Acquisition of Voicing Neutralization and Alternations in Dutch

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An eminent study in morphological acquisition is Jean Berko's (1958) paper entitled "The child's learning of English morphology". In her study, she examined children's productive knowledge of English allomorphs using a methodology called the Wug Test. Children were tested on their application of plural allomorphs: English words ending in final voiced obstruents, sonorants, and vowels take a /-z/ suffix (e.g. *dogs* [dɔgz]), words ending in final voiceless obstruents take a /-s/ suffix (e.g. *cats* [kæts]) and words with final sibilants take an /-əz/ suffix (e.g. *buses* [bʌsəz]). To test productive knowledge, children were shown pictures of non-words in the singular and asked for the plural, as for non-words they cannot fall back on memory. For example, "This is a *wug*. Now there is another one. There are two of them. There are two _____ (p. 165)". Berko found that while children aged four and five years displayed some productive knowledge, they were variable in their application of the different allomorphs. This example of plural suffix allomorphy shows how morphology (i.e. adding a plural suffix) and phonology (classically thought to involve voicing assimilation and vowel insertion) can interact. The suffix alternation is thought to be both regular and productive, which means it is acquired relatively early (Bernhardt & Stemberger, 1998).

Since the publication of Berko's study, the Wug Test has been used to look at first and second language acquisition (Snow & Hoefnagel-Hoehle, 1978), in children with Specific Language Impairments (Goad & Rebellati, 1994; Leonard, Eyer, Bedore & Grela, 1997; Oetting & Rice, 1993), and in a variety of phonological and morphological contexts (most famously the English past tense) across different languages such as Dutch (Kerkhoff, 2004), Hungarian (MacWhinney, 1978), Spanish (Bybee & Pardo, 1981; Kernan & Blount, 1966),

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Tagalog (Zuraw, 2000), and in artificial-language learning paradigms (Tessier, 2005).

In Dutch, the Wug Test has been used to address children's knowledge of voicing neutralization and morpho-phonological alternations. In Dutch voiceless and voiced obstruents can occur in both syllable-initial and syllable-medial positions (1a and b). In syllable-final position, only voiceless obstruents can occur, and voiced obstruents are phonotactically illegal (1c). This distribution is illustrated with /t/ and /d/ (1).

(1)		/t/			/d/		
	a.	[tɑk]	*tak*	'branch'	[dɑk]	*dak*	'roof'
	b.	[wɑtər]	*water*	'water'	[rɪdər]	*ridder*	'knight'
	c.	[pɛt]	*pet*	'cap'	*[bɛd]	*bed*	'bed'

The standard view is that voiced obstruents are neutralized to their voiceless counterparts when they occur in the phonotactically illegal syllable- or word-final position[1] (Booij, 1995; Trommelen & Zonneveld, 1979). Traditionally, voicing neutralization has been analyzed as a phonological rule of final devoicing, which is applied to an abstract underlying form containing a voiced obstruent, e.g., /bɛd/.

This process of voicing neutralization can result in an alternation between voiceless and voiced obstruents in nouns, verbs and adjectives. Compare the underlying voiceless /t/ in which voicing *does not* alternate between singular and plural nouns in (2a), to the underlying voiced /d/ in which voicing *does* alternate between the singular and plural nouns in (2b).

(2)		Singular			Plural		
	a.	[pɛt]	*pet*	'cap'	[pɛtən]	*petten*	'caps'
	b.	[bɛt]	*bet*	'bed'	[bɛdən]	*bedden*	'beds'

To determine the underlying voicing of the word-final segment of the singular nouns in (2), it is necessary to know how voicing is realized in the plural because here is where the underlying voice specification of the stem-final segment is realized. In contrast to the English plural alternation, Dutch voicing neutralization leads to an alternation in the stem rather than in the suffix. In traditional accounts (e.g. Chomsky & Halle, 1968), this phonologically conditioned alternation is taken to be evidence for the abstract nature of underlying forms (i.e. /pɛt/ vs. /bɛd/).

