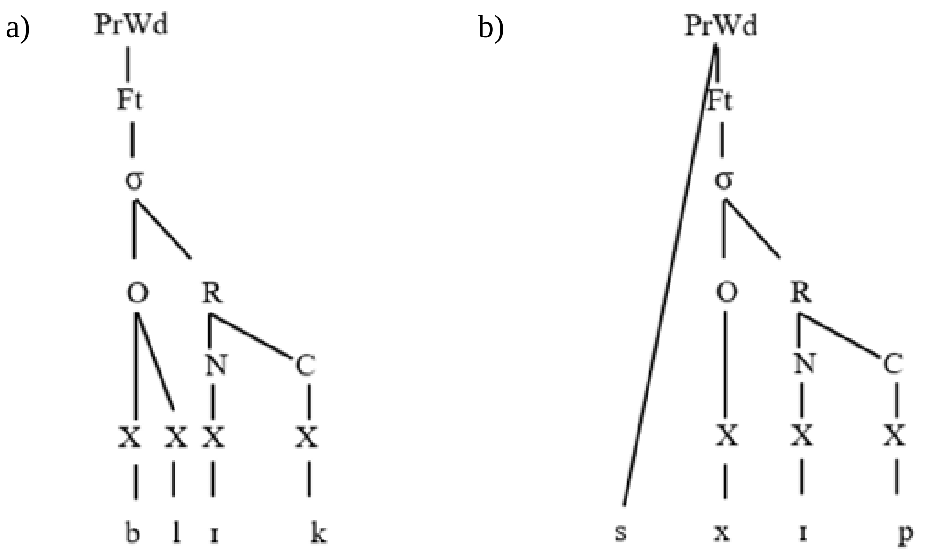
Figure 16: Examples of words with internal codas



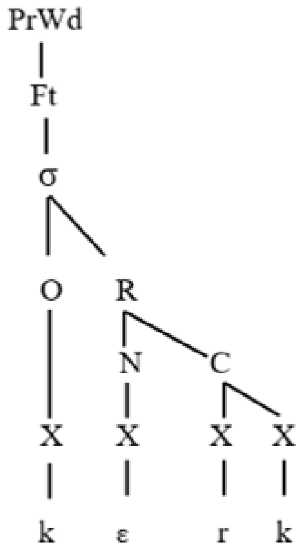
2.3. Summary on structures with and without /s/

As shown in the previous sections, structures differ between structures with and without /s/. Figure 17 illustrates the differences between biconsonantal clusters in initial, final and medial position since these are the most relevant for this study. Onsets obeying the sonority principle have branching onsets as illustrated in Figure 17a. On the other hand, initial consonant clusters with /s/ which do not obey the sonority principle have an appendix, as shown in Figure 17b. Turing to complex codas, when they obey the sonority principle the structure branches, as shown in 17c). On the other hand, if the cluster does not obey the sonority principle, the structure includes an appendix. In addition, medial clusters are structures as shown in e) and they do not consist of appendices.

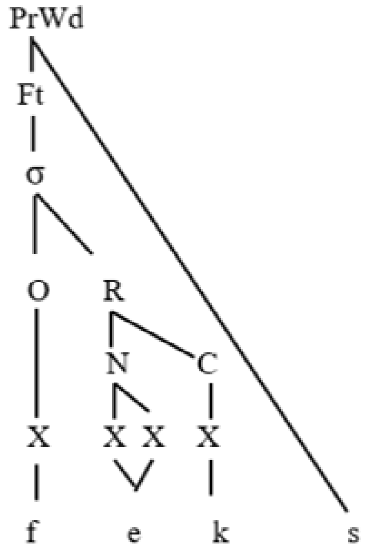
Figure 17: The structures of a) *blik* ('can'), b) *schip* ('ship'), c) *kerk* ('chruch'), d) *feeks* ('bitch') and e) *person* ('person').



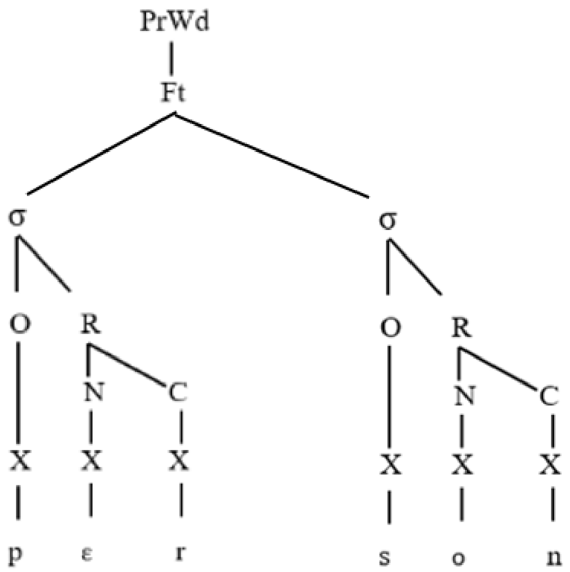
c)



d)



e)



2.4. Stress

Dutch is a language which has word stress (Van der Hulst, 1984; Trommelen & Zonneveld, 1989). This means that one of the syllables in a word is always more prominent than the others and receives main stress. Other syllables of the word can also be prominent, but less compared to the main stress. This is called secondary stress.

There are some principles important for stress in Dutch (Booij, 1995). One of these is schwa restriction, which means that syllables including schwa never receive stress. Another one is the Optimal Grid Principle. This means that there is always an alternating pattern concerning stress.

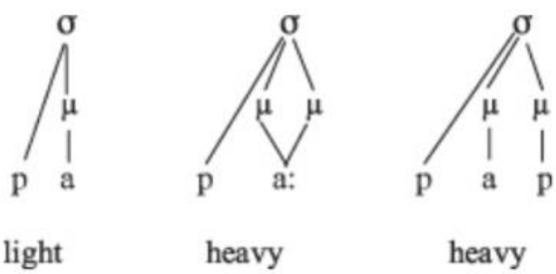
Fikkert (1994) makes some generalisations on the Dutch main stress pattern in words without schwas, based on Van der Hulst (1984). The first generalisation is that stress can fall on the initial, penultimate or final syllable. This shows "that stress is not completely free in Dutch" (Fikkert, 1994, p. 197). Second, in two syllable words, stress falls on the prefinal syllable in the majority of cases. Even though there are many exceptions, this pattern is taken as the default. In three syllable words, stress predominantly falls on the prefinal syllable.

Another generalisation is that stress is influenced by syllable structure and especially by the number of moras in a syllable (Van der Hulst, 1984). A mora (μ) is a phonological unit to convey syllable weight (Hyman, 1985; Hayes, 1989). Long vowels are heavier than short vowels, which is why long vowels have two moras, and short vowels have one. This is illustrated in Figure 18 (taken from Zsiga, 2012).

Figure 18: Moraic representation of short and long vowels (Zsiga, 2012).

In some languages, like English and Dutch, consonants in coda position also have a mora while consonants in onset position do not have moras (Kager, 1989). In this way, syllables can have two moras (bimoraic) and this is called a heavy syllable. Syllables can also be superheavy, in this case they end in VCC or VVC (Van der Hulst, 1984). On the other hand, syllables with one mora (monomoraic) are light. Figure 19 shows light and heavy syllables. However, these light syllables ending in a short vowel are not allowed in Dutch. Dutch syllables are always bimoraic (De Groot, 1931).

Figure 19: Moraic representation of syllable weight showing a light and two heavy syllables (Zsiga, 2012).



Van der Hulst (1984) explains that nouns containing two syllables (without a schwa) are usually stressed on the penultimate syllable. However, if the final syllable is super heavy (syllables ending in VCC or VVC), stress falls on the final syllable. This is a generalisation, and many exceptions exist. Nouns containing three syllables (without a schwa) almost always have prefinal stress, as mentioned above. However, when the penultimate syllable is open, and the following syllable is closed stress falls on the first syllable, as in *Honduras* [ˈhɔndyrɑs] for example (Van der Hulst, 1984; Trommelen & Zonneveld, 1989). In addition, when trisyllabic nouns contain an internal coda, stress cannot fall on the first syllable (Kager, 1989). It is important to note that trisyllabic words with a long vowel followed by a consonant cluster are only allowed if the second consonant is coronal (Kager & Pater, 2012). In addition, stress does not fall on the first syllable either when a word ends in a stress attaching sequence like /-ɑk, -ɛl, -ɑm, -ɛt, -ɔn/. In this case, stress is placed on the final syllable. In addition, when words contain 4 syllables, the following generalisations are made by Fikkert (1994): stress falls on the final syllable if the final syllable is superheavy, it falls on the penultimate syllable if the penultimate syllable contains a long vowel and the following syllable contains VC and in most other cases, stress falls on the prefinal syllable.

3. Dutch Child Phonology

An important part of language acquisition of a native language by children consists of, among other elements, the development of understanding and producing the speech sounds of the language. The following sections will discuss previous studies addressing the question at which age Dutch children acquire the phonemes of the Dutch language as single phonemes and in consonant clusters. In addition, the developmental path of (complex) onsets and codas will also be focussed on. Special attention will be given to consonant clusters including /s/. Not many studies have focussed on the acquisition of complex onsets and codas. The few studies that have focussed on this will be discussed. In addition, the acquisition of syllable structure will be discussed. At the end of this chapter, the phonological processes children undergo when producing consonant clusters will be described.

3.1. The acquisition of onsets

3.1.1. Single onsets

Children produce single onsets before they start producing complex onsets. Beers looked at the acquisition of single consonants. She investigated the spontaneous speech of 45 Dutch children, aged 1;3-4;0. The spontaneous speech of each child was recorded twice with a 6 months interval. 100 words of each speech sample were analysed and Beers (1995) looked at which segments occurred in initial or final position (information about final consonants can be found in 3.2.1.) and whether they were correctly produced, in comparison to adult production. Voiced fricatives /z,v,ɣ/ are not analysed by Beers (1995). Reason for this is that many Dutch speakers pronounce voiced onset consonants as voiceless sounds (Booij, 1995). This is mostly done by speakers in the western part of the Netherlands. The children Beers (1995) studied lived in this part of the Netherlands, and thus produced voiced fricatives as voiceless fricatives. Therefore, these are not part of the study. Sounds were seen by Beers (1995) as acquired when 75% of the instances of a certain sound were produced correctly by a child. Table 3 gives an overview of the results found by Beers (1995).

Phonemes are acquired in different stages based on the development of recognition of contrasts (Jakobson, 1941; Beers, 1995). In the first stage, from 1;3-1;8 years old, children acquire the contrasts between consonants and vowels, sonorants and obstruents, and coronal and labial phonemes. In the next stage, when the child is 1;9-1;11 years old, the feature dorsal is acquired. This feature contrasts with the previously acquired features and in this way the child acquires the dorsal phoneme /k/. In the next stage from 2;0-2;2 years old, the feature continuous is acquired and the consonants /s,x,h/ are acquired. Next, from 2;3-2;5 years old, the feature voiced is acquired, resulting in acquiring /b, ʋ/. After this, the contrast between lateral and rhotic phonemes is learned and /l,r/ are acquired. The other single phonemes are acquired later.

Table 3: Acquisition of consonants in initial position and vowels (Beers, 2003).

Age	Initial Consonant
1;3-1;8	p t m n j
1;9-1;11	k
2;0-2;2	s x h
2;3-2;5	b f ʋ
2;6-2;8	l r
2;9-2;11	d
3;0-3;2	

Fikkert (1994) looked at the speech, and mostly at the development of consonant clusters, of 12 Dutch children who were between 1;0 and 1;11 years old at the start of the study. The children were recorded at home every other week for about a year. The experimenters came to the children's house and interacted with them by playing with toys and reading books. Sometimes parents participated in the interaction as well. Sometimes word were elicited by asking questions about pictures in a book for example. These sessions were recorded and thus mostly included spontaneous speech in a natural setting. Recordings lasted for 30-45 minutes. Fikkert (1994) observed when consonant clusters were produced for the first time by the children and how they developed over time.

Fikkert (1994) identified three stages in the development of onsets. These stages are defined based on steps in acquisition, not on specific ages. The age when children are in a certain stage thus differs between children. In the first stage, only single onsets are produced. Onsets are obligatory in child language at this stage and they are always plosives. Adult words without onsets or with onsets containing other sounds than plosives are not selected for production by the child (i.e. they are not used or even attempted). In the next stage, adult words with empty onsets are selected for production by the child. One of the children, Tom, already selected onsetless words at age 1;2.27, showing that this is acquired early on. Even though onsetless words are chosen for production, a plosive is very often added as the onset. Fikkert (1994) illustrates this with data from Jarmo (among other examples). When he was 1;6.13 (1 year, 6 months and 13 days), he started selecting his first words without onsets for production. Before this age, he did not try to produce any of these. These onsetless words were produced with a plosive most of the time. For example, at 1;7 years old, Jarmo produced [ˈta:pi:] instead of [ˈa:pi:] (‘ape’). Sometimes, he produced onsetless words: he produced [ˈo:to:] as [ˈo:to:] (‘car’) at 1;6.13. However, these instances were rare and this shows that onsets are preferred over onsetless word productions. In the next stage of development, other single onsets next to plosives are produced. First children start using nasals as onsets. After this, the developmental path of fricatives, liquids and glides in initial position differs greatly between children.

3.1.2. Complex onsets

3.1.2.1. Complex onsets with two consonants

Complex onsets are onsets which consist of more than one consonant. They are seen as more marked compared to single onsets (Fikkert, 1995). Markedness (Trubetzkoy, 1931; Jakobson, 1971) in linguistics means that when an element is marked it deviates from the default or normal form. The default form can then be described as unmarked (Wurzel, 1998). In this case, the unmarked forms are single consonants and the marked forms are consonant clusters.

Fikkert (1994) observed that most children acquire consonant clusters consisting of an obstruent and a sonorant first, and obstruent-obstruent clusters later. Children do not avoid selecting words with complex onsets in the first stage of acquisition (again, these stages are not linked to a specific age). This means that these kind of words are used as targets (target words are the correct adult like productions). Fikkert (1995) observed that all target words with complex onsets are of the type plosive-liquid until 1;8.12 years old. However, all of these clusters are reduced to the plosive itself. For example, at age 1;4.18 Jarmo produced /klar/ as /ka/ (‘finished’). Other children followed this same pattern. For example, Tom produced [blum] as [pum] (‘flower’) at 1;6.11. The child strives to have the biggest contrast in sonority between the onset and the rhyme. The contrast between the plosive and the following vowel is bigger, compared to the sonority difference between the liquid /l/ and the following vowel. Therefore, the plosive is pronounced and not the liquid.

The development of the production of plosive-liquid clusters in Jarmo will be discussed now. However, this is only one possible path since not all children go through the exact same stages at the same time. Other paths will be discussed later. In the first stage, Jarmo did not produce any plosive-liquid clusters. The clusters were always reduced to single plosives. From 1;8.12 onwards, Jarmo sometimes produced plosive-liquid clusters (i.e. he pronounces two consonants). However, most of the time cluster reduction still occurred. When Jarmo grows older, less cluster reduction occurred. At the second stage, Jarmo started producing clusters containing a plosive and a glide, instead of a plosive and a liquid. In the third stage (from 2;3.9 – 2;4.1 years old) he even preferred plosive-glide productions over the correct plosive-liquid clusters since he produced a plosive-glide cluster in 75% of the cases, and a plosive-liquid cluster in only 25% of the cases. At this stage Jarmo produced clusters in 83% of the cases that a cluster should be produced. Table 4 below shows Jarmo's development of plosive-liquid clusters in the onset.

Table 4: Jarmo's realisation of adult plosive-liquid onsets (Fikkert, 1995, p. 73).

Stage	Age	Production of single plosive	Production of cluster	Plosive-liquid	Plosive-glide
Stage 1	1;4.18-1;7.29	100%	0%	0%	0%
Stage 2'	1;8.12-2.0.4	69%	31%	93%	7%
Stage 2	2;0.28-2;2.27	51%	48%	76%	24%
Stage 3	2;3.9-2;4.1	17%	83%	25%	75%

As mentioned before, the developmental path varies a lot between children. However, some generalisations were made by Fikkert (1995) and they are displayed in Table 5. The developmental stages of the production of each cluster is illustrated in this Table. Again, these stages are not related to a specific age. These stages were distinguished on basis of the different steps a child takes to pronounce a consonant cluster. The time these steps take is different for each cluster which is why the blocks in Table 5 are not similar in length. The cluster plosive-liquid was explained above. It can be seen in Table 5 that the step Jarmo took, to pronounce plosive-glides in stage three, is optional. In addition, some children also pronounced the liquid by itself in stage two.

Gillis & Schaerlaekens (2000) described the following generalisations based on Fikkert's (1994) data which is presented in Table 5. First, an obstruent-sonorant cluster is reduced to the obstruent. In this way, a maximal sonority contrast is made between the consonant and the vowel. In the next step, the child a) produces the sonorant by itself or b) the child produces a cluster but substitutes the sonorant for another sonorant in order to create a maximal sonority contrast or c) the child produces a cluster but harmonized the place of articulation. As a last step, the consonant cluster is produced correctly. Looking at the /s/-obstruent clusters, a similar pattern can be distinguished. First, the clusters are reduced to plosives. As a next step, only /s/ is produced. However, not all children do this. After this stage the clusters are produced correctly.

Table 5: Overview of developmental patterns in the acquisition of onset clusters (P = plosive, L= liquid, G = glide, N = nasal, F = fricative, s = /s/, [ ] optionality) (Fikkert, 1995, p. 103).

A	Target	STAGE 1	STAGE 2	STAGE 3
1	PL	P	[L]	[PG] PL
2	PG	P		PL PG
3	PN	P	[L]	PL PN

B	Target	STAGE 1	STAGE 2	STAGE 3
1	FL	P F	[L]	[PL] FL
2	FG	F	[G/L]	FL FG
3	FN	F	[N/L]	FL FN

C	Target	STAGE 1	STAGE 2	STAGE 3
1	sp	P	[s]	sP
2	sF	P F		sF

D	Target	STAGE 1	STAGE 2	STAGE 3
1	spl	P	PL or sP	sPL

Table 6 shows the order in which the children observed by Fikkert (1994) first produced adult target like clusters from left to right. The general pattern which can be seen is that children acquire plosive-liquid clusters first, followed by fricative-plosive clusters of the /s/-plosive kind. Robin and Noortje are not described in Table 6, because they did not follow this pattern. They only produced /s/-plosive clusters and no other onset clusters. Fikkert (1994) argues that the difference between producing plosive-liquid clusters or /s/-plosive clusters first is due to the initial extrasyllabic /s/. She states that there are two different parameters, one for branching onsets and one for initial extrasyllabicity. In default setting, both parameters do not allow the corresponding phenomenon. Most children, including the children in Table 5, first set the branching onsets parameter to the marked setting, resulting in allowing branching onsets (and thus producing clusters of the kind plosive-liquid), before they set the parameter for extrasyllabicity. Fikkert (1994) argues that Robin and Noortje first set the extrasyllabicity parameter to the marked setting and thus allow extrasyllabic /s/ in initial position. They have not set the branching onset parameter, which is why they do not allow plosive-liquid clusters yet.

Since most children acquire plosive-liquid clusters earlier than /s/-plosive clusters, and thus have set the branching onset parameter first to the marked setting before the initial extrasyllabicity parameter is set, this is taken as the default, most occurring pattern in initial cluster acquisition. The following generalisation can be made: clusters with /s/ are produced later than plosive-liquid and fricative-liquid clusters by most children.

Table 6: Order of first correct production of consonant clusters per child. The arrow indicates the order of acquisition for each child. The exact ages of acquisition for Enzo and Leon are not described in Fikkert (1994), but the order is, which is why only the order is displayed here.

Tom	PL (1;5.28)	FL (1;7.9)	PG (1;11.12)	sP (2;0.17)	sF (2;1.14)		
Tirza	PL (2;2.12)	FL (2;2.12)		sP (2;5.5)	sF (2;5.5)		
Elke	PL (2;3.27)			sP (2;4.15)			
Catootje	PL (2;0.6)	FL (2;0.6)		sP (2;0.6)		FN (2;0.20)	FG (2;1.3)
Jarmo	PL (1;8.12)	FL (2;4.1)					
Enzo	PL	FL	PG			FN	
Leon	PL	FL	PG	sF, sP			FG, PN

Stes (1977, 1997) also investigated the order of acquisition of consonant clusters in Dutch. However, he looked at Flemish children whereas Fikkert (1994) looked at Dutch children from the Netherlands. However, since Flemish and ('Netherlands') Dutch are phonologically similar in many aspects, the study by Stes (1977, 1997) is relevant for the current study. Stes (1977, 1997) analysed the spontaneous speech of 480 children. In addition, sometimes words were elicited via naming pictures. The children were between 3 and 10 years old. Points of interests were when 75% and 90% of the children were able to produce specific clusters, since Stes (1977, 1997) assumes that this is when sounds are acquired and mastered respectively. Table 7 shows the findings of this study. Unfortunately, it is not made explicit which criterion Stes (1977, 1997) uses with respect to how much percent of a certain cluster needs to be produced correctly by one child in order to be called acquired. Therefore, it is not known whether children still make errors in the data. Stes (1977, 1997) states that a sound is acquired when a sound is known to 75/90% of the children. However, it is not explained what 'known' means – how it is defined. In addition, Stes (1997) alternates between stating that children ‘are able to produce’ and children ‘correctly produce’. The first statement implies that errors are still made, while the second implies that no errors are made. The criterion is also not defined clearly in the manual of the *Nederlands Articulatie Onderzoek* (Dutch Articulation Research). This articulation test is based on the order of acquisition of consonant clusters found by Stes (1979, 1997). This test is used by speech therapists in the Netherlands and Belgium as a standard, to investigate whether Dutch children are slow or deviant in their acquisition of consonants and consonant clusters. The score form of this test reports that the test is based on Stes’ research as taken from the book from 1997 (Stes, 1997). After this it says that a sound is seen as ‘acquired’ when it is correctly produced, without any distortion. On the website of the test, www.logo-art.com, it says the following: “Dit zijn de spraakklanken die in het onderzoek van Stes en Elen door 75% van de kinderen van de betreffende leeftijd correct zijn uitgesproken. Correct is echt correct, dus ook zonder distorsie of devoicing.” (These are the sounds which were correctly produced by 75% of the children in Stes and Elen’s research. Correct is really correct, so without distortion or devoicing). Again, this utterance is ambiguous, since it can mean that the children produce the sounds 100% correct at times, but still make errors at other times or it can mean that they always produce them 100% correctly.

Table 7: The order of acquisition of Dutch consonant clusters in initial position according to Stes (1977,1997) divided by age of mastery by 75% and 90% of the children.

Consonant cluster	75%	90%
tw-	3 years	6 years
kw-	4 years	4 years
kl-, kn-		5 years
bl-, fl, pl		6 years
dw-, xl, vl		7 years
br-, fj-, kr-, pr-, vr-	5 years	7 years
xr-		8 years
xn-	6 years	6 years
dr-, fn-		8 years
tr-, zw-		9 years
sl-, st-		>10 years
pn-, sk-	7 years	9 years
sm-		10 years
sp-	8 years	10
sn-	9 years	9 years
sf-, spr-, str-		10 years
spl		>10 years

These patterns are not similar to the ones found by Fikkert (1994) described above. While Stes (1977,1997) found that children start producing plosive-glide first and plosive-liquid after this, Fikkert (1994) found the reversed pattern: plosive-liquid first, plosive-glide later on. Another difference which stands out is that /s/- plosive clusters are acquired very late, from six years onwards, according to Stes (1977,1997). However, Fikkert's (1994) data shows that children of 2;0-2;5 years old already produce these. It is important to keep in mind that Stes (1977,1997) looked at when either 75% or 90% of all children were able to produce the clusters correctly. On the other hand, Fikkert (1994) did not include a quantitative measure like this. It is logical that there are differences between the two sources, since Fikkert (1994) mainly looked at when children started producing certain clusters (with and without errors), while it is not known which criterion Stes (1977, 1997) followed in determining when a sound was acquired or known by an individual child. In addition, differences can also arise from the different age groups both studies looked at. Perhaps if Stes (1977,1997) would have included children of 2 years old as well, it may have shown that the first plosive-glide cluster was already acquired by 2 year olds, which would then be in line with some data by Fikkert (1994).

3.1.2.2. Complex onsets with two consonants in English

Considering that after Fikkert (1994) and Stes (1977,1997) no other major or in depth studies have been done in Dutch, it is useful to look at a different Germanic language for possible comparison. When comparing consonant clusters in English and Dutch it is found that, of course, there are differences in the consonant inventories in both languages. In addition, the allowed combinations of consonants within the clusters differ as well (Collin & Mees, 1984). For example, /kn-/ is allowed in Dutch, as in *knie* ('knee'), while this is not allowed in English. In addition, combinations like /hj-/, as in *huge*, and /ʃr-/, as in *shrimp*, are allowed in English but not in Dutch (Collin & Mees, 1984). Even though these differences exist, consonant clusters in Dutch and English are comparable. Similar tendencies are found in both languages (Priester et al., 2011). Quite a lot of studies have focussed on cluster acquisition in initial position in English. Table 8 show the ages of acquisition of different clusters (McLoad, Van Doorn & Reed, 2001) by (American) English children. Consonant clusters were seen as acquired when 75% of the children produced them correctly. These two studies both included many children; Templin (1957) looked at 480 children between 3 and 8 years old, and Smit et al. (1990) included 461 children from Iowa and 465 children from Nebraska of 3-9 years old. These studies found different results; no consistent pattern was found for each cluster across these studies. However, some similarities between these English studies can also be seen.

Smit et al. (1990) and Templin (1957) both found that /tw, kw/ are acquired early, and that clusters like /spr, str, skr/ are acquired late. Similarities between the English data and the Dutch data by Fikkert (1994) are that both groups of children start acquiring plosive-liquid clusters early on (even though the time frame is different, this order is comparable). Interestingly, when comparing Stes (1977,1997) to the results by Smit et al. (1990) and Templin (1957), it can be seen that /tw, kw/ are acquired early in all three data sets. Additionally, clusters with /s/ are mostly acquired late in the three data sets. The timeframes are not exactly similar, but sometimes they are close to each other or even exactly similar. For example, /sl/ is acquired in English at 6 according to Smit et al. (1990) and also at 6 according to Stes (1977, 1997) in Dutch.

Table 8: Age of acquisition of onset clusters by English children (McLeod, Van Doorn & Reed, 2001, p. 104).

Clusters	Smit et al. (1990) Females	Smit et al. (1990) Males	Templin (1957)
/tw, kw/	3;6	3;6	4;0
/sp, st, sk/	4;6	5;0–6;0[a]	4;0[a]
/sm, sn/	5;6	5;0[a]–7;0	4;0[a]
/sw/	4;6[a]	6;0	7;0
/sl/	6;0	7;0	7;0
/pl, bl, kl, gl, fl/	4;0–4;6	4;0–5;6	4;0–5;0
/pr, br, tr, dr, kr, gr, fr/	4;6[a]–6;0	5;0[a]–6;0	4;0[a]–4;6
/θr/	7;0	7;0	7;0
/skw/	4;6[a]	7;0	6;0
/spl/	6;0	7;0	7;0
/spr, str, skr/	8;0	8;0	5;0–7;0

[a] A reversal occurs in older age groups.

3.1.2.3.Complex onsets with three consonants

As discussed above, Dutch onsets of three consonants always consist of /s/-obstruent-liquid. Fikkert (1994) describes the development of these clusters, which is comparable to the two consonant clusters described above. First, these tri-consonantal clusters are reduced to one consonant, which is always a plosive (see Figure 20a). After this, it depends whether the child can already produce /s/-plosive clusters. If the child is not able to do this yet, but the child produces plosive-liquid clusters correctly, onsets with three consonants will be produced as plosive-liquid (Figure 20b). On the other hand, if the child is not able to produce plosive-liquid clusters but is able to produce /s/-plosive clusters (which was the case in Robin's and Noortje's data from Fikkert, 1994), onsets with three consonants will be reduced to /s/-plosive clusters (Figure 20c). Fikkert (1994) does not focus on the reduction patterns of three consonantal onsets if children are able to produce plosive-liquid and /s/-plosive clusters. As a next step, all three consonants are being produced correctly (20d). Robin and Leon were able to produce these correctly at 2;6.12 and 2;3.18 years old respectively. Looking at the ages mentioned in Figure 20 it must be noted that the different stages of acquiring clusters with three consonants occur at different time points for the children; there is a lot of variation. According to Stes (1981), onsets with three consonants like /spl/ are acquired late; around the age of nine. Fikkert's (1994) data did not pinpoint a specific age of acquisition for these clusters. This is because she only looked at children up until about three years old, and not all of them produced them correctly yet.

Figure 20: Examples of consonant cluster reduction in onsets with three consonants.

a. /strop/	→	[top]	(Beers, 1995)
b. /ˈsprɪŋə/	→	[prɪŋə]	(Catootje, 2;4.9; Fikkert, 1994)
c. /strɑnt/	→	[stɑnt]	(Robin, 2;3.29; Fikkert, 1994).
d. /strat/	→	[stra]	(Leon, 2;3.18; Fikkert, 1994).

3.1.3. Summary about onsets

First, single onsets are acquired. Fikkert (1994) identified 3 stages in the acquisition of single onsets. In the first stage, all words have onsets and they are always plosives and always realised as such. In the second stage, onsetless words are selected for production by children, and are sometimes realised without onsets, but usually plosives are inserted as the onset. In the last stage, other single onsets are produced, starting with nasals. After this, the developmental path of other phonemes in onset position differs greatly between children.

After single onsets, complex onsets (containing multiple consonants) are acquired. Although there is variation between children, Fikkert (1994) observed that most children first started trying to produce plosive-liquid clusters. These were reduced to the plosive. As a next step, some children started producing the cluster as a plosive-glide, before producing it as plosive-liquid. Most children acquired fricative-liquid clusters next. Most children acquired /s/ clusters in later than plosive-liquid and fricative-liquid clusters.

Fikkert (1994) observed that the acquisition of three consonant onsets is similar to two consonant onsets. First the cluster is reduced to the plosive and then the cluster is reduced to either a plosive-liquid or /s/-plosive cluster, depending on whether the child can already produce /s/-plosive clusters. If the child cannot do this yet, a plosive-liquid cluster is produced and otherwise a /s/-plosive cluster. As a next step, all three consonants are produced correctly. Stes

(1977, 1997) also looked at the acquisition of onsets. However, differences are found between Fikkert's (1994) and Stes' (1977, 1997) order and ages of acquisition of different clusters.

3.2. The acquisition of codas

3.2.1. Single codas

Single codas are acquired later than single onsets in Dutch. Moreover, single codas are seen as more marked than single onsets (Prince & Smolensky, 1993). Consonants in coda position are acquired according to the time frame in Table 9. When comparing the ages of acquisition of single codas and onsets (the ages of acquisition of single onsets are shown again in Table 9 for easier comparison), it can be seen that the order of acquisition of consonants is different in initial and final position.

Table 9: Acquisition of consonants in final and initial position (Beers, 2003).

Age	C final	C initial
1;3-1;8	p	p t m n j
1;9-1;11	k	k
2;0-2;2	t s x	s x h
2;3-2;5	m n	b f ʋ
2;6-2;8		l r
2;9-2;11		d
3;0-3;2		
Acquired later	l r f ŋ	

3.2.2. Complex codas

Not much literature has focussed on the development of complex codas. Fortunately, Fikkert (1994) is one of the few who did look at complex codas in Dutch. She observed that words with complex codas are avoided until, in Jarmo's case, he is 1;7.15 years old. After this, these words are selected for production as well. Jarmo partially or totally reduces these consonant clusters. Jarmo reduces these clusters to obstruents. When he gets older, he often keeps producing single obstruents instead of clusters. Sometimes it seems as if clusters are produced, for example /ts/, but this is most likely an affricate. Elke, one of the other children, showed a similar pattern; first sonorant-obstruent clusters are reduced to obstruents, then affricates and fricatives (mainly ʃ and tʃ) are produced and from 2;3.27 years old she starts producing sonorant-obstruent clusters (mostly nasal-plosive like /nt, mt/) and obstruent-obstruent clusters like /st/. Another child, Robin, follows the same pattern. He produced mainly nasal - obstruent clusters like /nt, ns/.

Fikkert (1994) does not provide a list with the ages of acquisition for complex codas. However, a list like this was made by Stes (1977, 1994) who investigated Flemish children and it can be seen in Table 10. Comparing the order of acquisition of consonant clusters in the onset and coda according to Stes (see Table 7 and 10), it can be seen that while in onset position many clusters are already acquired at age 4, many coda clusters are acquired much later. There are even many clusters in coda position which children start acquiring from 10 or even older than 10 years old according to Stes (1977, 1997). For onset clusters there are only a few clusters which are acquired at this late age. However, direct comparison of specific clusters in onset and coda position may not be very informative and accurate, since the strictness of sonority sequencing differs in both positions (i.e. the sonority contrast is bigger in onset than codas and therefore, more combinations are allowed in complex codas than in complex onsets).

When comparing the regular sonorant-plosive clusters to obstruent-/s/ clusters, it can be seen that clusters including /s/ are acquired a lot later, from the age of 6 onwards, while regular coda clusters are acquired from 3 years onwards. In addition, codas with three consonants are acquired from 6 years onwards.

Again, it is not clear whether the 75/90% cut off means that these children do not make any errors anymore, or whether they still make errors. If Stes' (1979, 1997) research is concerned with total acquisition, when children do not make any errors at all, it would explain why the ages of acquisition of some clusters (like most clusters including /s/) are so high. Not much other literature was found on /s/-consonant codas in Dutch other than the ages of acquisition showed in Table 10.

Table 10: the order of acquisition of Dutch consonant clusters in coda position according to Stes (1977,1997) divided by age of mastery by 75% and 90% of the children.

75%	90%	Consonant cluster (coda)
3 years	3 years	-ŋk
	4 years	-mp
4 years	6 years	-ft, -pt
	7 years	-xt
5 years	5 years	-nt
	8 years	-kt
	9 years	-lt
	10 years	-mt
6 years	8 years	-wr,- ŋt
	9 years	-ks
	10 years	-rt
	>10 years	-lx, -lpt

7 years	7 years	-mf
	9 years	-lxt
	10 years	-rxt
	>10 years	-lf, -lp, -rf, -rm, -rp, -lktm -rkt, -rmt, -rpt, -sxr
8 years	9 years	-xs
	10 years	-ws
	>10 years	-rx
9 years	10 years	-fs, -ls, -ms, -ŋs, -fst, -kst, -lts, -nst, -nts, -ŋks
	>10 years	-lk, -ns, -ps, -rn, -rs, -lks, -lms, -lmt, -mst, -st, -rft, -rks, -rps, -rst, -rts, -tst, -ŋst, -wst, -xst
10 years	>10 years	-lm, -lps, -lst, -rnt, -rxs, -spt
>10 years	>10 years	-xts

3.2.3. Internal codas

Internal codas are deleted by children up until about 2 years old (Fikkert, 1994). They delete the internal coda and pronounce the second consonant in the clusters as the onset of the next syllable. The time frame of when children start producing internal codas is again highly variable. For example, [ˈtɑndə[n]] is produced as [ˈtɑtə] ('teeth') at 1;11.20 by Jarmo. Jarmo first production of internal codas is at 2;1.22 years old. He produces [ˈstrœysˌvoxəl] as [ˈtrœysˌfoxo] ('ostrich') Robin produces his first internal coda, [ˈspelˌtœyn] as [ˈdynˌdœyn] ('playground'), at 1;9.10. However, these are compound nouns, and perhaps they are analysed as two separate words. On the other hand, non-compound words with internal codas are also produced around this age. Elke produces her first one at 2;2.6. She produces her name [ˈɛlkə] as [ˈɑlkə]. This shows that there is variation between children. Other examples of internal coda productions by Jarmo, Robin and Elke can be found in below in Figure 21. No general pattern of the order of acquisition of internal codas in described in Fikkert (1994). In addition, internal codas are difficult for children (Dos Santos & Ferré, 2016).

