

# **Voicing of obstruent clusters in Dutch past tense acquisition**

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*Abstract*

Language acquisition theory predicts young children to show a preference for unmarked structures. Voiced obstruents as well as obstruent clusters are marked contexts. What follows is that children should initially prefer voiceless obstruent clusters over voiced obstruent clusters. To provide empirical evidence for this claim, an experiment was designed that presented Dutch participants with past tenses, because Dutch verbs with voiceless or voiced obstruent-final verb stems yield past tenses with voiceless or voiced obstruent clusters, respectively. The present experiment was run with six-year-old and nine-year-old children as well as adults. The results show a clear preference for the voiced past tense suffix [-də] by the nine-year-old group against a preference for the voiceless past tense suffix [-tə] by the six-year-old group and the adults. Other important findings are that the orthographical representation results in less incorrect inflections and that phonotactically illegitimate pseudo-verbs trigger more incorrect inflections.

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## 1. Introduction

In its consonantal inventory, Dutch allows both voiceless and voiced obstruents. The inventory of the obstruents is as follows (Booij, 1995).

	Labial	Alveolar	Velar
Voiceless	p, f	t, s	k, x
Voiced	b, v	d, z	(g), ʁ

Table 1. Inventory of Dutch obstruents

The voiced velar obstruents have a doubtful status in the Dutch phoneme system: the voiced velar plosive only occurs in loan words and the voiced velar fricative is realized as voiceless by most speakers of Dutch (Gussenhoven & Bremmer, 1983). This issue will be ignored in the remainder of this thesis. Dutch conforms to a generalization that seems to be universally true, to the effect that voiced obstruents are marked in comparison to voiceless obstruents. One manifestation of this is the phenomenon of syllable-final obstruent devoicing. This process has been described in terms of a rule (Booij, 1977; Trommelen and Zonneveld, 1979), a parameter setting (Lombardi, 1991), and interacting constraints (Kager, 1999; Zonneveld, 2007). All of these frameworks demonstrate how the outcome results in neutralization towards the value [voiceless], the universally unmarked value. Pairs such as *bont* ‘multicolored’ ~ *bont-e* (inflected form) versus *bond* [-t] ‘union’ ~ *bond-en* (plural) are examples that illustrate syllable final obstruent devoicing in Dutch.

The markedness of voiced obstruents also holds for obstruent clusters, albeit under occasional additional restrictions. Zonneveld (1983) makes the observation that in Dutch obstruent clusters are generally voiceless within words, examples are *spat* ‘splash’, *pasta* ‘idem’, and *naakt* ‘naked’. Furthermore, both in words and word combinations (lexically and post-lexically) obstruent clusters never have a voiced fricative as their rightmost element due to fricative devoicing. This is a form of progressive voicing assimilation that follows final devoicing. An example is a word like *rondvaart* [rɔntfart] ‘boat trip’, which is realized with a voiceless obstruent cluster even though both obstruents might be realized as voiced in a different context, cf. *ronde* ‘round’ and *vaart* ‘boating’. Voiced clusters are not illegal per se in Dutch. They can occur in compounds as a result of regressive voicing assimilation. An

example is *zakdoek* [zakduk] ‘handkerchief’, but note that the rightmost obstruent is necessarily a plosive.

A well-known case of Dutch voicing in obstruent clusters occurs in the past tense. Examples of the Dutch past tense are in the paradigm below. The infinitives are given first.<sup>1</sup>

(1) a.	<i>schoppen</i> [sxɔpən] ‘to kick’	<i>ik schopte</i> [sxɔp.tə] ‘I kicked’
	<i>schrobben</i> [sxrɔbən] ‘to scrub’	<i>ik schrobde</i> [sxrɔb.də] ‘I scrubbed’
	<i>blaffen</i> [blafən] ‘to bark’	<i>ik blafte</i> [blaf.tə] ‘I barked’
	<i>leven</i> [levən] ‘to live’	<i>ik leefde</i> [lev.də] ‘I lived’
b.	<i>voelen</i> [vulən] ‘to feel’	<i>ik voelde</i> [vul.də] ‘I felt’
	<i>zwaaien</i> [zwajən] ‘waved’	<i>ik zwaaide</i> [zwai.də] ‘I waved’

The past tense suffix is realized as voiceless or voiced depending on the final obstruent of the verb stem. This voicing pattern is usually argued to be a case of progressive voicing assimilation. In an early generative abstract analysis, the obstruent in the past tense suffix is interpreted as a fricative (Zonneveld, 1983); an interpretation which survived Lombardi’s parametric account (1991). More recently, in an Optimality analysis, Zonneveld (2007) proposes that the effects of this process are the result of the mechanism of local conjunction of two relevant constraints, namely \*LAR (no marked laryngeal features) and \*LAR&OO-IDINF, an output-output faithfulness constraint which ensures that the past tense resembles the output of the infinitive it is based on. Due to the high ranking of the conjoined constraint, the past tense suffix shows voicing alternation in Dutch; therefore, a Dutch past tense can be realized with either a voiceless or a voiced obstruent cluster.

Since Jakobson (1941), markedness is a phenomenon closely associated with language acquisition. Generally, unmarked features appear early in acquisition, marked features appear later. In other words, marked language properties are ‘difficult’ to acquire, unmarked properties are comparatively easy to acquire. This thesis assumes that these principles of language acquisition also hold for the voice phenomena of Dutch obstruents, from which follows that voiceless obstruent clusters will be easier to acquire and thus these appear earlier in child productions than the marked voiced obstruent clusters.

<sup>1</sup> The final [-n] of the infinitives is not always realized in spontaneous speech. For matters of consistency it will be included in the phonemic transcriptions. All of the transcriptions in this thesis are based on the phonetic symbols used for Dutch by Booij (1995).

Within the OT framework it is suggested that children start out with markedness constraints ranked above faithfulness constraints. This claim is supported by the argument of the subset language, known from the Principles and Parameters framework (see e.g. Smolensky, 1996). In any case, this depiction of the initial grammar provides an explanatory basis for the common observation that child speech, generally speaking, exhibits unmarked features. In the course of acquisition the language learning child has to promote the faithfulness constraints (or demote the markedness constraints, depending on one's view, see Gnanadesikan, 2004 and Tesar & Smolensky, 2000) to arrive at the constraint ranking of the adult language. For the present case this implies that initially high ranked markedness constraints will rule out voiced obstruents and hence voiced clusters. The Dutch learning child will re-rank the constraints based on its input and learn when voiced obstruent clusters are and are not allowed in the language. By the end of the acquisition process the learner will produce voiceless obstruent clusters as well as voiced clusters in the appropriate contexts.

In line with this argument it can be inferred that, generally speaking, children start out with a higher preference for voiceless obstruent clusters than adults. However, very little experimental evidence is available to empirically sustain this claim. This is why an experiment was designed in which children were asked to produce past tenses for both Dutch verbs and pseudo-verbs that would include production of obstruent clusters, to obtain empirical evidence on voicing of obstruent clusters. The past tense is a suitable context to investigate how young Dutch children deal with obstruent clusters as the past tense suffix is subject to voicing alternation and both voiceless and voiced clusters are legal in Dutch past tenses. As voiced obstruent clusters are marked (single voiced obstruents already being marked, and there is no reason to suspect that in clusters this markedness will be ameliorated), it is to be expected that young children will prefer voiceless clusters over voiced clusters and thus that young children will produce more past tenses containing voiceless clusters than past tenses with voiced clusters. Adults will not show this preference for voiceless clusters.

Before considering the details of the experiment, a brief summary will be provided on the voicing and devoicing of obstruents in Dutch verbs and the interaction of voicing and

vowel length in verbs. This is followed by a brief summary of past tenses found in a body of Dutch child acquisition data and the research questions. The sections after that contain the research method, the experimental results, and a discussion of the findings.

### 1.1. Voicing in Dutch verbs

As was seen above, voicing assimilation and voice neutralization occur in nouns, adjectives and verbs. As Dutch past tenses are the morphological class relevant to the experiment at hand, the voicing patterns that are relevant for verbs will be elaborated on here. However, this does not imply that these voicing patterns are exclusively restricted to Dutch verbs (see Zonneveld, 1983 for more contexts that show voicing assimilation and voice neutralization in Dutch).

The Dutch regular past tense is formed by adding a suffix to the verb stem, as was illustrated in example (1) above. To repeat: the suffix is realized as voiceless [-tə] or voiced [-də] depending on whether the final phoneme of the verb stem is voiceless or voiced. This not only holds for verbs with obstruents, but for all verbs and is argued to be a case of progressive voicing assimilation. Examples of verbs with stem-final obstruents appear in (1a). Dutch also has verb stems that end with a sonorant or vowel; assuming that the underlying form of the suffix contains a voiced obstruent (an assumption no-one seems to doubt) these forms are always inflected with a voiced suffix; examples are in (1b). However, the latter examples are not relevant to this thesis and will not be discussed further. Only the verbs with obstruent-final verb stems will be discussed in this thesis because in those cases the past tense includes an obstruent cluster.

In the case of obstruent-final verb stems, the language learner would presumably have a fairly easy task of learning whether the obstruents are voiceless or voiced, when they were always realized the same. However, verbs with voiced obstruents have a neutralized form in the singular present tense, illustrated in (2), for the verbs given in earlier examples.

- (2) *ik schop* [sxɔp] 'I kick'  
*ik schrob* [sxrɔp] 'I scrub'  
*ik blaf* [blɔf] 'I bark'  
*ik leef* [lef] 'I live'

This is, of course, due to final devoicing, mentioned above. Children acquiring Dutch thus have to learn which lexical items have voiced obstruents from the infinitive or plural present tense (these two forms are homophones in Dutch) or the actual past tense in the input. This implies that the child has to develop verbal morphology to determine the voicing value of the final obstruent.

Besides final devoicing and progressive voicing assimilation there is a further generalization in Dutch verbs with relation to voicing. For verb stems that end in alveolar and bilabial fricatives, voicing and vowel length are related (in the basic form, i.e. disregarding final devoicing). Examples of infinitives are given in (3) for the fricative pairs /s, z/ and /f, v/ respectively.

- |     |   |                                      |
|-----|---|--------------------------------------|
| (3) | <i>passen</i> [pasən] 'to lift'         | <i>grazen</i> [xrazən] 'to graze'    |
|     | <i>lossen</i> [lɔsən] 'to unload'       | <i>blozen</i> [blozən] 'to blush'    |
|     | <i>blaffen</i> [blɔfən] 'to bark'       | <i>draven</i> [dravən] 'to trot'     |
|     | <i>opdoffen</i> [ɔpɔɔfən] 'to dress up' | <i>doven</i> [dovən] 'to extinguish' |

These examples illustrate the generalization that verbs with a voiceless fricative generally have a short vowel, whereas verbs with a voiced fricative generally have a long vowel. In the CELEX data base (Max Planck Institute for Psycholinguistics, 2001), this generalization is absolute for the fricative pair /f, v/. An overview of the type and token count based on regular past tenses is in table 2. Verbs with the vowels /i, u, y/ were excluded from this count because it is unclear whether they should be counted as long or short vowels: phonologically they behave like long vowels but phonetically they are short (Ernestus and Baayen, 2003). Diphthongs were counted as long vowels.<sup>2</sup>

<sup>2</sup> Only the verbs with a higher frequency than 1 per million were included in the type count and verbs with a prefix were counted as type of the verb it is based on, e.g. *opeiste* 'claimed' was counted as type of *eiste* 'demanded'. Plural and singular past tenses of a verb were counted as one type.

	Vowel length	Voiceless		Voiced	
		Types	Tokens	Types	Tokens
Alveolar	Short	20	115	-	-
	Long	5	40	11	65
Bilabial	Short	7	43	-	-
	Long	-	-	25	282

Table 2. Type and token count based on CELEX of regular verbs with fricative final verbs stems

For the fricative pair /s, z/ the generalization is a strong tendency. However, there are verbs with a long vowel that take a voiceless /s/. These vowels are diphthongs and included past tenses such as *eiste* ‘demanded’ and *kruiste* ‘crossed’. The token counts show that for the alveolar fricatives, the voiceless /s/ occurs with a higher frequency than the voiced counterpart /z/, in a 2:1 ratio, whereas for the bilabial fricatives the voiced fricative /v/ is much more frequent than the voiceless /f/ in a 7:1 ratio; so no generalization can be made with respect to frequency of verbs with voiceless or voiced fricatives. The token counts also show a higher overall number of voiced regular past tenses compared to past tenses with a voiceless suffix.

A related generalization concerns verb stems with a stem-final bilabial plosive /p, b/. If verb stems end with a voiced bilabial plosive it implies that the vowel length is short. Examples are given in (4).

- |     |                                |                         |
|-----|--------------------------------|-------------------------|
| (4) | schoppen [sxɔpən] ‘to kick’    | hopen [hɔpən] ‘to hope’ |
|     | klappen [klɒpən] ‘to clap’     | gapen [xapən] ‘to yawn’ |
|     | schrobben [sxrɔbən] ‘to scrub’ |                         |
|     | krabben [krɒbən] ‘to scratch’  |                         |

For verb stems with voiceless bilabial plosives there are no restrictions on possible vowel length. The frequency distribution for voiceless versus voiced bilabial plosives is different. CELEX lists 60 verb types and 391 tokens for regular past tenses of verbs with a stem-final /p/ compared to only four types and 11 tokens for regular past tenses of verbs with a stem-final /b/.<sup>3</sup> This means that the voiceless suffix is much more frequent for the bilabial plosives than the voiced past tense suffix.