Theories of learnability have argued that learners initially acquire knowledge of phonotactics. In this case, the learner first acquires the knowledge

[1] Regressive voicing assimilation may neutralize voicing in the opposite direction, i.e., in compounds such as /klɑp/ + /dør/ [klɑb.dør] 'swing door'.

that voicing is neutralized in syllable- or word-final position. This knowledge is then assumed to be applied to the subsequent acquisition of morpho-phonological alternations such as those in (2) (Hayes, 2004), when the learner acquires a lexicon and the processes that occur between stems and affixes. This is intuitive because learning phonotactic patterns does not require knowledge about specific lexical items or their morphological make-up[2].

To correctly produce patterns of voicing neutralization and morpho-phonological alternations as in (2), the learner must know both about how voicing or the set of voiced obstruents are neutralized in specific prosodic positions (i.e. syllable- or word-final position), and about how individual lexical items vary in their surface pronunciation. The knowledge of alternations could be reflected in the following ways, depending on the theoretical assumptions concerning phonological representations in the lexicon: i) knowing the correct underlying specification of a word-final consonant of a lexical item in combination with knowledge of how the singular and plural forms relate, ii) knowing the correct plural form of a word and inferring the singular based on knowledge of voicing neutralization, or iii) by learning the specific lexical items in both the singular and plural without any morphological decomposition. Using the Wug Test, the acquisition of voicing phonotactics and morpho-phonological alternations in Dutch has been addressed in two ways.

First, Zamuner, Kerkhoff, and Fikkert (in prep.) focused on children's knowledge of voicing neutralization. Children were presented with novel words in the plural (a Reverse-Wug Test) and asked to produce words in the singular. For example, children were shown a picture of two *slatten* [slɑtən] or two *sladden* [slɑdən]. In both cases, the singular form *slat* and *slad* are produced as [slɑt] due to final voicing neutralization. This task tested whether children can apply their knowledge of voicing phonotactics (the knowledge that voiced obstruents cannot occur in word-final position) to produce surface alternations between singulars and plurals. If children have productive knowledge of this pattern, they should be equally good at producing singulars from non-words that *do not* result in a surface alternation (two *slatten* [slɑtən] – one *slat* [slɑt]), and from non-words that *do* result in a surface alternation (two *sladden* [slɑdən] – one *slat* [slɑt]). While in general children were not very good at positing singulars from plural non-words, children were significantly worse at positing singulars when this would result in a surface alternation between singulars and plurals. Note that final voiced obstruents were never produced, e.g., [slɑd]; the typical error was a repetition of the novel plural. Children's preference for singulars with no surface alternation suggests that it was easier to posit a

[2] It is interesting to note that 9- and 11-month-old Dutch-learning infants do not prefer lists of non-words ending in final voiceless obstruents to lists of non-words ending in final voiced obstruents. Thus, they do not seem to be sensitive to voicing in word-final position in the first year of life (Zamuner, in press).

singular from a plural when the identity of the medial segment remained constant, in other words when the singular-plural pair conformed to Paradigm Uniformity (see below). This suggests that children do not have a robust knowledge of voicing neutralization – the phonological process that gives rise to the morpho-phonological alternations in Dutch if one starts from the plural. Changing the identity of plural /d/ to singular /t/ was difficult for children even as old as 5-years-of-age (see also Kerkhoff, to appear).

Second, Kerkhoff (2004) focused on children's knowledge of morpho-phonological alternations in Dutch. In this study, 59 children aged 2;9 to 7;8 were presented with the same non-words in the singular and asked to produce words in the plural (classic Wug Test). The goal of her study was to determine what mechanisms children use to determine the underlying voicing feature of the stem. For example, if a child hears [slɑt], are they then more likely to posit the final segment with an underlying voiceless /t/ as in the plural *slatten* or with an underlying voiced /d/ as in the plural *sladden*. Three possibilities were considered. The first option is Paradigm Uniformity or stem-to-stem faithfulness (e.g., Steriade, 2000), which would predict that children will prefer surface forms with no alternations (i.e. *slatten*). However, it is possible that children may extend voicing, producing novel plurals like *sladden*. This may be based on two different grounds. First, this may rise from similarity or exemplar based analogy with other words in the lexicon (e.g. Bybee, 1995; Cutler & Carter, 1987; Ernestus & Baayen, 2004). Secondly, phonological generalisations (Kager, 1999; Kenstowicz, 1994) may lead children to produce alternations in phonologically motivated contexts, such as intervocalic voicing (which may also be phonetically grounded, as argued for in Stampe (1973). Thus, children may initially posit an early phonological rule of intervocalic voicing, even though such a rule does not exist in Dutch.