Figure 21: Examples of internal codas by different children (Fikkert, 1994).

drinken	[ˈdrɪŋkə[n]]	→	[ˈtɪŋkə]	(2;2.6)
vliegtuig	[ˈvlixˌtœyx]	→	[ˈtixˌtœyx]	(2;2.27)
winkel	[ˈʋɪŋkəl]	→	[ˈʋɪŋkʉ]	(2;0.18)
vakantie	[vaˈkɑnsi]	→	[ˈtanti]	(2;1.7)
taxi	[ˈtaksi]	→	[ˈkas.si]	(2;4.29)

3.2.4. Summary about codas

At first, children produce CV syllables and do not produce any codas; single codas are acquired later than single onsets. In addition, the order of acquisition is also different in onset and coda position. Not much literature was found on the development of complex codas. Fikkert (1994) did look at complex codas in Dutch, and observed that consonant clusters in coda position are first reduced to either nothing, or to obstruents. As a next optional step, they are reduced to affricates and fricatives (mostly ʃ and tʃ). As a next step, they are produced correctly. Most children first produce sonorant-obstruent and obstruent-obstruent or nasal-obstruent clusters. Stes (1977, 1997) provides a list with ages of acquisition for complex codas. When comparing this list to the list with ages of acquisition for complex onsets, it can be seen that many coda clusters are acquired much later than onset clusters. Some clusters are acquired as late as age ten according to Stes (1977, 1997). However, direct comparison is difficult since the strictness of sonority sequencing differs in both positions.

Internal codas are deleted by children up until about 2 years old (Fikkert, 1994). Children first delete the internal coda and pronounce the second consonant in the clusters as the onset of the next syllable. As a next step, they produce them correctly. Internal codas are viewed to be difficult for children (Dos Santos & Ferré, 2016).

3.3. Summary on acquisition of structures with and without /s/

This section summarizes the acquisition patterns of structures with and without /s/, based on what has been discussed in the previous sections. First the onsets and then the codas will be discussed.

Single /s/ in onset position is acquired between 2-2;2 (Beers, 1995). 8 segments are acquired earlier or at the same time, while 6 are acquired later. When comparing the acquisition of single /s/ to other segments it can therefore be said that the time frame of the acquisition of single /s/ is almost in the middle of the acquisition of single segments in onset position. Turning to consonant clusters including /s/, these show deviant patterns compared to other clusters. Initial /s/ clusters are acquired late, usually after obstruent-sonorant clusters are acquired (Fikkert, 1994). According to Fikkert (1994), children start producing initial /s/-plosive clusters between 2;0-2;5 years old. However, Stes (1979, 1997) claims that they are acquired much later, from 6 years onwards. This is in contrast with the other clusters without /s/ which are acquired between 3-6 years old (Stes, 1979, 1997). When comparing the data by Fikkert (1994) to English data (Smit et al.,1990; Templin ,1957), it can be seen that plosive-liquid clusters are acquired early on in both data sets. In addition, when comparing Stes (1977,1997) to the results by Smit et al. (1990) and Templin (1957), it can be seen that /tw, kw/ are acquired early in all three data sets. Additionally, clusters with /s/ are mostly acquired late in all three data sets.

Before initial clusters are produced correct, they are reduced. All initial clusters with /s/ Fikkert (1994) looked at (/s/-plosive, /s/-fricative, /s/-plosive-liquid) are reduced to plosives in the first stage (e.g. /spak/ → /pak/ 'spoke'). This pattern is also shown in clusters without /s/ including plosives (e.g. /klɔk/ → /kɔk/, ('clock')). Clusters with /s/-fricative are reduced to the fricative or replaced by a plosive (/sxar/ → /xar/, /sxar/ → /tar/, 'scissors'). Clusters without /s/ including fricatives are also reduced and replaced by a plosive (/vlix/ → /tix/, 'fly') or reduced to the fricative (/zʋɑrt → /zɑrt/, 'black'). Reduction patterns in clusters consisting of two consonants with and without /a/ are thus comparable. In the case of three consonant clusters, the cluster is first pronounced as a plosive, than as either plosive-liquid or s-plosive, and as a last step as the correct cluster with three consonants. These cannot be compared to clusters with three consonants without /s/, since these are not allowed in Dutch.

The /s/ in coda position is acquired between 2-2;2 as a single segment (Beers, 1995). 4 other segments are acquired before or at the same time while 6 others are acquired later. Therefore it can be said that the time frame of the acquisition of single /s/ is almost in the middle of the acquisition of single segments in coda position. In addition, Fikkert (1994) found that children start producing /s/ clusters in coda position around the age of 2;3. Again, Stes (1977, 1997) found that the age of acquisition of these clusters was higher, around 7-10 years old. No comparison between the reduction patterns in clusters with and without /s/ was found in the literature. In addition, Fikkert (1994) observed that internal codas (with and without /s/) start occurring from 2 onwards. However, there is a lot of variation between the studied children by Fikkert (1994).

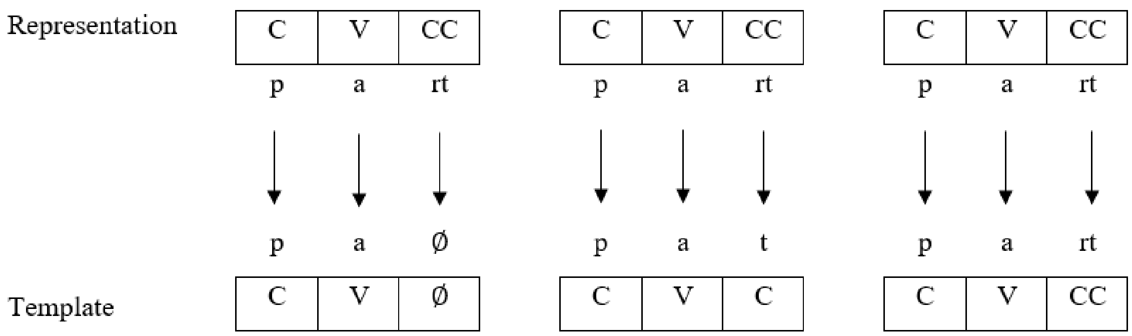
In conclusion, the most important observation concerning the comparison of acquisition of clusters with and without /s/ is that clusters with /s/ are acquired relatively late compared to other sounds. This is supported by Fikkert (1994) and Stes (1977, 1997), even though the time frames in both studies were different.

3.4. The acquisition of syllable types

3.4.1. The acquisition of syllable types in Dutch

There are many different syllables. Examples of syllables are CV, CVC and CCVC. These are all called syllable types. The acquisition of syllable types is related to but cannot simply be reduced to the acquisition of consonant clusters. It is more complicated than that since the acquisition of syllable types is about acquiring new structures. At first children only allow CV structures (Fikkert, 1994). The type of syllables children allow is represented in a syllable template. The notion of syllable templates, even though named differently sometimes, has been used since Waterson (1971). If a child learns a word which is more complex than the current template, the child will adapt the target structure to his syllable template (Gillis & Schaerlaekens, 2000 . For example, if the child learns *paard* ('horse'), which is of the syllable type CVCC, the child will fit the structure onto his syllable template as much as possible; he will only realise /pa/, since only CV is available in the current template. This is shown in Figure 22 (Gillis & Schaerlaekens, 2000, p. 166). The syllable template is extended over time. When the template is extended to CVC for example, a word like *paard* ('horse') will be realised with one consonant at the end, probably the plosive (Figure 22). Then, when the template also allows CVCC, *paard* ('horse') will be realised in an adult like manner. For clarity, a representation of this last stage was added to the Figure based on Gillis & Schaerlaekens (2000). The syllable template extends until all syllable types of the native language are allowed.

Figure 22: The adaptation of a target word to the syllable template of a child (Gillis & Schaerlaekens, 2000, p. 166).



Levelt, Schiller & Levelt (2000) conducted a study in which they focussed on the development of syllable types in the spontaneous speech of 12 Dutch children from 1;0 until 1;11 years old. Data collected by Fikkert (1994) and Levelt (1994) was used. The collection of this data lasted for 6 to 13 months, and recording were made every other week. This resulted in recordings of children of 2;9 at the latest. Only primary stressed syllables were analysed. In addition, syllables with extrasyllabic elements were not taken into account. In addition, no distinction is made between long and short vowels. This is based on Fikkert's (1994) observation that this difference in vowel length is not distinctive for young children. Syllable types were seen as acquired when a child produced it at least twice in the total recording period.

Levelt, Schiller & Schiller (2000) found that all studied children first started using the universal structure CV. After this, they acquired CVC, before V and then VC. As a next step, some children acquired complex codas first, while others acquired complex onsets first. The complexity of the structures is increased when the children get older in both tracks. Figure 23 illustrates the two different paths found by Levelt, Schiller & Levelt (2000) for the acquisition of syllables types. Eight of the children did not produce the final structure CCVCC. This can be explained by the young age of the children.

Figure 23: The acquisition of syllable types according to Levelt, Schiller & Schiller (2000).

	A:	CVCC → VCC → CCV → CCVC	
CV → CVC → V → VC			CCVCC
	B:	CCV → CCVC → CVCC → VCC	

3.4.2. The acquisition of syllable types in Dutch; duplication and age

A master thesis by Boxma (2018) aimed to duplicate the results by Levelt, Schiller & Level (2000) and Fikkert (1994) about the acquisition of syllable structure by children. She expanded the age range and looked at children between 1;0 and 4;0 years old. Another aim was to find out at which age children acquired certain syllable structures. Spontaneous speech of 31 children was analysed. Parents of the children recorded them every week or every other week for about 5 minutes, for a period of 6 months. The percentage of correctly realised syllable types was calculated for each syllable type that occurred at least three times. Ambisyllabic syllable types were analysed for CV and CVC. If a segment is ambisyllabic, it means that it is associated with two syllables. On the other hand, ambisyllabic syllables were analysed in VC and in syllables including consonant clusters. No additional information about the kind of words selected for analysis was found.

Boxma's (2018) results showed a different pattern than the one observed in Levelt, Schiller & Levelt (2000); CVC was acquired after VC, while Levelt, Schiller & Levelt (2000) found that this structure was acquired directly after CV (see Figure 24).

Figure 24: Difference in order of acquisition.

a. CV → **<u>CVC</u>** → V → VC (Levelt, Schiller & Levelt, 2000)

b. CV → V → VC → **<u>CVC</u>** (Boxma, 2018)

Boxma (2018) explains this difference by the different used methodologies. Levelt, Schiller & Levelt (2000) assumed that a structure was acquired when the child produced it at least two times. However, when a child first produces two instances of a certain structure, this does not necessarily mean the structure is totally acquired. On the other hand, Boxma (2018) calculated the percentage of correctly produced syllable types. She only calculated this percentage for syllable types which occurred three or more times in the speech of the children. She claims that this gives a better view of the order of acquisition. A percentage may give a better view of the acquisition pattern, but this explanation is not found satisfactory since two or three instances produced correctly is not a big difference. Maybe the different results arise from another methodological point. Levelt, Schiller & Schiller (2000) included only stressed syllables and no syllables including extrasyllabic elements. In addition, they did not make a distinction between short and long vowels. It appears that Boxma (2018) does not use these same criteria. No information is given on what kind of words are included in her study, other than that sometimes ambisyllabic words are included and sometimes they are not. Therefore, this difference in the kind of words which are included may be the cause for the different results in both studies.

Boxma (2018) found age ranges for the acquisition of syllable types shown in Table 11. Two measures were included; the age range when syllable types are acquired and when they are under development. This second measure was included to give more insight from which age the child tries to produce the structure. A syllable type was seen as not mastered, when less than 50% of that structure was produced correctly. In addition, correct production between 50-75% was seen as under development. Correct production of at least 75% was seen as mastered, or acquired. These percentages are in line with Beers (1995). Boxma (2018) included the measure when syllables are under development for clinical purposes; in this way a child's delay can be compared to control data. In this way, "the severity of a delayed syllable type development" (Boxma, 2018, p. 38) can be diagnosed.

Concerning consonant clusters, no age range for acquisition is presented in Table 11. Only the age range under development is displayed. Reason for this is that not enough VCC and syllables including the cluster CCC (in onset and coda position) were found in the data. Therefore this does not represent the entirety of the acquisition of consonant clusters. Consonant clusters were taken as one group and no information was given on specific clusters (e.g. obstruent-liquid, /s/-consonant clusters etc). In addition, no children older than 3;11 were included. Boxma (2018) notes that the development of consonant clusters is probably still ongoing at the age of 3;11, and very likely after as well. However, since no data of older children was included in Boxma (2018) it is difficult to pinpoint an exact age range for the acquisition of consonant clusters. In addition, Boxma (2018) notes that the age ranges for acquisition of complex clusters in Table 11 may not be accurate in all cases, since the calculations sometimes had to rely on very few instances of the syllable type. However, the number of instances per syllable type were not reported. In addition, since no children older than 3;11 were analysed, it is not known how the acquisition continues. However, the age ranges for development of CCV, CCVC, CVCC and CCVCC are expected to be accurate because enough tokens of each syllable type were found and analysed in the data.

In conclusion, according to Boxma (2018), the first acquired syllable type including a complex onset is CCVC and this type is acquired between 1;11 and 3;9 years old. This type is closely followed by CCV, which is acquired between 2;2 and 3;11 years old. On the other hand, the first syllables including clusters in coda position are VCC and CVCC. The ages of acquisition are very close; 1;9-no data and 1;11-3;11 respectively. It may seem strange that CCVC is acquired before CCV, since CCV is supposed to be easier. However, if the vowel is short, CCV is not allowed. In this case a C most follow. If children acquire this constraint early, the fact that CCVC is acquired before CCV may be explained. A surprising result is that the final age of acquisition has been found for CVCC but not for VCC. However, this can be due to the fact that the results concerning clusters may not be accurate due to not enough instances of the syllable type.

Table 11: Age ranges for the development and acquisition of each syllable type (Boxma, 2018, p. 38)

Syllable types	**Age groups (syllable type acquired)**	**Age groups (syllable type under development)**
CV	1;1 – 1;6	1;1 – 1;5
V	1;3 – 2;0	1;3 – 1;7
VC	1;4 – 2;5	1;2 – 1;10
CVC	1;1 – 2;8	1;1 – 2;3
CCV	2;2 – 3;11	1;11 – 2;8
CCVC	1;11 – 3;9	1;11 – 3;9
CVCC	1;11 – 3;11	1;9 – 2;7
VCC	1;8 – no data	1;8 – 3;9
CCVCC	2;7 – 3;10	2;7 – 3;0
CCC	3;4 – no data	1;11 – 3;9
Clusters combined	–	1;11 – 3;9

3.4.3. The acquisition of complex onsets vs. codas

3.4.3.1 The acquisition of complex onsets vs. codas in Dutch

The developmental path of the acquisition of syllable types as described by Levelt, Schiller and Levelt (2000), see Figure 23, shows that nine children acquired complex codas first, while three acquired complex onsets first. Boxma (2018) points out that the method used may not provide the best representation of the acquisition of syllable types since it focusses more on simplification (considering that certain words are left out) than accurate acquisition patterns. However, it still shows a trend towards the preference of developing complex codas first. The previously discussed study by Fikkert (1994) also pointed towards this pattern.

Boxma (2018) showed that 11 out of 23 children started producing consonant clusters, which was measured by at least two instances. The other 12 children did not produce any consonant clusters or produced a cluster once. 8 children (31 children participated in total) were not analysed here since they already produced two instances of clusters in their first recording, and all the following recordings. The same criterion as in Levelt, Schiller & Levelt (2000) was used, in order to be comparable. Table 12 shows at which age children produced consonant clusters twice for the first time. Table 12 shows that seven children started producing complex onsets and codas around the same time, while two children started producing complex onsets first and two others complex codas first. These ages do not give information about full acquisition without any errors but about when a child first starts using clusters. Boxma (2018) suggests that children start producing complex onsets between 1;7-2;7 years and complex codas between 1;7-2;10. However, since 12 children did not produce two instances of clusters, more variety is expected.

The pattern found by Boxma (2018) is not similar to the one found in Levelt, Schiller & Levelt (2000), but both studies show that there may not be one fixed pattern concerning acquisition of complex onsets and codas for all Dutch children.

Table 12: The first occurrence of two productions of complex onsets and complex codas (Boxma, 2018, p. 41).

	CCV + CCVC	VCC + CVCC
Participant 2	-[15]	-
Participant 7	-	-
Participant 10	-	-
Participant 17	1;7	1;8
Participant 21	1;7	-
Participant 24	-	-
Participant 25	-	-
Participant 34	-	-
Participant 36	-	-
Participant 3	1;10	-
Participant 9	1;11	1;11
Participant 12	1;8	1;7
Participant 15	-	-
Participant 19	-	-
Participant 20	-	1;10
Participant 29	-	-
Participant 6	2;2	2;3
Participant 11	2;4	2;4
Participant 22	-	2;6
Participant 27	-	-
Participant 26	2;7	2;7
Participant 31	2;6	2;6
Participant 33	2;6	2;10

3.4.3.2. The acquisition of complex onset vs. codas in other languages

The pattern of acquiring complex codas first by most children as found by Levelt, Schiller & Levelt (2000) and Fikkert (1994) has also been shown in different languages. Lleó and Prinz (1996) looked at five German children. They were aged 0;9-2;1 years old. Results were based on all children, no individual results were shown. The group results showed that the children first started correctly producing complex codas (at 1;6) before correctly producing complex onsets (one instance of a correctly produced complex onset was found at 1;8, none were found at 1;9 and more than one were found from 1;10 onwards). This pattern suggests that complex codas are acquired before complex onsets. Moreover, the children produced complex coda more accurately compared to complex codas. However, this last result was not significant. The English study by Templin (1957) also showed the same group effect: complex codas were produced more accurately than complex onsets by 3;0-3;6 year olds. Moreover, Kirk & Demuth (2003) also found that 6 out of 9 children produced complex codas more accurately than complex onsets. 3 out of these 6 children did not even produce any complex onsets. The other 3 out of the total 9 children produced complex onsets more accurately than complex codas, but the difference in performance was very small between complex onsets and codas. Based on these results, Kirk & Demuth (2003) concluded that English children aged 1;7-2;7 produced complex codas more accurately than complex onsets, and therefore they conclude that complex codas are acquired first.

However, these studies did not control for segmental complexity. Since different consonant clusters are acquired at different ages, and only certain clusters were produced by the children, these may be the reason the complex coda first pattern arises. Therefore, Kirk & Demuth (2005) conducted an English study in which this aspect was controlled for. They compared similar consonant combinations but in reversed order in onset and coda position (note that not all complex codas have complex onsets with the same sounds in reversed order). For example, they compared /s/-stop and stop-/s/ clusters in initial and finial positions (*school* versus *box*). In this way, segmental complexity could not be the reason for differences between the age of acquisition of complex codas and onsets. The same pattern was seen as in the previous studies; the English children produced complex codas more accurately than complex onsets (this analyses was based on the entire group, no individual results were shown). This may be due to the frequency of the clusters in both positions. Final stop-/s/ clusters occur four times more often than /s/-stop clusters. Considering that the segmental complexity was controlled for, this study is a strong argument in favour of the complex codas first pattern.

In contrast, Demuth & Kehoe (2006) focussed on the acquisition of complex onsets and codas in 14 French children aged 1;10-2;9 and found the opposite pattern: 8 out of the 14 children produced complex onsets more accurately than complex codas, while 5 children performed similarly on both positions and 1 child produced complex codas more accurately than complex onsets. In addition, complex onsets were produced correctly before complex codas. Since, as a group effect, the children showed that complex onsets were produced more accurately and earlier than complex codas, it was concluded that the French children in general acquired complex onsets before complex codas. They note that all previous studies were on Germanic languages, and that it may work differently for Romance languages in general. This is quite likely since the allowed consonant clusters differ. For example, many Germanic languages allow /s/-consonant clusters (e.g. Dutch, German, English) while the Romance Spanish does not allow this type of consonant cluster. On the other hand, French does allow these clusters, while this is a Romance language too. No explanation was found for this pattern.

It is surprising that the Germanic studies suggest that complex codas are acquired before complex onsets, considering that that single codas are more marked and usually acquired later than single onsets (Kirk & Demuth, 2005). However, as mentioned earlier; the order and timeframe of the acquisition of single onsets and codas is different. Therefore, it may be possible that the pattern seen in the acquisition of single onsets and codas differs from the complex consonant clusters. Unfortunately, no other studies known to us have focussed on this matter. Most studies discuss complex onsets, but not complex codas and not the difference between them while controlling for cluster type (e.g. plosive-liquid/liquid-plosive, /s/-consonant/consonant-/s/). Another element which may play a role is the universal asymmetry in sonority sequencing between onsets and codas. The maximum sonority contrast is bigger in onsets compared to codas, which results in more possible combination in coda position compared to onset position. Therefore, since the restrictions are looser in complex coda position, this may be a reason to be acquired earlier.

Another possible explanation for the difference between the preference of acquisition of complex onsets or codas first may rely on the frequency of these structures in a given language, as mentioned above (Kirk&Demuth, 2005). Levelt, Schiller & Levelt (2000) showed that more frequent syllable types were acquired earlier compared to less frequent types. Van den Berg (2012) notes that such a frequency effect was found in multiple languages, like Dutch, German, French, English and Polish (Jarosz, 2010). Another possible explanation for the complex coda first pattern is that complex codas often contain inflectional suffixes in Germanic languages (e.g. plural /s/, 3.sg. /t/). When children of 2/3 years old start acquiring morphology, it is possible that they start producing these suffixes (and thus consonant clusters) more accurately from then on.

3.5. Phonological Processes

As shown in the explanation of the development of complex onset and codas earlier, children change words in acquisition. This is usually done to avoid more complex structures which are not acquired yet. In this way, changing target words usually leads to a reduction of Markedness. A discussion of the possible errors children make in consonant clusters is relevant for this study, since we want to investigate which errors are made at what age, in order to be able to compare this to future data of children with Autism Spectrum Disorder (ASD). Earlier, many instances of reduction and substitution have been discussed. In this section the following relevant phonological processes used in child acquisition while producing consonant clusters will be discussed; cluster reduction, substitution, addition and metathesis or insertion. After this, the development of these phonological errors in Dutch and English will be addressed. However, not much literature was found on this.

3.5.1. Different phonological processes

Deletion of the final single consonant occurs often, as mentioned earlier (Stes, 1997). An example is shown in Figure 24a. As seen earlier and as explained in Gillis & Schaerlaekens (2000) and Beers (1995), children often reduce consonant clusters (CC/CCC) to either one or two consonants. At word initial position, a cluster of two consonants contains either obstruent-sonorant (e.g. /kl/), /s/-obstruent (e.g. /st/) or /s/-sonorant (e.g. /sm/). Obstruent-sonorant clusters can be reduced to the obstruent or the sonorant. Clusters of the kind plosive-liquid and fricative-liquid are often reduced to the plosive. This is shown in 24b and 24c. In addition, /s/-obstruent clusters are reduced to a plosive as can be seen in 24d below. The cluster /st/ is reduced to /t/; /s/ is deleted. Sometimes clusters are reduced to sounds which are not part of the cluster, as shown in 24e.

Clusters containing three consonants are reduced in a similar manner as clusters with two consonants (Fikkert, 1994). They are reduced to either one plosive (24f), plosive-liquid (24g) or /s/-plosive clusters (24h).

In final position, clusters can consist of sonorant-sonorant, sonorant-obstruent or obstruent-obstruent. Sonorant-obstruent clusters are usually reduced to the obstruent, as illustrated in 24i. Beers (1995) did not report on a specific pattern of reduction for obstruent-obstruent or for reduction of clusters with three consonants in final position. Reason for this is that these codas do not occur very often in young children's speech.

Figure 24: Examples of final consonant deletion and cluster reduction, a) *beer* ('bear'), b) *blad* ('leaf'), c) *fluit* ('flute'), d) *stoel* ('chair'), e) *zwem* ('swim'), f) *stroop* ('syrup'), g) *strooien* ('scatter'), h) *strand* ('beach') and i) *taart* ('cake').

a. [ber]	→	[be]	(Yara, 2;1.13, Gillis & Schaerlaekens, 2000)
b. [blɑt]	→	[lɑt]	
c. [flœyt]	→	[lœyt]	
d. [stul]	→	[tul]	(Maarten, 1;10.10, Gillis & Schaerlaekens, 2000)
e. [zʋɛm]	→	[vɛm]	(Stes, 1997)
f. [strop]	→	[top]	(Beers, 1995)
g. [ˈstrojə]	→	[trojə]	(Tirza, 2;3.27; Fikkert, 1994)

h. [strɑnt] → [stɑnt] (Robin, 2;3.29; Fikkert, 1994)
i. [tart] → [tat] (Maarten, 1;9.21, Gillis & Schaerlaekens, 2000)

Sometimes children replace sounds by other sounds. This is called substitution. This is usually done to avoid segments which are not acquired yet. These substitutions change the compilation of consonant clusters. Gillis & Schaerlaekens (2000) explain that substitution can occur regarding the place of articulation, manner of articulation, and voicing. The place of articulation can be moved forward, which is called fronting. In addition, the manner of articulation can be replaced as well. Usually, fricatives are substituted by plosives (Figure 25a) and liquids by glides. Liquids can also be vocalised (Beers, 1995). Furthermore, Gillis & Schaerlaekens (2000) state the third way of substituting phonemes is by making unvoiced consonants voiced. This is called voicing and it is shown in Figure 25b. In contrast, voiced consonants can be produced as voiceless ones, which is called devoicing. Children experience lots of problems with distinguishing voiced and their unvoiced counter sounds (Gillis, 2004).

Figure 25: Examples of substitution (Gillis & Schaerlaekens, 2000).

[sxrɛif] → [skrɛif] (Tine, 2;1.4)
[klɔk] → [glɔk] (Jelle, 2;9.4)

Another phonological process is addition, or insertion. An example of insertion in a consonant cluster is shown in Figure 26a. Children can also insert a sound between two consonants of a cluster. In this way, the difficult structure (CC) is reduced to the easier structure (CV.C). An example is shown in Figure 26b. Another process is called metathesis, or migration (Stes, 1997). This is when one sound of the word is inserted into a different place (Figure 26c) or when two sounds are switched (Figure 26d). It is also possible that a sound is inserted in a different place, and that the sounds that used to be in that new position, is deleted (Figure 26e).

Figure 26: Examples of insertion (a) and metathesis (b-d).

a. [plɑs] → [splɑs]
b. [brif] → [bərif]
c. [ˈplɑŋkən] → [ˈpɑŋklən]
d. [ˈplɑŋkən] → [ˈklɑŋpən]
e. [kliˈnik] → [kiˈlik]

3.5.2. The development of phonological processes over time in Dutch and English

Beers (1995) identified how phonological processes develop over time up until 4;0 years old. The calculations by Beers (1995) were done in the following manner; first, the number of occurrences of each process within 100 words were calculated for each child. After this, age groups were made and averages of how often a process occurred per age group were calculated. Four age groups consisted of 20 children, while one group (3;6-4;0) consisted of 10 children.

Figure 27 (taken from Gillis & Schaerlaeken, 2000, p.160, and based on Beers, 1995) shows the development of final consonant deletion and cluster reduction in child speech. Both decrease over time and deletion of the final consonant is the most frequent at 3;6-4;0.

Figure 27: The developmental path of cluster reduction and deletion of final consonants.

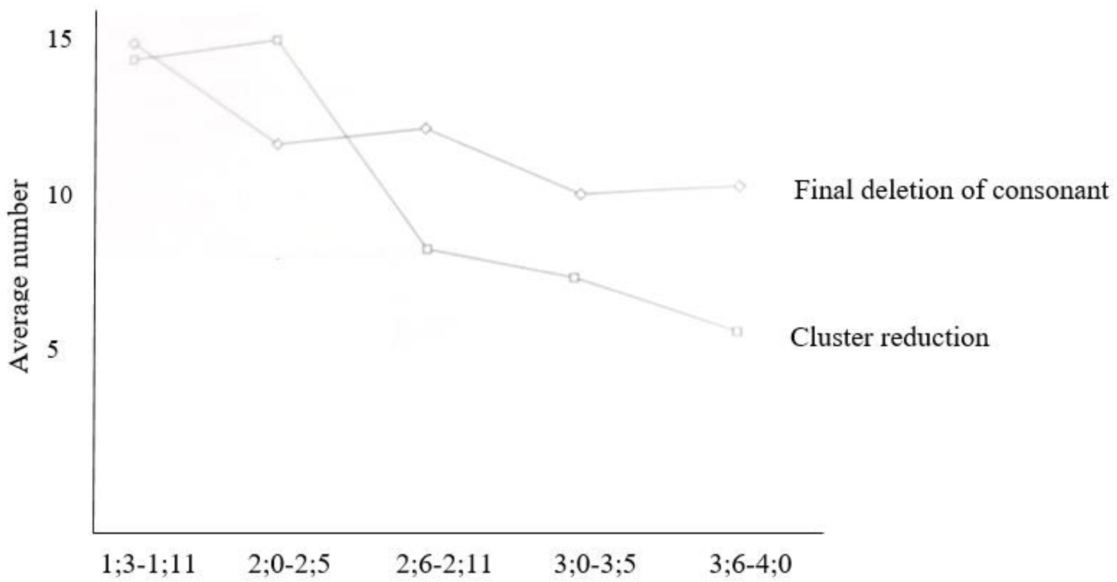
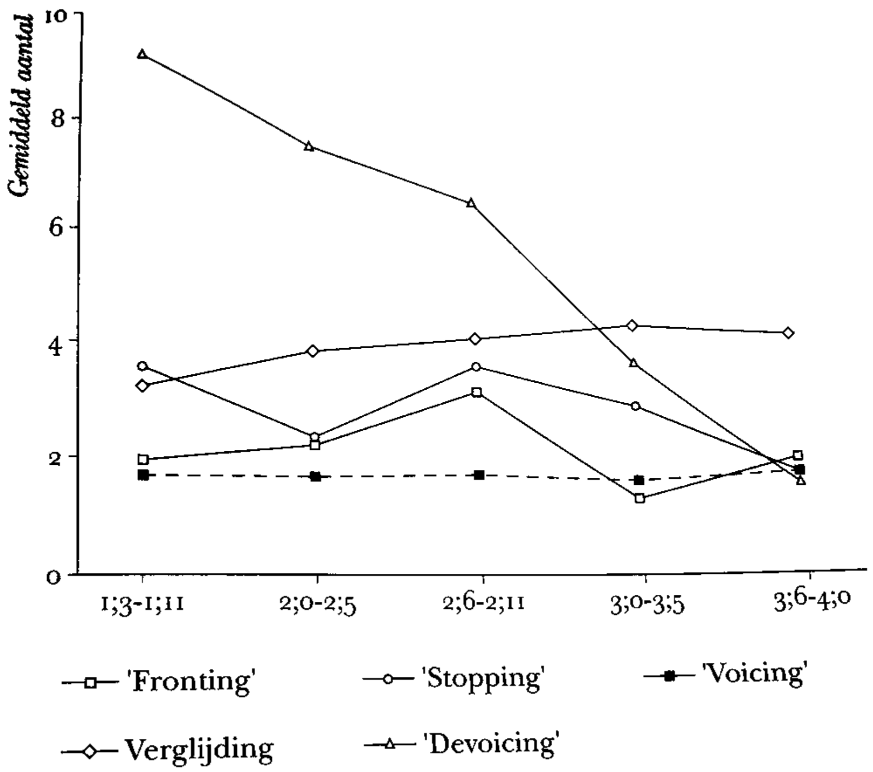


Figure 28 (taken from Gillis & Schaerlaeken, 2000, p. 161, and based on Beers, 1995) shows the substitution processes and their developmental paths. This figure takes single consonants and clusters into account. All these processes occur less often compared to the processes in Figure 27; all frequency are below 10/100 here while they are up until 15/100 in Figure 27. Devoicing is the most frequent process when children are very young, and this process decreases drastically over time. Moreover, all processes seem to decrease over time, except for gliding, which seems to increase. No course of development of insertion and metathesis by Dutch children was found concerning consonant clusters.

Figure 28: The developmental path of fronting, stopping, gliding (*verglijding*), voicing and devoicing.



Since no data of children older than 4;0 was included by Beers (1995), it is not known how these phonological processes develop after 4;0 in Dutch children. Therefore, it is useful to look at the developmental pattern of phonological processes in another Germanic language; English. Even though English and Dutch are quite different, as said before they are also similar in some aspects. Therefore, the English patterns may give some insight in the phonological process development of children in general.

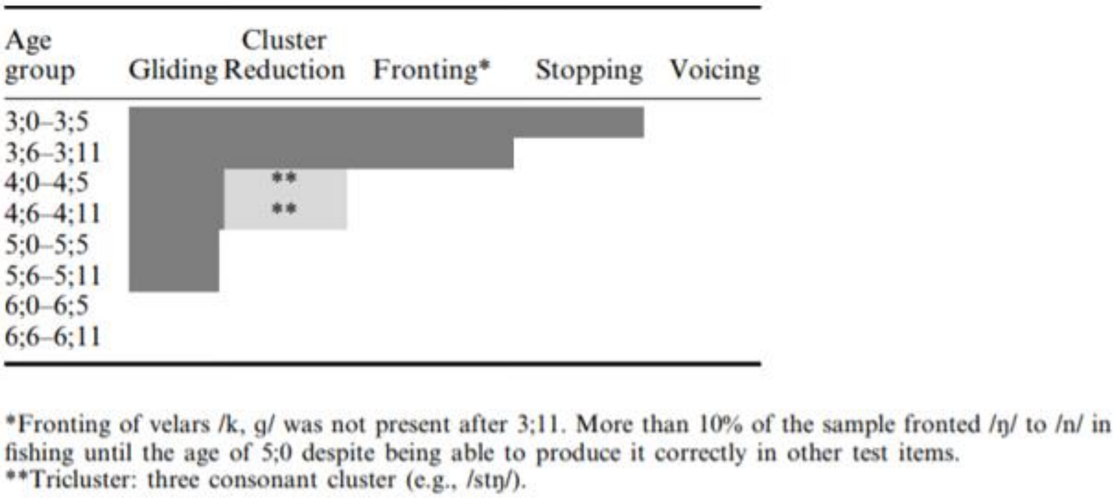
Dodd et al. (2003) analysed the phonological error patterns of 684 English speaking children. Phonological processes were seen as present when at least 10% of children in an age group showed the processes at least five times. Figure 29 shows which processes were present in which age groups.