<sup>3</sup> The same conditions as described in footnote 2 apply to the type and token counts given here.

A feature of fricatives in Dutch verbs is that alternating fricatives also alternate in orthographical representation. For instance, the singular present tense of the verb *leven* ‘to live’ is spelled with the letter <f>; thus in this case, final devoicing is represented in the orthography. The examples in (5) give infinitives, singular present tenses and past tenses to illustrate this orthographical difference for fricatives versus plosives. The non-alternating (voiceless) verbs are given in (5a), the alternating verbs are given in (5b).

(5) a.	<i>blaffen</i>	<i>ik blaf</i> ‘I bark’	<i>ik blafte</i> ‘I barked’
	<i>lossen</i>	<i>ik los</i> ‘I unload’	<i>ik loste</i> ‘I unloaded’
	<i>schoppen</i>	<i>ik schop</i> ‘I kick’	<i>ik schopte</i> ‘I kicked’
	<i>praten</i>	<i>ik praat</i> ‘I talk’	<i>ik praatte</i> ‘I talked’
b.	<i>leven</i>	<i>ik leef</i> [lef] ‘I live’	<i>ik leefde</i> [levdə] ‘I lived’
	<i>blozen</i>	<i>ik bloos</i> [blos] ‘I blush’	<i>ik bloosde</i> [blozdə] ‘I blushed’
	<i>schrobben</i>	<i>ik schrob</i> [sxrɔp] ‘I scrub’	<i>ik schrobde</i> [sxrobdə] ‘I scrubbed’
	<i>schudden</i>	<i>ik schud</i> [sxœt] ‘I shake’	<i>ik schudde</i> [sxœdə] ‘I shook’

These examples illustrate that verbs with alternating fricatives, change their orthographical representation in the present tense as well as in the past tense. Verbs with alternating plosives are not subject to spelling changes, although they are subject to final devoicing in the present tense.

## 1.2. Dutch past tenses in child acquisition data

The overview of voicing in Dutch verbs shows that the correct acquisition of the past tense requires children to acquire phonological knowledge of Dutch voicing rules as well as the lexical acquisition of the infinitives, implying that children have to develop their morphophonemic knowledge. According to Hayes (2004) such knowledge is acquired relatively late. Children acquire phonemic contrasts and phonotactics relatively early whereas children might be four or five years old before they acquire morphophonemic patterns like voicing alternations. This is confirmed by Kerkhoff (2007) for voicing alternation in Dutch noun plurals. She found that children aged seven still give 40,8% incorrect voicing on alternating nouns, e.g. [bɛtən] for the noun *bed* ‘bed’. Kerkhoff did not find evidence that children’s acquisition of alternations benefits from their knowledge of final devoicing. Possibly, the late acquisition of alternations is due to the child’s required

understanding of paradigms (Hayes, 2004); in the case of the past tense formation, the child has to acquire the verb paradigm.

As the Dutch past tenses can include alternating obstruents, the acquisition of these forms may develop late as well. To verify this, a corpus search was done based on several corpora in the CHILDES database (MacWhinney, 2000) in which all the regular past tenses were looked up. In addition to the child data from the CHILDES data base, the Nina files were also searched for past tense productions by Wim Zonneveld (personal correspondence). Only the corpora in CHILDES which included data of children above the age of two were searched, because it is not to be expected that children produce past tenses before that age. The following corpora were included in the search:

- The Van Kampen corpus (Van Kampen, 1994) which consist of dialogues between the mother and two daughters, Laura from age 1;9 - 5;6 and Sarah from age 1;6 - 5;2;
- The Groningen files (Bol, 1995), from which the data on the following six children is used: Abel, age 1;10.30 - 3;4.01, Daan, age 1;7 - 3;3, Josse, age 2;0 - 3;4, Matthijs, age 1;5 - 3;7, Peter 1;5 - 2;9, and Tomas, age 1;7 - 3;1;
- The Wijnen corpus (Wijnen, 1988). The child in the this corpus is less relevant for the overview of verb productions as the child was diagnosed with a language disorder and it does not produce regular past tenses at all, but it is relevant for the input analysis.

From all these corpora, the regular past tenses were counted in both the child's productions and the adult's inputs. Production and input are elaborated on separately, with a focus on verb stems ending in obstruents.

It should be noted that the data in these corpora have not been transcribed phonetically. The cases of which the actual production is unclear from the transcription are left out of the overviews below. An example is the transcription of the past tense *gilde* 'screamed', produced by Daan, which was given as 'gil(d)e'. As it is now unclear whether the child gave a correct past tense or not, it has been left out. The assumption is made that the other transcriptions are accurate.

### *Production of past tenses*

The earliest past tense in the Van Kampen corpus is at age 3;2.13 by Sarah, who produces a regular past tense *durfde* ‘dared’ with a voiced obstruent cluster. At age 3;7.25 there is an occurrence of a past tense with the voiceless suffix *heette* ‘named’. From that age onwards, Sarah produces more past tenses and she also makes several overgeneralizations. In the same corpus Laura starts producing past tenses at a age and she starts off with plural past tenses of irregular verbs. Laura produces irregular voiceless *moesten* ‘had to’ at age 4;4.23 and irregular voiced *zouden* ‘would’ at age 4;5.9. There are only a few regular past tenses in Laura’s productions up to age 5;6.

For the child data in the Groningen corpus the production of regular past tenses is earlier than in the Van Kampen corpus. The earliest past tense productions are by Tomas, who produces *maakte* ‘made’ and incorrect *hoorte* ‘heard’ at age 2;4.17. \**hoorte* contains a voicing error; the obstruent is produced as voiceless by Tomas even though the verb stem ends with a sonorant. The other children in the Groningen corpus produce their first past tenses at age 2;7 (Peter), age 2;9 (Josse), age 3;1 (Daan and Abel), and at age 3;2 (Matthijs). The Wijnen corpus does not give any child productions of past tenses, which is probably due to the fact that the child was delayed in language development. Another database that was searched is the recordings of Nina (personal correspondence with Wim Zonneveld). Nina produces quite some irregular past tenses and past participles by age 2;4. After age 2;6 she starts producing regular past tenses, e.g. *krabde* ‘scratched’ at age 2;8. She continues to use past tenses, both voiceless and voiced, as she gets older.

Tables 3a and 3b below present a combined overview of past tense productions that occur in the Van Kampen and Groningen files of verbs with an obstruent-final stem. The first table gives an overview of all past tenses with voiceless obstruents, subdivided into fricatives and plosives. The second table provides this overview for verbs with a voiced obstruent. There are no occurrences of regular past tenses with a voiced plosive. The token frequency in both tables is the total of the tokens over all the children’s productions in the corpora, singular and plural forms combined. The tables include overgeneralizations of irregular verbs that yield an obstruent cluster. The child productions of regular past tense

inflections for verbs with a sonorant-final stem are not given here, but can be found in appendix 1.

	Fricative			Plosive		
	Type	Tokens	Earliest production	Type	Tokens	Earliest production
Labial	*Geefte	3	Sarah 4;3.4	*Slaapte, *Sliepten	8	Matthijs 3;04.26 Laura 5;6.12
				*Koopten	1	Sarah 4;3.04
				Klopte(n)	5	Sarah 4;8.03
				*Sluipten	2	Sarah 4;8.03
Alveolar	Kuste	1	Sarah 4;4.28	Heette	6	Josse 3;4.17 Sarah 3;7.25
	*Wasten (waren)	1	Josse 2;11.9	Praatte	1	Sarah 4;3.04
				*Eette	1	Sarah 4;8.03
Velar	-ch	0		Maakte	4	Tomas 2;04.17 Josse 2;9.16 Sarah 4;6.12
				*Schrikte	1	Josse 2;11.9
				*Ruikte	1	Sarah 4;5.29
				Bakte(n)	4	Sarah 4;6.12
				*Zoekten	1	Sarah 4;8.03
				*Trekte	5	Laura 5;6.12

Table 3a. Productions of regular past tenses with voiceless obstruents

	Fricative		
	Type	Tokens	
Labial	Durfde	4	Sarah 3;2.13 Matthijs 3;2.29
	Leefde(n)	3	Sarah 4;8.03
	*Geefde	1	Sarah 4;9.29
Alveolar	*Blazede (blaasde)	1	Daan 3;1.28
	*Wasde (was)	0	Josse 3;0.6
Velar	*Vraagde	0	Josse 2;9.2

Table 3b. Productions of regular past tenses with voiced obstruents

Given the data in the CHILDES corpora that were included in this search, it can be observed that the number of past tenses children produce is not very high. This could be due to the fact that the recordings of the children in the Groningen corpus run only up to about three years of age. In the Van Kampen corpus, most of the past tenses found are produced by Sarah who was recorded up to 5;2 years of age, resulting in more available data. As a general picture it emerges that children start acquiring the regular past tense suffix between age two and three and show knowledge of its productivity and voicing pattern because they apply the correct voiced suffix to different verb types as well as to irregular verbs yielding the overgeneralizations also found in tables 2a and 2b above and in appendix 1.

Voice errors, i.e. applying a mismatching suffix to a verb stem, hardly occur. A voice error occurred in *\*hoorte* 'heard' by Tomas at age 2;4, in *\*zingte* 'sung' by Peter at age 2;7, and in *\*springte* 'jumped' by Laura at age 5;6. This might be due to the expected preference for a voiceless suffix for young children, as was argued before; although this is more likely

for the first two past tenses produced at age 2;4 and 2;7, than for the past tense \**springte* produced at age 5;6. Alternatively, a possible explanation for the two verbs with a velar nasal is that these are actually realized with a velar plosive between the nasal and the suffix, i.e. [zɪŋktə] and [spɪŋktə]. As the voiced velar plosive is not a phoneme in Dutch, the obstruent cluster is realized as voiceless due to voicing assimilation. The recordings of these items would have to be checked to determine the actual realization.

### *Input of past tenses*

The language learning child is able to infer Dutch voicing patterns for past tenses from more than just the actual past tenses present in the input. However, the verb paradigm is still difficult for the young child, thus it is relevant to determine the input of actual past tenses. This was based on a survey of Dutch children's books and on the corpus data from CHILDES.

A brief look at Dutch children's books show that most popular books are written in the present tense. This includes books by the popular authors Paul van Loon (*Dolfje Weerwolfje* series) and Carry Slee (e.g. *Afblijven; Help! De juf is verliefd*). An occasional past tense is often an irregular verb (frequency counts on several books by Carry Slee provided by Wim Zonneveld, personal correspondence). Table 4 shows an overview of past tenses in two books that are written in the past tense.

Past tense types	Children's book	
	Jaap ter Haar (1998), <i>Saskia en Jeroen in de lente</i> (41 pages)	Frank Herzen (2005), <i>Redding op Zee</i> (83 pages)
<b>Past tenses (total)</b>	<b>803</b>	<b>969</b>
- Irregular past tenses	582 (73%)	769 (79%)
- Regular past tenses	221 (28%)	200 (21%)
- Past tenses with sonorant final verb stem	136 (17%)	98 (10%)
- Past tenses with voiceless obstruent cluster	65 (8%)	55 (6%)
- Past tenses with voiced obstruent cluster	10 (1%)	23 (2%)

Table 4. Past tenses found in two children's books in numbers (%)

The number of irregular verbs is high for these books as well. The number of past tenses with obstruent clusters is given as percent of the total number of past tenses per book. This shows that past tenses with obstruent clusters are few.

The second source of input data is drawn from the corpora that were mentioned above. The corpora provide transcriptions of complete dialogues, i.e. both the child

productions as well as the adult responses, which allows for a brief analysis of the child's input. Most of the adult speech in the corpora is child-directed speech, but there are occurrences of adult-to-adult speech in the Groningen files. The following counts do not distinguish between the actual child-directed speech and the adult-to-adult speech because it can be assumed that the child is present during all the adult speech. The adults present in the Van Kampen and Wijnen corpora are the child's parents. In the Groningen files there was a researcher present as well.

The number of regular past tenses in the input of a child is quite low. The average percentage of regular past tense tokens is 0,09% of the total number of words uttered by the parents. In other words, for every 1100 words there is only one occurrence of a regular past tense. This percentage is 0,08% when the average is taken over all the adults present, both parents and researchers. There are instances of irregular past tenses, both singular and plural inflections, but these have not been counted as these are less relevant for the present study.

The total number of regular past tenses in the input in the corpora is 127 types and 630 tokens. There are 48 out of 127 types that have a voiceless suffix and 79 types are verbs with a voiced suffix.<sup>4</sup> Besides this, the past tense inflections with a sonorant- or vowel-final verb stem are the most frequently occurring verbs in the input. Of the 79 voiced past tense types, only 14 are verbs with an obstruent-final verb stem, the other 65 types are verb stems ending in sonorants or vowels. The table given below lists the five most frequent regular voiceless and voiced past tenses found in the input of the corpora mentioned above.