Although the voicing alternation was generally unproductive (suggesting effects of paradigm uniformity), Kerkhoff (2004) found that the youngest children were most sensitive to phonological generalisations, and that the effects of analogy were stronger with older children. However, Kerkhoff and de Bree (2005) found that children with Specific Language Impairment (SLI) resemble young children in producing overgeneralisations of voicing that are seemingly unmotivated by analogy. An analysis in terms an early rule of intervocalic voicing is less likely for this population, as it is generally thought that SLI children use 'lexical' strategies rather than rules (e.g. Goad & Rebellati, 1994). This suggests that both young children and language-impaired children may have difficulty with forming generalizations on the basis of a lexicon (e.g., Marchman & Bates, 1994). Also, phonetic processes could play a role in the overgeneralization of voicing. Kerkhoff and de Bree concluded that the lexicon plays a central role in the acquisition of Dutch voicing alternations (see also Bybee, 2001).

Thus, using two versions of the Wug Test, previous research has tapped into children's knowledge of voicing neutralization and morpho-phonological alternations. Surprisingly, both studies found that children's knowledge of these patterns is not very robust. However, comprehension often precedes production, such that children will often show passive or comprehensive knowledge of a language structure even though it may be absent or not adult-like in the children's productions. Therefore, it is possible that children might still have knowledge of voicing neutralization and morpho-phonological alternations, even though their productive knowledge of these patterns is not robust. The goal of the present study was to study children's comprehension of alternating and non-alternating non-words in Dutch to determine whether children have more knowledge than suggested by previous studies involving production.

1. Experiment: Perception of Alternations and Non-alternations

To determine whether children have comprehensive knowledge of voicing neutralization and morpho-phonological alternations, children were tested on how they identify singulars and plurals in non-words with /t/ and /d/.

There were three main goals of the experiment. First, in an experiment testing children's creation of singulars from plurals using the same non-words, it was found that children often gave plural responses (Zamuner et al., in prep.). For example, children responded "one *slatten*" or "one *sladden*". Therefore, the first goal was to look at children's knowledge of singulars and plurals in a task that did not require production. If children have difficulty with the singular-plural distinction, we predict that children will also have difficulty choosing the appropriate singulars and plurals in a comprehension task. However, if children's difficulty in producing novel singulars reflects the difficulty of the non-word production task, we predict that children will show better knowledge of singulars and plurals in comprehension. After all, the same children in Zamuner et al. had no problems producing the plurals of known words.

Second, previous research found a difference in children's creation of singulars from plurals depending on the underlying voicing of the stem (*slatten* vs. *sladden*) (Zamuner et al., in prep.). Therefore, the second goal was to determine whether this difference persisted in children's ability to comprehend singulars and plurals in both non-alternating versus alternating contexts. Thus, we compared [slɑtən] – [slɑt] to [slɑdən] – [slɑt]. If the distinction between non-alternating and alternating forms were also found in comprehension, this would suggest that it is difficult for children to determine the relationship between non-identical members of a paradigm. If the distinction between non-alternating and alternating forms were not found in comprehension, this would suggest that children can identify non-identical variants of a stem, but that their knowledge is not adult-like or tied to specific lexical items and not extended to novel forms. Hence, it may not show up in certain tasks (Bybee & Pardo, 1981).

Lastly, different ages were tested to determine whether there were developmental differences in children's comprehension of singulars and plurals, and in children's comprehension of alternating and non-alternating forms.

2. Methods

2.1 Participants

Two groups participated in the experiment: 2 1/2 and 3 1/2 year-old Dutch-speaking monolingual children; 18 children with an mean age of 2;7, and 15 children with an mean age of 3;7. Five additional children were tested but not included due to not completing the experiment (1) or for simultaneously choosing multiple items for at least half of the items (4). Participants were first tested on the production experiments described in Zamuner et al. (in prep). Children were recruited through the Baby Research Center of the Max Planck Institute for Psycholinguistics in Nijmegen, The Netherlands.