When comparing Beers' (1995) data on Dutch and Dodd et al.'s (2003) data on English, it can be seen that no voicing errors were present in English children, whereas these were present in Dutch speaking children. Comparing the processes gliding, cluster reduction, fronting and stopping in both languages, it can be said that the errors in both languages between 3;0-3;11 look similar.

After 3;11, English children still make gliding and cluster reduction mistakes until 4;11 years old. However, the other phonological errors are not made anymore (or at least, not by more than 10% of the children). After 4;11 years old, only gliding mistakes are still made until

5;11 years old. After 5;11 years old no phonological mistakes of the kind shown in Figure 27 and Figure 28 are made by English children. No information on final consonant deletion (by itself), addition, substitution or metathesis was given.

Figure 29: Phonological errors by English children (n=684) divided by age group (Dodd et al., 2003, p. 634).



3.5.3. Short summary on phonological processes

In summary, insertion, deletion, metathesis and substitution errors can be made while children produce consonant clusters. Beers (1995) showed that children up until 4 (she did not look at older children) make the following errors: cluster reduction, substitution of segments and deletion of final consonants. In addition, English data of older children by Dodd et al. (2003) showed that substitution errors were made until 5;11 and cluster reduction until 4;11.

4. The current study

4.1. Research Questions

The main goal of this study is to investigate the production of consonant clusters with and without /s/ in TD Dutch children of 3,4 and 5 years old. This study aims to answer the following specific research questions:

1. *At which age are Dutch TD children able to correctly realise consonant clusters with and without /s/?*
2. *Do Dutch TD children make more errors in certain consonant clusters compared to others?*
3. *Which errors do Dutch TD children make while realising consonant clusters at 3, 4 and 5 years of age?*
4. *Do Dutch TD children produce consonant clusters more accurately in initial or final position?*
5. *How does the performance on the Non-Word Repetition Task correlate with vocabulary?*

As mentioned in the introduction, a new Dutch Non-Word Repetition Task (NWRT) is developed in line with a French version called the LITMUS-NWR-FRENCH (Dos Santos & Ferré, 2016) in order to answers these research questions. This French task is designed to test phonological complexity rather than only phonological short term memory. In short, the French task includes non-words containing 0,1 or 2 consonant clusters to test phonological complexity and non-words contain maximally 3 syllables to reduce the effect of phonological short-term memory. In addition, the test consists of two parts; a quasi-language independent part, which includes syllable structure which are very common in the world's languages, and a language dependent part, which includes structures which are less common across languages but are present in the language they used, like /s/. The Dutch task is very similar to the just briefly described French task. One big difference is that a second language dependent part is included in the Dutch version. In this part, two frequent and typically Dutch sounds are included in the test. The task will be discussed in much more detail in the Method (Chapter 5).

4.2. Hypotheses

First the general expectations concerning performance on the Non-Word Repetition Task will be presented. The hypotheses for the specific research questions will be presented after this.

Starting with the hypothesis for the entire test, children of 4 years old are expected to perform well (around 80% correct) on the Dutch NWRT. This is based on similar results by Rochereau (2016) focussing on the French NWRT (Dos Santos & Ferré, 2016). Concerning the different parts of the test (language independent, language dependent 1 and language dependent 2), it is expected that the dependent parts are both more difficult than the language independent part. This is expected since more complex structures are added in the dependent parts. In addition, it is expected that the second dependent part is more difficult than the first dependent part, considering that the same structures are used but more complex sounds are part of the second dependent part compared to the first dependent part. It is expected that when structures are more difficult, more errors are made by children in these structures.

In addition, it is expected that the number of clusters in a non-word influences the performance. It is hypothesized that non-words including two clusters will be more difficult compared to zero and one cluster non-words. This is not in line with the results found by Dos Santos & Ferré (2016). They found that the number of clusters did not influence the performance of TD children and explain this by the fact that the children perform at ceiling. However, they looked at children from 5;04-8;05, and took all children together for this analysis. Since the current paper looks at younger children (3,4 and 5) it is expected that they do not perform at ceiling yet, which is why a different pattern than shown in Dos Santos & Ferré (2016) is expected. As also shown in Ferré & Dos Santos (2016), it is expected in the current study that the performance of the 3,4 and 5 year old children is similar on non-words with zero and one cluster, since the children are expected to do well on both structures.

Our Non-Word Repetition Task is supposed to test phonological complexity as the main component, and not phonological short term memory. Therefore, it is expected that the test which measures phonological short term memory, the Digit Span test, does not correlate with the scores on the Non-Word Repetition Task.

Hypotheses for research question 1

Fikkert (1994) observed that children of 2 years old are able to produce obstruent-liquid clusters in initial branching position, initial /s/-consonant clusters, single final codas and medial consonant clusters. Therefore, it is expected that children of 3, 4 and 5 are all able to produce these structures at times, while at other times errors are still being made. Fikkert (1994) did not discuss data on consonant-/s/ clusters in final position. However, since initial /s/-consonant clusters are already being produced, and all the other consonant clusters as well, it is expected that 3, 4 and 5 year old children will be able to produce this structure as well (while errors are also still being made in other productions).

There are different expectations concerning the age of acquisition of the clusters. As mentioned before, it is unclear how many instances of a sound needed to be produced correctly to be seen as acquired by Stes (1979, 1997). However, since the ages of acquisition are higher most of the time compared to Fikkert (1994) it is assumed that Stes does not look at when it is first produced, like Fikkert (1994), but at when children produce many instances correctly. In the current study, a sound will be seen as acquired when 75% of the children produce the sound correctly in 75% of the case. More information on this can be found in Method Section 5.6. It is expected that 75% of the 4 and 5 year old children have acquired obstruent-liquid clusters in initial branching position. The 3 year olds are not expected to have acquired this kind of cluster. This is based on Stes (1997) who claimed that these clusters are acquired at 4 years old. In addition, /s/-consonant clusters are expected to not have been acquired by 3, 4 and 5 year old children because Stes (1979, 1997) showed that these clusters are acquired between 6-8 years old. In addition, single consonants in final position are expected to be acquired by 3, 4 and 5 year old children. This is based on data of Beers (1995), who showed that these single consonants are acquired by 2;5 (she sees acquired as when a sound is produced 75% of the time correctly). In addition, /s/-consonants clusters in final position are not expected to be acquired by the 3, 4 and 5 year old children. This is based on Stes (1979, 1997) who shows that these clusters are acquired between 6 and 8 years old. Finally, there are no specific expectation about the performance on medial consonant clusters, since Stes (1979, 1997) did not focus on this. All these expectations about when the clusters and single consonants are acquired are summarized in Table 13 below. No hypothesis are formed about at which age children have fully acquired structures and do not make any errors anymore, since this was not found in the literature. However, it is hypothesized that when children get older, more children will fully acquire the structures.

Table 13: Hypotheses on which age groups will have acquired the different structures (+ indicates acquired, - indicates not acquired).

Initial	Abbreviation	3 yrs	4 yrs	5 yrs
Branching initial clusters	BIC	-	+	+
/s/-C clusters	ISC	-	-	-
Final				
Single coda	FC	+	+	+
C-/s/ clusters	FCS	-	-	-
Medial clusters	M	?	?	?

Hypothesis for research question 2

Children are expected to make more errors in structures with /s/ compared to structures without /s/, since /s/ has been shown to be difficult. The difficulty of this sound is for example reflected in the late age of acquisition which is between 6 and 8 years old (Stes, 1997). In addition, children are also expected to make more errors in medial consonant clusters compared to all other structures since this structure is also seen as difficult (Ferré et al., 2015).

Hypothesis for research question 3

Cluster reduction is expected to occur in all age groups. This is based on Beers (1995) who showed that cluster reduction occurred in the 1-4 year old children she studied. In addition, it is also expected that the 5 year old children make this error, since Beers (1995) showed that these errors still occurred in 5 and 10 instances out of 100 in 4 year old children. Therefore, cluster reduction is expected to continue after 4 years old. In addition, this expectation is also based on the English data by Dodd et al. (2003) which showed that children up until 4;11 make cluster reduction errors.

In addition, Beers (1995) also showed that 5 different substitution errors occurred in the 1-4 year old children she studied. One of these errors, gliding, was shown to occur until 5;11 by Dodd et al. (2003). In this study, substitution errors are all taken together. Based on Beers (1995) and Dodd et al. (2003) it is expected that substitution errors will occur in 3,4 and 5 year old children. There are no specific expectations for the other two processes coded in this study (insertion and metathesis) since no Dutch data was found on this.

It is expected that the processes diminish over time; the number of mistakes by 5 year olds is expected to be lower compared to the 4 year olds and the 4 year olds is expected to be lower than the 3 year olds. This is based on the declining pattern of the number of occurrences up until 4 years old as found by Beers (1995) as seen in Figure 27 and 28. A declining pattern is also found in the English data by Dodd et al. (2003), as can be seen in Figure 29. Based on these two sources, it is expected that this pattern continues in Dutch at 5 years old.

Hypothesis for research question 4

Based on the results by Levelt, Schiller & Levelt (2000), Lleó and Prinz (1996), Templin (1957) and Kirk & Demuth (2003) it is expected that most children will produce clusters in final position more accurately than clusters in initial position. It is not expected that all children follow the same pattern, as previous literature (e.g. Boxma, 2018) has not found one pattern either. The children who do not produce complex codas more accurately than complex onsets are expected to produce clusters in both positions at the same level of accuracy, based on the seven children in Boxma (2018) who started producing initial and finial clusters at the same time.

Hypothesis for research question 5

As mentioned earlier, the NWRT is not supposed to test phonological short-term memory but phonological complexity as a main component. Previous literature shows that there is a strong positive correlation between phonological short-term memory and the development of vocabulary in children (Gathercole and Adams, 1994; Gathercole and Baddeley, 1990; Michas and Henry, 1994). Since it is assumed that most NWRT mainly test phonological memory, it comes as no surprise that studies have found a positive correlation between scores on NWRT and vocabulary (Lee et al. 2013). However, since this NWRT is not meant to test phonological memory as such, it is expected that there is no correlation between the scores on this NWRT and the scores on the vocabulary test (PVVT).

5. Method

This research has been approved by the *Ethische Toetsingscommissie Linguïstiek* (ethical committee for Linguistics) of the Utrecht Institute of Linguistics OTS, University Utrecht. Active consent of the head of the institutes and parents was asked. The consent forms can be found in Appendix B and C. In addition, an information letter and a short questionnaire with questions about the child (asking about hearing problems, second languages etc.) were given to the parents. These forms can be found in Appendix D and E.

5.1. Participants

64 Dutch speaking children participated in this study. 21 children were 3 year old, 22 were of 4 years old and 21 were of 5 years old. 7 children were excluded because they were very shy, did not cooperate or produced many words which were nothing like the target words. In addition, 2 children were excluded because of difficulty with speaking. One of them had speech therapy, and the other one was advised to go to a speech therapist. This resulted in 55 TD children in total who were analysed; 17 3 year old, 18 4 year old and 20 5 year old children. None of the children had ADHD or a hearing or (suspected) language impairment. In addition, their native language was Dutch. 3 children were bilingual (they used two languages everyday) and 5 children spoke/practised different languages sometimes (for example once a week or once a month when they visit their grandparents). Their scores were not deviant from the other children, which is why they were included and treated like the other children.

All children were recruited in the Netherlands. 3 year old children were recruited at two kindergarten in the centre of Utrecht and in Voorburg. 4 and 5 year olds were recruited at two elementary schools in De Meern and Bleiswijk. In addition, 3 children (two 3 year olds and one 5 year old) were tested at home.

5.2. Design and Procedure

The children participated in three separate tasks. The tasks are described below. In between the tasks, there were short breaks. At the end of the session, the child received a colourful certificate and a sticker. All children were tested individually, under supervision of the researcher. The children were tested in a separate room inside the school or kindergarten, not in the classrooms. In principle, children were tested once; the three tasks were administered in one session. However, 9 of the 3 year old children were tested twice on the Non-Word Repetition Task

(NWRT). Reason for this is when the data collection began, the headphone which was supposed to be used for the NWRT was too big for the 3 year old children. Since testing was time sensitive, it was decided to start testing without headphones. However, the environment was quite noisy which may have caused the children to mishear the non-words, and therefore repeat them incorrectly. Since it was decided it would give a better indication of their ability to produce the non-words when they could hear well, it was decided to test these children again on the NWRT. The time between the first and second session was 7-14 days. No learning effect was expected, since the children were very young and they had to repeat non-words, which are hard to remember. This will be discussed further in the discussion (Section 7.5) at the end of this paper. The other two tests were not administered again in the second session and the 4 and 5 year old children were tested once on all tests.

5.2.1. The Non-Word Repetition Task (NWRT)

5.2.1.1. NWRT: a discussion

The first task was a Non-Word Repetition Task (NWRT). Before giving more information about the specifics of the NWRT used for this study, NWR in general will be discussed. In addition, information about previous versions will be given.

As mentioned before, NWRT are tasks in which a participant, usually a child, is asked to repeat non-words. A non-word is a sequence of phonemes which do not form an existing word in the used language. However, according to the phonology of the language, the sequence could have been an existing word; it does not violate any phonological rules. Repeating non-words is a good method to test phonological abilities since participants cannot rely on lexical knowledge (Chiat, 2015). In addition, if a child repeats a non-word correctly, it shows that the child is able to produce the specific phonemes included in the non-word.

NWRTs have been used for years, also in the Netherlands. One of the most used Dutch versions was developed by De Bree, Rispens & Gerrits (2007). This task contained 3 practice and 16 target non-words. Non-words consisted of 2-5 syllables. Four items were constructed for each syllable length and items contained single consonants, no consonant clusters were used. Used stress patterns were in line with Dutch prosody; stress was placed on the second syllable in 2-4 syllable words and on the third syllable in 5 syllable words. Examples of items are /jiˈnus/ and /waˈfeɪsin/. Another Dutch NWRT was developed by Rispens & Baker (2012). This task was based on an English NWRT by Dollaghan and Campbell (1998). This Dutch task also contained non-words of 2-5 syllables. 10 items were constructed for each syllable length, resulting in 40 items in total. The phonetic probability was controlled based on the frequency of occurrence of the used phonemes. Half of the items had high phonetic probability and the other half low phonetic probability. In addition, no consonant clusters were used and the stress pattern was based on Dutch prosody. Examples of items are /devunɔs/ and /xerɣtivanɔt/ (stress per item was not shown).

These tests include long words. NWRT performance decreases when children are asked to repeat non-words containing three syllables or more (Ellis Weismer et al., 2000; Archibald & Gathercole, 2006). This is seen as evidence for the influential hypothesis which says that NWRT scores mainly reflect phonological short-term memory. This hypothesis is supported by Archibald & Gathercole (2006) among many others. This is also supported by Rispens & Baker (2012), who found that the NWRT scores predicted the scores on the test which was supposed to test working memory (the digit span test, for more information about this test see Section 5.2.2.) in their Dutch study. They concluded from this that working memory, among other factors, correlate with performance on the NWRT.

However, others have argued against this view and state that NWRT scores mainly reflect phonology instead of working memory (Dos Santos & Ferré, 2016). They do not deny that working memory plays a role, but they say it is not the main element reflected by NWRT scores. Evidence for this is based on segmental complexity; children's performance is poorer when asked to repeat non-words containing consonant cluster compared to non-word containing single consonants (Jones et al., 2010; Armon-Lotem et al., in preparation).

It has been proposed that NWR can be used as a clinical marker to detect Specific Language Impairment (SLI), since children with SLI perform poorly on NWR (Bishop et al., 1996). SLI is defined as a language development deficit (Bishop et al., 2000), in which many aspects of language are impaired. For example, problems with phonology, grammar, pragmatics and lexical-semantics characterize this impairment (Leonard, 1998). However, not all aspects show the same degree of impairment. Interestingly, SLI does not correlate with hearing, neurological or behavioural problems or IQ (Bishop, 2006; Tallal & Stark, 1981). De Bree et al. (2007) and Rispens & Baker (2012) found that Dutch children with SLI were indeed distinguishable from typically developing (TD) children using NWR. In addition, NWR has also been used to distinguish between children with and without dyslexia in Dutch (De Bree et al., 2007).

Moreover, NWR has been proposed as a clinical marker to distinguish children with SLI from bilingual children. The COST Action IS0804 project has risen to focus on this under researched area. This framework is made up by many researchers from different European countries. In this framework, bilingual children are defined as children who speak two or more languages on a regular basis (Armon-Lotem et al., 2015). Dos Santos & Ferré (2016) are part of this framework and support the hypothesis that NWR mainly reflect phonological abilities instead of only working memory abilities. They indeed showed that NWR was a good way to distinguish bilingual children (French-Arabic) from children with SLI. In addition, bilingual children with SLI were also distinguishable with the task. In this framework, NWRTs are divided in a quasi-language specific and a quasi-language dependent part (for more information see Section 5.3 below). A quasi-language independent part has been designed for Dutch by Boerma et al. (2015) as part as the same project.

5.2.1.2. The NWRT used in this study

The first task was the Non-Word Repetition Task. This task was based on Ferré & Dos Santos (2012) and was mainly supposed to test phonology instead of mainly phonological short-term memory.

The child sat next to the researcher, in front of a laptop. This task was presented as a PowerPoint presentation. Animations, images, sounds and spoken instructions were used and adapted from the tasks in Dos Santos & Ferré (2018) and Boerma et al. (2015). An animation of an alien named Zubilu appeared on the screen. The child was told by the alien that he and his friends wanted to teach the child their alien language. In order to do this, the child was told that he needed to repeat the strange words the aliens said. First two practise items were presented auditorily by the alien (all stimuli were pre-recorded). The child had to repeat the non-words. The researcher gave feedback at this point. If children were shy or did not repeat the non-words correctly, the researcher explained again what the child had to do and asked the child to repeat again. No more feedback was given after the two practise items. In the test phase, 6 or 4 images of different aliens appeared on the screen at the same time. An arrow appeared above a picture of one of the aliens and at the same time the audio file of the non-word was heard. 2 blocks of 6 images and non-words were alternated with 1 block of 4. This was done to create a difference between the different blocks, to make it less boring for the child. Each alien said a non-word, and the child had to repeat them. After 28 items (which is 50% of the items) were presented and repeated, the animation of Zubilu the alien appeared on the screen again, giving the child a break. After this, the task continued. The task consisted of 56 non-words in total. This task lasted for about 5 minutes. If the child was shy, the task lasted longer sometimes because the child needed extra attention given by the researcher to make sure the child repeated the non-word. If the child did not hear well due to a noise in the background or wanted to hear it again, the non-word was played one more time. More replays were not allowed. The child's speech was recorded on a ZOOM H6 Handy recorder. This recorder was placed on a small tripod on the table next to the laptop which showed the PowerPoint presentation. In this way the researcher could stay focused on the child instead of trying to hear whether the child repeated the non-words correctly. The researcher transcribed the repetitions of the child after the session ended. The child was wearing 21665 Trust headphones. This was done in order for the child to hear the non-words better considering that even though the session was not in the classroom itself, it was still noisy at times. An excel sheet was used to code whether the child made mistakes and in which segment of the non-word. More information about transcription and coding can be found in section 5.4. below.

5.2.2. The Digit Span Task

To test phonological short-term memory separately, the standardized Digit Span Forward and Backward test was used from the Dutch Wechsler Intelligence Scale for Children-III (Van Haasen et al., 1986). The researcher read series of numbers out loud. The child was asked to repeat these. The first two sequences were two numbers long (they were asked separately). After this, the next two sequences were three numbers long, and then four numbers etc. When the child made mistakes in both sequences of the same length, the task ended. The researcher made a note when the child had made two mistakes in two sequences of the same length. For each correct repetition, one point was awarded. These raw scores could not be transformed into standard scores, since the children were too young. Therefore, analyses were done using the raw scores. The test (Forward and Backwards) lasted between 2-5 minutes.

5.2.3. The Picture Peabody Vocabulary Test

The Dutch version of the Picture Peabody Vocabulary Test (Schlichting, 2005) was used to determine the vocabulary of the child. The researcher showed the child four pictures. After this, the researcher said a word, and the child had to point at the corresponding picture. This test contained different sets of pictures, and it depended on the age of the child which set was used to start with. Each set contained 12 pages showing four pictures each. If 9 or more mistakes were made in one set, the test ended. This task lasted approximately 15-20 minutes. Raw scores were converted into standardized forms using the manual.

5.3. Materials Non-Word Repetition Task

The Dutch Non-Word Repetition Task was adapted from the French version called LITMUS-NWR-FRENCH (Dos Santos & Ferré, 2016) and the German version (Grimm, 2012). The stimuli of the French version (Dos Santos & Ferré, 2016) will be presented below, and the German stimuli (Grimm, 2012) can be found in Appendix G. The task was mainly supposed to test phonology instead of mainly phonological short-term memory. In order to minimize the effect of short term memory, non-words were no longer than 3 syllables long. The task included consonant clusters to measure phonological complexity. Non-words included zero, one or two consonant clusters. More specific information about the items will be given below.

The French and German versions contained two kind of items: (quasi) language independent and (quasi) language dependent items. All items were randomized. The language dependent part was supposed to be more difficult for the children than the language independent part. The Dutch task also consisted of a language independent and a language dependent part. However, a third part was added. This was the language dependent part 2. In this part, two consonants which are very frequent and characteristic in Dutch, were added. This part was added in order to make the test more Dutch specific, since the other parts were based on the French and German versions, and used the same sounds as these versions. All items of the different parts were also randomized in the Dutch version. In addition, the language dependent parts were supposed to be more difficult than the language independent part, and the language dependent part 2 was supposed to be more difficult than the language dependent part 1.The task consisted of 56 test items in total.

The Dutch task started with two practise items. The practise items consisted of sounds which did not occur in the test items. The practise items were [ˈtɛiby] and [ˈbo:tɛi].

In the following sections the different parts of the test will be discussed in detail. First, focus will be on the French task by Dos Santos & Ferré (2016). After information has been given on this version, focus will shift to the Dutch version and it will be explained how the Dutch items were constructed.

5.3.1. The Language Independent Part (LI)

Boerma et al. (2015) constructed a Dutch language independent part. However, this version was not used in this study. Reason for this is that Boerma et al.'s (2015) task included non-words up to 5 syllables and did not include consonant clusters. Since these items are quite long, the effect of phonological short term memory is assumed to be quite strong. Since the present study is concerned with consonant clusters and because the effect of short term memory is wanted to be minimized because we want to measure phonology, the Dutch task was developed in line with Dos Santos & Ferré (2016), who strived to test phonology rather than phonological short term memory.

The language independent part by Dos Santos & Ferré (2016) tested syllable structures which are very common across languages. Therefore, this part is being referred to as the language independent part. It is more accurate to describe it as quasi-independent part considering that it is not possible to design non-words which are not connected to language at all (Chiat, 2015). However, for simplicity it is called the language independent part of the test.

The French language independent part consisted of the most common syllable structures across the world's languages. The first chosen structure by Dos Santos & Ferré (2016) was the universal CV because it occurs in all studied language around the world (Dos Santos & Ferré, 2016). In addition, CCV and CVC were selected as well because they are more complex compared to CV and because these structures occur in many languages (Maddieson, 2006).

Table 14 below shows which sounds were included by Dos Santos & Ferré (2016). The stops [p] and [k] were chosen because this manner of articulation is acquired early for many languages like French and Dutch (Beers, 2011). These stops are also very common in many languages (Maddieson et al, 2011). [f] was included in order to be able to create items with the fricative/stop contrast. /s/ was not chosen because /s/ is included in the dependent parts (see Section 5.3.2 and 5.3.3.). When taking the complexity into account, [k] is more complex than [p] (Paradis & Prunet, 1991) and fricative [f] is more complex than both stops (Jakobson, 1969). A sound is seen as more complex when it is acquired later. To create stimuli with branching onsets, the liquid [l] was selected. In an early version of the French test (Dos Santos & Ferré, 2016) the rhotic [ʁ] was used instead of [l]. However, this sound is very variable in pronunciation in different languages (Walsh Dickey, 1997) and transcription proved to be difficult. Therefore, Dos Santos & Ferré (2016) decided to use the [l]. The vowels which were used are [i], [a] and [u]. The reason for this is that they are the most common vowels across languages (Maddieson et al., 2011).

Table 14: The sounds for the language independent part

Stops	[p] [k]
Fricative	[f]
Liquid	[l]
Vowels	[i] [a] [u]

Items were considered more complex when place and/or manner of articulation differed between consonants as compared to similar place and or/manner of articulation between consonants (Fikkert & Levelt, 2008). In addition, non-words consisted of one, two or three syllables in order to be able to create more different structures. Three syllable words were included because these words are very common in German. Therefore, Grimm (2012) included three syllabic words in the German version. To keep the different languages comparable, three syllable words were added in the French version as well. Words were made no longer than three syllables in order to minimize the effect of phonological short-term memory. Table 15 (taken and adjusted from Dos Santos & Ferré, 2016) shows what the classification of complexity is based on. Stress was placed on the last syllable in all items.

Table 15: Complexity aspects taken into account in the development of the LITMUS-NWR-FRENCH test (Dos Santos & Ferré, 2016, p. 4).

Complexity		-	+	Examples & References
Segmental	Labial	Dorsal	[p] vs. [k]	Jakobson 1969; Aicart-De-Falco & Vion 1987; Johnson & Reimers 2010 ; Yamaguchi 2012
	Stop	Fricative	[p] vs. [f]	
Syllabic	CV	CCV and CVC#	[ka] vs. [kla]	Jakobson & Halle 1965; Levelt, Schiller & Levelt 2000; MacNeilage 2008
Sequential	Segment	Same place	Different place and/or manner	Kern & Davis 2009; Fikkert & Levelt 2008
		Lab-Dor	Dor-Lab	Costa 2010; Gerlach 2010; MacNeilage 2008; Santos 2007
	CCV and CVC in 3 σ NW	In 1st and 3rd position	In 2nd position	Braud 2003; Demuth & Song 2012; Marshall & Van der Lely 2009

30 French language independent non-words (Dos Santos & Ferré, 2016) were constructed. 10 of these were control items. These were easy items, in order to see whether the child is able to produce consonant clusters in a one syllable word (e.g. *pli*), final consonants (e.g. *kip*) and the CVCV structure (e.g. *pilu*). The experimental items were considered more complex.

This task was designed for research and clinical purposes. For research, two examples of each structure were included in order to make good comparisons later. This version can be described as the long version and this version was used in Dos Santos & Ferré (2016). The non-words used in the long version can be seen in Table 16 below. However, since they also wanted the test to be of use in clinical settings, they wanted to reduce the number of items in the test in order to make the test less time consuming. Therefore, Tamiatto's master thesis (2014) investigated which non-words could be left out. The NWRT was administered to 85 children aged 5;2 to 8;10. Item reduction analysis was applied on the data, based on classical test theory. Results showed that several items were not informative enough; they were either too hard or too easy. Some of these easy items were control items. Some of these items were left out. However, it was decided to keep a few control items in the test. The decision which ones to leave in the test were based on difficulty; the hardest ones out of the easy items were kept in the test (based on the performance of the children). Reasons for keeping control items were that it will motivate the child, assuming that most children will be able to repeat these items. In addition, these non-words can be used to detect severe impairment, if children are not able to repeat these items correctly. The short version, based on the findings of Tamiatto (2014), consisted of 21 items and can be seen in Table 16 below.

Table 16: The French language independent items of the long and short version.

Control Items	French Long Version	French Short Version
CCV	[plu] [kla] [fli]	[plu]
CVC	[kip] [fuk] [paf]	[kip] [fuk]
CV.CV	[piˈlu] [kaˈpi] [faˈku] [laˈfi]	
Experimental Items		
CCV.CV	[pliˈfu] [fluˈka]	[pliˈfu]
CV.CCV	[paˈklu] [fuˈpli]	[paˈklu] [fuˈpli]
CV.CVC	[kaˈfip] [puˈkif]	[kaˈfip] [puˈkif]
CV.CVCV	[pufaˈki] [kifaˈpu]	[pufaˈki] [kifaˈpu]
CCV.CCV	[plaˈklu] [flaˈplu]	[plaˈklu] [flaˈplu]
CCV.CVC	[kliˈfak] [fluˈkif]	[kliˈfak] [fluˈkif]
CV.CCV.CV	[piklaˈfu] [kuflaˈpi]	[piklaˈfu] [kuflaˈpi]
CV.CV.CCV	[kupiˈfla] [fikuˈpla]	[kupiˈfla]
CCV.CV.CV	[klipaˈfu] [flipuˈka]	[klipaˈfu] [flipuˈka]
CV.CV.CVC	[kapuˈfik] [pifaˈkup]	[kapuˈfik] [pifaˈkup]

Now turning to the Dutch version, the same sounds and syllable structures as in the French version (Dos Santos & Ferré, 2016) were used. Stress placement was different in the Dutch task. In the French test (Dos Santos & Ferré, 2016) stress was placed on the last syllable and in the German version (Grimm, 2012) on the first syllable. In the Dutch version stress was placed on the first syllable in all items, except for the three syllabic words with internal codas, since it is not possible for these words to have initial stress (Kager, 1989). In these non-words, stress was placed on the second syllable. Reason for specific stress placement in the items is that studies on prosody in Swedish (Sahlén et al., 1999) and English (Chiat & Roy, 2007; Williams et al., 2013) showed that children benefit from stress patterns which are common in their native language. Initial main stress is a common stress pattern in Dutch. However, pre-final stress is almost as common (Kager, 1989). It was chosen to use initial stress since this was in line with the German version (Grimm, 2012). In this way, the stress pattern was similar in the German (Grimm, 2012) and Dutch version, except in the cases where this stress pattern is strictly not allowed in Dutch.

The 30 French language independent non-words from the long version (Dos Santos & Ferré, 2016) were used as a guideline to develop the non-words for the Dutch version. The French items were copied as much as possible. However, if these items were Dutch existing words, or closely resembled Dutch existing words, the items were changed. Change was done by switching the consonants and/or vowels (only using the sounds shown in Table 14). During the switching of sounds much attention was spend on keeping the balance between the different used sounds as equal as possible throughout the test. In order to keep this balance, sounds had to be changed.

After the Dutch non-words were either taken or changed from the French long version (Dos Santos & Ferré, 2016), a word likeness test was administered consisting of the resulting Dutch non-word list. This test (see Appendix F) was administered in order to know whether the non-words were associated with existing Dutch words. Dutch native participants were asked to indicate on a 5 point scale how much the non-word resembled an existing Dutch word or was an existing Dutch word. The non-words were printed on a sheet of paper and they were asked to indicate on the scale which was printed next to the non-words. In addition, the researcher read the non-words out loud. This was done to make sure all participants based their scores on the intended stress and syllable structure. The participants were also asked to write down which existing word(s) they were thinking of if they scored the non-word as a word that resembles an existing word. 15 students of Utrecht University filled in the word likeness test. 13 of them were enrolled in the master's programme Multilingualism and Language Acquisition and two students were enrolled in the research master's programme Linguistics. Two teachers filled in the word likeness test as well. Non-words judged as resembling an existing Dutch word by many participants (scored 4 or 5 on the 5 point scale) were changed. Many syllables which were existing Dutch words were excluded based on the word likeness test. The following syllables were excluded:

Figure 30: Syllables which were excluded based on the word likeness test.

[pa]	'dad'
[ku]	'cow'
[fla]	resembles [vla] 'custard'

[sla]	‘lettuce’
[ski]	‘ski’
[spa]	‘spa’

Even tough [fla] is not an existing word, [vla] is. Considering that many Dutch speakers produce [f] instead of [v] in many cases, this syllable resembles the existing word [vla] too much which resulted in exclusion of this syllable. However, the consonant combinations in Figure 30 were still used in combination with another sound in the same syllable. For example [kus], [flamp], [skif] and [spaf] were used since the meaningful syllable had been changed by inserting a sound. One syllable which was an existing word in isolation, [kup] (‘haircut’), was kept in the test in order to create more combinations in the non-words. This was only done since it was expected that children would not know this word. This syllable was not used in monosyllabic words, only in longer words in case the child knew the word after all. The effect would be smaller in a longer word compared to when the word would be recognized in isolation.

Changing non-words because they resembled existing Dutch words too much was difficult at times because many new combinations closely resembled others Dutch existing words. Therefore, it was not possible to balance the different sounds (mostly vowels) within structures. For example, the CCV items all contained the vowel [i]. However, it was decided that this imbalance was better than including words which highly resembled a Dutch existing word. Since the focus of this task was on the consonants and syllable structures and not on the combination of the specific vowels with the consonants, this vowel imbalance was not considered as a problem. However, it was made sure that all sounds were balanced across all structures of the entire test (across the three parts).

After this, the French short version was taken into account. This version was not taken into account earlier, because its existence was not known to the researcher at first. However, it was taken into account at this point because the researcher wanted to reduce the number of items of this part if possible, considering that a language dependent 2 part was added. The total test could not have too many items because it was hypothesized that children would become bored or not cooperate if the entire test consisted of too many items.

Some of the control items which were excluded in the French short version were excluded in the Dutch version as well. Reason for this is that it was shown by Tamiatto (2014) that these items were not informative (as discussed above). However, one instance of a structure which was left out in the French short version was kept in the Dutch version because it was believed to motivate the child and to detect severe impairment. Additionally, it was decided to keep one instance of this structure to see how the children performed on this structure. The structure was CVCV.

For the control items it was decided that one example of a structure was not a problem, considering that most children would be able to do these because they were considered easy. However, in the other items it was decided to keep two examples per structure for research purposes, considering that it would improve the comparison possibilities. In addition, the main aim of this study is to understand at what age children correctly produce which structures and consonant clusters. Since this goal is mainly research based and not clinically based, it was decided to include two examples of each structure in the more complex scales. Due to time issues, it was not possible to do a word likeness test with the resulting non-words again. The Dutch items can be seen in Table 17 below.

Table 17: The Dutch language independent items.

Control Items	Dutch Version
CCV	[pli]
CVC	[kuf] [fik]
CV.CV	[ˈlaki]
Experimental items	
CCV.CV	[ˈplifu] [ˈflika]
CV.CCV	[ˈpikla] [ˈkapli]
CV.CVC	[ˈkafip] [ˈpukaf]
CV.CVCV	[ˈpufaki] [ˈkifapu]
CCV.CCV	[ˈplaklu] [ˈklaplu]
CCV.CVC	[ˈklifak] [ˈflukif]
CV.CCV.CV	[ˈpiklafu] [ˈkaflipu]
CV.CV.CCV	[ˈkapufli] [ˈfikaplu]
CCV.CV.CV	[ˈklipufa] [ˈflipuka]
CV.CV.CVC	[ˈkapufik] [ˈpifakup]

5.3.2. The Language Dependent Part 1 (LD1)

The first Dutch language dependent part was adapted from Dos Santos & Ferré (2016). First, information will be given about the French language dependent part. Dos Santos & Ferré (2016) created the French language dependent items with the same sounds as in the language independent part: [p, k, f, l, i, a, u]. They added [s]. This sound was added in order to be able to create the following structures: #sCV, #sCCV, sC# and Cs#. These structures are considered to be complex and do not occur in many languages (Goad & Rose, 2004). However, they do occur in French, which makes this sound specific to French (not only to French, but to French among other languages). In addition, the acquisition of these kind of clusters have theoretical relevance since the structures deviate from consonant clusters without /s/, as shown in Chapter 2.