Voiceless		Voiced	
Types	Tokens	Types	Tokens
<i>Heette</i> 'called'	30	<i>Wilde</i> 'wanted'	89
<i>Maakte</i> 'made'	21	<i>Hoorde</i> 'heard'	73
<i>Paste</i> 'fitted'	14	<i>Gebeurde</i> 'happened'	39
<i>Stoote</i> 'bumped'	10	<i>Bedoelde</i> 'meant'	33
<i>Stopte</i> 'stopped'	7	<i>Vertelde</i> 'told'	14

Table 5. Top five of frequently occurring regular past tenses in the child's input

<sup>4</sup> Verbs with a prefix are counted as the same type, i.e. *schoonmaakte* 'cleaned' is counted as type of *maakte* 'made'. There is one instance of a voice error in the Van Kampen corpus: *\*krapte* 'scratched'. It has been counted under the verbs with a voiceless suffix although the correct past tense is voiced *krabde*.

The most frequently occurring voiced past tense containing an alternating obstruent is *hoefde* 'had to', the infinitive is *hoeven*. This past tense is not listed in the top five most frequently occurring voiced verbs; it occurs 11 times and is on position eight of the most frequently occurring voiced past tenses.

The token counts in the input include 630 regular past tenses of which 168 tokens have a voiceless suffix and 462 tokens have a voiced suffix. This implies that the voiced suffix occurs more than the voiceless suffix in the CHILDES corpora. This reflects a general trend in Dutch, namely that the voiced suffix has a higher frequency than the voiceless suffix. This was also found by Rispens and De Bree (2010) in their corpus search of Dutch past tenses using CELEX (Max Planck Institute for Psycholinguistics, 2001).

### 1.3. Previous past tense production experiments in Dutch

As was argued above, the Dutch past tense is a suitable context for an experiment on voiceless and voiced obstruent clusters. The corpus data also illustrated this: even though actual past tenses are scarce in a child's input, the child still starts producing past tenses from age 2;6 years old onwards. Thus it should be possible for children to participate in a production experiment at elementary school age. A small number of past tense production tasks have been carried out for Dutch past tense formation, both on adults and children. Three such experiments will be considered first.

Ernestus and Baayen (2003) report on a past tense production experiment with adults. The objective was to see how native speakers would interpret obstruents in a neutralized, i.e. word final, context in which voicelessness is due to final devoicing. This was done by giving the participants pseudo-verbs inflected in the first person singular present tense, e.g. *ik* [dɛnt] 'I + present tense' (Ernestus & Baayen, 2003). This way the participants were not presented with a cue for voicing alternation. The downside of this procedure is that the participants were primed with only voiceless obstruents which could have rendered more voiceless inflections.

Ernestus and Baayen (2003) provided auditory stimuli but the responses were to be written down. This created a problem as participants sometimes wrote down illegal clusters,

e.g. \*-<bte>, which Ernestus and Baayen chose to exclude from the analyses. Another drawback of the written response is the fact that orthography now comes into play. Some combinations of letters do not occur in Dutch and this might influence a participant's response, particularly with pseudo-verbs, whereas a spoken response will not be influenced by the orthographical picture of the word.

Ernestus and Baayen (2003) found that subjects base the choice of voicing on analogy to existing words. They compared the responses given on the production task to the types of past tenses that occur in the CELEX data base and found that the frequency patterns correspond. Overall, there was a bias for a voiceless obstruent in the past tense suffix. However, voicing depends on the final obstruent of the verb stem. Verb stems ending in fricatives, yielded more voiced interpretations than plosives. More specifically, velar fricatives yielded more voiced interpretations than alveolar fricatives; and alveolar fricatives yielded more voiced interpretations than labial fricatives. This hierarchy continued for the plosives with alveolar plosives yielding more voiced interpretations than labial plosives. In addition, voicing depends on the vowel of the verb stem with long vowels yielding more voiced interpretations than short vowels. All of these findings represented the patterns found in the data base. This confirms what has been said before concerning a difference between verbs with plosives versus fricatives. It also confirms the importance of vowel length in the Dutch past tense formation.

Ernestus and Baayen (2006) looked at the influence of incomplete neutralization of voiced obstruents on past tense formation in three different experiments. They found that both in production and perception incomplete neutralization of voiced obstruents is detectable. In a production task the participant was asked to read singular present tenses of pseudo-verbs out loud for which the stem-final obstruent was written as a voiceless obstruent, e.g. <t> or written as an alternating obstruent, e.g. <d>, e.g. *ik duut* 'I + present tense' versus *ik duud* 'I + present tense'. Acoustic analyses showed that the participant produced longer vocal cord vibration and shorter release noises for obstruents that were written with an alternating, i.e. voiced, obstruent. In other words, these obstruents were

realized with incomplete neutralization. This shows that the orthography plays a role in the realization of final obstruents.

In a second experiment, Ernestus and Baayen (2006) used the productions of the first experiment to determine whether listeners can perceive these subphonemic cues. Participants listened to the present tenses and were asked to produce past tenses. The production of a past tense forces the participant to interpret the voice value of the given obstruent. Verbs that had been produced with incomplete neutralized obstruents were interpreted as underlyingly voiced obstruents more often than the obstruents that had been produced as voiceless obstruents, thus the participants were sensitive to the subphonemic cues. Ernestus and Baayen stress the fact that the subphonemic cues are not just an artifact of orthography because in a manipulated setting in which the spelling always represented voiceless obstruents, participants were still able to perceive the difference between completely voiceless and incompletely neutralized obstruents. They argue that incomplete neutralization is strongly connected to lexical knowledge. If a word or pseudo-word is encountered, lexical neighbors and inflected forms will be activated in the mental lexicon and the interpretation of voiceless obstruents will be based on the voicing of these neighbors.

In a past tense production experiment for children, Rispens and De Bree (2010) introduced the verb, either a Dutch verb or a pseudo-verb, by means of a picture and a short story in which both the infinitive and present tense of the verb occurred. The children were then prompted to finish a sentence with “yesterday” and thus produce a past tense. Rispens and De Bree found that for existing verbs (with verb stems ending in the obstruents /k/ or /s/ and the sonorants /l/, /r/, or /w/) children score better on high frequency verbs, which confirms the finding by Ernestus and Baayen (2003) that participants base their decision on analogy.<sup>5</sup> Rispens and De Bree also found that for pseudo-verbs (with verb stems ending in the obstruents /p/ or /k/ and the sonorants /r/, /m/, or /n/) children score better on verbs with obstruents. This suggests that children generally prefer voiceless obstruent clusters,

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<sup>5</sup> Rispens and De Bree (2010) also found a significant difference between the production of past tenses by typically developing children and SLI children. This will not be elaborated on here.

despite the known fact that in Dutch the number of verbs inflected with the voiced suffix [-də] is higher than the frequency of verbs inflected with a voiceless suffix.

#### 1.4. Research questions

The main question that this thesis tries to answer is whether children have a preference for voiceless obstruent clusters over voiced obstruent clusters in the context of the past tense. Based on earlier experiments and on markedness theory it is to be expected that young children will show a preference for voiceless clusters in past tense production (Rispen & De Bree, 2010). However, the earlier experiments also show the strong influence of lexical knowledge and the influence of lexical neighbors. As children get older they will be able to determine the past tense formation by analogy. It is to be expected that children inflect pseudo-verbs in analogy to existing verbs. In line with Ernestus and Baayen (2003) it is to be expected that older children and adults will tend to produce voiceless suffixes on plosives and relatively more voiced suffixes for fricative final verb stems, as this is a general trend in Dutch. The vowel length of the verb stem will likewise determine whether children and adults prefer a voiceless or a voiced cluster in the past tense inflection of verbs with fricative final verb stem.

A second question that will be addressed is whether orthography affects the preference for a voiceless or voiced past tense suffix. An effect of orthography on voicing was found by Ernestus and Baayen (2006) in that graphemes used to represent voiced obstruents yielded incomplete neutralization in syllable final contexts. Treiman and Bourassa (2000) also found a beneficial effect of orthography for English school children in that they spelled better in a written spelling task than in an oral spelling task. Treiman and Bourassa claim that a written representation of a word assists children and adults in the phonological analysis of a word. In the context of the Dutch past tense, orthography is expected to affect the choice between a voiceless or voiced past tense suffix. Children who have learned to read and write will likewise be affected by orthography in their choice of the past tense suffix.

The experiment, described in further detail below, includes voiceless and voiced verbs and pseudo-verbs. The reason to include verbs and pseudo-verbs is because past tenses of existing Dutch verbs could be stored in the mental lexicon, whereas for pseudo-verbs the participants have to rely on their knowledge of Dutch past tense formation (Rispen & De Bree, 2010). The experiment will include two modalities of presentation to determine the effect of orthography. The auditory realization of the infinitives will be presented in both modalities, whereas the orthographical representation of the infinitive will be additionally provided in the “orthographical” modality. The pseudo-verbs will vary in stem-final obstruent and vowel length resulting in legal forms, i.e. consistent with Dutch phonotactics and illegal forms, i.e. inconsistent with Dutch phonotactics. If inflection is based on analogy, the latter pseudo-verbs will prove difficult to inflect and more errors will occur. However, if orthography can direct the participant, the effect of orthography is expected to be greater for the inconsistent pseudo-verbs as in those cases the participant cannot rely on analogy.

## 2. Method

This chapter presents the design of the present experiment, which included existing Dutch verbs and pseudo-verbs to elicit past tenses from the participants. After much deliberation in which several experimental designs were considered and evaluated (by the author of this thesis and the supervisors), the decision was made to employ the following methodological design. The children were presented with the infinitive form of the verb so as to provide them with the information on voicing of the obstruent in question. If children match the past tense inflection on the voicing of the verb stem-final obstruent, it implies that they have acquired the verbal paradigm and that they understand that past tense formation includes progressive voicing assimilation. This would argue in favor of the output-to-output faithfulness constraint mentioned above that states that the realization of the past tense has to resemble the realization of the infinitive. The presentation of the infinitive avoids priming the participants with voiceless obstruents due to final devoicing.

To see whether analogy plays a role in the way children inflect the pseudo-verbs, the experiment contains several categories of pseudo-verbs, which are either consistent or inconsistent with existing Dutch verbs. This will be elaborated on below. It is to be expected that if analogy is important to the participants they will perform better on consistent verbs than on inconsistent verbs. Participants may be expected to reverse the voicing on inconsistent pseudo-verbs to make them consistent with Dutch verbs.

To determine whether orthography plays a role in the voicing of past tense obstruent clusters, the experiment will be conducted in two versions. One version will be without any orthographical cues and another version will be with the orthographical representation of the infinitive. In addition, the test will be run with two child age groups. The youngest group is a group of six-year-olds. These children are the oldest group to have not begun reading and writing yet. The second age group will be nine years old. These children have developed reading and writing but have not been taught explicitly how to inflect verbs, based on orthographical cues. The first age group will only participate in the version without orthography; the second age group will be able to participate in both versions of the experiment. An adult control group will also participate in the experiment.

## 2.1. Participants

The experiment included children in two age groups and an adult control group. The youngest group consisted of 17 children (8 girls and 9 boys) with a mean age of 6;1 (0;4) years and an age range from 5;8 to 6;7 years. These children were pupils of the same Dutch elementary school and will be referred to as the six-year-old group. The nine-year-old group consisted of 56 children (31 girls and 25 boys), mean age 9;1 (0;6) years, with ages ranging from 8;0 to 10;5 years. These children were from three different Dutch elementary schools.<sup>6</sup> The children had not participated in earlier linguistic experiments. The control group consisted of 30 adults (16 women and 14 men) with a mean age 29 (7) years and an age range from 17 to 42 years.

## 2.2. Materials

The experiment included 32 test items. Of these, eight items were existing Dutch verbs and 24 were pseudo-verbs. The pseudo-verbs fell into three categories: neutral, consistent and inconsistent. The neutral category consisted of pseudo-verbs that adhere to Dutch phonotactics and that can phonotactically occur with either a voiced or a voiceless obstruent at the end of the verb stem, examples are given below. The consistent and inconsistent verbs are based on the phonotactic interplay of voicing and vowel length. As was pointed out above, among the Dutch obstruents, voiceless fricatives tend to follow a short vowel and voiced obstruents tend to follow a long vowel. Moreover, verbs stems that end in a voiced bilabial plosive only allow short vowels. The consistent stimuli adhere to this tendency, whereas the inconsistent stimuli all have the reverse pattern. Table 6, given below, shows the different categories of the stimuli and gives an example of a voiceless and voiced pair of test items.

Category	Number of items (voiceless-voiced)	Example (voiceless-voiced)
Verb	8 (4 - 4)	<i>klappen</i> 'to clap' - <i>krabben</i> 'to scratch'
Neutral pseudo-verb	8 (5 - 3)	<i>beisen</i> - <i>fleizen</i>
Consistent pseudo-verb	8 (4 - 4)	<i>taffen</i> - <i>spaven</i>
Inconsistent pseudo-verb	8 (4 - 4)	<i>trofen</i> - <i>drovven</i>

Table 6. Inventory of stimuli

<sup>6</sup> One of these schools was the same school as the school the six-year-olds attended.