Therefore these structures were used for the language dependent part. The following consonant clusters were included in initial position: /sp-, sk-, spl-/ and in final position: /-sp, -sk, -ps/. In addition, the single final consonants /-s, -l/ were also added. In addition, internal codas /-l-/ and /-s-/ were also added in this part. Reason for this was that children with SLI have difficulty with internal codas (Ferré et al., 2015). Since the French test aimed to disentangle children with SLI form bilingual children, it was useful to include this structure since children with SLI are not able to produce them correctly. In this way it could be used to detect which children had SLI. The language dependent part was considered to be more complex than the language independent part, considering that more difficult structures were added. Similar to the language independent part, two version of the French test were constructed. First the long version, which was used in Dos Santos & Ferré (2016), and later the short version based on the findings of Tamiatto (2014). Both version are displayed in Table 18 below. The long version consisted of 41 items and the short version of 29 items.

Table 18: The French language dependent items of the long and short version.

Control Items	French Long Version	French Short Version
CVC	[kis] [fal]	[kis]
sCV	[spu]	[spu]
Experimental Items		
CV.CVs	[kiˈfus] [faˈpus]	[faˈpus]
CV.CVL	[faˈpul] [kuˈfal]	
CV.CV.CVs	[kifaˈpus] [pifuˈkas]	[pifuˈkas]
CV.CV.CVL	[fikaˈpul] [pakiˈfal]	
CCVC	[klaf] [fluk]	
CCVL	[plal] [klil]	[plal] [klil]
CVCs	[fips] [piks]	[fips] [piks]
CVsC	[pusk] [kusp]	[pusk] [kusp]
CCVs	[flis] [klis]	[flis] [klis]
sCV.CV	[skaˈfu] [spiˈku]	[skaˈfu]
sCCV	[skla] [spli]	[skla] [spli]
sCVC	[skap] [spaf]	[skap] [spaf]
CVL.CV	[pilˈfu] [filˈpa]	[pilˈfu] [filˈpa]
CVs.CV	[kusˈpa] [fisˈka]	[kusˈpa]
CCVCs	[pliks] [klups]	[pliks] [klups]
CCVsC	[klisp] [plusk]	[plusk]
CV.CVL.CV	[kufalˈpi] [kupalˈfi]	[kufalˈpi] [kupalˈfi]
CV.CVs.CV	[pafusˈki] [fikusˈpa]	[pafusˈki] [fikusˈpa]
sCV.CV.CV	[skapuˈfi] [spakiˈfu]	[skapuˈfi] [spakiˈfu]

Turning to the Dutch version, the same sounds and syllable structures as in the French version (Dos Santos & Ferré, 2016) were used. This means that for the Dutch part, [s] and internal codas were also added. This was done since these are allowed in Dutch as well.

Moreover, consonant clusters including [s] are very common in Dutch. Therefore, the addition of [s] and internal coda was also good to form the Dutch dependent part.

The used consonant clusters were different in the Dutch version compared to the French one. For a comparison of the used consonant clusters in the dependent part in French, German and Dutch, see Appendix H. The inital /sp-, sk-, sl-, spl-/ and the final / -ks, -ps/ were selected for the Dutch version, because these were the most frequent clusters which were possible to construct with the given sounds. The frequencies can be found in Table 19 and they were taken from CELEX (Baayen, Piepenbrock & Gulikers 1995) by Kager (personal correspondence, 2018). More particularly from the CELEX DPL (Dutch Phonology Lemma) file. This lexicon consisted of 9861 lemmas and 46654 phonemes. The frequency of /spl-/ is quite low, but it was included in order to include an onset with three consonants in the test. The other possible combinations which could be made with the available sounds were /sfl-/, which does not occur in the Dutch language, and /skl-/ of which the frequency was 0 in the CELEX list (however, it can occur in one word in Dutch; *sklerose* ('sclerosis')). In addition, /sf-, -sp, -sk, -fs/ were also not used because of their low frequency in Dutch. since they are not frequent in Dutch. The frequencies of these clusters can also be seen in Table 19.

Table 19: The frequencies of the used consonant clusters

Used consonant cluster	Example	Frequency of cluster
sp-	*speer* ('spear')	208
sk-	*ski* ('ski')	41
sl-	*slaap* ('sleep')	142
spl-	*spleet* ('cleft')	11
-ks	*ex* ('ex')	46
-ps	*chips* ('crisps')	18
Not used consonant clusters		
sf-	*sfinx* ('sphinx')	2
skl-	*sklerose* ('sclerosis')	0
-sp	*wesp* ('wasp')	7
-sk	*basilisk* ('cockatrice')	11
-fs	*zelfs* ('even')	2

In addition, the final consonant /-l/ and internal coda /-l-/ were not used, since this sound tends to be vocalised in Dutch. Since it would be very difficult to transcribe this sound in syllable final position, it was decided to leave internal coda /-l-/ out. It was chosen to include internal coda /-s-/ just as in the French version, since this is possible and quite common in Dutch. An example is the word *as-bak* (‘ashtray’). Since internal coda /-l-/ was left out, internal coda /-s-/ was used in two structures (also in the structure which included internal /-l-/ in the French version). This resulted in the use of internal coda /-s-/ in bi and trisyllabic non-words. This was done to see how children would perform on internal consonants in different word lengths.

It was decided that no control items were included in the Dutch version of this part. This was done because the language dependent part was supposed to be more complex than the language independent part, and considering control items are seen as easy, these were not wanted in this more difficult part of the test. Moreover, as also mentioned in the description of the Dutch language independent part (Section 5.3.1), priority was given to reducing the number of items in this part compared to the French version, because the Dutch version also included a second language dependent part. The entire test could not have too many items, because it would take too long for the young participants to complete the task. Therefore, the language dependent part 1 of the test needed to be shorter than the language dependent part of the French test.

Additionally, almost no non-words with initial /pl-, kl-, fl-/ were used in this part. Considering that /pl-, fl-, kl-/ were already included in the language independent part and that they are less complex than clusters with [s], it was decided to leave them out in the dependent part to reduce the number of items. These clusters were only used twice in the Dutch dependent part in order to create CCVCC structures with different consonants in initial and final position.

After it was decided which consonant clusters and single consonant to use and which items and consonant clusters not to use in the Dutch dependent part, the structures used in the French test in which these chosen sounds could be used were selected. The Dutch language dependent part 1 items were constructed in a similar way as the Dutch language independent part items; the French dependent items were copied were possible. However, if these non-words resembled Dutch existing words, they were changed. The existing words found by the word likeness test portrayed in Figure 30 were not used in this part either. Changes were done by changing the consonants and/or vowels (only using the sounds shown in Table 14). Again, it was tried to keep all used sounds balanced across the test. In order to keep this balance, sounds had to be changed. Again, due to time issues, it was not possible to administer a word likeness test. The Dutch items of the language dependent part are shown in Table 20. Again, in order to make better comparisons later on, two items of each structure were included.

Table 20: The Dutch language dependent 1 items.

Experimental Items	Dutch Version
CV.CV.CVs	[ˈkifapus] [ˈpifukas]
CVCs	[faps] [puks]
sCV.CV	[ˈslipu] [ˈslufa]
sCCV	[spla] [spli]
sCVC	[skif] [spaf]
CVs.CV	[ˈkusfi] [ˈfuspi]
CCVCs	[plaks] [flaps]
CV.CVs.CV	[piˈfuska] [faˈkuspi]
sCV.CV.CV	[ˈskapufi] [ˈspikafu]

5.3.3. The Language Dependent Part 2 (LD2)

This part was not based on Dos Santos & Ferré (2016). This part was added in order to add typically Dutch sounds. In this way, this language dependent part is more based on the Dutch language; it is more dependent on Dutch. The same sounds were used as in L1. However, [x] and [m] were added. They were chosen because they are both frequent in initial and final position in Dutch. As explained above, internal coda /-l-/ was not used since transcription would have been difficult considering that /l/ tends to be vocalised in Dutch. /m/ is a good alternative for /l/; they are both sonorants, occur both in single and complex initial and final positions and are both allowed in internal coda position. However, internal coda /-m-/ is not 100% allowed in Dutch words after a long vowel if the second consonant of the cluster (the one after the internal /m/) is not a coronal (Kager & Pater, 2012). Since the next consonant needed to be a /p,t,k/ or order to be comparable with the rest of the test and with the French test, the next consonant was never a coronal in this test. Possible solutions were that short vowels were used in this case, however, than the Dutch set would be not comparable to the French one, and we want them to be comparable. Another option was to use /-n-/ instead. However, then a new place of articulation would have been introduced which also would result in less comparable sets. Another consideration could have been to use other labials like /p,f/ but these were already part of the French set. Since it was desirable to include internal codas in the second dependant part as well, in order to compare the two dependent parts to each other and to the French version, it was decided that using internal /-m-/ was the best option.

Additionally, [x] is a typically Dutch sound. It is also acquired quite late (around the age of 2;0-2;2) (Beers, 2012). In consonant clusters it is acquired and mastered even later; around the age of 4 (Stes, 1977). Therefore, it can be considered a complex sound. Since LD was supposed to be more complex than LI, it was decided to add [x] to make LD2 more complex than LD1 and LI.

Table 21 shows which single consonants and consonant clusters in initial and final position were used to create the LD2 items. Consonant clusters with and without /s/ were included. /pl,kl,fl/ were only used to create different consonants in the CCVCs structure just as in the language dependent part 1. They were not used in other items because they are already used in L1 and because they are not considered difficult (considering that they are acquired early, see Fikkert, 1994).

Table 21: The used consonant and consonant clusters to create the Dutch LD2 items

Onset	Coda
xl-	-x
sm-	-m
sx-	-ms
	-m-

After choosing the consonants and consonant clusters, they were matched with structures. The same structures were used as in the Dutch LD1 part. In this way, the same structures could be compared with the different sounds. Not all structures used in L1 were used in L2 because it would result in too many items. Table 22 shows the Dutch items of the LD2 part matched with the LD1 structures.

Table 22: The Dutch language dependent items of LD1 and LD2 (C stands for the consonants p,k,f,l).

Experimental Items	Dutch LD1	Dutch LD2
CV.CV.CVs/x/m	[ˈkifapus] [ˈpifukas]	[ˈpukifax][ˈfapukix][ˈpifukam][ˈkapufim]
CVCs	[faps] [puks]	
SC/mV.CV	[slipu] [slufa]	[ˈsmuka] [ˈsmapu]
sCCV	[spla] [spli]	
s/xCVC	[skif] [spaf]	[xlap] [xlik]
CVs.CV	[ˈkusfi] [ˈfuspi]	
CCVC/ms	[plaks] [flaps]	[flims] [klums]
CV.CVs/m.CV	[piˈfuska] [faˈkuspi]	[puˈkimfa] [kaˈfimpu]
sC/xV.CV.CV	[ˈskapufi] [ˈspikafu]	[ˈsxapuki] [ˈsxufapi]

5.3.4. Overview: The Dutch NWRT

The previous sections showed how the Dutch version of the NWRT was created. Table 23 gives an overview of the Dutch NWRT with three parts; a) the language independent part (LD1), b) the language dependent part (LD1) and c) the language dependent part (LD2).

Table 23: All items in the Dutch NWRT (LI = language independent, LD = language dependent).

Control Items; LI	
CCV	[pli]
CVC	[kuf] [fik]
CV.CV	[ˈlaki]
Experimental Items ; LI	
CCV.CV	[ˈplifu][ˈflika]
CV.CCV	[ˈpikla] [ˈkapli]
CV.CVC	[ˈkafip] [ˈpukaf]
CV.CVCV	[ˈpufaki] [ˈkifapu]
CCV.CCV	[ˈplaklu] [ˈklaplu]
CCV.CVC	[ˈklifak] [ˈflukif]
CV.CCV.CV	[ˈpiklafu] [ˈkaflipu]
CV.CV.CCV	[ˈkapufli] [ˈfikaplu]
CCV.CV.CV	[ˈklipufa] [ˈflipuka]
CV.CV.CVC	[ˈkapufik] [ˈpifakup]
Experimental Items; LD1	
CV.CV.CVs	[ˈkifapus] [ˈpifukas]
CVCs	[faps] [puks]
sCV.CV	[ˈslipu] [ˈslufa]
sCCV	[spla] [spli]
sCVC	[skif] [spaf]
CVs.CV	[ˈkusfi] [ˈfuspi]
CCVCs	[plaks] [flaps]
CV.CVs.CV	[piˈfuska] [faˈkuspi]
sCV.CV.CV	[ˈskapufi] [ˈspikafu]
Experimental Items; LD2	
CV.CV.CVx	[ˈpukifax] [ˈfapukix]
CV.CV.CVm	[ˈpifukam] [ˈkapufim]
smV.CV	[ˈsmuka] [ˈsmapu]
xLVC	[xlap] [xlik]
CCVCs	[flims] [klums]
CV.CVs.CV	[puˈkimfa] [kaˈfimpu]
sCV.CV.CV	[ˈsxapuki] [ˈsxufapi]

5.4. Transcription and coding

The NWRT was transcribed after the recording session ended. Transcription was done in an Excel sheet. The target production and incorrect productions by the child were transcribed in IPA. If the child production was corrected, this was indicated with a 1. A non-word was counted as incorrect when at least one error occurred in the child's production. The following instances were *not* coded as errors:

1. If target /s/ was pronounced as /ʃ/.*
2. If target /m/ was pronounced as /n, ŋ/.*
3. If unvoiced target consonants were produced as voiced consonants. Reason for this is that it can be very difficult for the transcriber to notice the voicing contrast in child speech (Scobbie, 1998). In addition, it was not marked as incorrect in Dos Santos & Ferré (2016) and in a picture naming task focussing on consonant acquisition by Kirk & Demuth (2005).*

   *1,2 and 3 were not coded as errors, since this study is concerned with the ability to produce certain type of consonants in clusters, and not as much in the precise place of articulation.
4. If a vowel was produced which differed only one feature from the target vowel. For example, if target /u/ was pronounced as /o/, these two sounds only differed in the fact that the mouth is more open in /o/. These kind of differences were not counted as errors. Tense was seen as an extra feature. Therefore, the difference between a tense vowel like /u/ and the lax vowel /ɔ/ was counted as incorrect, since two features differed; tense-lax and close-mid.
5. Whenever the transcriber was not sure about the exact production of the child, and the production was in between two sounds. For example, if it was not sure whether /a/ or /ɛ/ was produced, it was transcribed as /a/ and counted as correct.

In addition, if the child produced a false start (for example, /pi/ short break /pli/), the second production was always used for transcription. In addition, if children made many errors in a non-word, this non-word was included. No exclusion of single non-words occurred based on many errors. In addition, there was one instance in which a child did not produce any sounds. This instance was excluded since it was not informative about the production ability of the child.

Table 24 shows what the coding file looked like. The structure of the file was similar to the French file. However some changes were made in grouping the segments together.

Consonant clusters were grouped together in one cell. The file contained more information (date of birth, date of testing etc.) but this is left out here. All the productions of one child were listed and all the productions of the next child were listed underneath etc. The coding of errors was done based on the manual of the French NWRT (Dos Santos & Ferré, 2016). This manual can be found in Appendix I. The following errors were coded: insertion (I), substitution (S), metathesis (M = switching of sounds) and deletion (D). Examples of these errors can be found in Table 24, example 15,2,8 and 4 respectively. The subgroups (different kinds of substitution like gliding for example) were not coded. Coding of the errors was done in the corresponding structure on the right. The abbreviations in Table 24 are explained in Figure 31 below. All the abbreviations used in this paper can also be found in Appendix A. The different shades of grey indicate the three different syllables in Table 24.

Figure 31: Abbreviations and examples of the structures used for coding

FC	=	final consonant, e.g. /pi.fa.kus/
FCS	=	final consonant + /s/, e.g. /plaks/ (consonant cluster)
V	=	vowel, e.g. /pi.fa.kus/
ISCC	=	initial /s/ + two consonants, e.g. /spli/ (consonant cluster)
ISC	=	initial /s/ + consonant, e.g. /spi.ka.fu/ (consonant cluster)
BIC	=	branching initial cluster, e.g. /plaks/ (consonant cluster)
IH	=	initial head, e.g. /pi.fa.kus/
MC	=	medial consonant, e.g. /fus.pi/
M	=	metathesis
D	=	deletion
I	=	insertion
S	=	Substitution

Table 24 is to be read from right to left. The first three examples in Table 24 show a mono-, bi- and trisyllabic non-word, and were the place of the segments in the coding table is. If no errors occurred, as in the first line in Table 24, 0's were placed in the corresponding cells for the segments of the non-word. For example, /xlap/ has an initial branching cluster /xl/, and a vowel /a/ and a final consonant /p/. All these segments/clusters are coded separately. However, if an error occurred, the 0 was replaced by a letter indicating the error. The second example in Table 24 shows a substitution error; /p/ is substituted by /f/. The code for substitution, S, is written in the initial head cell, since this is the substituted segment.

Every segment or cluster was coded separately. If an error was made in a consonant cluster, it was indicated in which part of the cluster the error occurred. 4,5, and 6 in Table 24 illustrate this; if an error was made in the first, second or third segment of the clusters, this was indicated with a 1, 2 or 3 respectively. If a combination of errors was made, this was also indicated in the corresponding cell, as shown in example 7. This was then counted as two errors.

The number of errors were counted automatically in Excel. In addition, whether the total item was correct or not was also indicated in the file (1 = correct, 0 = in correct).

Table 24: Example of coding file. The shades of grey indicate the different syllables (TargetP = target production, ChildP = child production, C/IC = correct/ in correct, NrE = number of errors, E = extra, FCS = final consonant + /s/, FC = final consonant, V = vowel, ISCC = initial /s/ + 2 consonants, ISC = initial /s/ + consonant, BIC = branching initial cluster, IH = initial head, MC = medial consonant).

Nr	**TargetP**	**ChildP**	**C/IC**	**NrE**	**E**	**FCS**	**FC**	**V**	**ISCC**	**ISC**	**BIC**	**IH**	**MC**	**V**	**ISC**	**BIC**	**IH**	**MC**	**V**	**ISC**	**BIC**	**IH**
1	xlap	1	1	0	0		0	0			0											
2	kus.fi	pus.fi	0	1	0			0			0		0	0			S					
3	spi.ka.fu	1	1	0	0			0				0		0			0		0	0		
4	kla.plu	ka.plu	0	1	0			0			0			0		D2						
5	kla.plu	pla.plu	0	1	0			0			0			0		S1						
6	spli	spi	0	1	0			0	D3													
7	plaks	pla	0	2	0	D1D2		0			0											
8	fli.ka	kli.fa	0	1	0			0				m		0			M					
8	fli.ka	fi.kla	0	1	0			0			(m)			0		M2						
9	fli.pu	flip.ku	0	2	0			0				MI	(m)	0		0						
10	ka.pu.fi	ka.fup.fi	0		0			0				0	(Im)				M		0			0
11	fli.ka	fli.kas	0	1	0		(I)	0				0		0		0						
12	ka.fip	kas.fip	0	1	0		0	0				0	(I)	0			0					
13	ka.fip	ka.fips	0	1	0		I	0					0	0			0					
14	ka.fip	kla.fip	0	1	0		0	0				0		0		(I)	0					
15	flaps	flapts	0	1	0	I		0			0											
16	plaks	plats	0	1	0	S1L		0			0											
17	pli	plika	0	2	2			0			0											
18	fli.ka	flik	0	3	0			D				D	(I)	0		0						

Some changes were made to the French coding system. These are shown in the list below.

1. Whenever metathesis occurred, this was indicated with M in the cell of the first affected segment. In addition, the second involved segment, or the place where the first segment moved to, was indicated with m. This is shown in Table 24, 8.This (m) did not count as an extra error for the total number of errors made in the non-word. This was done in order to mark that a change occurred in the place where the segment lands. This was useful for the consonant cluster analysis later, in which (m) was counted as an error since it changed the structure of the second segment.
2. Difficult metathesis cases like /fli.pu/ → /flip.ku/ (shown in 9, in which the /p/ moves forward) were coded in the following way. The sound which moved was coded as metathesis, and the place where that sound originated was marked as insertion, since an extra sound was inserted there. These kind of errors were not coded as insertion in the

internal position (*flip.ku*) because the segment came from the next syllable; it is a difficult case of metathesis. 10 shows an example in which the metathesis moves the other way.

3. If an error occurred in a new position (i.e. a position which was not included in the target structure) this was indicated with brackets. This is shown in Table 24, 11 and 12.
4. Additions to single consonants (resulting in consonant clusters) were coded in the cell of the single consonant (as shown in 13), except when they formed branching initial clusters (by added /l/, /r/). In this last case they were coded in the branching initial cluster cell, as can be seen in 14. Note: additions to clusters were coded in the cluster cells (15).
5. Lexicalisation was only coded as such if the entire production was an existing word. For example, if the child said /plats/ ('place') instead of /plaks/, this was coded as lexicalisation. However, if a child produced /ku/ ('cow') in a bi- or trisyllabic word, this was not seen as lexicalisation. Lexicalisation was marked by an L, as can be seen in 16. Lexicalisation did not count as an extra error.
6. If a syllable was added, this was coded as shown in 17. The segments corresponding with the target segments were coded, and the extra segments which did not fit into the grid, were counted and written in the column extra. Each extra segment counted as an error. The addition of two segments thus resulted in two errors.
7. If a syllable was deleted or insertion, simplification occurred when the deleted/inserted syllable was not a separate syllable, as shown in 18. The deleted segments were counted and written in the extra column. If an extra sound was added as a final consonant to the existing structure, this error was coded as addition. Coding these syllable deletion was simplified since no metathesis was taken into account. This was not done because it proved to be too difficult to also incorporate this.

5.5. Analyses

All the Figures accompanying the results were made in Word, SPSS and Statistica. As shown in Table 24, it was coded whether a non-word was correct or not. This was called exact repetition of a non-word. The analyses are divided in three main parts: the analyses on exact repetition, the analyses on the number of errors, the analyses on exact repetition of different structures and the analyses on the different kind of errors.

5.5.1. Analyses on exact repetition

Multiple analyses were done concerning the exact repetition, as shown in the list below. These analyses were mainly about different aspects of performance of the children on the NWRT. In addition, analyses about the relation between the performance on the NWRT and phonological working memory and between performance and vocabulary were included in this part.

1. **Exact repetition of non-words per age group**
   A one way between groups ANOVA with post-hoc analysis was done.
2. **Exact repetition of non-words in LI, LD1 and LD2**
   The correct number of responses in each part was converted into a percentage taken the number of items per part into account, since these are not similar (LI = 24, LD1 = 18 and LD2 = 14). After this, three paired sample t-tests were done for each age group to see whether the scores on each part differed.
3. **Exact repetition of non-words containing 0,1 and 2 consonant clusters**
   The correct number of responses per non-word group (including 0,1 or 2 consonant clusters) was converted into a percentage taken the number of items per part into account, since these are not similar (0 clusters = 15, 1 cluster = 35, 2 clusters = 6). After this, Wilcoxon tests were performed to compare whether the performance was different in non-words containing 0,1 and 2 clusters.
4. **The correlation between exact repetition of non-words and Digit Span**
   Only the scores on the Digit Span Forward Test were analysed, since this is the test that measures phonological short-term memory which is what we wanted to investigate. In addition, many of the young children were not able to do the Backwards test. To assess whether the number of exact repetitions and the scores on the digit span test correlated, a Kendall’s tau-b test was used for the 3 and 5 year old children. Since the data for the 4 year old children was normally distributed, a bivariate Pearson’s product-moment correlation coefficient (r) was calculated.
5. **The correlation between exact repetition of non-words and PVVT**
   To assess whether the number of exact repetitions and the scores on PVVT correlated, a Kendall’s tau-b test was used for all age groups.

5.5.2.Analyses on the number of errors

This analysis focused on the number of errors made in total in the non-words. This is not just the reversed perspective on the measure used in the previous analyses. In the previous analyses, the exact repetition of non-words was counted in a binary fashion (i.e. 1 = correct, 0 = not correct). However, the number of errors are not a binary measure; more than 1 error can be made in 1 non-word or one structure. The following analysis was done in order to get an overall impression about how the children performed on the test.

The number of errors per age group

All errors were included in this analysis, also errors in vowels and single initial and final consonants. Since the assumption of normality was violated for one of the three age groups, a Krukal-Wallis ANOVA was used. To see which age groups differ significantly, separate Mann-Whitney *U* tests were used.

5.5.3. Analyses on exact repetition of different structures

Some of the coded segment groups, as shown in Table 24, were taken together to form new cluster groups. The initial branching consonant clusters from the three syllables were taken together, forming the obstruent-liquid cluster group. This group was named the branching initial cluster group. 23 instances occurred per set (the entire non-word list for 1 child). In addition, the initial /s/-consonant structures and the /s/ + two consonant structures were taken together to form the /s/ + Consonant group (ISC), of which 12 instances were present in the set. The medial consonant clusters were taken together as well, forming the medial C group (M) with 6 instances. Lastly, the final consonants formed the last group: Final C (FC) with 18 instances. These cluster groups are shown in Table 25. Initial heads were not analysed, since they were no point of interest. Since it was decided earlier to design the test in line with the French version, unfortunately no equal number of instances were present per group. This will be discussed further in the discussion (Chapter 7).

Table 25: Cluster groups with the number of instances per group (C = consonant).

Structure	**Branching initial (BIC)**	**Initial /s/ + C (ISC)**	**Final C + /s/ (FCS)**	**Final C (FC)**	**Medial C (M)**
	Pl 7	sp 2	ks 2	p 3	s 4
	kl 7	sl 2	ps 2	f 5	m 2
	fl 7	sx 2	ms 2	k 4	
	xl 2	sm 2		s 2	
		sk 2		x 2	
		spl 2		m 2	
Total	**23**	**12**	**6**	**18**	**6**

The coding file included the errors in letters (I, M, m, D and S). To clarify, m was taken into account and seen as an error (because this was looked at from the cluster groups and a change occurred in a cluster group, which is seen as an error) in these analyses. Another clarification needs to be made; when deciding whether an error was made in medial structure, the consonant after the internal codas was also taken into account because it form the consonant cluster together.

The letters which coded the errors were changed into the number one. If there were multiple errors in one cell, they were counted as one. This is because we wanted to know whether the structure was produced correctly or not in a binary way (the analysis for the specific number of errors was presented in Section 5.5.2). In this way the number of errors per age group and per structure could be counted. The following analyses were done tying in with research question 1 about the specific age when children can produce the different structures, with research question 2 about whether more errors are made in certain structures and with research question 4 about whether consonant clusters are produced more accurately in initial or final position.

1. **Exact repetition of different structures**

   In order to compare the number of exact repetitions on the different structures, Wilcoxon signed rank tests were performed. To compare between age groups, Mann Whitney U tests were used. These tests were selected since the data was not normally distributed. It was specifically decided to do these analyses in the same way as the analyses done by Dos Santos & Ferré (2016) and Ferré et al. (2015), in order to keep both data sets comparable.
2. **Descriptive analyses: The ability to produce and make 0 errors and the acquisition of structures**

   Per age group, it was counted how many children were able to produce the different structures and did not make any errors. The number of children who did not make any errors were also changed into percentages per age group and structure. Note that since the total was taken as how often the structure occurred in the target items, and insertion in new positions was also counted, it is possible to have an error rate of more than 100%.

   In addition, the minimum, maximum and average percentage correct on the different structures was noted per age group and per structure. In addition, the average percentage incorrect was also noted. In addition, it was calculated how many of the children had acquired the different structures. More information about when structures are seen as acquired can be found in Section 5.6.

5.5.4. Analyses on the different kind of errors

These analyses were done in order to get insights in the kind of errors children made. These analyses tie in with research question 3.

Descriptive analyses on the different kind of errors

Only the consonant clusters were taken into account in these analyses (i.e. final consonant-/s/ clusters, branching initial clusters, initial /s/-consonant clusters and medial clusters). This means that the total number of mistakes in this section is not similar to the total number of mistakes used in the statistically consonant cluster analyses. However, this is not a problem since the analysed clusters in this section are the clusters this research is interested in. Single consonants in initial and final position were not analysed. The reason for this is that it is expected that children of 3-5 are able to produce these correctly and because this research is interested in consonant clusters rather than single consonants.

The different kind of errors were analysed by counting how often they occurred in Excel in the specific structures in the different age groups. First the focus was on the absolute numbers, and as a next step percentages were calculated. These percentages take into account how often the structure occurred in the target items controlled for the number of children. For example, if a specific error occurred 8 times in structure X, the percentage was calculated by focussing on the total. The total was how often the structure occurs in the target items multiplied by the number of children (for example, 6 occurrences per target item list x 17 children of 3 years old = 102). As a next step, the number of mistakes, 8 in this case, were divided by this total and multiplied by 100: (6/102)*100 = 7.8%. This percentages showed that when looking at structure X, errors were made in 7.8% of the cases by 3 year old children. In addition, it was also calculated how often each kind of mistake occurred in general per age group (i.e. not per structure). A percentage was calculated again. This percentage showed the ratio between this absolute number and the total (in which total is the number of items in each item list, 56, multiplied by the number of children).

As a next step, the different kind of errors were focussed on separately. This was done because it is possible to make different kind of errors within one error group. For example, substitution is a type of error and within this group different errors can be made (e.g. substitution of first/second/third consonant in cluster, substitution due to metathesis, substitution in combination with addition etc.). A percentage of the specific error within the error group was calculated (i.e. the number of errors in one error group, for example substitution, is taken as the total). This percentage did not control for age since this was analysed focussing on the number of mistakes made in one error group.

5.6. Acquisition criterion

As mentioned before, no golden standard was found in the literature when a sound was seen as acquired. According to Beers (1995), a sound is acquired when 75% of the instances of that certain sound are produced correctly. However, nothing is said about which percentage of children need to be able to produce this sound correctly in 75% of the cases. On the other hand, Stes (1979, 1997) indicates that something is seen as acquired when 75% of the children produce the sound correctly. However, no specifications are described about how many instances of a certain sound need to be produced correctly in order to be called acquired by 1 child. The third source used in this study is Fikkert (1994). Fikkert (1994) did not specify criteria for acquisition. She observed when certain structures were produced for the first time, and how these productions developed in children up until 2. The fourth source, Boxma (2018), statet that a structure was mastered or acquired when at least 75% of the instances were produced correctly.

Since previous literature did not point towards one criterion which could be assumed automatically, it was decided for the current study to combine the criterion by Beers (1995), Stes (1979, 1997) and Boxma (2018). This study sees a sound or structure as acquired when at least 75% of the instances are produced correctly by at least 75% of the children in an age group. Structures are seen as fully acquired when children produce 100% of the instances correctly. However, no percentage of children is matched with this, since no Dutch literature was found on this specifically. It is thus possible to state something like x% of the children have fully acquired structure y.

6. Results

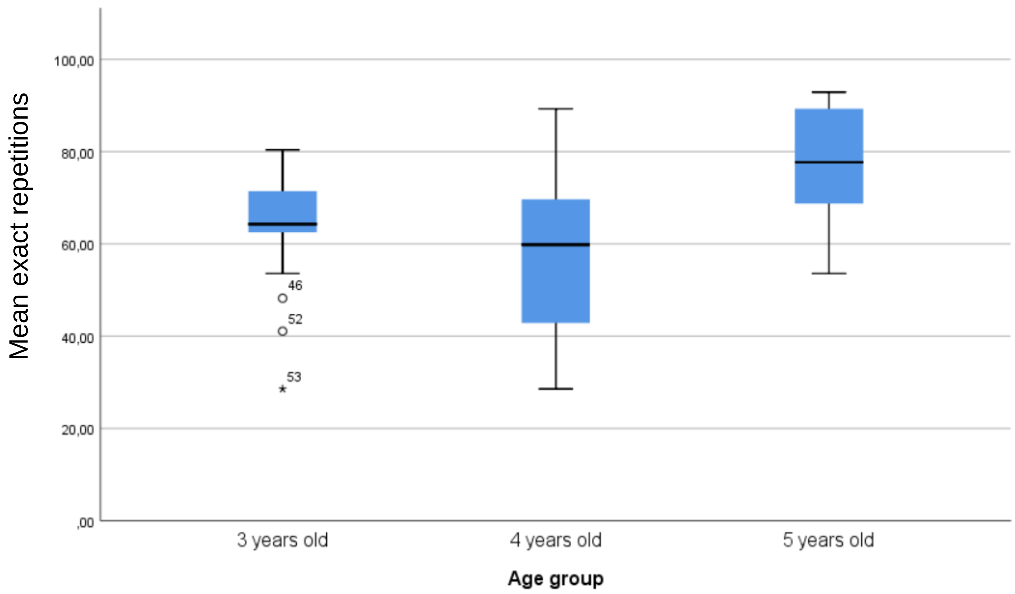
The results will be presented in the following sections. Three main sections can be distinguished. In the first section, 6.1., the results of the analyses on exact repetition, or performance, of the children on the NWRT will be presented. This part contains results about different aspects of performance of the children on the NWRT. In addition, results about the relation between the performance on the NWRT and phonological working memory are presented. This section also includes results about the relation between performance and vocabulary, which is linked to research question 5. In the second main section, 6.2, the number of errors will be discussed on the test. In 6.3., results on exact repetition, or performance, of the children on different structures are addressed. This section is linked to the first research question about the specific age when children can correctly produce the consonant clusters, to the second research question about the kind of structures in which children make more errors and to the fourth research question about whether consonant clusters are produced more accurately in initial or final position. This section also presents results about when a sound is seen as acquired. Lastly, in the fourth main section, 6.4, the different kind of errors are addressed. This ties in with the third research question.

6.1. Results on exact repetition

6.1.1. Exact repetition of non-words per age group

Figure 32 shows the exact repetition of non-words for 3,4 and 5 year old children. The averages and distributions of the data are also illustrated in Figure 32.

Figure 32: Average exact repetitions in percentages by 3 (n = 17), 4 (n= 18) and 5 (n = 20) year old children.



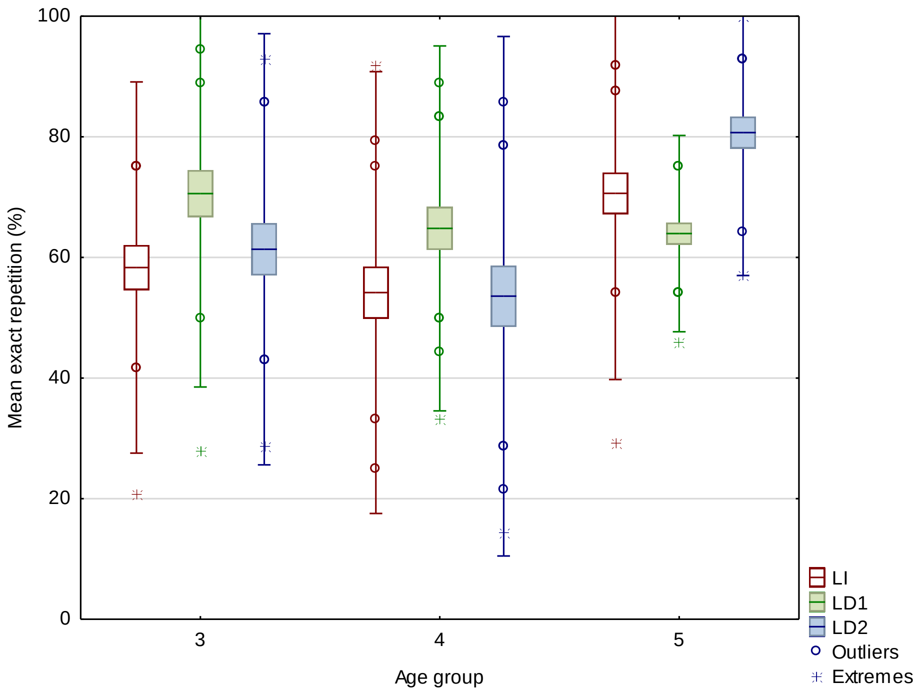
A one-way between groups analysis of variance (ANOVA) was used to investigate the impact of age on the exact repetition of non-words. Inspection of the skewness, kurtosis and Shapiro-Wilk statistics indicated that the assumption of normality was supported for all age groups. The homogeneity of variance assumption was not violated either, since Levene's statistic was not significant, $F(2,52) = 2.282$, $p = 0.112$.

The ANOVA was statistically significant, indicating that number of exact repetitions was influenced by the age of the children, $F(2,52) = 11.11$, $p < 0.001$, $\eta 2 = 0.299$. Post hoc analyses with Gabriel's procedure (using an α of .05) showed that children of 5 years old ($M = 43.60$, $SD = 6.23$) had significantly more exact repetitions compared to children of 3 years old ($M = 35.29$, $SD = 7.56$). In addition, children of 5 years old had significantly more exact repetitions than children of 4 years old ($M = 32.17$, $SD = 9.31$). However, there was no significant difference between the number of exact repetitions by 3 and 4 year old children. Effect sizes for these three comparisons were $d = 0.90$, 1.26 and 0.33, respectively. These first two are considered to be large while the last effect size is seen as small.

6.1.2. Exact repetition of non-words in LI, LD1 and LD2

Figure 33 shows the mean exact repetitions for the different parts of the test (LI, LD1,LD2) for the age groups. The averages and distributions of the data are also illustrated in Figure 33.

Figure 33: The mean exact repetitions for each part (LI = language independent, LD1 = language dependent 1 and LD2 = language dependent 2) for each age group in percentages.



3 paired samples t-tests with α = 0.05 were used to assess whether the number of exact repetitions (controlled for the number of items in each part) differed on the 3 different parts of the test (LI, LD1 and LD2) for 3 year old children. The exact repetitions per non word controlled for the number of items in each part in percentages was significantly higher in LD1(M = 70.59, SD = 16.03) compared to LI (M = 58.33, SD = 15.38), t(16) = -4.13, p = 0.001, d = 0.78. This effect can be described as large. No significant difference was found between LI and LD2 (M = 61.35, SD = 17.87), t(16) = - 0.73, p = 0.476 or between LD1 and LD2, t(16) = 1.98, p = 0.065.

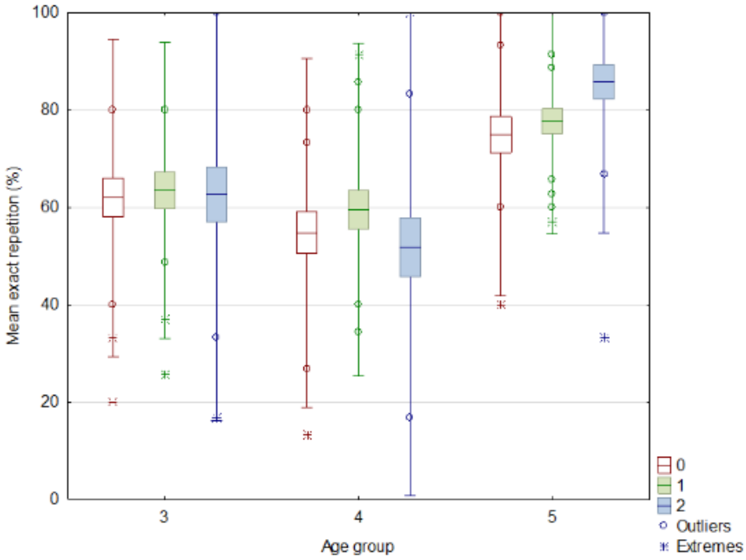
In addition, 3 paired samples-t tests were also done for 4 year old children. Figure 33 illustrates the performance on the different parts. Exact repetitions per non word controlled for the number of items in each part in percentages was significantly higher in LD1 (M = 64.81, SD = 15.12) compared to LI (M = 54.17, SD = 19.31), t(17) = -4.07, p = 0.001, d = 0.63 and it was also significantly higher in LD1 compared to LD2 (M = 53.57, SD = 21.53), t(17) = 3.21, p = 0.005, d = 0.61. No significant difference was found between the number of exact repetitions on LI and LD2, t(17) =0.177, p = 0.862.

Lastly, 3 paired samples t-tests were performed for 5 year old children. Figure 33 illustrates the performance on the different parts. Exact repetitions per non word controlled for the number of items in each part in percentages was significantly higher in LI (M = 70.63, SD = 15.44) compared to LD1 (M = 63.95, SD = 8.14), t(19) = 2.34, p = 0.31, d = 0.57, and significantly higher in LD2 (M = 80.71, SD = 11.85) compared to LI, t(19) =-3.28, p = 0.004, d = -0.74, and significantly higher in LD2 compared to LD1, t(19) = -8.00, p < 0.001, d = 1.68.

6.1.3. Exact repetition of non-words containing 0,1 and 2 consonant clusters

Figure 34 shows the mean exact repetitions for non-words including 0,1 or 2 consonant clusters for the age three groups. The distributions of the data are also shown in Figure 34.

Figure 34: Mean exact repetition for non-words containing 0,1 and 2 consonant clusters per age group in percentages.



In order to compare the number of exact repetitions in non-words with 0,1 and 2 consonant clusters, Wilcoxon tests were done for each age group (since the data was not normally distributed). They showed that no significant difference was found on the number of exact repetitions of 3 year old children between non-words with 0 clusters and 1 cluster, T = 79.5, N – ties = 16, p = 0.776, two-tailed, or with 0 clusters and 2 clusters, T = 76.5, N – ties = 16, p = 0.659, two tailed, or between 1 cluster and 2 cluster non-words, T =79.5, N - ties = 17, p = 0.887, two tailed.

Other Wilcoxon tests showed that no significant difference was found on the number of exact repetitions of 4 year old children between non-words with 0 clusters and 1 cluster, T = 113.5, N – ties = 18, p = 0.222, two-tailed, or with 0 clusters and 2 clusters, T = 64.5, N – ties = 17, p = 0.570, two tailed, or between 1 cluster and 2 cluster non-words, T =45.5, N - ties = 18, p = 0.081, two tailed.

Other Wilcoxon tests were performed for 5 year old children. No significant difference was found on the number of exact repetitions of 5 year old children between non-words with 0 clusters and 1 cluster (z = -0.54 p = 0.588). Other Wilcoxon tests indicated that the number of exact repetitions on non-words with 2 clusters was significantly higher compared to non-words with 0 clusters (z = -2.54, p = 0.011) and also higher compared than non-words with 1 cluster (z = -2.24, p = 0.025).

In summary, the number of clusters in a non-word did not statistically influence the number of exact repetitions of 3 and 4 year old children. However, 5 year old children performed better on non-words with 2 clusters compared to non-words with 0 and 1 cluster.

6.1.4. The correlation between exact repetition of non-words and Digit Span

To assess whether the number of exact repetitions and the scores on the digit span test correlate, a Kendall’s tau-b test was used for the 3 and 5 year old children. This test was used since the scores were not normally distributed. τ was calculated for each age group separately. The test indicated that the correlation between these two variables was not significant for 3 year old children, $\tau = 0.24$, p = 0.224, two-tailed, $N = 17$ and 5 year old children, $\tau = 0.07$, p = 0.716, two-tailed, $N = 20$. Since the data for the 4 year old children was normally distributed, a bivariate Pearson’s product-moment correlation coefficient (r) was calculated. The bivariate correlation between these two variables was also not significant for 4 year old children, $r(16) = 0.383$, p = 0.117. Prior to calculating r, the assumptions of normality, linearity and homoscedasticity were assessed and found to be supported.

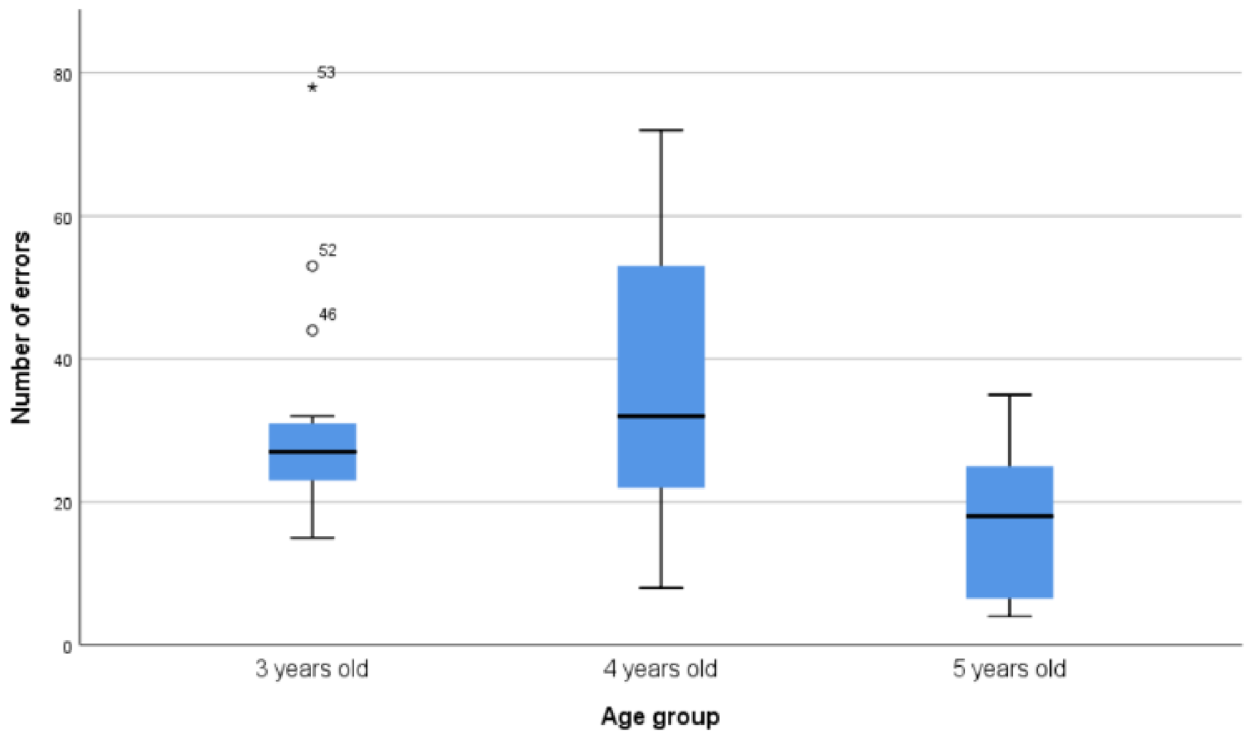
6.1.5. The correlation between exact repetition of non-words and PVVT

To assess whether the number of exact repetitions and the scores on the Peabody Picture Vocabulary Test (PVVT) correlate, a Kendall's tau-b test was used. This test was used since the scores were not normally distributed. τ was calculated for each age group separately. The test indicated that the correlation between these two variables was not significant for 3 year old children, $\tau = 0.26$, p = 0.157, two-tailed, $N = 17$. Since the data for the 4 and 5 year old children was normally distributed, a bivariate Pearson's product-moment correlation coefficient (r) was calculated for both age groups. The bivariate correlation between these two variables was significant, positive and strong for 4 year old children, $r(16) = 0.532$, p = 0.023. However, it was not significant for 5 year old children, $r(18) = 0.316$, p = 0.175.

6.2. Results on the number of errors

Figure 35 shows the number of total errors made by 3, 4 and 5 year old children (including errors in other segments of the non-word than consonant clusters). The distribution of the data is also shown.

Figure 35: the number of errors made by 3 (n = 17), 4 (n= 18) and 5 (n = 20) year old children.



Since the assumption of normality was violated for one of the three age groups, a Krukal-Wallis ANOVA was used. This test indicated that there were statistically differences between the number of errors made by 3 year old (*Mean Rank* = 31.74), 4 year old (*Mean Rank* = 36.50) and 5 year old children (*Mean Rank* = 17.18), *H* (corrected for ties) = 15.146, *df* = 2, *N* = 55, p = 0.001, Cohen's *f* = 0.389. This effect size is considered to be large.

To see which age groups differ significantly, separate Mann-Whitney *U* tests were used to compare each pair of mean ranks. The test indicated that the number of errors made by 3 (*Mean Rank* = 15.97, n = 17) and 4 year old children (*Mean Rank* = 19.92, n = 18) did not differ significantly, *U* = 118.50, p = 0.255, two-tailed. On the other hand, another Mann-Whitney *U* indicated that children of 3 (*Mean Rank* = 24.18 n = 17) made significantly more errors than children of 5 years old (*Mean Rank* = 14.10, n = 20), *U* = 72.00, p = 0.003, two-tailed. This effect can be described as large (r = 0.49). In addition, another Mann-Whitney *U* test showed that that 4 year old children (*Mean Rank* = 26.08, n = 18) make significantly more mistakes than 5 year old children (*Mean Rank* = 13.58, n = 20), *U* = 61.50, p = 0.001, two-tailed. This effect is also considered large (*r* = 0.56).

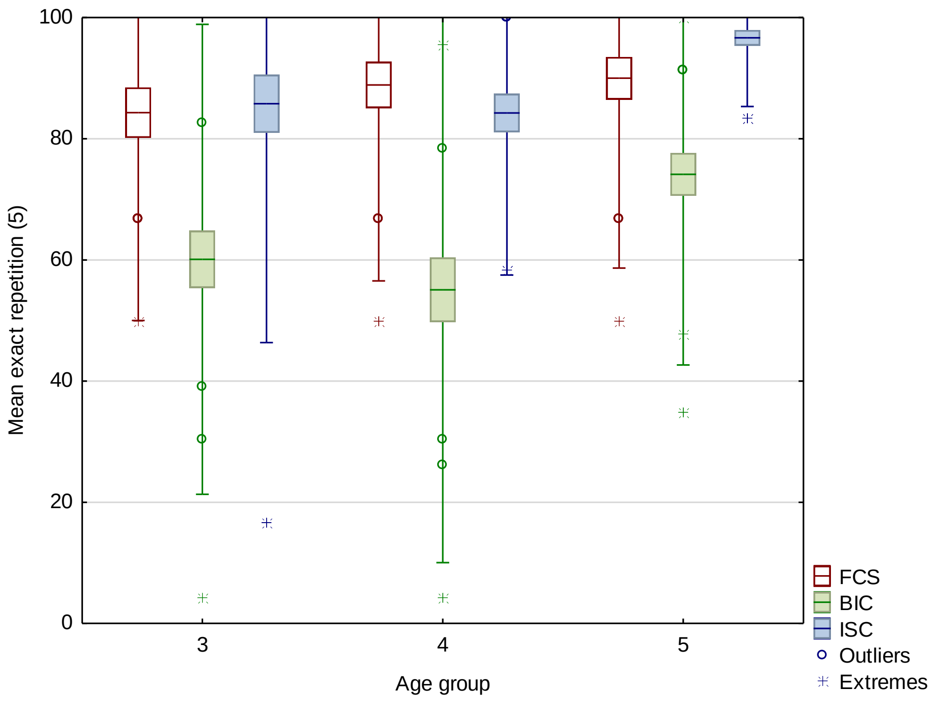
6.3. Results on exact repetition of different structures

In order to compare the number of exact repetitions on the different structures, Wilcoxon tests were performed. To compare between age groups, Mann Whitney U tests were used. These tests were selected since the data was not normally distributed.

6.3.1. Exact repetition of structures with and without /s/

The exact repetition of consonant clusters with /s/ and without /s/ were compared. Figure 36 gives information on the performance of these structures. The initial structures branching initial clusters (BIC) and initial /s/-consonant clusters (ISC), were compared (for a list of abbreviations see Appendix A or Figure 31 in the Method). The number of exact repetitions was significantly higher on ISC compared to BIC for 3 year old children ($z = 3.62$, $p < 0.001$), 4 year old children ($z = -3.59$, $p < 0.001$) and 5 year old children ($z = -3.75$, $p < 0.001$). In summary, the comparison shows that the exact repetition was significantly higher for the structures containing /s/ in contrast to the structures without /s/.

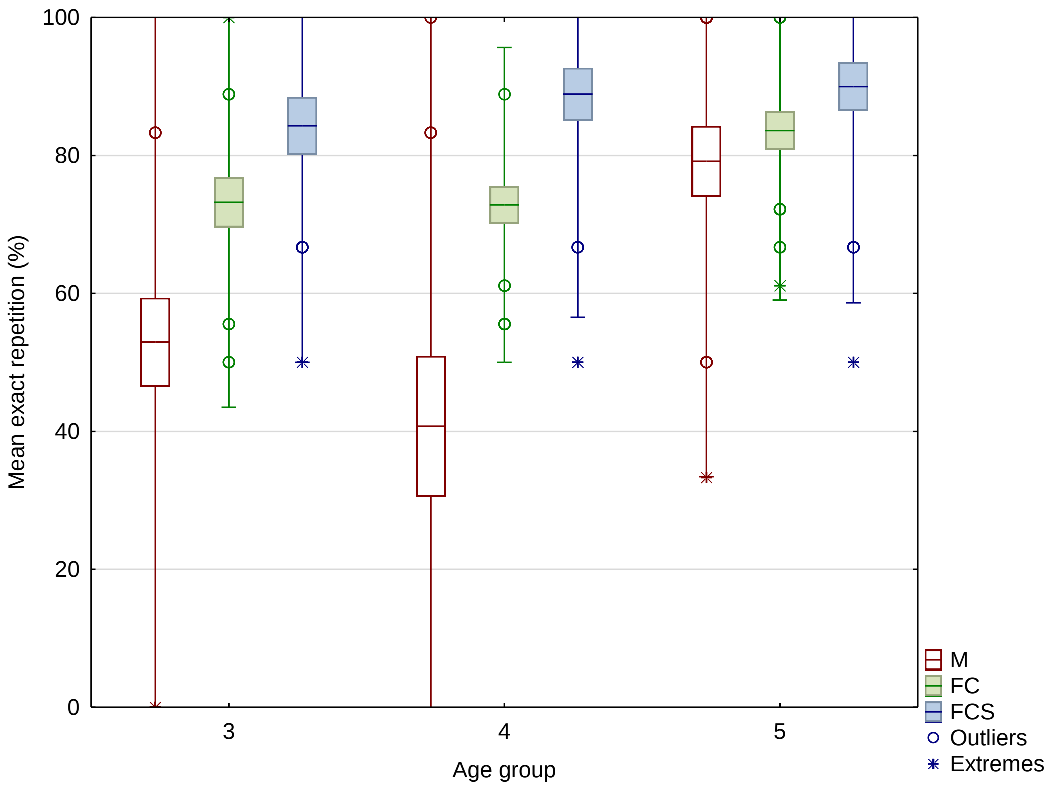
Figure 36: Percentage of exact repetition of structures without /s/ (BIC = branching initial clusters and FC = final consonant) and with /s/ (ISC = initial s- consonant cluster and FCS = final consonant -/s/ cluster) for each age group.



6.3.2. Exact repetition of final and medial structures

The final structures were compared to the word medial structures. Figure 37 gives information on the performance of these structures. The pattern in 3 and 4 year old children was similar. The number of exact repetitions was significantly lower on the medial consonant clusters (M) compared to final single consonants (FC) for 3 year olds (z = -2.36, p = 0.018) and 4 year olds (z = -2.90, p = 0.004) and also significantly lower on M compared to final consonant + /s/ clusters (FCS) for 3 year olds (z = -2.89, p = 0.004) and 4 year olds (z = -3.42, p = 0.001). However, for 5 year old children no significant difference in the number of exact repetitions was found between M and FC (z = -0.96, p =0.337) and M and FCS (z =-1.59, p =0.113). In addition, the final structures FCS and FC were also compared. The performance was significantly higher on FCS than on FC for 3 year olds (z = -2.15, p = 0.031), 4 year olds (z = -2.93, p = 0.003) and 5 year olds (z = -2.00, p = 0.049).

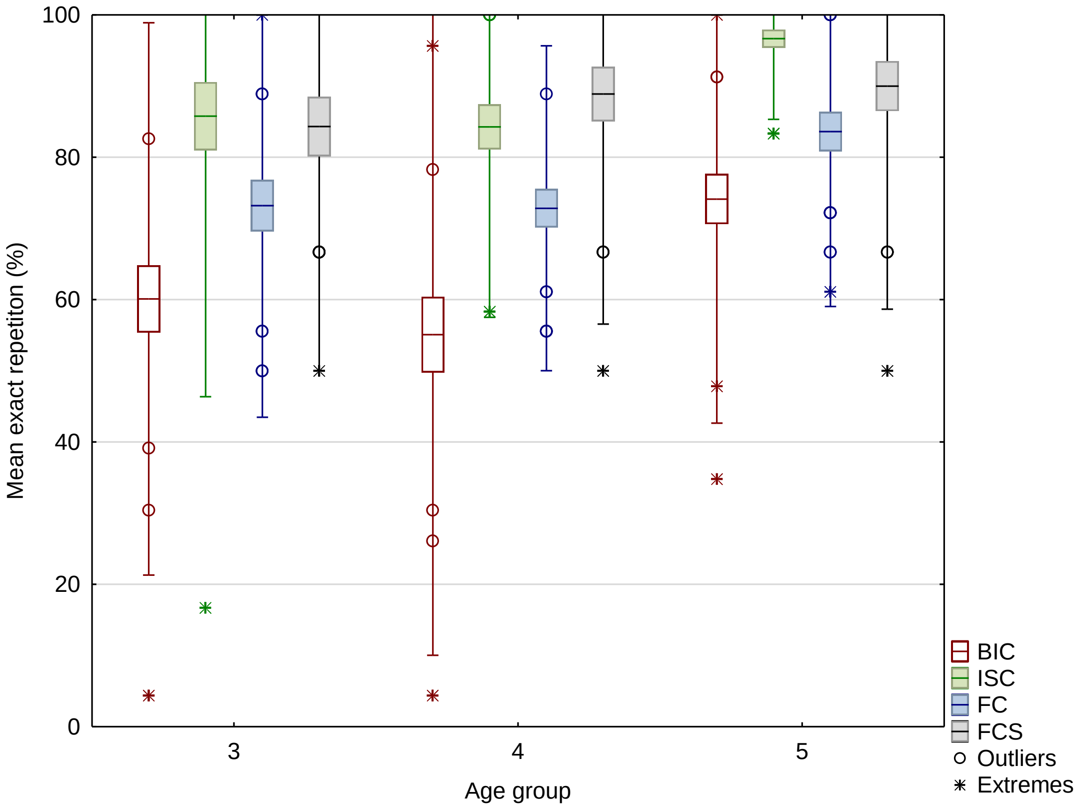
Figure 37: Percentage of exact repetition of medial structures (M = medial consonant cluster) and final structures (FC = final consonant, FCS = final consonant- /s/ cluster) for each age group.



6.3.3. Exact repetition of initial and final structures

Initial structures were compared to final structures. Figure 38 gives information on the performance of these structures. Almost similar patterns were found for all age groups. The number of exact repetitions was lower on branching initial clusters (BIC) compared to final consonants (FC) for 3 year olds (z = -2.49, p = 0.013), 4 year olds (z = -3.16, p = 0.002), and 5 year olds (z = -3.18, p = 0.001), and lower on BIC compared to final consonant + /s/ clusters (FCS) 3 year olds (p = -3.20, p = 0.001), 4 year olds (z = -3.72, p < 0.001), and 5 year olds (z = -3.02, p = 0.003), and higher on ISC compared to FC for 3 year olds (z = -2.56, p = 0.011), 4 year olds (z = -2.90, p = 0.004), and 5 year olds (z = -3.23, p = 0.001). In addition, the number of exact repetitions was slightly significantly higher on ISC compared to FCS for 5 year olds (z = -1.98, p = 0.048), but this difference was not significant for 3 (z= -0.35, p = 0.729) and 4 year olds (z = -1.02, p = 0.306).

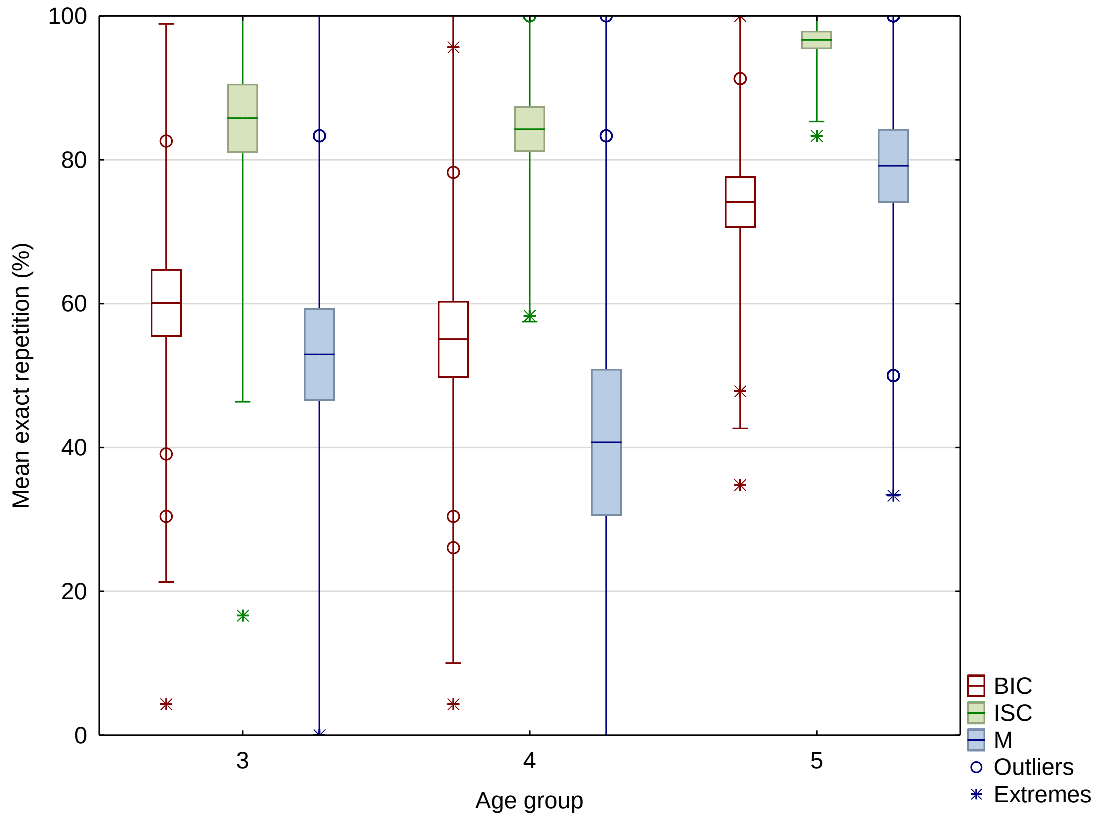
Figure 38: Percentage of exact repetition of initial structures (BIC = branching initial cluster, ISC = initial /s/ + consonant cluster) and final structures (FC = final consonant, FCS = final consonant-/s/ cluster) for each age group.



6.3.4. Exact repetition of initial and medial structures

Initial structures were also compared to medial structures. Figure 39 gives information on the performance of these structures. No significant difference in performance was found for BIC compared to M for 3 (z = -0.62, p = 0.538), 4 (z = -1.55, p = 0.122) and 5 year olds (z = -0.97, p = 0.332). However, the number of exact repetitions was significantly higher on ISC compared to M for 3 (z = -3.18, p = 0.001), 4 (z = -3.18, p = 0.001) and 5 year olds (z = -2.68, p = 0.007).

Figure 39: Percentage of exact repetition of initial structures (BIC = branching initial cluster, ISC = initial /s/-consonant cluster) and medial structures (M = medial consonant cluster) for each age group.



6.3.5. Exact repetition of different structures compared by age

Separate Mann-Whitney *U* tests were used to see whether the number of exact repetitions was different for the age groups on the different structures. The results are shown in Table 26 below. Table 26 shows that no differences in performance between 3 and 4 year olds were found on the different structures. This is in contrast with the other age groups. The number of exact repetition of 5 year old children was significantly better compared to 3 and 4 year old children on FC, FCS, BIC, ISC and M. The effect sizes (r) can be seen in Table 26 as well. All effect sizes for the significant differences are medium (around r = 0.3) or large (around r = 0.5). No significant differences were found for the FCS structure when comparing the three age groups.

Table 26: Results of separate Mann-Whitney U tests comparing the number of exact repetitions of 3 (n = 17), 4 (n = 18) and 5 (n = 20) year old children on the different structures (MR = Mean Ranks, r = effect size, grey cells/* indicate significant differences between groups, FC = final consonant, FCS = final consonant + /s/, BIC = branching initial cluster, ISC = initial /s/ + consonant, M = medial structure).

	3 & 4 years old	3 & 5 years old	4 & 5 years old
FC	3: MR = 18.18 4: MR = 17.83 U = 150.00, p = 0.920 r = 0.02	3: MR =15.09 5: MR = 22.33 U = 103.50, p = 0.041* r = 0.36	4: MR = 14.89 5: MR = 23.65 U = 97.00, p = 0.014* r = 0.40
FCS	3: MR = 16.62 4: MR = 19.31 U = 129.50, p = 0.393 r = 0.14	3: MR = 17.09 5: MR = 20.63 U = 137.50, p = 0.269 r = 0.18	4: MR = 19.11 5: MR = 19.85 U = 173.00, p = 0.812 r = 0.04
BIC	3: MR = 19.35 4: MR = 16.72 U = 130.00, p = 0.445 r = 0.13	3: MR = 14.65 5: MR = 22.70 U = 96.00, p = 0.023* r = 0.37	4: MR = 14.42 5: MR = 24.08 U = 88.50, p = 0.007* r = 0.44
ISC	3: MR = 19.71 4: MR = 16.39 U = 124.00, p = 0.346 r = 0.17	3: MR = 13.94 5: MR = 23.30 U = 84.00, p = 0.005* r = 0.47	4: MR = 13.83 5: MR = 24.60 U = 78.00, p = 0.001* r = 0.52
M	3: MR = 19.24 4: MR = 16.83 U = 132.00, p = 0.482 r = 0.12	3: MR = 13.65 5: MR = 23.55 U =79.00, p = 0.005* r = 0.47	4: MR = 14.06 5: MR = 24.40 U = 82.00, p = 0.004* r = 0.47

6.3.6. Descriptive results: The ability to produce and make 0 errors and the acquisition of structures

Tables 27, 28 and 29 give information on different elements. They show how many of the children are able to produce the structures. This means that the children produce the structures correctly, but not necessarily all the time (errors can still be made). In addition, the number of children who do not make any errors are also shown in Tables 27, 28 and 29. The ability to produce the structures and the number of children who make 0 errors will be described in more detail below. Table 27, 28 and 29 show the minimum and maximum percentages correct, and the averages of correct and incorrect. The Tables show per age group that the minimum, maximum and average percentage correct varies on the different structures. Note: since insertion resulting in a new position (position x) in the structure was counted as an error of that position x, it is possible to have more than 100% incorrect on structure x (the number of occurrences in the target items of a certain structure (structure x) are taken as 100%).

Table 27: The number of 3 year old children (N = 17) who are able to produce different structures and who do not make any errors and the percentage minimum, maximum, and average (in)correct responses.

	Ability to produce	0 errors	Min. Correct (%)	Max. correct (%)	Average correct (%)	Average incorrect (%)
FC	N = 17	N = 1	50	100	73,2	26,8
FCS	N = 17	N = 8	66,7	100	84,3	15,7
BIC	N = 17	N = 0	4,3	73,2	60,1	39,9
ISC	N = 17	N = 4	83,3	100	85,8	14,2
M	N = 15	N = 0	0	83,3	52,9	47,1

Table 28: The number of 4 year old children (N =18) who are able to produce different structures and who do not make any errors and the percentage minimum, maximum, and average (in)correct responses.

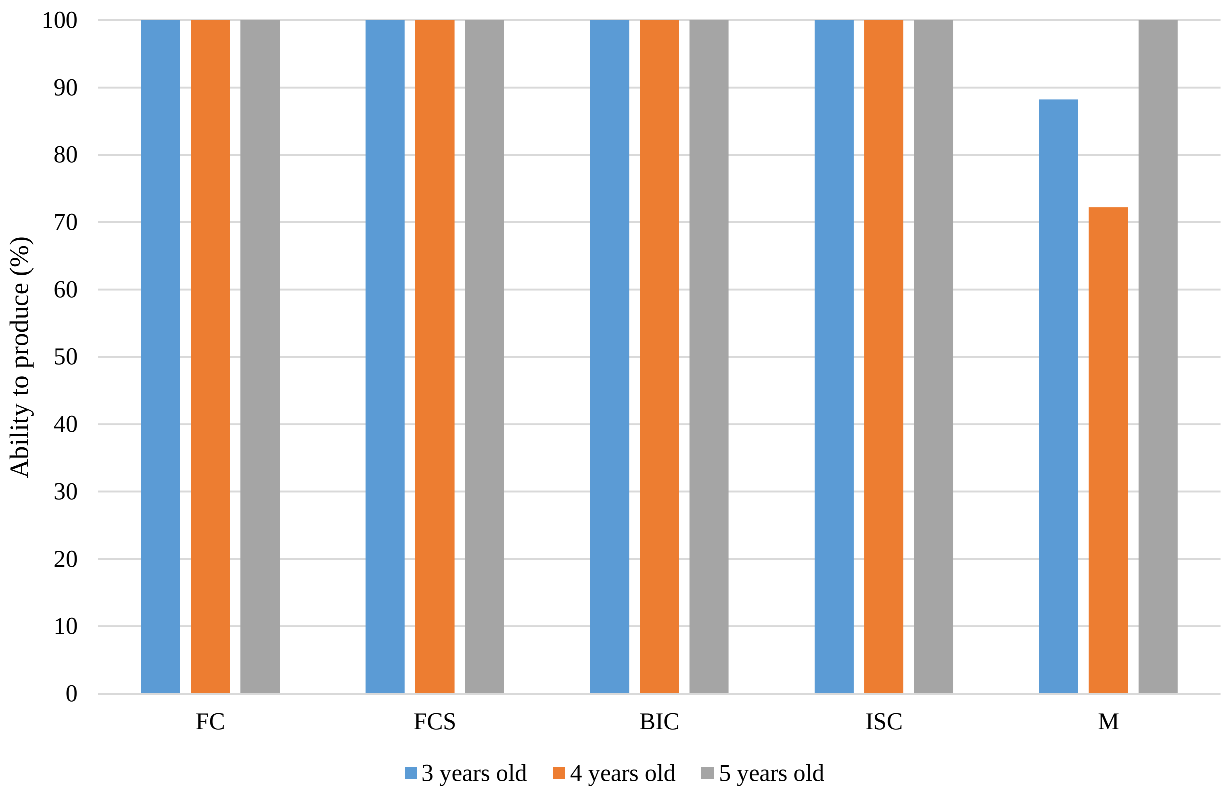
	Ability to produce	0 errors	Min. Correct (%)	Max. correct (%)	Average correct (%)	Average incorrect (%)
FC 4	18	0	55,6	88,9	72,8	27,2
FCS	18	11	50	100	88,9	11,1
BIC	18	0	4,3	95,7	55,1	44,9
ISC	18	5	58,3	100	84,3	15,7
M	13	2	-16,7	100	40,7	59,3

Table 29: The number of 5 year old children (N = 20) who are able to produce different structures and who do not make any errors and the percentage minimum, maximum, and average (in)correct responses.