All categories have a balanced number of voiced and voiceless stimuli, except the neutral pseudo-verbs. This is because two items were included with the obstruent /p/ to balance the occurrence of the voiced /b/ in the consistent and inconsistent categories.

The pseudo-verb stimuli included the plosives /p, b/ and the fricatives /s, z, f, v/. These were chosen because they are subject to the consistency pattern in Dutch. The alveolar plosives /t, d/ are unsuitable because in the past tense these do not yield an obstruent cluster due to degemination. An example of this is given in (6).

- (6) *praten* 'to talk'      *ik praatte* [pratə] 'I talked'  
*schudden* 'to shake'    *ik schudde* [sxœdə] 'I shook'

The voiceless velar plosive was excluded because it does not have a voiced counterpart in Dutch. The velar fricatives were also rejected because these do not adhere to the fricative generalization that relates voicing to vowel length. In addition, the voicing distinction is not realized by all speakers of Dutch (see Gussenhoven & Bremmer, 1983 for an overview of Dutch fricatives). Thus, it could be difficult to perceive and produce the difference between the voiceless and voiced fricative for both the experimenter and the participants.

A limited variation of vowels was chosen for the pseudo-verb stimuli so as to not have to include the 'vowel' criterion as another variable. The consistent and inconsistent pseudo-verb types included the long and short vowel pairs /a~a, e~ε, o~ɔ/. The eight verbs in the neutral category included four pseudo-verbs with the short vowels /ε/ and /ɔ/ followed by a liquid /l/ or an alveolar nasal /n/; there were two verbs with the diphthong /ei/; the verbs with a stem-final /p/ were preceded by the vowels /a, ɔ/.

The experiment included eight filler items. Four of these were pseudo-verbs, which were added to draw the participant's attention away from the fact that the focus of the experiment is on obstruent clusters. Four other fillers were Dutch irregular verbs, included to avoid the rhythm of the addition of the past tense suffix. The test stimuli and filler items were pseudo-randomly ordered to ensure that obstruents that only differ in voice were never consecutive. This way, a past tense can not function as a prime for the verb immediately following it. For example, the pseudo-verb *taffen* was never immediately followed by the

item *drovven*. A complete list of the stimuli and the two orders in which the stimuli were presented can be found in appendix 2.

The experiment was first run for a group of nine-year-old children, through which it appeared that the test was too long for some children; they got bored and lost their concentration. For this reason, the number of stimuli was reduced for the six-year-old group, in an attempt to accommodate the younger children, who are expected to have an even shorter concentration span. The verbs and fillers from the long version were all included in this shorter version. From the pseudo-verbs, half of the items were selected so that there were four items in each category. The respective numbers of stimuli are now as in table 7.

Category	Number of items (voiceless-voiced)	Example (voiceless-voiced)
Verb	8 (4 - 4)	<i>klappen</i> 'to clap' - <i>krabben</i> 'to scratch'
Neutral pseudo-verb	4 (2 - 2)	<i>beisen</i> - <i>fleizen</i>
Consistent pseudo-verb	4 (2 - 2)	<i>taffen</i> - <i>spaven</i>
Inconsistent pseudo-verb	4 (2 - 2)	<i>trofen</i> - <i>drovven</i>

Table 7. Inventory of stimuli included in shorter version

Again, a complete list of the stimuli for the shortened version can be found in appendix 2.

The stimuli are presented auditorily. The audio recordings were done by a female Dutch speaker who was not further involved in the experiment. All items were read out loud in a soundproof booth and recorded and stored on a computer using “Audacity” software. The relevant voiced or voiceless syllables of the test items were then spliced from pseudo-words with a neutral context to ensure the voiced or voiceless quality of the production. For instance, the final syllable of the pseudo-verb [bɛi.sən] was spliced from the pseudo-verb ['bɔ.lə.sən]. In the latter context the relevant syllable is preceded by a schwa which phonotactically does not affect the voicing quality. Using PRAAT (Boersma & Weenink, 2010) and “Audacity” software, the correct voiced or voiceless suffixes were added to the audio recordings of the previously recorded and spliced verb stems.

### 2.3. Procedure

The set-up of the experiment resembles that of the earlier experiment by Rispens and De Bree (2010). The material was presented using a laptop computer and consisted of 40 slides in a PowerPoint presentation with an animated picture on each; most of the slides had a

picture of a single animal, six slides had a picture of two or three actors.<sup>7</sup> Some children tended to produce an infinitive instead of a past tense for the multiple character pictures. In that case the child was asked to make another sentence supposing there was only one animal. An audio recording of the infinitive was built into each slide and was played over external speakers after clicking on the picture.

The possible role of orthography in this experiment was alluded to above. To determine its role, the experiment has two modalities in which the stimuli is presented. Each participant partakes in either an 'auditory' version or an 'orthographical' version. The auditory version includes the pictures and the recordings as described above. The slides of the orthographical version are extended with the written representation of the infinitive at the heading of the slide, thus it includes both an auditory and a written presentation of the infinitive. For convenience, these two modalities are referred to as the auditory and orthographical version, even though the latter includes both. The stimuli are presented in two pseudo-randomized orders. Again, each participant is subjected to one order.

During the experiment, the children are presented with the slide, after which the picture is introduced using a sentence such as "look, this animal is...", after which the audio recording was played twice.<sup>8</sup> The child was only presented with the infinitive; the present tense was not given so that the child was not primed with a voiceless context. The children were prompted to produce a sentence in the past tense by saying "yesterday...". The responses were thus spoken by the participants, both in the auditory and orthographical version, because it would be too time-consuming to have nine-year-old children write out their answers to 40 verbs. This procedure also avoids the problem of participants writing down illegal clusters (cf. Ernestus & Baayen, 2003). Sometimes children produced a past tense construction with an auxiliary verb. In this case the experimenter asked the child to make a shorter sentence and sometimes assisted the child by articulating the onset of the relevant verb.

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<sup>7</sup> The animated pictures were free downloads of [www.animationlibrary.com](http://www.animationlibrary.com)

<sup>8</sup> Most of the children heard the audio recording twice but some children were fast in their response so they sometimes heard it only once. For the auditory version of the task it was emphasized beforehand that the child would get to hear the stimulus twice and after a few items the child might be reminded again to listen carefully both times.

The experiments were recorded digitally, using a Zoom Handy Recorder H4 with an external table microphone. The scoring of the responses was done online as well as offline. During the online scoring (done by the author of this thesis), it was indicated whether a voiced or voiceless suffix was produced. When a child gave a different response than the expected regular past tense suffix, the verb was written down in its full form on the score sheet. In unclear cases the response was listened to again offline. Cases that remained unclear were scored offline by both the author as well as two supervisors.

The past tense production experiment was preceded by the Peabody Picture Vocabulary Test-III-NL (Pearson, 2005). This was included to obtain a general measure of the children's language development.

### 3. Results

This chapter presents the results of the past tense production experiment. The response types will be presented first; these provide a measure to determine whether there is a preference for voiceless over voiced obstruent clusters. The results are given for the three age groups. In the following sections the effects of consistency, modality, and stem consonant are analyzed for the nine-year-old age group and the adults; the six-year-old age group is excluded from these analyses because the amount of data is too small. Besides this, modality is irrelevant for the six-year-old age group. Then, the responses on the fillers are presented and finally, correlations with the vocabulary task are investigated.

The long and short version of the experiment were both carried out in two pseudo-randomized orders. Each participant was provided with one of these orders. A repeated measures ANOVA on the number of correct responses with both age and stimuli order as between-subjects factors show that the order is not-significant ( $F(1,97)=0.098$ ,  $p=.755$ ).

#### 3.1. Response type

The responses on the past tense production experiment were scored as “correct” or “incorrect”. Incorrect responses were of two types: “voice error” and “other”. A response was scored as “correct” when the participant’s past tense suffix matched the voicing of the infinitive stimulus, even if the infinitive was of an inconsistent verb type. For example, the response to the inconsistent pseudo-verb [dʁɔvən] was scored “correct” when the participant said [dʁɔvdə] and it was scored as “voice error” when the participant said [dʁɔftə]. “Voice errors” are responses for which the voicing of the past tense does not match the voicing of the infinitive that was presented.

The incorrect responses scored as “other response” in the tables given below consist of several different responses. The high number of “other responses” for the child groups is primarily due to the fact that the six- and nine-year-old children were not able to consistently produce past tenses, both with verbs and pseudo-verbs. In the six-year-old group, eight children (47%) failed to produce a past tense for more than half of the items. In the nine-year-old group, nine children (16%) failed to produce a past tense for more than half

of the items. Some children avoided a past tense by using a construction such as *gister ging hij ook rennen* ‘yesterday went he too running’. Another type of response some children produced was the infinitive, for example, *\*gister knase(n)* ‘yesterday+pseudo-verb infinitive’ or *\*gister knase(n) het hondje* ‘yesterday+pseudo-verb infinitive the doggie’. In some cases the child seemed to use an inflected verb form with an ə-suffix, in which case they consistently stressed the vowel suffix, for example *\*gister eisse* [ɛi'sə] ‘yesterday demand(ed)’. These responses were clearly not infinitives, but it is unclear if they can be interpreted as a past tense as they are not inflected with the Dutch past tense suffix [-tə] or [-də]. Some children gave present tense responses, for example, *gister knaast de hond* ‘yesterday+pseudo present tense the dog’.

The adult group produced relatively few “other” responses; the “other responses” that they produced are vowel length changes (mostly changing a long vowel into a short vowel), e.g. [daptə] as past tense of [dapən], as well as several irregular inflections, e.g. [bes] as past tense of [beisən].

The tables below indicate the type of responses the participants gave for verbs and pseudo-verbs depending on the voiceless or voiced stem-final obstruent. Table 8a shows the type of response for all test items in the experiment (verbs and pseudo-verbs). The number of test items was 32 items for the nine-year-old and adult age group and 20 items for the six-year-old age group. The type of response is given in numbers of items and in percentages (per age group, per infinitive type). For instance, of all the voiceless obstruents that the six-year-olds encountered (170 items), 67 correct responses were given, which amounts to 39% of the voiceless verbs. The tables 8b and 8c show the type of response for the verbs and pseudo-verbs respectively.

Infinitive voicing	Age group	Type of response		
		Correct	Voice error	Other
Voiceless	six-year-olds	67 (39%)	26 (15%)	77 (45%)
	nine-year-olds	409 (43%)	359 (38%)	184 (20%)
	adults	358 (70%)	101 (20%)	51 (10%)
Voiced	six-year-olds	52 (31%)	27 (16%)	91 (54%)
	nine-year-olds	480 (57%)	149 (18%)	211 (25%)
	adults	245 (54%)	157 (35%)	48 (11%)

Table 8a. Response type in number of items (%)

Infinitive voicing	Age group	Type of response		
		Correct	Voice error	Other
voiceless obstruent	six-year-olds	33 (49%)	7 (10%)	28 (41%)
	nine-year-olds	148 (66%)	52 (23%)	24 (10%)
	adults	109 (91%)	11 (9%)	0 (0%)
voiced obstruent	six-year-olds	31 (46%)	10 (15%)	27 (54%)
	nine-year-olds	153 (68%)	33 (15%)	38 (17%)
	adults	96 (80%)	22 (18%)	2 (2%)

Table 8b. Response type for verbs in number of items (%)

Infinitive voicing	Age group	Type of response		
		Correct	Voice error	Other
voiceless obstruent	six-year-olds	34 (33%)	19 (19%)	49 (48%)
	nine-year-olds	261 (36%)	307 (42%)	160 (21%)
	adults	249 (64%)	90 (23%)	51 (13%)
voiced obstruent	six-year-olds	21 (21%)	17 (17%)	64 (63%)
	nine-year-olds	327 (53%)	116 (19%)	173 (28%)
	adults	149 (45%)	135 (41%)	46 (14%)

Table 8c. Response type for pseudo-verbs in number of items (%)

A general measure of the number of voiceless and voiced suffixes that were produced can be found in table 9 below. This measure is independent of the voicing of the infinitive. To obtain these numbers, the number of correct responses on the voiced verbs, given in table 6a above, were added to the voice error responses on the voiced verbs and vice versa.<sup>9</sup>

	Number of voiceless suffixes [-tə]	Number of voiced suffixes [-də]	Number of other responses	Total number of infinitives presented
Six-year-olds	94 (28%)	78 (23%)	168 (49%)	340
Nine-year-olds	558 (31%)	839 (47%)	395 (22%)	1792
Adults	515 (54%)	346 (36%)	99 (10%)	960

Table 9. Total voiceless and voiced suffixes on verbs and pseudo-verbs in number of items (%)

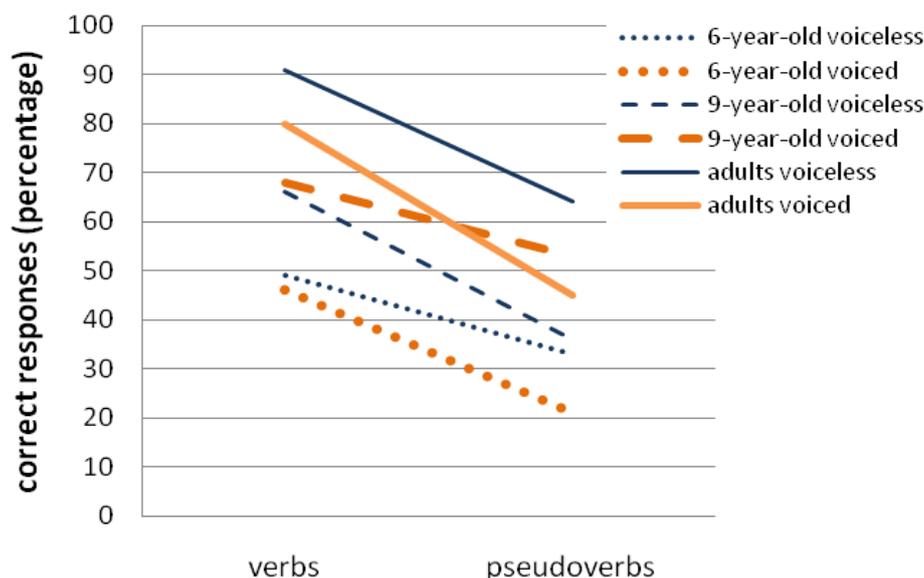
The six-year-old children show a marginal preference for the voiceless suffix, but the number of data is limited with only 172 past tenses produced from 340 infinitives presented. The nine-year-old group, on the other hand, shows a clear preference for the voiced past tense suffix. The adult participants produce the voiceless suffix more often than the voiced suffix.