	Ability to produce	0 errors	Min. Correct (%)	Max. correct (%)	Average correct (%)	Average incorrect (%)
FC	20	3	61,1	100	83,6	16,4
FSC	20	13	66,7	100	90,0	10,0
BIO	20	1	34,8	100	74,1	25,9
ISC	20	14	83,3	100	96,7	3,3
M	20	9	33,3	100	79,2	20,8

The information given in Tables 27, 28 and 29 above about how many of the children are able to produce the structures and made 0 errors is converted into percentages and visualized in Figure 40 and 41 below. As mentioned above, the ability to produce does not automatically imply that no errors are made anymore. It shows whether the child has ever produced an instance of that structure correctly. Figure 40 shows that 3, 4 and 5 year old children are all able to produce FC,FCS, BIC, ISC. The percentage of 4 year old children who is able to produce the word medial consonant clusters (M) is lower compared to the percentage of 3 year old children. This means that not all 3 and 4 year olds correctly produced instances of medial consonants.

Figure 40: The percentage of children able to produce the different structures by age group.

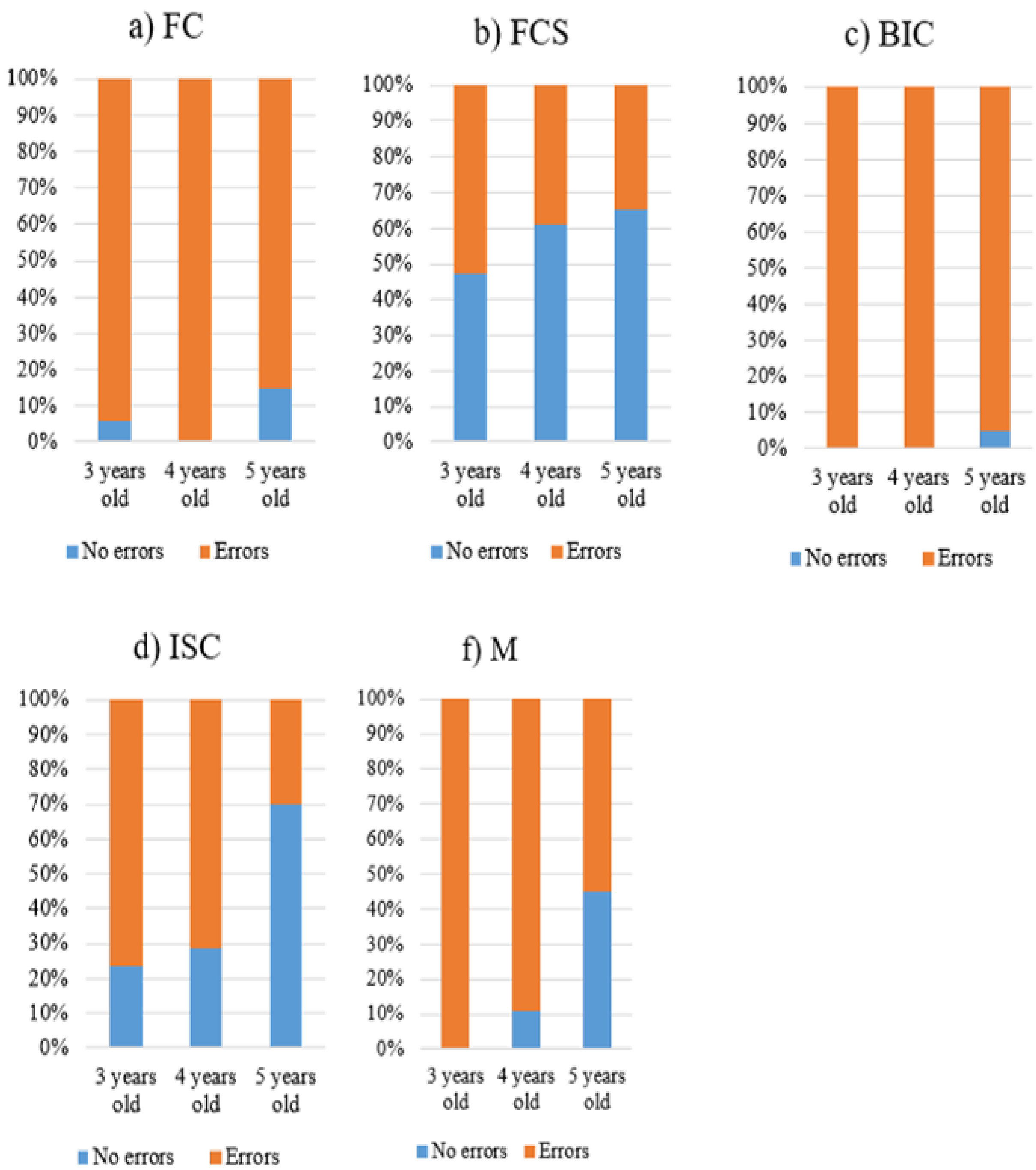


Even though 100% of the children are able to produce certain structures, this does not automatically mean that they produce all of the instances in the structures correctly; they can still make errors. Table 30 and Figure 41 give information about this. Table 30 shows the absolute number and percentage of children who do not make any errors in the different structures. This is visualised in Figure 41. In Figure 41, the bars go to 100%, which stands for all the children in an age group. Figure 41 shows that when focussing on the FC structure, 5.9 % of the 3 year old do not make errors in this structure at all whereas the other 94.1 % of the children do still make errors. This in contrast with the 4 year olds, who all make mistakes in this structure. 15% of the 5 year olds do not make errors in this structure while the other 85% do. All the other structures in Figure 41 follow the same pattern: more percent of the children do not make any errors when the children are older.

Table 30: The absolute/percentage number of children who do not make any errors divided by structure.

	3 year olds		4 year olds		5 year olds	
	Absolute	Percentage	Absolute	Percentage	Absolute	Percentage
FC	1	5.9%	0	0%	3	15%
FCS	8	47.1%	11	61.1%	13	65%
BIC	0	0%	0	0%	1	5%
ISC	4	23.5%	5	27.8%	14	70%
M	0	0%	2	11.1%	9	45%

Figure 41: The percentage of children who do not make any mistakes (no errors) and who do make mistakes (errors) divided by structure and age.



It was counted how many of the children per age group produced at least 75% of the clusters in a cluster group correctly. This is shown in Table 31 below. The grey parts of the Table indicate that at least 75% of the children produced 75% of the clusters in a cluster group correctly. This was taken as the criterion when a sound was acquired (see Section 5.6.).

Table 31: The percentage of children who produced at least 75% of the consonant clusters in different structures correctly (grey: the percentage of children is > 75%).

	FC	FCS	BIC	ISC	M
3 years old	47%	65%	5.9%	88.2%	17.6%
4 years old	50%	77.8%	11.1%	88.9%	27.8%
5 years old	70%	80%	50%	100%	60%

6.4. *Descriptive results: Different kind of errors*

The number of different errors was counted in an Excel sheet per age group. Table 32 shows for the different age groups how often each kind of error occurred in a specific structure (i.e. absolute numbers). To the right of these absolute numbers, a percentage is calculated. This percentages takes into account how often the structure occurred in the target items controlled for the number of children. Table 32 shows that when looking at the structure final CS, addition mistakes were made 1% of the time the structure occurred, and metathesis, deletion, substitution and a combination of errors were made 0%, 4.9%, 7,8%, 2,0% respectively by 3 year old children. Table 32 also shows that in 9% of all the items produced by the three year old children, addition errors were made. In addition, metathesis, deletion, substitution and a combination of errors were made in 4.5%, 11.8%, 8.3%, 1.2% of all the produced items. Note that because of rounding in the vertical columns, the numbers in a vertical column in Tables may not precisely add up to the exact same number written as the total. This may differ 0.1% since the total is calculated separately based on the absolute total number, not by adding the rounded percentages in the columns.

Table 32: Number of errors of a) 3 year old children (n=17), b) 4 year old children (n=18) and c) 5 year old children (n=20) in absolute numbers and in percentages (the number taken as the total to calculate the percentage is calculated by how often structure occurs * number of children, this total is shown between brackets under % sign, FCS = final consonant + S cluster, BIC = branching initial cluster, ISC = initial s + consonant cluster, M = medial cluster, I = insertion, M = metathesis, D = deletion, S = substitution and Com. = combinations of errors).

a) 3 year old children

	FCS	% (102)	BIC	% (391)	ISC	% (204)	M	% (102)	**Total**	**% (952)**
I	1	1.0	44	11.3	0	0.0	27	26.5	**72**	**7.6**
M	0	0.0	30	7.7	0	0.0	9	8.9	**39**	**4.1**
D	5	4.9	44	11.3	12	5.9	10	9.8	**71**	**7.6**
S	8	7.8	36	8.7	9	3.4	8	7.8	**61**	**6.4**
Com.	2	2.0	2	1.0	2	2.0	0	0.0	**6**	**0.6**
Total	**16.0**	**15.7**	**156.0**	**39.9**	**23.0**	**11.3.0**	**54.0**	**52.9**	**249.0**	**26.2**

b) 4 year old children

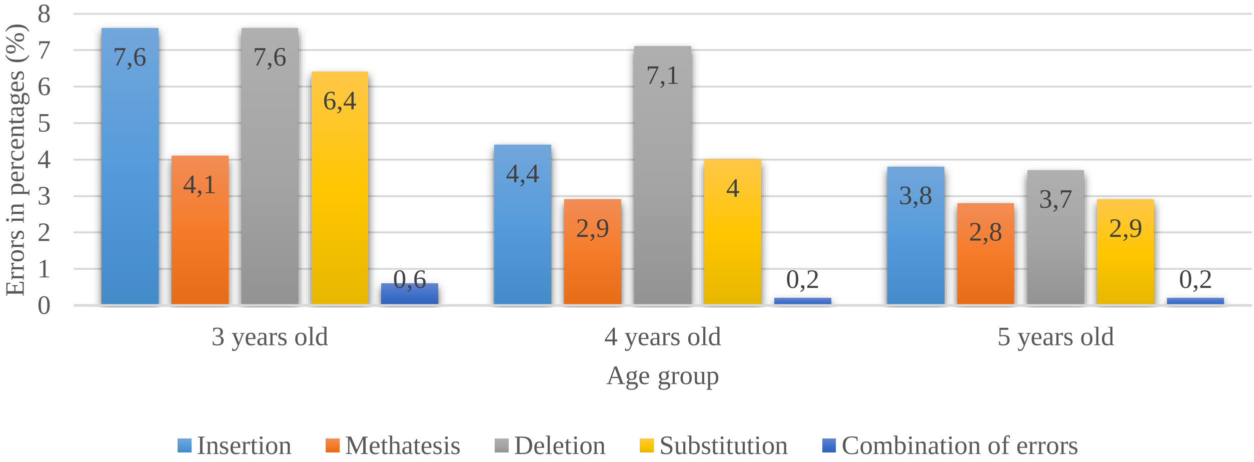
	FCS	% (108)	BIC	% (414)	ISC	% (216)	M	% (108)	**Total**	**% (1008)**
I	0	0.0	42	10.1	0	0.0	32	29.6	**74**	**7.3**
M	1	0.9	34	8.2	2	0.9	20	18.5	**59**	**5.9**
D	1	0.9	61	14.7	22	10.2	12	13.0	**96**	**9.5**
S	10	9.3	38	9.2	5	2.3	9	8.3	**62**	**6.2**
Com.	0	0	10	2.4	4	1.9	0	0.0	**14**	**1.4**
Total	**12**	**11.1**	**185**	**44.69**	**33**	**15.3**	**73**	**67.6**	**303**	**30.1**

c) 5 year old children

	FCS	% (120)	BIC	% (460)	ISC	% (240)	M	% (120)	**Total**	**% (1120)**
I	2	1.7	41	8.9	0	0.0	0	0.0	**43**	**3.8**
M	0	0.0	26	5.7	0	0.0	5	4.2	**31**	**2.8**
D	2	1.7	36	7.8	2	0.8	1	0.8	**41**	**3.7**
S	8	6.7	15	3.3	4	1.7	5	4.2	**32**	**2.9**
Com.	0	0.0	1	0.2	0	0.0	0	0.0	**1**	**0.2**
Total	**12**	**10.0**	**119**	**25.9**	**6**	**2.5**	**11**	**9.2**	**148**	**13.2**

In addition, the results shown in Table 32 are also visualised in Figure 42. This Figure shows how often the different kind of errors are made by 3,4 and 5 year old children. Figure 42 shows that insertion and deletion occur most often in 3 and 5 year old and deletion occurs most often in 4 year olds. After that, substitution (in combination with insertion for 4 year olds and with metathesis for 5 year olds) occurs most often. The combination of errors occurs less often in all age groups. Figure 42 also indicates that all coded mistakes are found in each age group. The errors were more specifically coded than the main groups shown above. For example, within the group of substitution errors, substitution can occur in the first, second or third segment of a consonant clusters. These sub errors were coded as well. Tables showing the sub errors within one error group can be found in Appendix J

Figure 42: The different kind of errors made by 3, 4 and 5 year old children based on the descriptive analysis, controlled for number of children per group.



7. Discussion

The results of this study will be discussed in the following sections. First, the general performance on the test will be discussed. This consists of the discussion of results on exact repetition per age group, exact repetition in LI, LD1 and LD2, exact repetition in non-words with 0,1 and 2 consonant clusters and the relation between performance on the NWRT and phonological short-term memory. After this, each research question will be addressed separately. They are answered and results linking to the questions will be discussed. The performance of children on structures with and without /s/ and medial structures are discussed separately in the following two sections. After this, the performance of 3 and 4 year old children is discussed. The limitations of the current study and directions for future research are addressed in the final section.

7.1. Performance on the NWRT

This section is based on statistical analyses (Sections 6.1.1-6.1.3 and 6.1.5). 5 year old children performed statistically better on the NWRT compared to 3 and 4 year old children. Respectively, they produced 77.9%, 62.9% and 57.4% of the non-words correctly. No statistical difference was found between 3 and 4 year olds. This is discussed in more detail later in Section 7.5. In addition, 5 year old children made significant less errors compared to 3 and 4 year old children. Again, no significant difference was found between 3 and 4 year olds (see Section 7.5). It was expected that 4 year old children would perform well on the test. This was defined as 80% based on French data (Rocherau, 2016). However, they performed only at 62.9%. It is not surprising that the performances between the languages differ since the languages are very different; French is a Romance language while Dutch is Germanic. Therefor the order and age of acquisition of sounds may differ. Independent of the comparison to French data, it is surprising that the 4 year olds did not score high on the test (see Section 7.5).

Not one clear pattern arose concerning the performance on the three parts of the test (LI, LD1 and LD2). This is not in line with the expectations. It was expected that LD2 was more difficult than LD1 and that both dependent parts were more difficult than LI. These results show that no coherent pattern was found across age groups. Even though no clear pattern was found, sometimes performance was significantly higher on dependent parts compared to LI, which is the reversed pattern as was expected. Perhaps these results are due to the unequal number of items in each part (LI = 24, LD1 = 18 and LD2 = 14). Even though a percentage was taken (i.e. number of items correct in part x/total number of items in part x *100) and thus it was believed that the unequal number of items in each part was controlled, differences may have arisen since the ratios are distorted. For example, if a child, by change, produces 8 instances correctly of a structure which occurs 12 times, this is 67%. However, if there are a few instances more, 18 for example, 8 out of 18 is 44.4%.

The results on the performance of non-words with 0,1 and 2 clusters were not in line with expectations either. It was expected that the performance would be lower in 2 cluster words, compared to 1 and 0 cluster words. However, results showed that no differences were found between non-words with 0,1 and 2 clusters for 3 and 4 year olds. Surprisingly, 5 year olds performed better on 2 cluster words compared to 1 and 0 cluster words. Again, this may be due to the design of the test. Even though the comparison took the unequal sizes for each group (non-words with 0, 1 and 2 clusters) into account by calculating percentages, the unequal sizes may have influenced the results anyway. Only 6 instances of 2 cluster non-words were included, whereas 0 and 1 cluster non-words occurred 15 and 35 times, respectively. It is possible to assume that simply more errors can be made in 35 instances compared to 6. Therefore, the different sizes for each non-word group could have influenced the proportions and the relations to each other. In addition, the length of words (1, 2 or 3 syllables) was not equally distributed over the groups either. This may have influenced these results as well. This factor has not been taken into account in the analysis. On the other hand, one result was in line with the expectations. It was expected that the performance on 0 and 1 cluster words would not differ significantly since children would perform well on both kind of non-words, and this is found for 3,4 and 5 year olds in this study.

As discussed earlier in this thesis, the NWRT is mainly supposed to test phonology and not as much phonological short term memory. The results show that indeed, this test does not test memory as a main component; the score on the Digit Span test, which tests phonological memory, did not correlate significantly with the performance on the test for all age groups.

7.2. Answers to the research questions

1.At which age are Dutch TD children able to correctly realise consonant clusters with and without /s/?

This section is based on descriptive results (Section 6.3.6). All 3 year old children were able to produce consonant clusters in initial and final position (FC, FCS,BIC and ISC) correctly at times (i.e. errors were also still made at other times). However, 2 out of 17 3 year old children (11.8%) were not able to correctly produce medial consonant clusters at all. This pattern is also found in 4 year olds: they were all able to produce all structures correctly at times except the medial clusters. 5 out of 18 4 year old children (27.8%) never produced these clusters correctly. In addition, all 5 year old children were able to produce all structures correctly at times. These results are mostly in line with the expectations. However, based on Fikkert (1994) it was expected that all 3,4 and 5 year old children would have been able to produce medial structures correctly (while still making errors at times) but some 3 and 4 year olds in the current study did not produce any medial clusters correctly. The fact that some children in this study never produced medial structures correct can be explained by individual variation between children; some children may be slower in being able to produce certain clusters.

Turning to age of acquisition for specific structures, as defined earlier as when ≥ 75 % of the clusters are produced correctly by ≥75% of the children (see Section 5.6), the FCS (final consonant-/s/) structure is acquired by 4 year old children and ISC (initial /s/-consonant clusters) by 3 year old children. These results are not in line with the expectations which were based on Stes (1977, 1997). This will be discussed in detail in Section 7.3. below. The other structures including consonant clusters, BIC (branching initial clusters) and M (medial consonant clusters) are not acquired yet according to the criteria. No specific hypotheses were made concerning the acquisition of medial structures. This study gave new information and showed that these structures are not acquired by 3,4 and 5 year old children.

Then, turning to full acquisition, defined as when children do not make any errors in a structure anymore, Table 33 shows the percentages of children who did not make any errors. In general, the number of children who did not make any errors increased over age in all structures, as was expected. Table 31 shows that at 5 years old, 15%, 65%, 5%, 70% and 45% of the children have fully acquired the different structures (FC, FCS, BIC, ISC and M respectively).

In summary, 3, 4 and 5 year old children are able to produce all structures at times except for 11.8% of the 3 year olds and 27.8% of the 4 year olds who never produced medial clusters correctly. In addition, FCS is acquired at 4 years old and ISC is acquired at 3 years old. In general when looking at full acquisition the number of children who did not make any errors increased over age in all structures.

Table 33: The absolute/percentage number of children who made 0 errors divided by structure.

	3 year olds		4 year olds		5 year olds	
	Absolute	Percentage	Absolute	Percentage	Absolute	Percentage
FC	1	5.9%	0	0%	3	15%
FCS	8	47.1%	11	61.1%	13	65%
BIC	0	0%	0	0%	1	5%
ISC	4	23.5%	5	27.8%	14	70%
M	0	0%	2	11.1%	9	45%

2. Do Dutch TD children make more errors in certain consonant clusters compared to others?

The following section is based on statistical analysis (Section 6.3.1-6.3.5). All age groups performed significantly better on ISC compared to BIC. It can be concluded that all age groups performed better on structures with /s/ (ISC) compared to structures without /s/ (BIC). This was not in line with expectations. This will be discussed in more detail in Section 7.3. In addition, children performed better on FCS than on FC (note that FC also included /s/). It may seem surprising that children produced consonant clusters better than single consonants since it is assumed that clusters are acquired later than single consonants (Fikkert, 1994). However, the deletion of single consonants is described as a frequent error in acquisition and as Figure 27 in Chapter 3 based on Beers (1995) shows, it occurs more often than consonant reduction. In light of this error occurrence showed by Beers (1995) it is not surprising that the clusters is produced more accurately than the single final consonant.

In addition, 3 and 4 year old children perform significantly more poorly on medial (M) structures compared to final consonant-/s/ structures (FCS) and initial /s/-consonant (ISC) structures. This will be discussed further in Section 7.4. No significant difference was found between branching initial (BIC) structures and medial structures for the age groups. Children performed poorly on both structures and therefore it is not surprising that there is no significant difference between the performance of these structures for the age groups. In addition, no significant difference was found between medial structures and final structures for 5 year old children. Reason for this can be that they performed at ceiling. The initial and final structures are discussed in the section about research question 4.

When comparing between the age groups, 5 year olds performed significantly better on all structures except FCS compared to 3 and 4 year old children. Again, no difference between 3 and 4 year olds was found. No difference between age groups was found for the final consonant- /s/ (FCS) structures. This can be explained by the fact that all groups performed well on this structure; it can be said that the children already performed at ceiling.

3.Which errors do Dutch TD children make while realising consonant clusters at 3, 4 and 5 years of age?

This section is based on descriptive results (see Section 6.5.4). The coded errors in this study were insertion, substitution, deletion, metathesis and a combination of these errors. All these errors occurred in all age groups. Noticeably less errors occurred in the productions of 5 year old children compared to 3 and 4 year old children. Again, not much difference was noticeable between 3 and 4 year old children but the percentages of errors made were a little lower in 4 year olds compared to 3 year olds. Insertion and cluster reduction occurred most often in 3 and 5 year olds and deletion occurred most often in 4 year olds. After that, substitution (in combination with insertion for 4 year olds and with metathesis for 5 year olds) occurred most often. The combination of errors occurred less often in all age groups. It was expected that 3,4 and 5 year olds made cluster reduction and substitution errors. This is borne out by the data. No other specific expectations were made about metathesis, insertion and a combination of errors. Therefore it is useful that this study showed that metathesis and insertion also occur in 3,4 and 5 year old children.

4.Do Dutch TD children produce consonant clusters more accurately in initial or final position?

This section is based on statistical analyses (Section 6.3.1-6.3.5). All age groups performed significantly better on final consonant-/s/ structures (FCS) compared to branching initial clusters (BIC). In addition, 5 year old children also performed better on final consonant-/s/ clusters (FCS) compared to initial /s/-consonant structures (ISC), but this significant difference did not exist for 3 and 4 year olds. No significant differences were found between the initial ISC and the final FCS.

From these results it can be concluded that consonant clusters in final position are produced more accurately by most children. This is in line with the expectations and with previous studies (Levelt, Schiller & Levelt, 2000; Lleó and Prinz, 1996; Templin,1957; Kirk & Demuth, 2003). It was also expected that if final structures were not produced more accurately, that initial and finial structures would be produced with similar accuracy. This was found for 3 and 4 year old children for the comparison of 1 structure (ISC = FCS).

5.How does the performance on the Non-Word Repetition Task correlate with vocabulary?

This section is based on statistical analysis (see Section 6.1.4). No correlation between the scores on the NWRT and the scores on the vocabulary test was found for 3 and 5 year old children. This is in line with the expectations, since this NWRT does not measure phonological memory as a main component and phonological memory is the element which correlates with vocabulary (Gathercole &Adams, 1994; Gathercole & Baddeley, 1990; Michas & Henry, 1994). However, a positive correlation was found for 4 year old children. It is possible that this is due to the analysis method. As described later in section 7.6, the chance of a type 1 error was bigger in this study since the dependencies between participants and stimuli were not taken into account in the analysis. Therefore, it is possible that this significant result would not have been significant if these dependencies were taken into account. In addition, since only one of the three age groups shows this correlation, it may be assumed that the other two age groups show the correct trend.

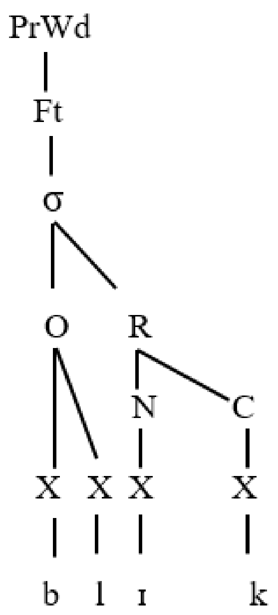
7.3. Discussion of the performance on structures with and without /s/

The results of this study showed that all age groups performed better on ISC compared to BIC. It can thus be concluded that all age groups performed better on initial structures including consonant clusters with /s/ (ISC) compared to structures including consonant clusters without /s/ (BIC). This result is not in line with the expectations. It was expected that performance was lower on structures including /s/, since they are seen as complex (Dos Santos & Ferré, 2016), compared to structures without /s/. In addition, the results on the acquisition of clusters was not expected either. The results showed that ISC was acquired by 3 year old children (≥ 75 % of the clusters are produced correctly by ≥75% of the children) and that 88.9% of the 4 year olds and 100% of the 5 year olds produced at least 75% of the ISC structures correctly. These percentages are very high. Results also showed that FCS was acquired by 4 year old children. On the other hand, BIC was not acquired by the 3,4 and 5 year olds. It can thus be concluded that consonant clusters including /s/ were acquired before consonant clusters without /s/, which was not expected. It was expected that the consonant clusters including /s/ (ISC and FCS) were not acquired by the 3,4 and 5 year old children. This was based on Stes (1979, 1997) who stated that these kind of clusters are acquired between 6 and 8 years old. In addition, based on Stes (1979, 1997) 5 year old children should have acquired BIC, but the data showed they did not. This big difference in the ages of acquisition may partially be caused by the possibility that Stes (1979, 1997) used a different criterion when a sound/structure was seen as acquired, in which more than 75% of the instances must have been produced correctly to be called acquired. Even though results were not in line with the expectations based on Stes (1979, 1997), they are in line with Fikkert's (1994) observation that two of the children she studied also acquired consonant clusters including /s/ first. This shows that this pattern has been observed before, even though in Fikkert's (1994) work it was a minority pattern and in the current study it is the main pattern. Since this study shows an acquisition pattern which has not been shown as a main pattern before, this has implications for the order of acquisition of clusters as we know it. It has clinical implications as well. Speech therapist in the Netherlands and Belgium use an articulation test based on the results by Stes (1979, 1997), but since the current study suggests that the order of acquisition of consonant clusters is not accurate, more research needs to be done on this. Eventually, the articulation tests should perhaps be revised if future research finds the same patterns as found in the current study.

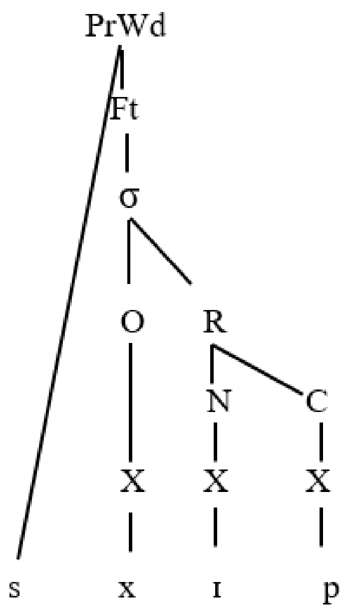
The fact that children performed better on initial structures including consonant clusters with /s/ and acquired these earlier than structures including consonant clusters without /s/ can be linked to the different representations of most of the consonant clusters in each group. As discussed multiple times before, initial structures with consonant clusters without /s/ have branching onsets and obey the sonority principle, while clusters with /s/ which do not obey the sonority principle are analysed with an appendix, which is adjoined directly under the prosodic word and not under the syllable. These different structures are shown in Figure 43 below.

Figure 43: The structures of *blik* ('can') and b) *schip* ('ship')

a)



b)



The fact that these structures are different may suggest different ages of acquisition, but it does not explain why initial structures with /s/ are produced more accurately and acquired earlier than structures without /s/. This may be explained in terms of frequency. The frequencies of the chosen clusters for the dependent parts were taken into account when designing the test. However, the frequency of the clusters with /s/ in one group, compared to the frequency of the clusters without /s/ in the other group, were not compared or taken into account. The option that this possible difference in frequency can explain the results will be explored now.

Levelt, Schiller & Levelt (2000) found that the order of acquisition of syllable types correlated with the frequency of the types in the Dutch language. Structures which are very frequent in Dutch were acquired first. This may also hold for consonant clusters. If the frequency of consonant clusters including /s/ is higher than the frequency of clusters without /s/ (i.e. plosive-liquid clusters), this can explain why clusters with /s/ are acquired first and produced more accurately.

In order to investigate this, the frequencies of the used consonant clusters from the relevant structures (ISC and BIC) in Dutch were taken from CELEX (Baayen, Piepenbrock & Gulikers 1995) by Kager (personal correspondence, 2018). More particularly, they were taken from the CELEX DPL (Dutch Phonology Lemma) file This lexicon consisted of 9861 lemmas and 46654 phonemes. The frequencies are shown in Table 34. When comparing the initial structures BIC and ISC, it can be seen that the some of the frequencies in the ISC group are much higher than the ones in the BIC group. For example, ISC includes frequencies of 208 and 289, while the highest frequency in BIC is 178. Since the different consonant clusters were grouped together in either BIC or ISC for the analysis, it is useful to look at the average frequency per group. The average frequency of ISC is 125.8, while the frequency of BIC is 101. The frequency of /s/-consonant clusters (ISC) is thus higher on average in Dutch than the average frequency of branching initial clusters (BIC). The fact that ISC occur more often in the Dutch language can thus explain the higher performance and earlier acquisition of these structures. It seems that the correlation found by Levelt, Schiller & Schiller (2000) between the development of syllable types and frequency also holds for the development of the investigated initial consonant clusters.

Table 34: The frequencies of the used consonant clusters

Type	Frequency	Average Frequency
Obstruent-liquid (BIC)		101
pl-	112	
kl-	178	
fl-	73	
xl-	41	
/s/-consonant cluster (ISC)		125.8
sp-	208	
sl-	142	
sx-	289	
sm-	64	
sk-	41	
spl-	11	
Consonant-/s/ cluster (FCS)		23
-ks	46	
-ps	18	
-ms	5	
Medial consonant clusters (M)		26.4
sf	0*	
sp	18	
sk	22	
mf	5	
mp	87	

* The frequency of 0 shows that this cluster is very rare.

In addition, FCS was also acquired earlier than BIC by 4 and 5 year old children. Looking into the frequencies to see if these can explain the difference in performance, it was found that the average frequency of FCS (23) is lower than the average frequency of BIC (101). Therefore, frequency is not able to account for the fact that the cluster with /s/ (FCS) is acquired before the cluster without /s/ (BIC).

It must be noted that the used CELEX frequencies are based on adult directed written language and not on child directed speech. Therefore, the used frequencies of the sound children hear (the input) may not be exactly the same to what is displayed in CELEX. This issue was also addressed by Levelt, Schiller & Levelt (2000) concerning syllable types. They investigated this by comparing the frequencies of syllable types in the adult directed CELEX to frequencies of child directed speech. The child directed speech was a preliminary analysis by a caretaker, which was obtained via personal communication with Van de Weijer. The frequencies of the syllable types for child directed and adult directed language are shown in Table 35 below (Levelt, Schiller & Levelt, 2000, p.260, based on personal communication with Van de Weijer). Comparison showed that the frequencies in child and adult directed language differed for the syllable V; it was higher in child directed speech. These are instances of the type "*Oja*? 'Oh,really?',*O,o* 'Uh,o',*oke* 'Okay', and *au* 'ouch' (Levelt, Schiller & Levelt, 2000, p. 260). It makes sense that these occur more often in child directed speech than in adult directed written language. The other frequencies were quite similar. Since syllable types contain consonant clusters, the results by Levelt, Schiller & Levelt (2000) suggest that the frequencies of consonant clusters in child directed speech and adult directed written language may be comparable as well. This supports the frequency explanation of the data on clusters with and without /s/.

Table 35: The frequencies of syllable types in child directed speech and adult directed written language, C = consonant, V = vowel (Levelt, Schiller & Levelt, 2000, p. 260, based on personal communication with Van de Weijer).

Syllable Type	*Child Directed*	*Adult Directed*	*Developmental Order*
CV	42.1	36.2	1
CVC	30.1	31.9	2
VC	11.3	14.3	4
V	3.6	4.3	3
CVCC	3.6	5.0	5 (A)/7 (B)
CCVC	2.9	2.1	8 (A)/6 (B)
CCV	2.0	2.1	6 (A)/5 (B)
VCC	0.4	1.1	7 (A)/8 (B)
CCVCC	0.4	0.6	9

To summarize, results of the current study showed that all age groups performed better on initial structures including consonant clusters with /s/ (ISC) compared to structures including consonant clusters without /s/ (BIC). In addition ISC and FCS were acquired earlier than BIC. This is linked to the different structures of clusters with and without /s/ (appendix vs. no appendix). In addition, these results can partly be explained in terms of frequency. The frequency of ISC in Dutch is higher compared to the frequency of BIC and can therefore explain the higher performance and earlier acquisition of ISC compared to BIC. It seems that the correlation found by Levelt, Schiller & Schiller (2000) between the development of syllable types and frequency also holds for the acquisition of ISC and BIC. However, frequency cannot account for the earlier acquisition of FCS compared to BIC.

7.4. Discussion on the results on medial structures

Children performed better on ISC and FCS compared to medial structures (M). These differences in performance cannot just be explained by the occurrence of the segment /s/ or not since some medial structures also included the segment /s/. However, the difference between the performance on ISC and M may still be explained by looking at the different structures. Medial structures fall under the syllable, while most of the clusters in ISC have an appendix. Unfortunately, these two structures occur in different positions and can thus not be compared as nicely as ISC and BIC, which were both consonant clusters in initial position. However, the fact that M falls under the syllable, and part of ISC falls outside the syllable in the form of an appendix is still a big difference. In terms of frequency it can be noted that the average frequency of M (26.4) is much lower than the frequency of ISC (125.8). We can thus say that frequency can account for the result that children performed better on ISC than on M.

On the other hand, the better performance on FCS compared to M cannot be explained by the frequencies of the different cluster groups. The average frequency of FCS is namely 23, while the frequency of M is 26.4. However, the difference in frequencies is small and the frequency of one cluster in M was very high (mp = 87) which caused the average to be higher, but this does not represent the seperate consonant clusters well. Considering that the average frequencies of the two cluster groups are very close together, it would be expected that performance was the same on these two cluster groups, if frequency was the only relevant factor. However, a significant difference was found. Therefore, it can be concluded that an explanation in terms of frequency is not satisfactory is this case. The fact that performance on M is lower compared to other structures does support the idea that medial structures are seen as a difficult structure, as stated by Dos Santos & Ferré (2016). Further research should focus on why medial structures seem to be more difficult for children and how they relate to other consonant clusters including /s/.

7.5. Discussion of the results of 3 and 4 year old children

This study has found multiple instances when no statistical difference was found between the performance of 3 and 4 year old children. This could be due to the fact that by change, the 3 year old children are very good, or the 4 year olds very poor, or that not much development occurs during 3 and 4 years of age. This last account can be disregarded immediately, because it is known that phonology develops when children are young. In addition, it could be argued that the 3 year olds performed very well because some of them were tested twice, while all of the 4 year olds were only tested once. All 3 year olds who were tested twice performed better the second time. It is assumed that this is because the children were less shy the second time. The first time, almost all 3 year olds were very shy (whereas 4 and 5 year old children were usually less shy/not shy) but the second time they knew the researcher and knew what the test was going to look like on the computer. Because of this, it is believed they felt less shy and more secure and that this was the reason they cooperated and scored better in the test. The researcher noticed that the children chatted more, were less shy and cooperated better the second time. Even though the 4 and 5 year old were usually less shy compared to the 3 year olds, the older children would perhaps also have scored better on a second testing moment if they would be less shy then. The fact that 3 year olds performed better the second time is not assumed to be due to a learning effect. The change of a learning effect is very small; the children were young (3 years old) and tested two weeks apart. It is not expected that young children can remember 56 instances after two weeks after hearing all of them only once. In addition, they were asked to repeat non-words, which are harder to remember than real words. Therefore, it is very unlikely that they performed better the second time because of a learning effect.

In addition, the fact that 4 year olds did not perform better cannot be explained by speech therapy. The included children did not have speech therapy. However, many children in that particular class did go to speech therapy but this should not have affected the other children much. Both age groups were recruited in different places: the 3 year olds in the centre of Utrecht and Voorburg and the 4 year olds in The Meern and in Bleiswijk. No information was gathered about social economic status, and possible differences in the social economic status may have influenced the results. In addition, gender was not taken into account in this study and may have influenced the results as well.

Lee et al. (2013) also focussed on a NWRT and also did not find significant differences on performance between 3 and 4 year olds, but only between 3 and 5 year olds. They say there is a developmental difference, and do not explain that no difference was found between 3 and 4 year olds. Perhaps there is not much difference between 3 and 4 year olds at this stage after all.

In conclusion, the fact that no difference was found in performance between 3 and 4 year old children may be due to being tested twice (and being less shy the second time which caused better cooperation and better scores), social economic status or gender. The other option, based on Lee et al., is that there may not be much difference between the age groups after all. However, this is not seen as a likely explanation.

7.6. Limitations and future research

One of the main limitations of this study is the way the statistical analysis is performed. Non-parametric tests were used, which give less robust results than parametric tests. In addition, the non-parametric tests which were used to compare the performance between different consonant clusters (Wilcoxon's tests) and this performance between age groups (Mann-Whitney U tests) do not take into account that each non-word is repeated by all participants and that there are repeated measures for each participant. Therefore, the chance of a type 1 error is bigger: the results may show to be significant, even though they would not have been if these factors were taken into account. However, it was chosen to analyse it like this, since this was in line with the French analyses method, which makes comparison easier. In addition, it was not possible to analyse this differently due to lack of time and statistical knowledge of the author. Even though the results may be overestimated, they are still useful since they still show a trend. In addition, some conclusions are based on descriptive results. This is not very reliable since it is not statistically tested. Therefore, future studies should try to analyse this kind of data taking the dependencies between participants and stimuli into account and analysing everything with statistical tests.

Another limitation is that the number of items in each consonant cluster group was not equal. This is due to the fact that the test was designed in line with the French test (Dos Santos & Ferré, 2016). However, the current study compared consonant clusters in specific positions while this was not done by Dos Santos & Ferré (2016). Since this was not the main point for Dos Santos & Ferré (2016), the number of items in each consonant cluster group (these groups were formed in the current study) were not equal. Results would be more accurate if these groups were similar in size. Future research should therefore design the test differently in order to get better, more trustworthy results for the specific purpose of analysing consonant clusters with and without /s/.

In addition, the fact that some of the three 3 old children were tested twice on the NWRT may have influenced the results. Even though, as described previously in section 7.5., it is not expected that a learning effect occurred, they may have performed better because they were less shy the second time. Considering that many 3 year olds were very shy (the first time and sometimes even the second time a little as well) it would perhaps be better in future research to start the testing session with the PVVT instead of the NWRT. It was chosen to start with the NWRT since this was the most important test for this study, and if the children were unable to do all tests at least the data from the NWRT was collected. However, children were able to complete all 3 tests. Some of the 3 year old children were shy and found it very strange to pronounce the non-words. If the PVVT was administered first, the child would have some time to open up to the researcher while pointing at the pictures (which is not a strange task for the children) and then would maybe also perform better on the NWRT later. Maybe if this is done, children will participate better and less children have to be excluded for not cooperating due to shyness (in this study 7 children were excluded because they were too shy and did not cooperate).

Another limitation is that it was not always quiet in the rooms where the children were tested. It was tried to find a quiet room, but this was not always possible since many rooms were always used in the schools. The children were always tested in a separate room (i.e. not in the classroom itself) but sounds from adjacent rooms or playgrounds could sometimes still be heard. Noise may have influenced the hearing of the children, and therefore may have prevented them from repeating the non-word correctly because they could not hear well. However, this chance is small since the researcher tried to avoid this; headphones were used and if there was too much noise she waited for a little bit or tried to lower the noise by asking or closing windows/doors etc.

Another limitation of this study is that the frequency of Dutch sounds has not been taken into account when the test was designed in the sense that the most frequent clusters were not included in the test (like /-ts/ for example). This was not possible since the same sounds as in the French version (Dos Santos & Ferré, 2016) had to be used to keep the versions as similar to each other as possible, for later comparison. However, it was tried to control for frequency as much as possible while using the same sounds as in the French test (Dos Santos & Ferré, 2016). For example, /-sk/ was not selected for the Dutch test while it was part of the French stimuli (Dos Santos & Ferré, 2016), since it is very infrequent in Dutch. If the frequency of consonant clusters was controlled, and the most frequent Dutch clusters were included in the test, the test would have been more Dutch specific. In addition, maybe performance would be better if only very frequent clusters were used.

Another limitation is that previous literature did not use one criterion when a sound was seen as acquired. This made comparison more difficult. However, this was solved by creating a criterion, which combined criteria from the literature and stating this criterion very clearly.

Even though 55 children were included in this study analyses, results would be more robust if more children would participate. Therefore, future research should include more children. In addition, further research should also look at the length of the non-words and how it combines with the number of clusters in an items. It would be interesting to see whether word length is a trivial factor which shows working memory, or that syllable complexity interacts with word/syllable length on the level of phonological representations. Another interesting point for future research would be to look at which specific errors (also different kind of substitution errors, like gliding and fronting) occur in structures with and without /s/ in a systematic way.

In addition, further research should include children older than 5 years old to see when the other structures are acquired according to the criteria (≥75% of the structure acquired by ≥75% of the children). Additionally, as already mentioned at the beginning of this thesis, further research should test children with Autism Spectrum Disorder and compare them to this control data, to see whether a language impairment in children with ASD can be found with the NWRT. Expanding the age range for TD children will thus also be useful for this future aim, since the autistic children are expected to develop slower than TD children and the expanded age range TD data can then also be used for comparison. Lastly, as mentioned in the earlier sections, further research should focus on why medial structures seem to be more difficult for children and on consonant clusters with /s/ and without /s/ in general.

8. Conclusion

The main aim of this study was to investigate the production of consonant clusters with and without /s/ by Dutch TD children of 3,4 and 5 years old. There were several specific questions related to this main aim. The first one was concerned with the kind of errors children make while producing consonant clusters. Results showed that the most occurring errors in the production of 3 and 5 year old children was insertion and cluster reduction, while it was only cluster reduction in 4 year old children. Another sub question was about whether children produce consonant clusters more accurately in initial or finial position. Results showed that consonant clusters were produced more accurately in final position than in initial position by most children. In addition, the Non-Word Repetition Task which was adapted from French (Dos Santos & Ferré, 2016) to Dutch in this study, was not supposed to test phonological short-term memory as a main component. This was borne out by the data. Another aim was to investigate how the performance on the Non-Word Repetition Task correlates with vocabulary. Results showed that performance on the Non-Word Repetition Task did not correlate with vocabulary for most children, which was expected. The last aim was to make a control group of data from TD Dutch children, so that when children with Autism Spectrum Disorder (ASD) are tested with this test as well, the two data sets can be compared. This may give insights in a possible language impairment in children with ASD.

The main findings of this study were on clusters with and without /s/ and were in contrast with most previous literature. Results showed that children performed better on initial structures with /s/ compared to initial structures without /s/. In addition, initial consonant clusters with /s/ were acquired before consonant clusters without /s/. These results can be explained in terms of the different structures of most of the clusters in one group compared to the other (appendix vs. no appendix) and in terms of frequency; the clusters including /s/ are more frequent in Dutch than the clusters without /s/. Therefore, it is logical that children acquire them earlier because they hear them often. Results also showed that final consonant clusters including /s/ were acquired before initial clusters without /s/. This result cannot be explained by frequency. In addition, performance was higher on initial and final clusters with /s/ compared to medial structures. The first can be explained in terms of frequency, while the second cannot. More research should be done on the acquisition of consonant clusters with and without /s/ in order to come closer to understanding why difference in performance and order of acquisition occurs. This study has clinical implications, since a different order of acquisition for clusters was found compared to previous literature on which articulation tests are based. If further research finds similar patterns as found in this study, perhaps the articulation tests should be revisited.

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Appendix A: List of abbreviations

TD	=	typically developing
NWRT	=	non-word repetition task
DS	=	digit span
PVVT	=	Peabody Picture Vocabulary Test
FC	=	final consonant
FCS	=	final consonant + /s/ cluster
V	=	vowel
C	=	consonant
ISCC	=	initial /s/ + two consonants cluster
ISC	=	initial /s/ + consonant cluster
BIC	=	branching initial cluster
IH	=	initial head
MC	=	medial consonant
M	=	metathesis
D	=	deletion
I	=	insertion
S	=	substitution

Appendix B: Informed consent form for head of institution

ETCL

Ethische(Toetsingscommissie(
Linguïstiek Universiteit Utrecht

ETCL-referentienummer: 4135555-03-2018

TOESTEMMINGSVERKLARING voor deelname aan:

Een nieuwe klank test voor Nederlandstalige kinderen

Ik bevestig als leidinggevende van de school/het peutercentrum/het kinderdagverblijf/andere instelling: (s.v.p. doorhalen wat niet van toepassing is)

(Naam instelling) ____ gevestigd te: ______________________

- dat ik via de informatiebrief naar tevredenheid over het onderzoek ben ingelicht;
- dat ik in de gelegenheid ben gesteld om vragen over het onderzoek te stellen en dat mijn eventuele vragen naar tevredenheid zijn beantwoord;
- dat ik gelegenheid heb gehad om grondig over deelname van mijn instelling aan dit onderzoek na te denken;
- dat ik uit vrije wil instem met deelname van mijn instelling.
- dat ik de ouder(s) of wettelijk voogd van elke potentiële deelnemer uiterlijk twee weken voor aanvang van het onderzoek via een individueel overhandigde of toegezonden informatiebrief zal informeren over het onderzoek, zodat deze indien gewenst tijdig (mondeling of schriftelijk) aan de directie te kennen kunnen geven geen toestemming voor deelname van hun kind te geven.

Ik stem er als leidinggevende van bovengenoemde instelling mee in dat:

- de verzamelde gegevens voor wetenschappelijke doelen worden verkregen en bewaard zoals in de informatiebrief vermeld staat;
- er voor wetenschappelijke doeleinden geluidsopnamen worden gemaakt.

Ik begrijp dat:

- ik het recht heb om mijn toestemming op ieder moment weer in te trekken zonder dat ik daarvoor een reden hoef op te geven;
- de verzamelde gegevens worden behandeld volgens de VSNU Gedragscodes (www.vsnu.nl/gedragscodes).

Naam: ____________________________________ Geboortedatum: ___ / ___ / ____ (dd/mm/jjj)

Handtekening: ______________________________ Datum, plaats: ___ / ___ / ____, ________________

Bijbehorende verklaring omtrent evt. hergebruik van gegevens

(1) Onderzoekers delen regelmatig onderzoeksgegevens met andere onderzoekers, zodat de gegevens nóg beter benut worden. Uiteraard zijn die gegevens dan niet te herleiden tot individuele personen of organisaties. Gaat u er mee akkoord dat eventueel ook de via uw instelling verzamelde onderzoeksgegevens anoniem gedeeld worden met andere onderzoekers?

[ ] Ja, daar ga ik mee akkoord. Handtekening: ____________________________ [ ] Nee, niet akkoord.

(2) Soms worden geluidsopnames ook gebruikt in wetenschappelijke lezingen of lessen (die op hun beurt soms ook weer op het internet worden geplaatst). Dergelijke opnames zijn natuurlijk wél te herleiden tot individuele personen. Hoe staat u tegenover zulk hergebruik van de binnen uw instelling gemaakte opnames?

[ ] Ja, daar ga ik mee akkoord. Handtekening: ____________________________ [ ] Nee, niet akkoord.

z.o.z.

In te vullen door de eindverantwoordelijk onderzoeker:	
Ik verklaar dat ik bovengenoemde leidinggevende heb uitgelegd wat deelname voor zowel de instelling als de betrokken kinderen inhoudt (alsmede wat de regels zijn omtrent passieve *informed consent*), en dat ik borg sta	Naam: ___________________________ Datum: ___ / ___ / _____ (dd/mm/jjjj)

Appendix C: Informed consent form for parents

ETCL
Ethische(Toetsingscommissie(
Linguïstiek Universiteit Utrecht

TOESTEMMINGSVERKLARING voor deelname aan:

Een nieuwe klank test voor Nederlandstalige kinderen

Ik, ouder of voogd van het hieronder genoemde kind, bevestig:

- dat ik via de informatiebrief naar tevredenheid over het onderzoek ben ingelicht;
- dat ik in de gelegenheid ben gesteld om vragen over het onderzoek te stellen en dat mijn eventuele vragen naar tevredenheid zijn beantwoord;
- dat ik gelegenheid heb gehad om grondig over deelname aan het onderzoek na te denken;
- dat ik uit vrije wil samen met mijn kind deelneem.

Ik stem er mee in dat:

- de verzamelde gegevens voor wetenschappelijke doelen worden verkregen en bewaard zoals in de informatiebrief vermeld staat;
- er voor wetenschappelijke doeleinden geluidsopnamen worden gemaakt.

Ik begrijp dat:

- ik het recht heb om mijn toestemming op ieder moment weer in te trekken zonder dat ik daarvoor een reden hoef op te geven;
- de verzamelde gegevens worden behandeld volgens de VSNU Gedragscodes (www.vsnu.nl/gedragscodes).

Naam ouder of voogd: ______________________________ Geboortedatum: ___ / ___ / ____ (dd/mm/jjjj)

Handtekening ouder/vgd.: __________________________ Datum, plaats: ___ / ___ / ____, __________

Bijbehorende verklaring omtrent evt. hergebruik van gegevens

(1) Onderzoekers delen regelmatig onderzoeksgegevens met elkaar, zodat de gegevens nóg beter benut worden. Uiteraard zijn die onderzoeksgegevens dan niet te herleiden tot individuele personen. Gaat u er mee akkoord dat de onderzoeksgegevens van uw kind <u>anoniem</u> gedeeld kunnen worden met andere onderzoekers?

[ ] Ja, daar ga ik mee akkoord. Handtekening: __________________________ **[ ]** Nee, niet akkoord.

(2) Soms worden geluidsopnames ook getoond in wetenschappelijke lezingen of lessen (die op hun beurt soms ook weer op het internet worden geplaatst). Dergelijke opnames zijn natuurlijk wél te herleiden tot individuele personen. Hoe staat u tegenover zulk hergebruik van de evt. van u en uw kind gemaakte opnames?

[ ] Ja, daar ga ik mee akkoord. Handtekening: __________________________ **[ ]** Nee, niet akkoord.

In te vullen door de uitvoerend onderzoeker:

Ik verklaar dat ik bovengenoemde deelnemer heb uitgelegd wat deel-

Naam: __________________________

Datum: ___ / ___ / _____ (dd/mm/jjjj)

Appendix D: Information letter

Informatie over deelname aan

Een nieuwe klank test voor Nederlandstalige kinderen

---

1. Inleiding

Via deze brief willen wij uw toestemming vragen om uw kind mee te laten doen aan het onderzoek **"Een nieuwe klank test voor Nederlandstalige kinderen"** van de Universiteit Utrecht en de Universiteit van Amsterdam. Het onderzoek zal plaatsvinden op [naam school/BSO]. De directeur van [naam school/BSO] heeft toestemming gegeven dat dit onderzoek op [school/de BSO] plaatsvindt. Mocht u hier vragen over hebben kunt u [naam directeur] bereiken op [gegevens]. Dit onderzoek is getoetst door de Ethische Toetsingscommissie Linguïstiek van de Universiteit Utrecht.

2. Wat is de achtergrond en het doel van het onderzoek?

Het doel van dit onderzoek is om een test te ontwikkelen die vast kan stellen op welke leeftijd kinderen woorden van verschillende mate van complexiteit goed beheersen. We willen ook kijken hoe leeftijd samenhangt met woordenschat.

3. Hoe wordt het onderzoek uitgevoerd?

Dit onderzoek vindt niet plaats in de klas, maar in een aparte ruimte. Tijdens het onderzoek zit uw kind aan een tafel. De onderzoeker zit naast uw kind. De test wordt afgenomen via een computer. Het is een soort spelletje met een leuk plaatje van een alien. Uw kind wordt gevraagd om de woorden die de alien zegt na te zeggen. De woorden zijn niet-bestaande woorden, maar ze zijn zo ontworpen dat ze volgens de Nederlandse klankregels echte woorden zouden kunnen zijn. Om het aantrekkelijk te houden voor de kinderen is er een ander plaatje van een alien bij elk woord. Deze test wordt opgenomen met een audiorecorder. We maken deze opnames zodat we na afloop alles kunnen uitschrijven en kunnen bepalen of uw kind het woord correct herhaald heeft. De opnames worden niet zonder uw toestemming publiek gemaakt. U kunt hier op het toestemmingsformulier wel of geen toestemming voor geven. Verder doen we een kort testje waarin uw kind cijfers moet nazeggen. Dit doen we om het geheugen te testen. Daarnaast testen we de woordenschat van uw kind door middel van een korte test waarin uw kind 4 plaatjes te zien krijgt. De onderzoeker zegt dan een woord, en uw kind moet het plaatje aanwijzen wat hier bij hoort.

4. Wat wordt er van uw kind verwacht?

Uw kind wordt gevraagd de 3 taken uit te voeren die in het vorige kopje beschreven staan. De eerste taak, waarin het kind niet bestaande woorden moet nazeggen, duurt ongeveer 20 minuten. De tweede taak, waarin het kind cijfers moet nazeggen, duurt ongeveer 5 minuten. De derde taak duurt ongeveer 20 minuten en hierin wordt uw kind gevraagd het goede plaatje bij een woord aan te wijzen. Er zijn korte pauzes tussen de testjes. Hierdoor zal het hele onderzoek in totaal ongeveer 60 minuten in beslag nemen.

5. Wat zijn mogelijke voor- en nadelen van deelname aan dit onderzoek?
U of uw kind heeft zelf geen direct voordeel van deelname aan dit onderzoek. Voor de toekomst zal het onderzoek echter wél zeer nuttig zijn omdat we de resultaten van de kinderen uit deze studie in een volgend onderzoek willen vergelijken met kinderen met autisme. Op deze manier willen we meer inzicht krijgen in de taalproblemen van kinderen met autisme en kunnen we ze hopelijk beter helpen. Een eventueel nadeel van deelname zou kunnen zijn dat uw kind zich ongeveer 45 minuten moet concentreren. Er zijn echter pauzes tussen de verschillende taken en de eerste taak lijkt op een soort spelletje. Hierdoor wordt het leuker en minder belastend voor uw kind.

6. Wat gebeurt er bij verzet van de deelnemer tijdens het onderzoek?
Het kan zijn dat uw kind tijdens het onderzoek niet echt meewerkt of aangeeft te willen stoppen. In dit geval zal het onderzoek altijd worden gestopt.

7. Vrijwillige deelname
Uw kind doet vrijwillig mee aan dit onderzoek. Als we aan het testen zijn en uw kind wil stoppen, dan kan dat altijd. Uw toestemming betekent niet dat uw kind alle testen moet afronden. U kunt de deelname aan het onderzoek ook na het onderzoek nog intrekken. U hoeft ons niet te laten weten waarom u niet meer wilt meewerken. Als uw kind niet meer mee wil doen of u de deelname intrekt, dan verwijderen we alle gegevens definitief. Ook is het mogelijk dat de onderzoeker het testen stopt, omdat uw kind bijvoorbeeld niet goed meewerkt.

8. Wat gebeurt er met de verzamelde gegevens?
De gegevens van uw kind worden beheerd door de medewerkers van dit onderzoek. Mocht u deze gegevens willen aanpassen, dan kunt u dit doen door contact op te nemen met: Ellen Collee (k.e.collee@students.uu.nl). Wij zijn verplicht de onderzoeksgegevens, geanonimiseerd, 10 jaar te bewaren. Dit betekent dat de resultaten niet meer terug te koppelen zijn aan uw kind. U geeft hiervoor toestemming als uw kind meedoet aan dit onderzoek. Als u dat niet wilt, kan uw kind niet meedoen aan dit onderzoek. Gegevens verzameld tijdens het onderzoek zullen geheel geanonimiseerd worden opgeslagen en bewaard op een door de Universiteit Utrecht beveiligde server.

De verzamelde opnames zullen nooit gebruikt worden voor presentaties of andere publieke doeleinden, tenzij we uw toestemming daarvoor krijgen. U kunt op het toestemmingsformulier aangeven of u hier wel of niet toestemming voor geeft. Geeft u hier geen toestemming voor, dan zullen de opnames niet gebruikt worden.

9. Is er een vergoeding wanneer u besluit aan dit onderzoek mee te doen?
Uw kind krijgt na afloop een mooie diploma. Tussendoor krijgt uw kind stickers die later op de diploma geplakt kunnen worden. Als het onderzoek is afgerond zullen we op de [naam school/BSO etc] een korte presentatie geven. In deze presentatie bespreken we de

belangrijkste uitkomsten van ons onderzoek. Als u wilt, ontvangt u dan ook een samenvatting met de algemene resultaten van het onderzoek

10. Goedkeuring van dit onderzoek
De ethische toetsingscommissie linguïstiek van het UiL OTS (ETCL), heeft dit onderzoek goedgekeurd. Wanneer u een klacht wilt indienen over de procedure omtrent dit onderzoek, dan kunt u contact opnemen met: M.K.A. de Klerk (Maartje), telefoon: (030-) 253 8472, e-mail: m.k.a.deklerk@uu.nl

11. Meer informatie over dit onderzoek?
Als u nog verdere informatie wilt over dit onderzoek, dan kunt u contact opnemen met master student Ellen Collée (k.e.collee@students.uu.nl) of onderzoeker Prof. René Kager (telefoon: 030 253 8064; e-mail: R.W.J.Kager@uu.nl; Trans 10, 3512 JK Utrecht, kamer 1.20) of onderzoeker Prof. Jeannette Schaeffer (telefoon: 020-525 2083; e-mail: j.c.schaeffer@uva.nl; Spuistraat 134, 1012 VB Amsterdam, kamer 4.24).

12. Bijlagen:
Als bijlage van deze brief vindt u de toestemmingsverklaring. Als u bereid bent toestemming voor de deelname van uw kind aan dit onderzoek te verlenen vragen wij u de verklaring te ondertekenen. Wij willen u vragen of u de verklaring ingevuld aan [de leerkracht op school/leidster op de BSO] of aan mij wilt retourneren. Naar mij kan dit kan per post of per email met bijgevoegde scan van het formulier:

Ellen Collée
Laan van Soestbergen 15bis
3582SR Utrecht
k.e.collee@students.uu.nl

Appendix E: Short questionnaire for parents

Informatie over uw kind die relevant kan zijn

Universiteit Utrecht

Is er een vermoeden dat uw kind een taalstoornis (bv. dyslexie) heeft?	Ja/Nee
Zo ja, welke? ________________________	
Heeft uw kind TOS (taalontwikkelingsstoornis)?	Ja/Nee
Heeft uw kind ADHD?	Ja/Nee
Heeft uw kind een gehoorstoornis?	Ja/Nee
Is Nederlands de moedertaal van uw kind?	Ja/Nee
Spreekt uw kind nog andere talen dan Nederlands?	Ja/Nee
Zo ja, welke? ________________________	
Hoe vaak? ________________________	

Appendix F: Word likeness test for the language independent items

Geef op de onderstaande schaal aan of de weergegeven vorm lijkt op een bestaand Nederlands woord. Als de weergegeven vorm een bestaand Nederlands woord is, dan schijf je in de laatste kolom waar dit woord naar verwijst, Is de weergegeven vorm bijvoorbeeld *okapi*, dan schrijf je in de laatste kolom “bestaand ; dier”. Als je vindt dat de weergegeven vorm op een Nederlands woord lijkt, geef dan in de laatste kolom aan op welk woord de weergegeven vorm lijkt. Aan het einde van de enquête is er ruimte voor eventuele extra opmerkingen over op welk woord de weergegeven vorm lijkt of welke weergegeven vorm een bestaand woord is.
De schaal gaat van 1 : lijkt helemaal niet op een bestaand Nederlands woord tot 5 : lijkt heel erg op een bestaand Nederlands woord.

lijkt :		helemaal niet	niet	neutraal	wel	heel erg	
		1	**2**	**3**	**4**	**5**	**bestaand/ lijkt op**
1	**ploe**	☐	☐	☐	☐	☐	
2	**kafip**	☐	☐	☐	☐	☐	
3	**paaf**	☐	☐	☐	☐	☐	
4	**kapi**	☐	☐	☐	☐	☐	
5	**piklafoe**	☐	☐	☐	☐	☐	
6	**plifoe**	☐	☐	☐	☐	☐	
7	**pakloe**	☐	☐	☐	☐	☐	
8	**foepli**	☐	☐	☐	☐	☐	
9	**koeflapi**	☐	☐	☐	☐	☐	
10	**plakloe**	☐	☐	☐	☐	☐	
11	**pifakoep**	☐	☐	☐	☐	☐	
12	**floekif**	☐	☐	☐	☐	☐	
13	**kifapoe**	☐	☐	☐	☐	☐	
14	**flaploe**	☐	☐	☐	☐	☐	
15	**foek**	☐	☐	☐	☐	☐	
16	**kapoefik**	☐	☐	☐	☐	☐	
17	**klifak**	☐	☐	☐	☐	☐	
18	**poekif**	☐	☐	☐	☐	☐	
19	**flika**	☐	☐	☐	☐	☐	
20	**fakoe**	☐	☐	☐	☐	☐	
21	**klipafoe**	☐	☐	☐	☐	☐	
22	**poefaki**	☐	☐	☐	☐	☐	
23	**floe**	☐	☐	☐	☐	☐	
24	**faap**	☐	☐	☐	☐	☐	
25	**koepafli**	☐	☐	☐	☐	☐	
26	**piloe**	☐	☐	☐	☐	☐	
27	**kli**	☐	☐	☐	☐	☐	
28	**flipoeka**	☐	☐	☐	☐	☐	
29	**lafi**	☐	☐	☐	☐	☐	
30	**fikoepla**	☐	☐	☐	☐	☐	

Optioneel : Geef hieronder meer uitleg over welke weergegeven vorm een Nederlands woord is. Omschrijf waar het naar verwijst. Geef ook aan welke weergegeven vorm je vindt lijken op welk Nederlands bestaand woord.

Appendix G: The German stimuli

The German stimuli are presented below. LI stands for language independent items while LD stands for language dependent items. Stress was placed on the first syllable, and written *s* was pronounced as a ʃ and sometimes as s (no details were provided).

LI	CVCV	pilu
LI	CVCV	kapi
LI	CVCV	lafi
LI	CVCV	faku
LI	CCV	pli
LI	CCV	kla
LI	CCV	flu
LI	CVC	kip
LI	CVC	paf
LI	CVC	fuk
LI	CVCCV	paklu
LI	CVCCV	fupli
LI	CCVCV	fluka
LI	CCVCV	plifu
LI	CCVCCV	plaklu
LI	CCVCCV	flaplu
LI	CVCVC	kafip
LI	CVCVC	pukif
LI	CVCVCV	kifapu
LI	CVCVCV	pufaki
LI	CVCVCCV	fikupla
LI	CVCVCCV	kupafli
LI	CCVCVCV	klipafu
LI	CCVCVCV	flipuka
LI	CVCCVCV	piklafu
LI	CVCCVCV	kuflapi
LI	CVCVCVC	kapufip
LI	CVCVCVC	pifakup
LI	CCVCVC	flukif
LI	CCVCVC	klifak
LS	CVCV	sapi
LS	CVCV	Saku
LS	CVC	kiS
LS	CVC	kas
LS	CCVCCV	Spaklu
LS	CCVCCV	sfupli
LS	CCCVCV	Spluki

LS	CCVCCV	sklifu
LS	CCVCCV	Splaklu
LS	CCCVCCV	sklaplu
LS	CCVCVC	skifup
LS	CCVCVCVC	Spukif
LS	CCVCVCV	skifapu
LS	CCVCVCV	Spafika
LS	CCVCVCCV	sfikupla
LS	CCVCVCCV	skupifla
LS	CCCVCVCV	sklipafu
LS	CCCVCVCV	sflipuka
LS	CCVCCVCV	Spiklafu
LS	CCVCCVCV	skaflipu
LS	CCVCVCVC	skapifuk
LS	CCVCVCVC	Spifakup
LS	CVCVCC	kafipS
LS	CVCVCC	pukifs
LS	CVCVCVCC	kapifaps
LS	CVCVCVCC	fikapuks
LS	CVCCVC	pafluS
LS	CVCCVC	kuflas
LS	CVCVCCV	fikuspa
LS	CVCVCCV	kufiski
LS	CVCVCCVC	pafiklas
LS	CVCVCCVC	fapuplaS
LS	CCVCCV	kluspi
LS	CCVCCV	plisfu
LS	CVCCV	pusfa
LS	CVCCV	faspi

Appendix H: Used consonant clusters in LD1 in French, German and Dutch

The used consonant and consonant clusters in the language dependent part in initial and final position for the French, German and Dutch versions (X indicates that the cluster occurs in the version, - indicates that the cluster is absent).

Initial	French	German	Dutch
sp-	X	X	X
sk-	X	X	X
sf-	-	X	-
sl-	-	-	X
spl-	X	X	X
skl-	-	X	-
Final			
-s	X	X	X
-l	X	-	-
-sp	X	-	-
-sk	X	-	-
-ks	-	X	X
-fs	-	X	-
-ps	X	X	X
-s-	X	-	X
-l-	X	-	-

Appendix I: Coding manual for the NWRT

User guide and coding manual of the LITMUS-NWR-FRENCH Test

Contents

1 Contents of the data and coding sheet

Column titles	**commentaries**
File	name of the original data file in case of multiple coding sheets
Child code	anonymous child code
Sex	F/M
Birth Date	01/01/2000
Date of testing	01/01/2000
Age	annee;mois or age in month
Group predefined	groupe type (ex. followed by SLT, TD, …)
Group final	BISLI/BITD/MOSLI/MOTD
language	ex. L1 portuguese
Production	child production

verification	verification par another transcriber
Order	randomized order
NW	target
structural information about the NW (to be extracted when analyzing)- These columns should not be modified	
Structure	syllable structure of NW
Nb syllables	..
Nb clusters	..
Nb codas	..
Nb segments	..
SC CLUSTER	nb of …
#sC	nb of…
sC#	nb of …
internal sC	nb of …
CS CLUSTER	nb of …
Test	part of the test : LI or LD
NbSeg	…
R-order-A1	true order of the test
results	
Score	score per length((nb total of phoneme in item-nb oferror)/nb total of phoneme in item) - ex /pilu/ produced /pitu/ ((4-1)/4)=0,75 (automatic formula)
Score/item	success at the whole item (yes or not) (automatic formula) it is a calculation of the success at the item (without any considerations of the number of errors). It allows to get the general success at the test
Lexicalisation	item lexicalized ?
NbErr	total nb of error (automatic formula)
coding of the structure (we code the item from the right to the left)	
Add.others	additions other than those coded in the regular structure
FCS	final cluster with final s ex. piks
FSC	final cluster with post final s ex. pisk
FL	final l ex. pil
FC	final C other than l or s
V1	vowel 1 → p**i**k pap**i** kupap**i**
BO1	branching onset 1 → **pl**i
HO1	Head of onset 1 (first C in onset of a 1-syll item ex. **p**i, 2nd C of a 2-syll item ex. ka**p**i, 3rd C of a 3-syll item ex. faku**p**i)
M2C	consonant in internal coda position 2 (pa**k**ti)
M2L	l in internal coda position 2 (pa**l**ti)

M2S	s in internal coda position 2 (pa**s**ti)
V2	vowel 2 → p**a**ki / kuk**a**pi
BO2	branching onset 2 → p**l**aku / fik**l**apu
HO2	Head of onset 2 (1st C in onset in a 2-syll item, 2nd C in a 3-syll item) → **k**api /fa**k**upi
M3C	consonant in internal coda position 3 → ki**p**fapu
M3L	l in internal coda position 3 → ki**l**fapu
M3S	s in internal coda position 3 → ki**s**fapu
V3	vowel 3 → k**u**kapi
BO3	branching onset 3 → p**l**afifu
HO3	Head of onset 3 (1st C in onset of a 3-syll item) → **p**ikafu / **p**likafu
AppS	extrametrical s → **s**pi / **s**kafu / **s**pikafu

Coding the errors		
S	Substitution	kip → tip
M	metathesis	kip → pik (more on metathesis in manual)
A	addition	kip → kisp
E	deletion	kip → ki
L	lexicalization	kip → klip (clip)
D	disturbance	
NA	Not Applicable	in case of no repetition of the whole item or a part of it

If the phoneme is well-produced → 0 in the column (as already specified) : understanding zero error

If the phoneme is false → replace the 0 by the code of the error in the column For example: kip → tip = S-0-0 (in columns H01- V -FC)

Additions are directly added as an A in the column that corresponds to the structure. When it is an additional vowel or an additional final consonant, we write the number of additional phoneme in the column ‘add.others’.