A repeated measures ANOVA with verb type (verb or pseudo-verb) and voicing of the infinitive (voiceless or voiced stem-final obstruent) as within-subjects factor and age group as a between-subjects factor, shows that for the number of correct responses there is a significant effect of age group ( $F(2,100)=17.634$ ,  $p<.000$ ) with adults scoring more correct than the child groups. There is a significant effect of verb type ( $F(1,100)=187.026$ ,  $p<.000$ )

<sup>9</sup> The occasional "other" responses that do include a voiceless or voiced past tense suffix but also, e.g. a vowel change, are not included here.

with more correct items for existing verbs than for pseudo-verbs. There are several significant interactions; between verb type and age group ( $F(2,100)=3.291$ ,  $p=.041$ ) with a larger difference between verbs and pseudo-verbs for the adults than for both child groups; between infinitive voicing and age group ( $F(2,100)=5.077$ ,  $p=.008$ ) with the nine-year-old group producing more correct past tenses on voiced infinitives and the other two groups producing more correct past tenses on voiceless infinitives. There is also a significant interaction between verb type, infinitive voicing, and age group ( $F(2,100)=6.361$ ,  $p=.003$ ). Games-Howell post hoc analysis shows significant differences for correct responses between the adults and the nine-year-olds (mean difference=0,14 (0,03),  $p<.000$ ), between the adults and the six-year-olds (mean difference=0,33 (0,06),  $p<.000$ ), as well as a difference between the nine-year-olds and the six-year-olds (mean difference=0,18 (0,07),  $p=.024$ ).

The graph given below illustrates the responses for the three groups on both verbs and pseudo verbs. The type of infinitive, voiceless or voiced, is indicated for each group as well.



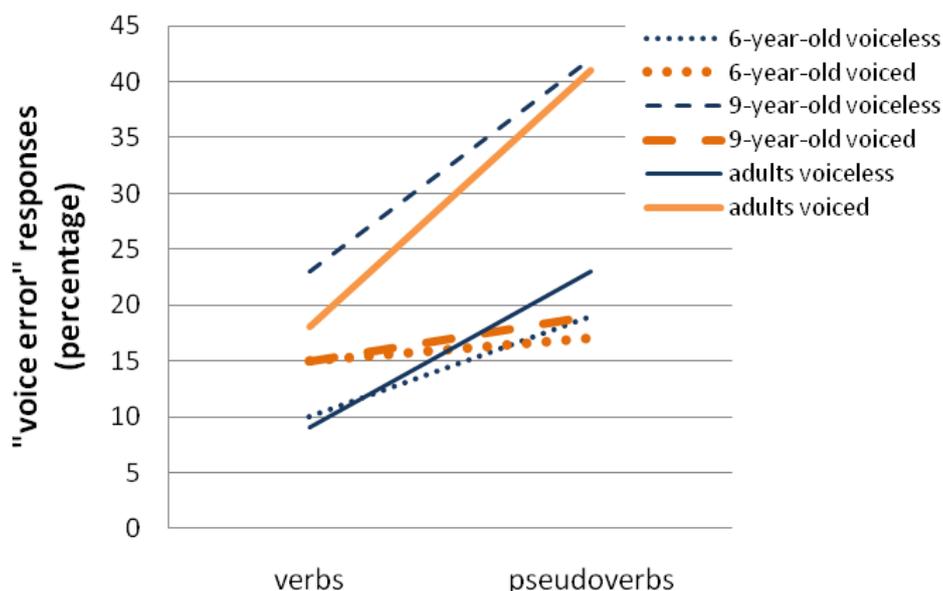
Graph 1. Correct responses by the three age groups for voiceless and voiced verbs and pseudo-verbs

In all three age groups, the number of correct responses is higher for verbs than for pseudo-verbs. The graph illustrates the pattern that was mentioned above as well: the six-year-old children produce more correct responses for voiceless infinitives, whereas the nine-year-old children produce more correct responses for voiced infinitives. This effect is stronger for pseudo-verbs than for verbs in these two groups.

The number of voice errors has also been scored. For the adult group this approximates the mirror image of the correct items as the number of other responses is quite small (10%). For the two child groups the number of other responses is high (49% and 22% for the six-year-old and nine-year-old group respectively); in which case the number of voice errors is not the mirror image of the correct items.

A repeated measures ANOVA with verb type (verb or pseudo-verb) and voicing of the infinitive (voiceless or voiced obstruent) as within-subjects factors and age group as a between-subjects factor shows that for the number of voice errors there is a significant effect of age group ( $F(2,100)=4.739$ ,  $p=.011$ ) with the nine-year-old group producing more voice errors on the voiceless verbs and the six-year-old and adult group producing more voice errors on the voiced verbs. There are significant interactions between age group and verb type ( $F(2,100)=5.753$ ,  $p=.004$ ), age group and infinitive voicing ( $F(2,100)=7.816$ ,  $p=.001$ ), and between age group, verb type, and infinitive voicing ( $F(2,100)=5.610$ ,  $p=.005$ ). Games-Howell post hoc analysis shows a significant difference for voice error responses between the six-year-old group and the nine-year-old group (mean difference=-0,096 (0,038),  $p=.044$ ). Verb type is significant ( $F(1,100)=65.030$ ,  $p=.004$ ) with more voice errors on pseudo-verbs than existing verbs.

The number of voice errors for the three age groups are illustrated in the graph below.



Graph 2. Voice error responses by the three age groups for voiceless and voiced verbs and pseudo-verbs

Both child groups produced more voice errors for pseudo-verbs than for verbs. The six-year-old group produced more voice errors with voiced verbs and with voiceless pseudo-verbs. The nine-year-old group inflected voiceless verb types with a voiced suffix more often than that they inflected voiced verb types with a voiceless suffix; the effect is greater for pseudo-verbs.

In the following sections, more specific analyses are conducted to determine the influence of consistency and modality on the voicing of the past tense productions. These analyses are run on the nine-year-old children and adult group only. The amount of relevant data is too small for the six-year-olds age group as almost half of the children in that group did not produce regular past tenses consistently.

### 3.2. Consistency of pseudo-verbs

As pointed out above, the stimuli included consistent and inconsistent pseudo-verbs. Inconsistent pseudo-verbs are instances of pseudo-verbs with long vowels followed by voiceless fricatives, e.g. [krafən], or pseudo-verbs with short vowels followed by voiced fricatives, e.g. [drɔvən]. There were also two instances of verbs with a long vowel followed by a voiced bilabial plosive, e.g. [frobən]. In these cases, a response with a voice error will actually make the past tense consistent with Dutch phonotactics. An overview of the responses given by the two age groups on the consistent and inconsistent pseudo-verbs is in table 10.

Infinitive voicing	Age group	Type of response per pseudo-verb type					
		Consistent pseudo-verbs			Inconsistent pseudo-verbs		
		Correct	Voice error	Other	Correct	Voice error	Other
Voiceless	Nine-year-olds	87 (39%)	86 (38%)	51 (22%)	60 (27%)	115 (51%)	49 (22%)
	Adults	95 (79%)	17 (14%)	8 (7%)	46 (38%)	42 (35%)	32 (27%)
Voiced	Nine-year-olds	130 (58%)	38 (17%)	56 (24%)	114 (51%)	35 (16%)	75 (33%)
	Adults	62 (52%)	46 (38%)	12 (10%)	44 (37%)	51 (43%)	25 (21%)

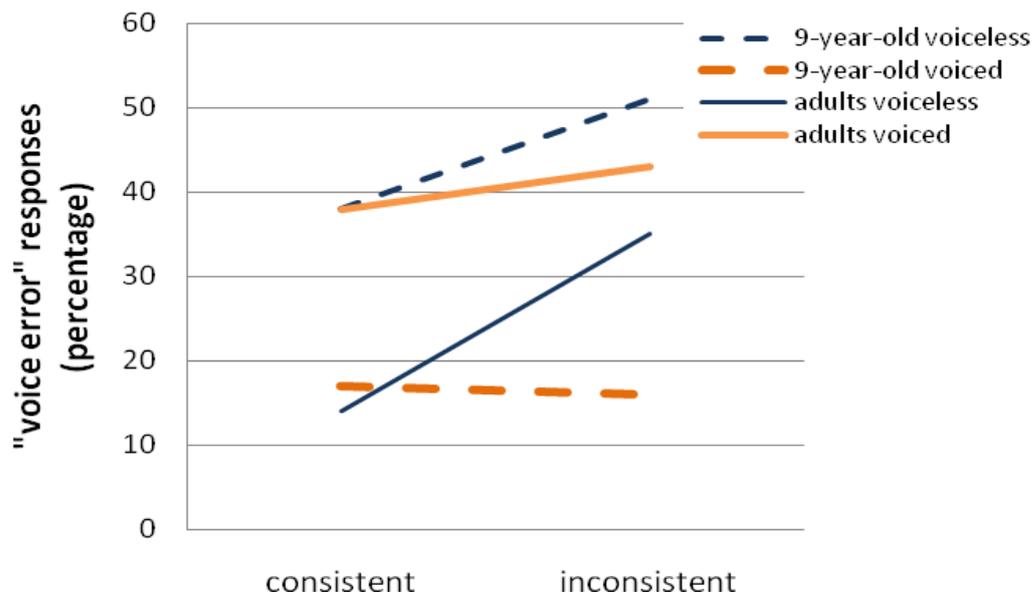
Table 10. Responses on consistent and inconsistent pseudo-verbs in number of items (%)

The number of voice errors is high for both age groups on voiceless inconsistent pseudo-verbs. The adults also have a high number of voice errors for inconsistent voiced pseudo-

verbs. This is not the case for the nine-year-old group due to their preference of the voiced suffix, which was seen earlier.

A repeated measures ANOVA on the number of voice errors for the subset of pseudo-verbs (consistent and inconsistent) with consistency and infinitive voicing as within-subjects factor and age group as between-subjects factor shows that the factor consistency is significant ( $F(1,84)=16.294$ ,  $p<.000$ ) with more voice errors on inconsistent pseudo-verbs than for consistent pseudo-verbs. Age group is not significant ( $F(1,84)=0.329$ ,  $p=.568$ ), so both age groups turn inconsistent verbs into consistent past tenses by changing the voicing of the obstruent. The interaction between consistency and infinitive voicing is significant ( $F(1,84)=15.490$ ,  $p<.000$ ) which is illustrated in graph 3 below; there is a stronger effect of consistency for voiceless pseudo-verbs with more voice errors on inconsistent voiceless pseudo-verbs than on consistent voiceless pseudo-verbs. There is also a significant interaction between age group and infinitive voicing ( $F(1,84)=17.709$ ,  $p<.000$ ), because the nine-year-old group still uses the voiced suffix more than the voiceless suffix, whereas the adults apply the voiceless suffix more often.

Graph 3 illustrates the number of voice errors on the consistent and inconsistent pseudo-verbs for the two age groups combined.



Graph 3. Voice errors by adult and nine-year-old groups on consistent and inconsistent pseudo-verbs

Particularly voiceless inconsistent pseudo-verbs trigger voice errors, e.g. [trovdə] as past tense of [trofən]. In other words, the past tenses of voiceless inconsistent pseudo-verbs are realized with a voiced suffix more often than that voiced inconsistent pseudo-verbs are realized with a voiceless suffix.

Table 10 above, lists the number of inconsistent verbs that were made consistent by changing the voicing of the pseudo-verb in question. However, changing an inconsistent verb into a consistent past tense by adjusting the vowel length was also a strategy that some participants applied, e.g. [frɔptə] as past tense of [frobən]. A complete list of the inconsistent verbs is in table 11 below, together with the possible responses yielding a consistent past tense. The numbers in the last two columns indicates the number of participants that adjusted the vowel length to make the verb consistent.

Verb	Consistent past tense by		Number of consistent responses by vowel length adjustment	
	voice error	vowel length adjustment	Nine-year-olds (6)	Adults (16)
[trofən]	[trovdə]	[trɔftə]	3	3
[drɔvən]	[drɔftə]	[drovdə]	-	1
[krafən]	[kravdə]	[kraftə]	-	7
[navən]	[naftə]	[navdə]	-	1
[trebən]	[treptə]	[trɛptə] or [trɛbdə]	3 (2 voiceless)	3 (3 voiceless)
[frobən]	[froptə]	[frɔptə] or [frɔbdə]	2 (1 voiceless)	5 (4 voiceless)
[drosən]	[drozdə]	[drɔstə]	-	8
[knasən]	[knazdə]	[knɔstə]	1	4

Table 11. Inconsistent verbs made consistent by vowel length adjustment in number of participants

Not all adults and nine-year-old children used the vowel length adjustment strategy. The nine such responses by the nine-year-old group are from six different participants; the 32 such responses by adults are from 16 different participants.

### 3.3. Modality

The experiment was run in two modalities with regard to stimuli presentation for the nine-year-olds and adults. Either the stimuli were presented auditorily only, or the stimuli were presented auditorily and orthographically. These two modalities are referred to as “auditory” and “orthographical”, respectively. An overview of the responses given by the two age groups on the auditory and orthographical version is in table 12.

Infinitive voicing	Verb type	Age group	Type of response per version					
			Auditory			Orthographical		
			Correct	Voice error	Other	Correct	Voice error	Other
Voiceless	Verb	Nine-year-olds	73 (65%)	27 (24%)	12 (11%)	75 (67%)	25 (22%)	12 (11%)
		Adults	53 (88%)	7 (12%)	0 (0%)	56 (93%)	4 (7%)	0 (0%)
	Pseudo-verb	Nine-year-olds	142 (39%)	144 (40%)	78 (22%)	119 (33%)	163 (45%)	82 (22%)
Voiced	Verb	Adults	122 (63%)	55 (28%)	18 (10%)	127 (65%)	35 (18%)	33 (17%)
		Nine-year-olds	76 (68%)	18 (16%)	18 (16%)	77 (69%)	15 (13%)	20 (18%)
	Pseudo-verb	Adults	46 (77%)	13 (22%)	1 (2%)	50 (83%)	9 (15%)	1 (2%)
		Nine-year-olds	162 (53%)	71 (23%)	75 (25%)	165 (54%)	45 (15%)	98 (32%)
		Adults	69 (42%)	77 (47%)	19 (11%)	80 (48%)	58 (35%)	27 (17%)

Table 12. Responses on pseudo-verbs in the auditory and orthographical version in number of items (%)

Orthography is expected to be of lesser influence on existing verbs, which is why the following analysis is conducted on the pseudo-verbs only.

A repeated measures ANOVA on the voice errors for pseudo-verbs with age group and modality as between-subjects factors shows that modality is significant ( $F(1,82)=4.489$ ,  $p=.037$ ). There are generally fewer voice errors in the orthographical version compared to the auditory version. There is a significant interaction between age group and infinitive voicing ( $F(1,82)=17.212$ ,  $p<.000$ ). This is due to the high number of voice errors by the nine-year-old group on the voiceless pseudo-verbs compared to voiced pseudo-verbs; whereas for the adult group the number of voice errors on the voiced pseudo-verbs is higher than the number of voice errors on the voiceless pseudo-verbs.

Table 13 below gives an overview of the correct and voice error responses on a subset of pseudo-verbs: the consistent and the inconsistent verbs.

Infinitive		Age group	Type of response per version			
Category	Voicing		Auditory		Orthographical	
			Correct	Voice error	Correct	Voice error
Consistent	Voiceless	Nine-year-olds	49 (44%)	38 (34%)	38 (34%)	48 (43%)
		Adults	44 (73%)	12 (20%)	51 (85%)	5 (8%)
	Voiced	Nine-year-olds	66 (59%)	21 (19%)	64 (57%)	17 (15%)
		Adults	30 (50%)	23 (38%)	32 (53%)	23 (38%)
Inconsistent	Voiceless	Nine-year-olds	36 (32%)	57 (51%)	24 (21%)	58 (52%)
		Adults	28 (47%)	22 (37%)	18 (30%)	20 (33%)
	Voiced	Nine-year-olds	60 (54%)	24 (21%)	54 (48%)	11 (10%)
		Adults	22 (37%)	32 (53%)	22 (37%)	19 (32%)

Table 13. Responses for consistent and inconsistent pseudo-verbs by modality in number of items (%)

It is to be expected that for the inconsistent verbs orthography might have a greater influence than on consistent pseudo-verbs, because the inconsistent pseudo-verbs have an unfamiliar orthographical picture.

A repeated measures ANOVA on the subset of pseudo-verbs (consistent and inconsistent) again shows the significant interaction between age group and infinitive voicing ( $F(1,82)=17.505$ ,  $p<.000$ ) as well as an effect of consistency ( $F(1,82)=16.512$ ,  $p<.000$ ) with fewer voice errors on consistent pseudo-verbs than on inconsistent pseudo-verbs, and a significant interaction between consistency and infinitive voicing ( $F(1,82)=16.199$ ,  $p<.000$ ). There is no significant effect of modality as between-subjects factor ( $F(1,82)=2.496$ ,  $p<.118$ ).

A separate repeated measures ANOVA was run on the subset of pseudo-verbs for the adult data only, with consistency and infinitive voicing as within-subjects factors and modality as between-subjects factor, because modality is expected to have a greater influence on the adult group. This results in a significant effect of modality ( $F(1, 28)=5.465$ ,  $p=.027$ ) with generally fewer voice errors for the orthographical version. There is also a significant effect of consistency ( $F(1,28)=10.788$ ,  $p=.003$ ) with fewer voice errors on the consistent pseudo-verbs than on inconsistent pseudo-verbs; there is a significant effect of infinitive ( $F(1,28)=4.301$ ,  $p=.047$ ) with fewer voice errors on voiceless pseudo-verbs than on voiced pseudo-verbs; and there is a significant interaction between consistency and infinitive voicing ( $F(1,28)=5.668$ ,  $p=.024$ ) and between consistency, infinitive voicing, and modality ( $F(1,28)=4.591$ ,  $p=.041$ ), with a larger effect of modality on voiced inconsistent infinitives than on voiceless inconsistent infinitives: the presence of orthography leads to fewer voice errors on voiced inconsistent infinitives.

### 3.4. Stem consonant

The pseudo-verbs included three pairs of stem-final consonants: voiceless and voiced alveolar fricatives /s, z/ and bilabial fricatives /f, v/ and voiceless and voiced bilabial plosives /p, b/. The response type for the separate stem consonants are given in table 14.

Consonant		Age group	Type of response	
Voicing	Type		Correct	Voice error
Voiceless	S	Nine-year-olds	120 (31%)	178 (45%)
		Adults	129 (61%)	28 (28%)
Voiced	Z	Nine-year-olds	83 (49%)	43 (26%)
		Adults	43 (48%)	38 (42%)
Voiceless	F	Nine-year-olds	78 (35%)	102 (46%)
		Adults	70 (58%)	29 (24%)
Voiced	V	Nine-year-olds	131 (58%)	43 (19%)
		Adults	55 (46%)	52 (43%)
Voiceless	P	Nine-year-olds	63 (56%)	27 (24%)
		Adults	50 (83%)	3 (5%)
Voiced	B	Nine-year-olds	113 (50%)	30 (13%)
		Adults	51 (43%)	45 (38%)

Table 14. Response type for pseudo-verbs by consonant types

The percentage of voice errors by the nine-year-old group on the alveolar and bilabial fricative is comparable; both fricatives show the same generalization of verbs with voiceless obstruents being inflected into past tenses with voiced clusters twice as often as that voiced obstruents are made voiceless. For the adult group there is little difference between the two fricative pairs as well, but the adult group does give more correct inflections for voiceless fricatives over voiced fricatives.

The number of voice errors is lower for the plosives in comparison to the fricatives. A repeated measures ANOVA on voice errors, with consonant type and infinitive voicing as within-subjects factor and age group as a between-subjects factor, shows a significant effect of consonant when all three consonant types are included ( $F(2,168)=27.896$ ,  $p<.000$ ). There is a significant interaction between infinitive voicing and age group ( $F(1,84)=18.282$ ,  $p<.000$ ) as the nine-year-olds have more voice errors with voiceless infinitives and adults have more voice errors with voiced infinitives, and between consonant and voicing ( $F(2,168)=4.701$ ,  $p=.010$ ), with fewer voice errors on pseudo-verb stems ending in /p/, compared to pseudo-verbs ending with the voiceless fricatives. There is no significant effect of age group ( $F(1,84)=0.140$ ,  $p=.709$ ). A post hoc analysis (Bonferroni) shows that there is a significant difference in percentage of voice errors between the alveolar fricatives and the bilabial plosives (mean difference 0,15 (0,023),  $p<.000$ ) and between the bilabial fricatives and the bilabial plosives (mean difference 0,13 (0,025),  $p<.000$ ). However, the difference between the two fricative types is not significant.

The data per consonant is limited (particularly for the plosives). Therefore there will be no consonant by consonant analysis of the responses to determine the effect of modality

for each consonant on the past tense productions. However, a more elaborate overview of the responses for the different consonants by pseudo-verb category and some remarks on the influence of modality can be found in appendix 3.

### 3.5. Fillers

The fillers that were in the task have not been discussed so far. There are four irregular verbs that were included as fillers to prevent participants of taking on a rhythm of adding a past tense suffix. There are four pseudo-verb fillers that were included to mask the pattern of the test items which all included verb stems ending in the alveolar fricatives /s, z/, bilabial fricatives /f, v/ and bilabial plosives /p, b/. The pseudo-verbs had verb stems that ended in voiceless plosives: [klupən] and [xreikən]; or sonorants: [spənən] and [bɪnkələn].

The responses on the fillers are given in table 15.

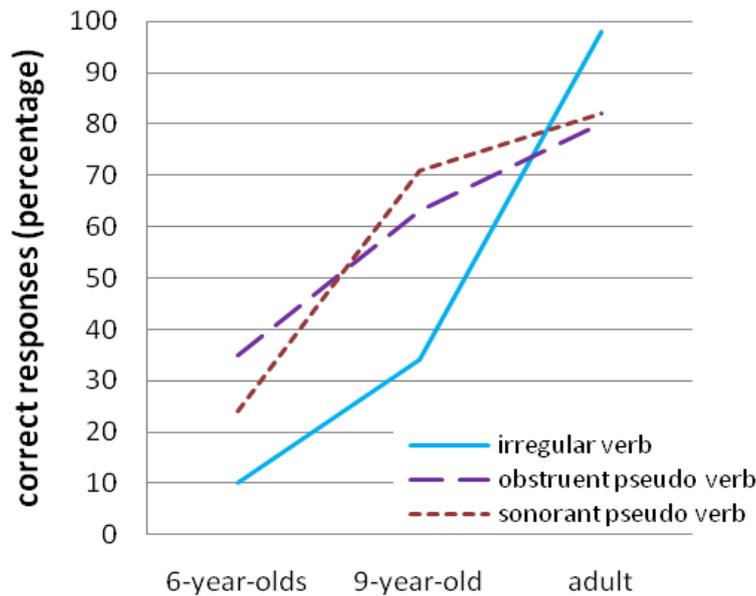
	Type of response								
	Verbs			Pseudo-verbs					
	Correct	Voice error	other	Obstruent-final stem			Sonorant final stem		
Correct				Voice error	other	Correct	Voice error	other	
Age group									
Six-year-olds	7 (10%)	0 (0%)	61 (90%)	12 (35%)	3 (9%)	19 (56%)	8 (24%)	1(3%)	25 (74%)
Nine-year-olds	77 (34%)	1 (0%)	146 (65%)	71(63%)	19 (17%)	22 (20%)	79 (71%)	3 (3%)	30 (27%)
Adults	118 (98%)	0 (0%)	2 (2%)	48 (80%)	3 (5%)	9 (15%)	49 (82%)	3 (5%)	8 (13%)

Table 15. Response type on fillers in numbers (%)

The irregular filler verbs were inflected correctly by the children in 84 cases and as regular verbs in 205 cases. These overgeneralizations were not always correct in voicing, yielding voice errors such as \*[ləstə] for the past tense of *lezen* ‘to read’, \*[kopdə] for the past tense of *kopen* ‘to buy’, and [slapdə] for the past tense of *slapen* ‘to sleep’. The adult group inflected the irregular verbs correctly, with the exception of two overgeneralizations \*[koptə], for the verb *kopen*.

The majority of the pseudo-verb fillers were inflected correctly. However, there were still several voice errors on the pseudo-verbs *kloepen*, *grijken*, *binkelen*, and *spennen*; 26 “voice errors” were produced by the six and nine-year-old age groups and six voice errors were produced by the adults.

A repeated measures ANOVA on the responses on the filler items, with age group as between-subjects factor and filler type (irregular, obstruent, and sonorant) as within-subjects factor shows a significant effect for age group ( $F(2,100)=46.337$ ,  $p<.000$ ) and for filler type ( $F(1,100)=3.963$ ,  $p=.021$ ). There is a significant interaction between age group and filler type ( $F(4,200)=9.773$ ,  $p<.000$ ). This is illustrated in graph 4.