Nasalization of final vowels are not counted (even if they are written in the transcription)

2 Error coding

Summary:

Coding	
If the target phoneme is well-produced = 0 (implicitly zero error)	
If the phoneme is erroneous, we note the error type instead of the zero.	
S	Substitution
M	Metathesis (MS in some specific cases Cf. examples (3.3) et (3.4))
A	Addition
E	Omission
L	Lexicalization (Each phoneme different from the target gets a L in its column + 'lexicalisation in the dedicated column)
D	Disturbance (Each phoneme of the target gets a D in its column)
	e.g. kip --> tip = S.0.0 (in the columns HO1. V. FC)

Error coding is always done according to the target structure (Cf. example 2.1).

2.1 Metathesis:

2.1.1 Simple metathesis including 2 consonants or 2 vowels

This is the case when 2 segments are involved whatever their position (now called MetInter for metathesis 'interversion')

a) First case: the 2 phonemes are in the same prosodic position. In example (1.1) below: /ʁ/ and /n/ are both heads of onset.
   The error coding M is done on the first phoneme that undergoes the metathesis (in (1.1) it is the /n/)

Example (1.1): /anorak/→/aronak/

Target	a	N	o	ʁ	a	k
Production	a	ʁ	o	n	a	k
Coding		M				

Example (1.2) is the same as example in (1.1) but illustrated with vowels. Example (1.2): /a da/ →/a ad /

Target	a			d	a
Production	a		a	d	
Coding			M		

b) Case where the two phonemes are not in the same prosodic position. In example (1.3), the 1st target [b] is in the head of a syllable onset and the 2nd target [ʁ] is in coda position. The rule is the same: the error coding M is done on the first phoneme that undergoes the metathesis (in (1.1) it is the /n/)

Example (1.3): /ob ʁ in/→/oʁ b in/

Target	o	b	ʁ	i	n
Production	o	ʁ	b	i	n
Coding		M			

2.1.2 Simple Metathesis that involves the movement of only one segment

Case when only one phoneme is involved and takes a position that was empty in the target (it moves from one syllable to another or from one prosodic position to another). Now called MetDep for Metathesis 'Déplacement'.

The error coding « M » is done on the prosodic position where the phoneme was in the target. In example (2.1) below, the /ʁ/ was in branching onset in the unstressed syllable and goes to the stressed syllable. The coding is done on the initial position of the phoneme because it allows coding several changes on several positions when there are several errors in a word (as in example 3.1 in next section), where there are a metathesis + a substitution).

In example (2.1), [ʁ] is in the same syllabic position (i.e. branching onset), but move from the first syllable to the second one.

Example (2.1):/tʁ pe/ →/t p ʁe/

Target	t	ʁ	p		e
Production	t		p	ʁ	e
Coding		M			

In example (2.2), [ʁ] stays in the same syllable but go from the branching onset to the coda position.

Example (2.2): /pʁ te/→/p ʁte/

Target	p	ʁ		t	e
Production	p		ʁ	t	e
Coding		M			

Example (2.3) is the mirror of example (2.2): [ʁ] is in coda position in the target and go to the branching onset.

Example (2.3): /parti/→/prati/

Target	p		a	ʁ	t	i
Production	p	ʁ	a		t	i
Coding				M		

In example (2.4), we can think that both consonants are involved in the metathesis, but in fact, only the /s/ moves. In this case, we note the metathesis on the target position of the moving phoneme.

Example (2.4): /psi/→/spi/

Target		p	s	i
Production	s	p		i
Coding			M	

We decided to code the glide as a vowel in a position other than the nucleus. It is then natural to consider the movement of a glide in the head of a nucleus – and thus which will be produced as a plain vowel – as a metathesis. This case is illustrated in the example (2.5) below.

Example (2.5): /kaftj ʁ/→/kafit /

Target	k	a	f		t	j		ʁ
Production	k	a	f	i	t			ʁ
Coding						M		

2.1.3 Metathesis + other process

2.1.3.1 Omission + Metathesis

This is just possible if, without an omission, there would be two phonemes involved.
Example (3.1): /sp ktakl/→/p stakl/ in two steps:

1. Omission

Target	s	p		k	t	a	k	l
Step 1	s	p			t	a	k	l
Coding				E				

2. Methathesis

Step 1	s	p			t	a	k	l
Production (=step2)		p		s	t	a	k	l
Coding	M			E				

N.B.: If we decided to code the metathesis where the phoneme was produced and not in its original place, we would be forced to code the elision in the initial position, as below

Analysis not chosen:

Step 1	s	p			t	a	k	l
Production		p		s	t	a	k	l
Coding	E			M				

2.1.3.2 Substitution + Metathesis

As usual, we start from the target. In example (3.2), we have the case where two phonemes commute together with the phonemic substitution of one of them (here the second one). In this case, we note the metathesis as usual on the first phoneme, and the substitution on the second one.

Example (3.2) – Simple Metathesis involving two consonants with a substitution of the second consonant of the target.

Target	k	u	p	e
Production	b	u	k	e
Coding	M		S	

If, in the case of a Simple Metathesis involving two consonants, the first consonant undergoes the substitution, then we have a specific code 'MS' as in example (3.3).

Example (3.3) – Simple Metathesis involving two consonants with a substitution of the first consonant of the target.

Target	k	u	p	e
Production	p	u	g	e
Coding	MS			

In the case of a metathesis involving only one phoneme, MS code is also used. Example (3.4) shows the case of [ʁ] in « horloge » which is substituted by a vocalic length and also undergoes a metathesis.

Example (3.4) – simple metathesis involving one phoneme which is also substituted

Target		ʁ	l			
Production			l		ː	
Coding		MS				

ATTENTION: Use this coding only when you are sure that the phoneme which is substitute is closed to the target phoneme and that the substitution is possible between them in general.

2.1.3.3 Double metathesis

Example (3.5): /kineziteʁapøt/→/kinetirezapøt/ (*In this Table, we only give the part of the word that is affected by the modifications)*

a. Metathesis 1 (step 1)

Target	z	i	t	e	ʁ	a
step 1	t	i	z	e	ʁ	a
Coding	M					

b. Metathesis 2 (+1) (step 2)

Target	z	i	t	e	ʁ	a
step 1	t	i	z	e	ʁ	a
production	t	i	ʁ	e	z	a
Coding			M			

c. Combination Metathesis 1 + Metathesis 2 (step 3)

Target	z	i	t	e	ʁ	a
Production	t	i	ʁ	e	z	a
Coding	M		M			

2.1.3.4 Metathesis + addition

a) If in a word, the error analysis gives two possible places for the metathesis, you have to choose firstly the analysis where the metathesis is inside the same syllable, and to consider the other place as the addition of a phoneme (Cf. example (3.6)). In example (3.6), the addition is then noted in the last syllable and not in the second one. We thus consider in this case that the /l/ moves inside its syllable from the coda position to the onset position.

Example (3.6) – Metathesis inside the syllable and addition: /kupalfi/→ /kuplafli/

Target	k	u	p		a	l	f		i
Production	k	u	p	l	a		f	l	i
Coding						M		A	

b) If in a word, two positions are possible for the metathesis, but that they are outside the syllable that contained the moved phoneme, then the syllable in the left is preferred. In example (3.7), the addition is then noted on the final syllable, because the /l/ of the central syllable is considered as moving to the first syllable.

Example (3.7) – Metathesis outside the syllable and addition: /piklafu/ → /plikaflu/

Target	p		i	k	l	a	f		u
Production	p	l	i	k		a	f	l	u
Coding					M			A	

c) If in a word, a vowel disappears to give the corresponding glide, than we can analyze this as a metathesis. In example (3.8), adding a vowel place the existing vowel in a non-nuclear position and make it produce as a glide due to its new prosodic position. The coding of the metathesis is made in the original place of /i/ which is then produced /j/. **The addition of the vowel /e/ has to be noted as '1' in the add.other column**.

Example (3.8) – metathesis of the vowel in non nuclear position + addition of a vowel /flapi/ → /flapje/

Target	f	l	a	p		i	+1 in the column « add other »
Production	f	l	a	p	j	e	
Coding						M	

2.2 Coalescence

We do not use a specific coding for coalescence. We just use elision + substitution. The question is then: which phoneme will be coded as elided, and which one will be substituted.

The manner of articulation will be considered as more important than the place of articulation, and this will give the coding of example (B.1). In this example, [ps] is replaced by [f]. [s] and [f] have the same manner (fricative), thus the [s] will be not considered as omitted (we keep the manner and not the place), but the /p/ which is a stop will be considered as omitted.

Example (B.1): /klups/→/kluf/

Target	k	l	u	p	s
Production	k	l	u		f
Coding				E	S

2.3 Substitution

2.3.1 Substitution of a phoneme by a length

When a target phoneme is not more present in the production and a lengthening appears, we then consider that the target phoneme was substituted.

Example (C.1) shows the phonemic substitution by the lengthening of the vowel.

Example (C.1) Substitution by the lengthening of the vowel

Target	k	u	s	p	a
Production	k	u	ː	p	a
Coding			S		

Example (C.2) shows the phonemic substitution by the lengthening of the consonant.

Example (C.2) Substitution by the lengthening of the consonant

Target	s	p	a
Production	p	ː	a
Coding	S		

2.4 Other specificities

2.4.1 Vowels

We code the errors on vowels in NWR except if the difference between the two vowels is minimal and not distinctive in the target language. For French:

 High and low mid-vowels (position rule) = non coded as an error ○ Example : album [alb m] →[albo] : only an omission as the consonant that leads to a closing of the vowel (French phonological rule), and thus no error on the vowel Addition of a final vowel as [œ] = error (filling of an empty position, except when dialectal) Production of a dialectal schwa as in 'cafetière' [kaføtj ʁ]: no error.

2.4.2 Various

- Pauses are non coded as error, but keep the transcript of them, especially when produced to break clusters
- [ç] is noted as an error when it is not a systematic articulatory process to replace the [s]. When it is used to replace another consonant : error
- No error coding if [s] → [θ] in French
- [pafu] → [paftu] as add.other and not as M2C
- Error coding (substitution) if [pli] → [pji], except if immature articulation (TD children up to 3-4 in French)
- **No coding of voicing errors in NWR**

Appendix J: Results: Different kind of errors within one error group

The following Tables show the different kinds of errors, or sub errors, made within one error group made by 3,4 and 5 year old children respectively. For example, within the group of substitution errors, substitution can occur in the first, second or third segment of a consonant clusters. These sub errors were coded as well but not used in the main analyses. However, in this analysis, these sub errors are the point of interest.

The following error groups are used: insertion (addition of a sounds), metathesis (switching/moving of sounds), deletion (deletion of a sound), substitution (replacement of a sound) and one left over category in which all the instances fall where different errors are combined (combination of errors). An example of this last category is /slipu/ → /kipu/: the first consonant /s/ is substituted (error 1) and the second segment is deleted (error 2). If two similar errors occur in one segment, this does not fall into the last category. For example, if two substitution errors occur in structure x, this is seen as a substitution error and shown in this way (not in the combination of errors category).

The sub errors are shown in the Tables below for each age group. Explanations for the sub errors can be found under the Tables. The given examples in the explanations are to be read in the following manner: the first non-word is the target word, the non-word below that is (an example of) child production. Under this, it is shown which segment is coded with which letter (for example if Im stand under a certain segment, it means that insertion due to metathesis occurred in this segment. Whenever metathesis occurs, the place where the sound originated is indicated with a capital M, and wherever the sounds lands is indicated with a m. This is shown for clarity; however, since the errors are looked at per structure, the m when looking at M is not taken into account. The m is taken into account when looking at that structure.

If an error occurred in a new position (i.e. a position which was not included in the target structure) this was indicated with brackets. The number of mistakes within the group, for example 86 in the insertion Table below, are taken as the total. Percentages within error groups are always based on this total. These Tables thus show how often the different sub errors were made within the error group. If certain sub errors are shown in one Table but not in the next one, it means that these errors did not occur in that structure for that age group. Note that because of rounding in the vertical columns, the numbers in a vertical column in Tables may not precisely add up to the exact same number written as the total. This may differ 0.1% since the total is calculated separately based on the absolute total number, not by adding the rounded percentages in the columns.

The different kinds of errors for 3 year old children within the following error groups: a) insertion, b) Metathesis, c) Deletion, d) Substitution and e) Combinations of errors (FCS = final consonant + /s/ cluster, FC = final single consonant, BIC = branching initial cluster, ISC = initial /s/ + consonant cluster).

a) Insertion

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
I	1	1.2	6	7.0	2	2.3	0	0.0	8	9.3	**17**	**19.8**
(I)	0	0.0	7	8.1	42	48.8	0	0.0	13	15.1	**62**	**72.1**
(Im)	0	0.0	1	1.2	0	0.0	0	0.0	2	2.3	**3**	**3.5**
Im	0	0.0	0	0.0	0	0.0	0	0.0	4	4.7	**3**	**4.7**
Total	**1**	**1.2**	**14**	**16.3**	**44**	**51.1**	**0**	**0.0**	**27**	**31.4**	**86**	**100**

Sub error	Definition	Structure	Example
I	Insertion	FC	*p i f a k u s* *p i f a k u ps* I
I	Insertion	FCS	*spl i* *f spl i* I
(I)	Insertion in a position which was not part of the target non-word.	BIC*	*p i f a k u s* *pl i f a k u s* (I)
(I)	Insertion in a position which was not part of the target non-word.	M	*p i f a k u s* *p i f as k u s* (I)
Im	Insertion due to metathesis	M	*k u s f i* *k u fs p i* Im M
(Im)	Insertion due to metathesis in a position which was not part of the target non-word.	BIC	*pl i f u* *p i fl u* M2 (Im)**

* insertion is coded on the segment if it is in final consonant position, initial head position, in medial position or in initial /s/ + consonant cluster position. If a /l/ or /r/ is added to the initial head, this was coded in the branching initial cluster cell (as explained in the Method).
** M2 signals here that the second segment of a cluster is affected.

b) Metathesis

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
M	0	0.0	1	2.3	0	0.0	0	0.0	5	11.6	**6**	**14.0**
m	0	0.0	0	0.0	0	0.0	0	0.0	2	4.7	**2**	**4.7**
(m)	0	0.0	3	7.0	15	34.9	0	0.0	2	4.7	**20**	**46.5**
M2	0	0.0	0	0.0	15	34.9	0	0.0	0	0.0	**15**	**34.9**
Total	**0**	**0.0**	**4**	**9.3**	**30**	**69.8**	**0**	**0.0**	**9**	**20.9**	**43**	**100**

Sub error	Definition	Structure	Example
M	Metathesis (first involved segment)	M	*f a k u s p i* *f a k u p s i* M m
m	Metathesis (second involved segment)	M	*sp i k a f u* *sp i k a f* m M D***
(m)	Metathesis lands in a new position which was not part of the target non-word.****	BIC	*pl i f u* *p i fl u* M2 (m)
M2	Methathesis (first segment involved) of the second sound in a cluster.	BIC	*pl i f u* *p i fl u* M2 (m)

******* It is possible that another error occurs somewhere else in the non-word. However, we are only looking at a specific structure and not at the rest of the non-word. In this case, we are only looking at medial structure, and in this structure one error, metathesis occurs.
**** In this case, the landed metathesis sound can substitute the sound that was previously there, or insert the sound if it is in a new position.

c) Deletion

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
D	0	0.0	40	35.7	0	0.0	0	0.0	9	8.0	**49**	**43.8**
D1	3	2.7	0	0.0	3	2.7	11	9.8	0	0.0	**17**	**15.2**
D2	2	1.8	0	0.0	41	36.6	0	0.0	0	0.0	**43**	**38.4**
D3	0	0.0	0	0.0	0	0.0	1	0.9	0	0.0	**1**	**0.9**
Dm	0	0.0	1	0.9	0	0.0	0	0.0	1	0.9	**2**	**1.8**
Total	**5**	**4.5**	**41**	**36.6**	**44**	**39.3**	**12**	**10.7**	**10**	**8.9**	**112**	**100**

Sub error	**Definition**	**Structure**	**Example**
D	Deletion	FC	*k a p u f i m* *k a p u f i* D
D1	Deletion of first segment of a cluster.	BIC	*pl i f u* *l i f u* D1
D2	Deletion of the second segment of a cluster.	BIC	*pl i f u* *p i f u* D2
D3	Deletion of the third segment of a cluster.	ISC	*spl i* *sp i* D3
Dm	Deletion due to metathesis.	FC	*fl u k i f* *fl u f i* M Dm

d) Substitution

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
S	0	0.0	20	24.1	1	1.2	0	0.0	8	9.6	**29**	**34.9**
S1	7	8.4	0	0.0	24	29.0	1	1.2	0	0.0	**32**	**38.6**
S2	1	1.2	0	0.0	8	9.6	6	7.2	0	0.0	**15**	**18.1**
S2L	0	0.0	0	0.0	1	1.2	0	0.0	0	0.0	**1**	**1.2**
Sm	0	0.0	2	2.4	0	0.0	0	0.0	0	0.0	**2**	**2.4**
S1S2	0	0.0	0	0.0	2	2.4	2	2.4	0	0.0	**4**	**4.8**
Total	**8**	**9.6**	**22**	**26.5**	**36**	**43.4**	**9**	**10.8**	**8**	**9.6**	**83**	**100**

Sub error	Definition	Structure	Example
S	Substitution	FC	*fl u k i f* *fl u k i k* S
S1	Substitution of first segment in a cluster.	BIC	*pl i f u* *kl i f u* S1
S2	Substitution of the second segment in a cluster.	ISC	*spl i* *sfl i* S2
S2L	Substitution of the second segment in a cluster, resulting in lexicalisation.	ISC	*spl i* *spr i* S3
Sm	Substitution due to metathesis.	FC	*p i f a k u s* *p i f a p u k* M Sm
S1S2	Substitution of first and second segment of consonant cluster.	BIC	*kl a p u* *xr a p u* S1S2******

****** Even though this is a combination of errors, it is kept in the substitution category because both errors are substitution errors.

e) Combination of errors

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
SmI	0	0.0	1	14.3	0	0.0	0	0.0	0	0.0	**1**	**14.3**
S1I	1	14.3	0	0.0	0	0.0	0	0.0	0	0.0	**1**	**14.3**
S1D2	1	14.3	0	0.0	1	14.3	0	0.0	0	0.0	**1**	**28.6**
M1D2I	0	0.0	0	0.0	1	14.3	0	0.0	0	0.0	**1**	**14.3**
M1S2	0	0.0	0	0.0	0	0.0	1	14.3	0	0.0	**1**	**14.3**
D1S2	0	0.0	0	0.0	0	0.0	1	14.3	0	0.0	**1**	**14.3**
Total	**2**	**28.6**	**1**	**14.3**	**2**	**28.6**	**2**	**28.6**	**0**	**0.0**	**7**	**100**

Sub error	Definition	Structure	Example
SmI	Substitution due to metathesis + insertion.	FC	*fl u k i f* *fl u p i ks* M SmI
S1I	Substitution in first segment of cluster + insertion.	FCS	*fl i ms* *fl i fts* S1I
S1D2	Substitution of first segment of cluster + deletion of second segment of cluster.	FCS	*f a ps* *f a f* S1D2
M1D2I	Metathesis of the first segment of a cluster + deletion of the second segment + insertion.	M	*k a p u fl i* *k a p uf x i* (m) M1D2I

M1S2	Metathesis of first segment of cluster + substitution of second segment of cluster.	ISC	*sx u f a p i* *k u f as p i* M1S2 (m)
D1S2	Deletion of first segment of cluster + substitution of second segment of cluster.	ISC	*sm a p u* *x a p u* D1S2

The different kind of errors for 4 year old children within the following error groups: a) Insertion b) Metathesis c) Deletion, d) Substitution and e) Combinations of errors (FCS = final consonant + /s/ cluster, FC = final single consonant, BIC = branching initial cluster, ISC = initial /s/ + consonant cluster).

a) Insertion

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
I	0	0.0	7	8.3	1	1.2	0	0.0	11	13.1	**19**	**22.6**
II	0	0.0	0	0.0	1	1.2	0	0.0	0	0.0	**1**	**1.2**
(I)	0	0.0	0	0.0	40	47.6	0	0.0	16	19.0	**56**	**66.7**
(II)	0	0.0	0	0.0	0	0.0	0	0.0	1	1.2	**1**	**1.2**
(Im)	0	0.0	1	1.2	0	0.0	0	0.0	4	4.8	**5**	**6.0**
Im	0	0.0	2	2.4	0	0.0	0	0.0	0	0.0	**2**	**2.4**
Total	**0**	**0.0**	**10**	**11.9**	**42**	**50.0**	**0**	**0.0**	**32**	**38.1**	**84**	**100**

Sub error	**Definition**	**Structure**	**Example**
I	Insertion	FC	*p i f a k u s* *p i f a k u ps* I
I	Insertion	FCS	*spl i* *f spl i* I
II	Insertion of two sounds	BIC	*fl i m s* *fsvl i m s* II
(I)	Insertion in a position which was not part of the target non-word.	BIC*	*p i f a k u s* *pl i f a k u s* (I)
(I)	Insertion in a position which was not part of the target word.	M	*p i f a k u s* *p i f as k u s* (I)
(II)	Insertion of two sounds in a position which was not part of the target non-word.		*kl i p u f a* *kl i p u pf f a* (II)
Im	Insertion due to metathesis	M	*k u s f i* *k u fs p i* Im M

(Im)	Insertion due to metathesis in a position which was not part of the target non-word.	BIC	*pl i f u* *p i fl̲ u* M2 (Im)**

* insertion is coded on the segment if it is in final consonant position, initial head position, in medial position or in initial /s/ + consonant cluster position. If a /l/ or /r/ is added to the initial head, this was coded in the branching initial cluster cell (as explained in the Method).
** M2 signals here that the second segment of a cluster is affected.

b) Metathesis

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
M	0	0.0	1	1.6	0	0.0	0	0.0	8	12.9	**9**	**14.5**
M1	0	0.0	0	0.0	2	3.2	1	1.6	0	0.0	**3**	**4.8**
M2	0	0.0	0	0.0	13	21.0	0	0.0	0	0.0	**13**	**21.0**
M3	0	0.0	0	0.0	0	0.0	1	1.6	0	0.0	**1**	**1.6**
m	0	0.0	3	4.8	0	0.0	0	0.0	8	12.9	**11**	**17.7**
(m)	0	0.0	1	1.6	15	24.2	0	0.0	4	6.5	**20**	**32.3**
m1	1	1.6	0	0.0	3	4.8	0	0.0	0	0.0	4	6.5
M1M2	0	0.0	0	0.0	1	1.6	0	0.0	0	0.0	**1**	**1.6**
Total	**1**	**1.6**	**5**	**8.1**	**33**	**53.2**	**2**	**3.2**	**20**	**32.3**	**62**	**100**

Sub error	**Definition**	**Structure**	**Example**
M	Metathesis (first involved segment)	M	*f a k u s̲ p i* *f a k u p̲ s i* M m
M1	Metathesis of the first segment in a cluster.	BIC	*p l i k u* *k̲ l i p u* M1 (m)
M2	Metathesis of the second sound in a cluster.	BIC	*pl i f u* *p i fl̲ u* M2 (m)
M3	Metathesis of the third sound in a cluster.	ISC	*spl i* *sp i l* M3 (m)
m	Metathesis (second involved segment)	M	*sp i k a f u* *sp i k af̲* m M D***
(m)	Metathesis lands in a new position which was not part of the target non-word.****	BIC	*pl i f u* *p i fl̲ u* M2 (m)
m 1	Metathesis (second involved segment) of first segment in cluster where it lands.	BIC	*p i kl a* *k̲ i pl a* M m1

M1M2	Metathesis of 2 segments in a cluster.	BIC	*p i kl a f u* *pl i f a k u* (m2)M1M2 (m)*****

******* It is possible that another error occurs somewhere else in the non-word. However, we are only looking at a specific structure and not at the rest of the non-word. In this case, we are only looking at medial structure, and in this structure one error, metathesis occurs.
**** In this case, the landed metathesis sound can substitute the sound that was previously there, or insert the sound if it is in a new position.
***** Normally combinations of errors are part of the combination of errors category, but not in this case because the two errors are both the same kind of error (metathesis).

c) Deletion

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
D	0	0.0	41	29.3	1	0.7	1	0.7	12	8.6	**55**	**39.3**
D1	1	0.7	0	0.0	14	10.0	16	11.4	0	0.0	**31**	**22.1**
D2	0	0.0	0	0.0	43	30.7	2	1.4	0	0.0	**45**	**32.1**
D2L	0	0.0	0	0.0	3	2.1	1	0.7	0	0.0	**4**	**2.9**
D3	0	0.0	0	0.0	0	0.0	2	1.4	0	0.0	**2**	**1.4**
Dm	0	0.0	3	2.1	0	0.0	0	0.0	0	0.0	**3**	**2.1**
Total	**1**	**0.7**	**44**	**31.4**	**61**	**43.6**	**22**	**15.7**	**12**	**8.6**	**140**	**100**

Sub error	**Definition**	**Structure**	**Example**
D	Deletion	FC	*k a p u f i m* *k a p u f i* D
D1	Deletion of first segment of a cluster.	BIC	*pl i f u* *l i f u* D1
D2	Deletion of the second segment of a cluster.	BIC	*pl i f u* *p i f u* D2
D2L	Deletion of the second segment of a cluster resulting in lexicalisation.	ISC	*xl a p* *x a p* D2L
D3	Deletion of the third segment of a cluster.	FC	*spl i* *sp i* D3
Dm	Deletion due to metathesis.	FC	*fl u k i f* *fl u f i* M Dm

d) Substitution

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
S	0	0.0	25	27.8	0	0.0	0	0.0	7	7.8	**32**	**35.6**
Sm	0	0.0	3	3.3	0	0.0	0	0.0	2	2.2	**5**	**5.6**

S1	10	11.1	0	0.0	25	27.8	1	1.1	0	0.0	**36**	**40.0**
S2	0	0.0	0	0.0	10	11.1	4	4.4	0	0.0	**14**	**15.6**
S2L	0	0.0	0	0.0	1	1.1	0	0.0	0	0.0	**1**	**1.1**
S1S2	0	0.0	0	0.0	2	2.2	0	0.0	0	0.0	**2**	**2.2**
Total	**10**	**11.1**	**28**	**31.1**	**38**	**42.2**	**5**	**5.6**	**9**	**10.0**	**90**	**100**

Sub error	**Definition**	**Structure**	**Example**
S	Substitution	FC	*fl u k i f* *fl u k i k* S
S1	Substitution of first segment in a cluster.	BIC	*pl i f u* *kl i f u* S1
S2	Substitution of the second segment in a cluster.	ISC	*spl i* *sfl i* S2
S2L	Substitution of the second segment in a cluster, resulting in lexicalisation.	ISC	*spl i* *spr i* S3
Sm	Substitution due to metathesis.	FC	*p i f a k u s* *p i f a p u k* M Sm
S1S2	Substitution of first and second segment of consonant cluster.	BIC	*kl a p u* *xr a p u* S1S2******

****** Even though this is a combination of errors, it is kept in the substitution category because both errors are substitution errors.

e) Combination of errors

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
D3II	0	0.0	0	0.0	0	0.0	1	6.7	0	0.0	**1**	**6.7**
S1D2	0	0.0	0	0.0	4	26.7	0	0.0	0	0.0	**4**	**26.7**
S1M2	0	0.0	0	0.0	2	13.3	0	0.0	0	0.0	**2**	**13.3**
S2I	0	0.0	0	0.0	0	0.0	1	6.7	0	0.0	**1**	**6.7**
D1S2	0	0.0	0	0.0	0	0.0	2	13.3	0	0.0	**2**	**13.3**
M1D2	0	0.0	0	0.0	3	20.0	0	0.0	0	0.0	**3**	**20.0**
M1I1	0	0.0	0	0.0	1	6.7	0	0.0	0	0.0	**1**	**6.7**
Total	**0**	**0.0**	**1**	**6.7**	**10**	**66.7**	**4**	**26.7**	**0**	**0.0**	**14**	**100**

Sub error	**Definition**	**Structure**	**Example**
D3II	Deletion of third segment in cluster + 2 insertions.	ISC	*spl i* *pssp i* E3II

S1D2	Substitution of first segment of cluster + deletion of second segment of cluster.	FCS	*f a ps* *f a f* S1D2
S1M2	Substitution of first segment in cluster + metathesis of second segment in cluster.	BIC	*k a fl i p u* *kl as w i p u* (m) S1M2
S2I	Substitution in second segment of cluster + insertion.	ISC	*sm a p u* *srv a p u* S2I
M1D2	Metathesis of fist segment of cluster + deletion of second segment of cluster.	BIC	*p i kl a f u* *p i p a k u* M1D2 (m)
D1S2	Deletion of first segment of cluster + substitution of second segment of cluster.	ISC	*sm a p u* *x a p u* D1S2
M1I1	Metathesis of first segment of cluster + insertion in first segment of cluster.	BIC	*pl i* *kl i p* M1I1 (m)

The different kind of errors for 5 year old children within the following error groups: a) Insertion b) Metathesis c) Deletion, d) Substitution and e) Combinations of errors (FCS = final consonant + /s/ cluster, FC = final single consonant, BIC = branching initial cluster, ISC = initial /s/ + consonant cluster).

a)Insertion

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
I	2	4.1	1	2.0	0	0.0	0	0.0	0	0.0	3	6.1
(I)	0	0.0	5	10.2	41	83.7	0	0.0	0	0.0	46	93.9
Total	2	4.1	6	12.2	41	83.7	0	0.0	0	0.0	49	100

Sub error	**Definition**	**Structure**	**Example**
I	Insertion	FC	*p i f a k u s* *p i f a k u ps* I
I	Insertion	FCS	*spl i* *f spl i* I
(I)	Insertion in a position which was not part of the target non-word.	BIC*	*p i f a k u s* *pl i f a k u s* (I)

(I)	Insertion in a position which was not part of the target word.	M	*p i f a k u s* *p i f as k u s* (I)

* insertion is coded on the segment if it is in final consonant position, initial head position, in medial position or in initial /s/ + consonant cluster position. If a /l/ or /r/ is added to the initial head, this was coded in the branching initial cluster cell (as explained in the Method).

b) Metathesis

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
M	0	0.0	0	0.0	0	0.0	0	0.0	1	3.0	**1**	**3.0**
M1	0	0.0	0	0.0	1	3.0	0	0.0	0	0.0	**1**	**3.0**
M2	0	0.0	0	0.0	13	39.4	0	0.0	0	0.0	**13**	**39.4**
m	0	0.0	1	3.0	0	0.0	0	0.0	1	3.0	**2**	**6.1**
(m)	0	0.0	1	3.0	12	36.4	0	0.0	3	9.1	**16**	**48.5**
Total	**0**	**0.0**	**2**	**6.1**	**26**	**78.8**	**0**	**0.0**	**5**	**15.2**	**33**	**100**

Sub error	**Definition**	**Structure**	**Example**
M	Metathesis (first involved segment)	M	*f a k u s p i* *f a k u p s i* M m
M1	Metathesis of the first segment in a cluster.	BIC	*p l i k u* *k l i p u* M1 (m)
M2	Methathesis of the second sound in a cluster.	BIC	*pl i f u* *p i fl u* M2 (m)
m	Metathesis (second involved segment)	M	*sp i k a f u* *sp i k af* m M D***
(m)	Metathesis lands in a new position which was not part of the target non-word.****	BIC	*pl i f u* *p i fl u* M2 (m)

******* It is possible that another error occurs somewhere else in the non-word. However, we are only looking at a specific structure and not at the rest of the non-word. In this case, we are only looking at medial structure, and in this structure one error, metathesis occurs.
**** In this case, the landed metathesis sound can substitute the sound that was previously there, or insert the sound if it is in a new position.

c) Deletion

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**

D	0	0.0	36	45.6	0	0.0	0	0.0	1	1.3	**37**	**46.8**
D1	2	2.5	0	0.0	6	7.6	1	1.3	0	0.0	**9**	**11.4**
D2	0	0.0	0	0.0	30	38.0	1	1.3	0	0.0	**31**	**39.2**
Dm	0	0.0	2	2.5	0	0.0	0	0.0	0	0.0	**2**	**2.5**
Total	**2**	**2.5**	**38**	**48.1**	**36**	**45.6**	**2**	**2.5**	**1**	**1.3**	**79**	**100**

Sub error	**Definition**	**Structure**	**Example**
D	Deletion	FC	*k a p u f i m* *k a p u f i* D
D1	Deletion of first segment of a cluster.	BIC	*pl i f u* *l i f u* D1
D2	Deletion of the second segment of a cluster.	BIC	*pl i f u* *p i f u* D2
Dm	Deletion due to metathesis.	FC	*fl u k i f* *fl u f i* M Dm

d) Substitution

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
S	0	0.0	10	22.2	0	0.0	0	0.0	5	11.1	**15**	**33.3**
S1	7	15.6	0	0.0	10	22.2	1	2.2	0	0.0	**18**	**40**
S2	0	0.0	0	0.0	5	11.1	3	6.7	0	0.0	**8**	**17.8**
Sm	0	0.0	3	6.7	0	0.0	0	0.0	0	0.0	**3**	**6.7**
S1S2	1	2.2	0	0.0	0	0.0	0	0.0	0	0.0	**1**	**2.2**
Total	**8**	**17.8**	**13**	**28.9**	**15**	**33.3**	**4**	**8.9**	**5**	**11.1**	**45**	**100**

Sub error	**Definition**	**Structure**	**Example**
S	Substitution	FC	*fl u k i f* *fl u k i k* S
S1	Substitution of first segment in a cluster.	BIC	*pl i f u* *kl i f u* S1
S2	Substitution of the second segment in a cluster.	ISC	*spl i* *sfl i* S2
Sm	Substitution due to metathesis.	FC	*p i f a k u s* *p i f a p u k* M Sm

S1S2	Substitution of first and second segment of consonant cluster.	BIC	*kl a p u* *<u>xr</u> a p u* S1S2******

****** Even though this is a combination of errors, it is kept in the substitution category because both errors are substitution errors.

e) Combination of errors

	FCS	%	FC	%	BIC	%	ISC	%	M	%	**Total**	**%**
M1D2	0	0.0	0	0.0	1	100	0	0.0	0	0.0	**1**	**100**
Total	**0**	**0.0**	**0**	**0.0**	**1**	**100**	**0**	**0.0**	**0**	**0.0**	**1**	**100**

Sub error	**Definition**	**Structure**	**Example**
M1D2	Metathesis of fist segment of cluster + deletion of second segment of cluster.	BIC	*p i kl a f u* *p i p a k u* M1D2 (m)