Graph 4. Correct responses (percentage) on filler items by filler type and age group

There seems to be a general trend of more correct scores as age increases. However, the two child groups give less correct responses on the irregular verbs than on the pseudo-verbs due to the high number of overgeneralizations. The adult group produces more correct on the irregular verbs over the pseudo-verb filler items.

Post hoc analyses were done on the percentage of correct responses for the three age groups and on the three filler types. There is a significant difference between all three age groups: six-year-old and nine-year old group (mean difference=-0,3306 (0,06),  $p<.000$ ); six-year-old and adult group (mean difference=-0,6363 (0,07),  $p<.000$ ); and nine-year-old and adult group (mean difference=-0,3057 (0,05),  $p<.000$ ). There is also a significant difference between the number of correct responses on the irregular verbs and the obstruent pseudo-verbs (mean difference=-0,119 (0,048),  $p=.043$ ) and between the irregular verbs and the

sonorant pseudo-verbs (mean difference=-0,109 (0,045),  $p=.052$ ). This is not the case for the two types of pseudo-verb fillers.

### 3.6. Correlations between vocabulary and past tense productions

The children that participated in the past tense production experiment also participated in the Dutch Peabody Picture Vocabulary Test-III-NL (Pearson, 2005) so that a general measure of language development could be obtained per child. There are no significant correlations between the standardized score on the vocabulary task and the correct or voice error responses given in the past tense task; for correct responses on voiceless verbs, Pearson's  $r=0.09$ ,  $p=.437$ ; and for correct responses on voiced verbs, Pearson's  $r=-0.12$ ,  $p=.314$ .<sup>10</sup>

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<sup>10</sup> Other correlations did not yield significant results either.

#### 4. Discussion

The main question that the experiment investigates is whether children show a preference for voiceless obstruent clusters in the context of the Dutch past tense. The experiment that was conducted, elicited past tenses that contained obstruent clusters by presenting the participants with voiceless and voiced infinitives and requesting them to give a sentence that contains a past tense. Dutch verbs and pseudo-verbs were included that varied in stem-final obstruent as well as vowel length.

The results of the experiment suggest a preference for voiceless past tense for children age six years. These children produced more voiceless suffixes than voiced suffixes. In spite of this, the conclusion that children age six show a preference for voiceless clusters cannot be drawn based on the amount of data obtained. The nine-year-old group generally applied the voiced suffix [-də] as a default past tense suffix. They gave more correct responses on voiced infinitives than on voiceless infinitives; the pattern for voice errors also shows their preference for the voiced past tense suffix as there are more voice errors on voiceless infinitives. Assuming that the six-year-old group indeed shows a preference for voiceless clusters, it is quite surprising that the nine-year-old group shows a preference for the voiced past tense suffix as the adults show a preference for the voiceless suffix again. This implies an unlikely U-shaped curve in the development, with an initial preference for voiceless obstruent clusters, then a preference for voiced obstruent clusters, resulting in a preference for voiceless obstruent clusters by the time children reach adulthood.

The responses of the nine-year-olds are probably influenced by the high frequency of the voiced suffix in Dutch, discussed earlier. This is against the findings of Rispens and De Bree (2010) who found that children scored more correct on voiceless plosives but their stimuli did not include fricative final verb stems or verb stems ending in a bilabial plosive. The velar plosive included in Rispens and De Bree is always voiceless in Dutch (with exception of loanwords) and therefore unlikely to be inflected with a voiced past tense suffix. The present study showed more correct responses for the plosives compared to the fricatives, which would explain the high number of correct responses for the plosives in Rispens and De Bree's investigation as well.

As pointed out above, differently from the nine-year-old group, the adult group does show a preference for the voiceless past tense suffix. They produce more correct responses on voiceless infinitives compared to voiced infinitives and more voice errors on voiced infinitives compared to voiceless infinitives; this can only be the case if they apply the voiceless suffix more than the voiced suffix. Adults seem to prefer voiceless obstruent clusters. This would fit with the trend that more and more voiced fricatives are realized as voiceless in Dutch; e.g. the voiceless and voiced velar fricative are hardly distinguished by current Dutch speakers.

The factor consistency affects the responses of both the nine-year-old and the adult group. There is a preference for past tenses that match the Dutch pattern of voiced fricatives preceded by long vowels or voiceless fricatives preceded by short vowels. The participants showed this preference by producing more correct inflections on consistent verbs and by producing a voicing change in the inconsistent verbs. The inconsistent verbs were sometimes rendered consistent by adjusting the vowel length by both nine-year-olds and adults. Participants that change the verb stem must find faithfulness to the output form of the infinitive less important than the consistency requirement. The past tenses that were rendered consistent by changing the verb stem result in past tenses that show analogy to existing Dutch past tenses.

In some cases orthography assists the adult participants in their choice on voicing. They score more correct answers in the orthographical modality, for instance, on the neutral pseudo-verbs with the fricatives /s, z/, as in the pseudo-verb *beisen*. In some cases, however, it seems that the orthographical representation of an inconsistent pseudo-verb does not lead adults to base their decision on the spelling, but it leads the participant to inflect the verb as an irregular verb or to change the vowel length. This is particularly the case for the verbs with a stem-final /b/ (see also appendix 3). It might be the case that the orthographical picture of the verb looks so unfamiliar that the participants assume it must be an irregular verb. The nine-year-old group does not rely on the orthographical cue when it comes to the consistent versus inconsistent pseudo-verbs. This might be because these children have not been explicitly educated in the past tense inflection and the corresponding spelling rules:

this is usually taught at age eleven and twelve in Dutch elementary schools. Besides the fact that children have not been educated formally in verbal inflections, it seemed that some children were not even paying attention to the orthographical representation as they would change the onset of the verb in their response. For these children the task perhaps required all their attention so that they were not able to use the orthographical cue.

The pseudo-verb fillers that were added to the experiment were not all inflected correctly. Both children and adults produced voice errors on these items. The nine-year-old children produced incorrectly voiced past tenses, which can be due to their overapplication of the voiced suffix. As said before, this can be related to the fact that the voiced suffix has a higher frequency than the voiceless suffix. The voice errors made by the adults for these items are probably due to the experimental setting, because a past tense such as \*[spɛntə] is decidedly ungrammatical. Note, however, that the full word as such does not include an illegally formed cluster and might be produced in analogy to a noun like *lente* 'spring'. Likewise, in an attempt to justify a response such as \*[bɪnkəltə], a plural noun form such as *bult-en* 'bumps' illustrates that a lateral can be followed by a voiceless [t]. Unfortunately, this does not apply to the illegally formed past tenses \*[xreɪkdə] and \*[klɪpdə].<sup>11</sup>

The experiment also included four irregular verbs as filler items. Performance on these verbs show a clear pattern of development. The six-year-old group produced the least correct responses (giving these irregular verbs a regular past tense inflection if all), followed by the nine-year-old group, in which some children produced irregular past tenses but others still produced overgeneralizations; the adults correctly inflect the irregular verbs. This same pattern of development was found for the existing Dutch verbs that were part of the test items (see graph 1 above). It is clear that past tense formation is acquired relatively late. The difference in correct responses on voiceless versus voiced Dutch verbs is not great, so no conclusions can be drawn on the influence of voicing for the existing verbs.

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<sup>11</sup> These last past tenses form should be analyzed using acoustic measurements to determine whether the plosive is realized as voiceless or voiced or perhaps partly voiced.

A type of child overgeneralization that has not been discussed so far is that both child groups often used the plural past tense form with a singular pronoun. The singular and plural past tenses only differ in the addition of the suffix [-n] for the plural. The final [-n] is regularly dropped in verbs in Dutch colloquial speech but surprisingly, many children clearly articulated the final [-n] in the experiment. This may be interpreted as some kind of hypercorrection which they applied because they are self-conscious about their responses. A further analysis would have to determine whether this phenomenon is age dependent. In this experiment the incorrect use of singular and plural was not scored as incorrect as the focus of the experiment was on voicing.

An unexpected effect of gender was found. Repeated measures ANOVA of correct responses with verb type (verb or pseudo-verb) and infinitive voicing (voiceless and voiced) with gender and age group as between-subjects factors, show gender is significant ( $F=8,880$ ,  $p=.004$ ). Male participants give more correct responses than female participants. There are no significant interactions between gender and other variables in the analysis. The underlying causes for this difference should be investigated in future research as it is beyond the scope of this thesis to elaborate on this effect. However, see Hartshorne and Ullman (2006) for more on the relation between gender and language processing.

## 5. Conclusion

The aim of this thesis was to determine whether young children show a preference for voiceless obstruent clusters over voiced clusters. A past tense production experiment was conducted to determine whether there would be more voiceless productions by young children as opposed to older children and adults. The child groups that participated in the experiments included a group of six-year-old children and a group of nine-year-old children. The experiment was also conducted to determine the role of the verb stem-final consonant and the vowel length in past tense production.

An important finding of this past tense production experiment is that nine-year-old children show a preference for the voiced past tense suffix and thus produce more past tenses with a marked voiced obstruent cluster than that they produce voiceless obstruent clusters. This is contrary to the adult group which shows a preference for the voiceless past tense suffix. Overall, the six-year-old children produced more past tenses with voiceless clusters than with voiced clusters. This preliminary conclusion is based on the data by 17 children of whom not all children were able to produce past tenses consistently. More research on six-year-old children should be able to determine whether these children indeed show a preference for the unmarked voiceless cluster. In future research on six-year-old children, eliciting past tenses remains a suitable way of eliciting obstruent clusters, despite the fact that about half of the children aged six years were not capable of producing past tenses in the task.

To fully answer the research question, whether there is an initial preference for the unmarked voiceless obstruent cluster, an additional experiment will have to be run with infants. As was stated earlier, a preference for unmarked structures is expected in the initial state of a child's grammar. When infants are presented with voiceless and voiced obstruent clusters in an experimental setting, they should show a preference for voiceless clusters at a young age. Again, the Dutch past tense would be a suitable context in which it is possible to present participants with both voiceless and voiced clusters. However, designing a suitable experiment for infants is difficult, because there are generalizations and frequencies patterns regarding verb stem-final consonants and vowel length that come into play when

the Dutch past tense is encountered; these have been elaborated on in the introduction. The feasibility of an infant experiment that takes these different factors into account was explored by the author and supervisors of this thesis. The design that was eventually developed employed the head-turn preference procedure (Kemler Nelson et al., 1995). This is a perception task in which infants are presented with auditory stimuli; the infant's looking time is assumed to reflect its attention for a given stimulus. The experiment has not been carried out at the present as it would require many participants, which implies that it is a time-consuming and expensive experiment to run.

Previous past tense production tasks already illustrated the influence of lexical frequency and analogy as factors affecting the participant's choice between the voiceless and voiced manifestations of the past tense suffix (Ernestus & Baayen, 2003; Rispens & De Bree, 2010). The present experiment shows the additional importance of phonotactics, as both nine-year-olds and adults show a higher correct response rate for consistent pseudo-verbs (i.e. pseudo-verbs that are phonotactically legitimate), compared to inconsistent pseudo-verbs (i.e. pseudo-verbs that are inconsistent with Dutch phonotactics due to the illegitimate combinations of voicing and vowel length). Both the consistent and inconsistent infinitives in the stimuli were spliced from different sound files so that the voiceless obstruents were truly voiceless and the voiced obstruents were truly voiced. Based on vowel length the inconsistent infinitives were interpreted as having the opposite voicing quality and were inflected accordingly or the past tenses were produced in analogy to legal Dutch past tenses.

Future research could include a more in-depth analysis of the precise acoustics of the responses. This could make clear whether orthography contributes to some form of incomplete neutralization in the past tense productions of inconsistent verbs such as [drɔftə], produced as a past tense of [drɔvən], represented orthographically as *drovven*, or the past tense production [nɔftə], from the infinitive [nɔvən], represented as *navven*. The adults were visually presented with the grapheme <v>, regularly associated with voiced obstruents, a situation that should affect the output, according to the findings by Ernestus and Baayen (2006). Acoustic analyses are likewise relevant for a small number of responses that were difficult to score, as it might even be the case that speakers subconsciously give

responses with partly voiced obstruents for items they are uncertain about. Several child overgeneralizations call for acoustic analysis as well as the children seem to disregard voicing assimilation, producing past tenses such as \*[kopdə] for the past tense of *kopen* 'to buy' and \*[slapdə] for the past tense of *slapen* 'to sleep'.

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## Appendix 1. Past tenses with sonorant final verb stems in CHILDES

## Past tenses in corpus data with sonorant verbs

	Sonorant		
	Type	Tokens	Earliest production
nasal	*Brenge	1	Abel 3;1.7
	Droomde	1	Sarah 4;9.13
	Kende	2	Josse 3;0.6 Sarah 4;11.15
	Woonde	6	Daan 3;2.25 Abel 3;3.8 Sarah 4;8.03
	*Springte	1	Laura 5;6.12
	*Zingte	1	Peter 2;07.14
vowel	Aaide	1	Sarah 4;3.04
	Belde	4	Sarah 4;6.12
	*Gade (ging)	1	Abel 3;3.8
	Gooide	1	Laura 5;6.12
	*Woode	2	Tomas 2;6 Laura 5;5.14
	zouden	1	Laura 4;5.09
liquid	Huilde	2	Laura 5;3.12 Sarah 4;3.04
	Speelde	1	Sarah 3;7.25
	*Steelede	1	Laura 5;6.12
	Vertelde	1	Sarah 4;11.15
	Wilde	4	Abel 3;1.7 Laura 4;7.30 Sarah 4;10.9
r	*Boorde (werd geboren)	1	Sarah 4;8.03
	Gebeurde	1	Sarah 4;0.30
	Hoorde(n)	14	Peter 2;07.14 Abel 3;3.8 Daan 3;3.30 Sarah 4;3.4
	*Hoorte	1	Tomas 2;4.17
	Toverde	1	Sarah 4;11.15

Table 16. Past tenses with sonorant final verb stems found in child production data

Note that irregular *springen* ‘to jump’ and *zingen* ‘to sing’ are inflected with a voiceless suffix, yielding *springte* and *zingte*, although a voiced suffix would be expected to follow a nasal.

## Appendix 2. Stimuli

The complete list of stimuli was used for the nine-year-old and adult group. The stimuli are listed per category. The verbs marked with a ← in the final column are included in the experiment for the six-year-old group.

Verb/Pseudo-verb	Verb category	voicing	obstruent	infinitive	Included in short version
Verb	Practice item	-	-	rennen	←
Verb	Practice item	-	-	fietsen	←
Verb	-	Voiceless	S	eisen	←
Verb	-	Voiced	S	reizen	←
Verb	-	Voiceless	F	blaffen	←
Verb	-	Voiced	F	draven	←
Verb	-	Voiceless	P	klappen	←
Verb	-	Voiced	P	krabben	←
Verb	-	Voiceless	T	praten	←
Verb	-	Voiced	T	schudden	←
Pseudo-verb	Neutral	Voiceless	S	beisen	←
Pseudo-verb	Neutral	Voiced	S	fleizen	←
Pseudo-verb	Neutral	Voiceless	S	tonsen	
Pseudo-verb	Neutral	Voiced	S	kronzen	
Pseudo-verb	Neutral	Voiceless	S	kelsen	←
Pseudo-verb	Neutral	Voiced	S	brulzen	←
Pseudo-verb	Neutral	Voiceless	P	bloppen	
Pseudo-verb	Neutral	Voiceless	P	dapen	
Pseudo-verb	Consistent	Voiceless	F	taffen	←
Pseudo-verb	Consistent	Voiced	F	spaven	←
Pseudo-verb	Consistent	Voiceless	F	kreffen	
Pseudo-verb	Consistent	Voiced	F	breven	
Pseudo-verb	Consistent	Voiced	P	dabben	
Pseudo-verb	Consistent	Voiced	P	trobben	←
Pseudo-verb	Consistent	Voiceless	S	nossen	
Pseudo-verb	Consistent	Voiceless	S	gressen	←
Pseudo-verb	Inconsistent	Voiceless	F	trofen	←
Pseudo-verb	Inconsistent	Voiced	F	drovven	←
Pseudo-verb	Inconsistent	Voiceless	F	krafen	
Pseudo-verb	Inconsistent	Voiced	F	navven	
Pseudo-verb	Inconsistent	Voiced	P	treben	←
Pseudo-verb	Inconsistent	Voiced	P	froben	
Pseudo-verb	Inconsistent	Voiceless	S	drosen	
Pseudo-verb	Inconsistent	Voiceless	S	knasen	←
Verb	Filler	-	-	kopen	←
Verb	Filler	-	-	slapen	←
Verb	Filler	-	-	eten	←
Verb	Filler	-	-	lezen	←
Pseudo-verb	Filler	-	-	spennen	←
Pseudo-verb	Filler	-	-	binkelen	←
Pseudo-verb	Filler	-	-	kloepen	←
Pseudo-verb	Filler	-	-	grijken	←

Table 17. Overview of stimuli

## Pseudo-random order

## Order 1

1	drosen
2	breven
3	tonsen
4	schudden
5	kloepen
6	brelzen
7	spaven
8	klappen
9	navven
10	lezen
11	froben
12	taffen
13	reizen
14	grijken
15	kronzen
16	praten
17	nossen
18	drovven
19	dapen
20	eisen
21	trobben
22	knasen
23	kopen
24	spennen
25	bloppen
26	krafen
27	dabben
28	beisen
29	krabben
30	kreffen
31	fleizen
32	slapen
33	treben
34	blaffen
35	binkelen
36	gressen
37	draven
38	kelsen
39	trofen
40	eten

## Order 2

1	eisen
2	dapen
3	drovven
4	nossen
5	praten
6	kronzen
7	grijken
8	reizen
9	taffen
10	froben
11	lezen
12	navven
13	klappen
14	spaven
15	brelzen
16	kloepen
17	schudden
18	tonsen
19	breven
20	drosen
21	eten
22	trofen
23	kelsen
24	draven
25	gressen
26	binkelen
27	blaffen
28	treben
29	slapen
30	fleizen
31	kreffen
32	krabben
33	beisen
34	dabben
35	krafen
36	bloppen
37	spennen
38	kopen
39	knasen
40	trobben

## Pseudo random orders for short version

## Order 1

1	schudden
2	kloepen
3	fleizen
4	praten
5	spaven
6	klappen
7	lezen
8	treben
9	taffen
10	reizen
11	grijken
12	breizen
13	slapen
14	blaffen
15	spennen
16	trofen
17	eisen
18	trobben
19	kelsen
20	draven
21	eten
22	knasen
23	kopen
24	beisen
25	krabben
26	binkelen
27	gressen
28	drovven

## Order 2

1	blaffen
2	slapen
3	breizen
4	grijken
5	reizen
6	taffen
7	treben
8	lezen
9	klappen
10	spaven
11	praten
12	fleizen
13	kloepen
14	schudden
15	drovven
16	gressen
17	binkelen
18	krabben
19	beisen
20	kopen
21	knasen
22	eten
23	draven
24	kelsen
25	trobben
26	eisen
27	trofen
28	spennen

### Appendix 3. More on stem consonants

The responses are given per consonant pair and by age group for pseudo-verbs. The six-year-old age group was not included as the amount of data was small and this age group did not participate in the orthographical modality of the experiment.

#### 1. Alveolar fricatives /s, z/

Consonant	Pseudo-verb category	Age group	Type of response		
			Correct	Voice error	Other
/s/	Neutral	Nine-year-old	51 (30%)	79 (47%)	38 (23%)
		Adult	58 (64%)	28 (31%)	4 (4%)
	Consistent	Nine-year-old	41 (37%)	41 (37%)	30 (27%)
		Adult	48 (80%)	8 (13%)	4 (6%)
	Inconsistent	Nine-year-old	28 (25%)	58 (52%)	26 (23%)
		Adult	23 (38%)	22 (37%)	15 (25%)
/z/	Neutral	Nine-year-old	83 (49%)	43 (26%)	42 (26%)
		Adult	43 (48%)	38 (42%)	9 (10%)

Table 18. Responses for /s, z/ by category: neutral, consistent and inconsistent in number of items (%)

The consistent voiceless verbs that are scored under voice error are remarkable because these past tense forms are made inconsistent, e.g. [nɔzdə]. A past tense like this, with a short vowel and a voiced obstruent cluster is not allowed in Dutch and does not come up in database searches of CELEX (Max Planck Institute for Psycholinguistics, 2001). Yet 41 items are inflected that way by the nine-year-old group and eight items by the adult group. In the child group this might be due to the overapplication of the voiced suffix that was found. In the adult group this might be due to the experimental setting in which these responses were given because it is not to be expected that Dutch speakers produce these forms in spontaneous speech. A corpus study on spoken Dutch (using the Corpus Geproken Nederlands, Nederlandse Taalunie 2004) could be conducted to determine whether this claim holds.

The correct responses for inconsistent verbs are not illegal forms in Dutch although they are less frequent. These include verbs of the type long vowel followed by [-stə]. The nine-year-old group shows a preference for a voiced cluster for these inconsistent verbs; this is in accordance to the more general pattern in Dutch discussed in the introduction.

Generally, the nine-year-old groups give more “other” responses for both voiceless and voiced alveolar fricatives. The exception is for the inconsistent voiceless pseudo-verbs for which adults give 25% (15 items) “other” responses.

For reasons of clarity the table above does not make a distinction between the responses on the auditory versus orthographical version. A few apparent differences per version regarding the alveolar fricatives is that orthography helps adults come up with the correct response for the neutral contexts. For the voiceless /s/ there are 34 correct responses (76%) for the orthographical version and 24 (53%) correct responses on the auditory version; for the voiced /z/ there are 26 correct responses (58%) on the orthographical version and 17 (38%) correct responses for the auditory version. In the nine-

year-old group the advantage of orthography only holds for the neutral verbs with voiced /z/: 47 correct responses (56%) on the orthographical version against 36 correct responses on the auditory version.

## 2. Bilabial fricatives /f, v/

Consonant	Pseudo-verb category	Age group	Type of response		
			Correct	Voice error	Other
/f/	Consistent	Nine-year-old	46 (41%)	45 (40%)	21 (19%)
		Adult	47 (78%)	9 (15%)	4 (7%)
	Inconsistent	Nine-year-old	32 (29%)	57 (51%)	23 (21%)
		Adult	23 (38%)	20 (33%)	17 (29%)
/v/	Consistent	Nine-year-old	70 (63%)	17 (15%)	25 (23%)
		Adult	35 (58%)	18 (30%)	7 (11%)
	Inconsistent	Nine-year-old	61 (54%)	26 (23%)	25 (22%)
		Adult	20 (33%)	34 (57%)	6 (10%)

Table 19. Responses for /f, v/ by category: neutral, consistent and inconsistent in number of items (%)

The test items for the bilabial fricatives were either of the consistent or inconsistent categories. The adult group gives more correct responses on consistent verbs than on inconsistent verbs, which is the effect of consistency that has been discussed above. This also holds for the nine-year-olds, although the percentage of correct responses is lower compared to the adult group.

Again, there are quite a high number of consistent pseudo-verbs that are made inconsistent by voice errors, both for the nine-year-old group and the adult group. These past tenses are illegal for Dutch. Examples of these illegal forms are \*[tavdə] from the pseudo-verb *taffen* and \*[krevdə] from *kreffen*. The same possible explanation holds for these fricatives, namely that this might be due to the experimental setting in which these responses were given. The voice errors on the inconsistent verbs are expected because these past tenses are made consistent by changing the voicing. Examples of such past tenses are [kravdə] and [trovdə].

The nine-year-old group does not give very different responses in either of the two modalities, for the adults there is an apparent difference in responses on inconsistent voiceless verbs on the two modalities. Orthography in this case does not help to decide on the correct score but it seems to encourage the adults to give alternative responses, such as irregular inflections and vowel length changes. There are 16 correct responses (53%) in the auditory version and only seven (23%) in the orthographical version; in the latter version there are eight more “other” responses. Likewise, for the voiced inconsistent verbs, e.g. *drovven*, adults give no “other” responses in the auditory version, whereas when the orthographical representation is given, some participants give an alternative response (six “other” responses).

## 3. Bilabial plosives /p, b/

Consonant	Pseudo-verb category	Age group	Type of response		
			Correct	Voice error	Other
/p/	Neutral	Nine-year-old	63 (56%)	27 (24%)	22 (20%)
		Adult	50 (83%)	3 (5%)	7 (12%)
/b/	Consistent	Nine-year-old	60 (54%)	21 (19%)	31 (28%)
		Adult	27 (45%)	28 (47%)	5 (8%)
	Inconsistent	Nine-year-old	53 (47%)	9 (8%)	50 (45%)
		Adult	24 (40%)	17 (28%)	19 (32%)

Table 20. Responses for bilabial plosives per category

The nine-year-olds have difficulty producing the past tense of the voiceless bilabial plosive; they produce voice errors on 27 items (24%). An example of such a response is the past tense [dabdə], which occurs ten times and is illegal in Dutch. The other possible response in that category is [blɔbdə]. This is possible in Dutch, in analogy to, e.g. the past tense *schrobde* ‘scrubbed’. However, this suggests that the children heard a voiced plosive in the infinitive given, which is unlikely because the voiceless plosive is usually easy to produce and perceive. For adults the correct response is high. The voice errors are three cases of [blɔbdə].

The voiced plosive yields a consistent pseudo-verb when the vowel is short and an inconsistent pseudo-verb when the vowel is long. The voice errors in the consistent verbs are cases of [trɔptə] from the infinitive [trɔbən] and [dabtə] based on the infinitive [dabən]. These inflections are not correct but they are not surprising either as participants inflect the Dutch verb *krabben* ‘to scratch’ with a voice error as well. This illustrates the tendency to use voiceless inflections for adults. The inconsistent pseudo-verbs were difficult for adults and children alike. There were 50 “other” responses for the nine-year-olds and 19 “other” responses in the adult group. In the adult group these responses were mainly in the orthographical version.