2.2 Materials

There were four singular-to-plural trials and four plural-to-singular trials. For both types of trials, half of the items had /t/ and half of the items had /d/. A full list of the items is given in Table 1. These are a subset of items used in Kerkhoff (2004) and Kerkhoff and de Bree (2005).

Table 1: Plural and Singular Non-words with /t/ or /d/

/t/ plural	/d/ plural	/t/ and /d/ singular
slatten /slɑtən/	*sladden* /slɑdən/	*slat* and *slad* /slɑt/
jitten /jɪtən/	*jidden* /jɪdən/	*jit* and *jid* /jɪt/
knoten /knotən/	*knoden* /knodən/	*knoot* and *knood* /knot/
ketten /kɛtən/	*kedden* /kɛdən/	*ket* and *ked* /kɛt/
mitten /mɪtən/	*midden* /mɪdən/	*mit* and *mid* /mɪt/
zoten /zotən/	*zoden* /zodən/	*zoot* and *zood* /zot/
feten /fetən/	*feden* /fedən/	*feet* and *feed* /fet/
klaten /klatən/	*kladen* /kladən/	*klaat* and *klaad* /klat/

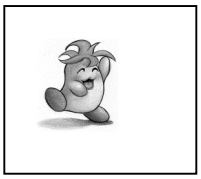
Children were tested on a subset of the stimuli in Table 1: four non-words with /t/ and four non-words with /d/. Each word was presented to the children with either /t/ or /d/. In other words, children were tested on either [slɑtən] – [slɑt]) or [slɑdən] – [slɑt], but not both.

On each trial, children had the choice between three pictures: Correct Number Nonce-Animal, Incorrect Number Nonce-Animal, and Filler. In the singular-to-plural trials, the non-word was first presented in singular, e.g., *slat* paired with a picture of a fantasy animal. Next came the test trial, where children

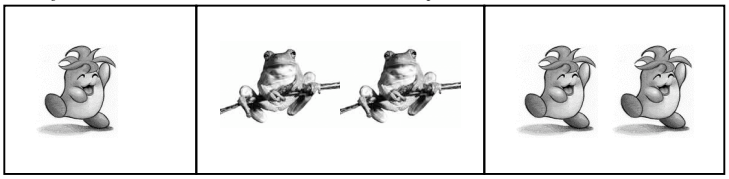
saw (1) Correct Number Nonce-Animal: two pictures of the identical non-animal, (2) Incorrect Number Nonce-Animal: one picture of the identical non-animal, and (3) Filler: two pictures of the same known animal. The fillers were used as a control to ensure that children were not just randomly choosing pictures. An example of a singular-to-plural trial is given in Figure 1.

Figure 1: Singular-to-plural Trial

Training
Dit is een slat/slad. "This is a *slat/slad*"



Test
Kun je de slatten/sladden vinden? "Can you find the *slatten/sladden*?"



The order of the Correct Number Nonce-Animal, Incorrect Number Nonce-Animal and Filler pictures were randomized across trials.

2.3 Procedure

Children were tested at the Child Production Lab at the Radboud University Nijmegen. On singular-to-plural trials, children were shown a picture of a non-animal using PowerPoint. For example, the experimenter said, "This is a *slad* [slɑt]". Children were then given the choice of three pictures, and asked to point to "the *sladden*", see Figure 1. The experimenter did not use the numbers *one* and *two*, to avoid giving additional cues about the singular-plural distinction.

2.4 Coding

Children's first responses were coded. Responses were coded as either Correct Non-word or Incorrect Non-word. No child chose the Filler pictures.

2.5 Results

The first analyses looked at whether children understood the difference between singulars and plurals. Children's responses on singular-to-plural trials and plural-to-singular trials were compared to chance. While chance can be calculated in a number of ways (e.g., chance for choosing the correct number or the correct animal), we calculated chance at 33% because there were three items to choose from at test. Two-tailed *t*-tests were used to determine whether children performed above chance. Children's performance on the singular-to-plural trials were significantly better than chance ($t(32) = 6.72$, $p < .001$) (Singular = 2.61 (SD = 2.13), Chance 1.33 (SD = 0.00)), and children's performance on the plural-to-singular trials was also significantly better than chance ($t(32) = 3.32$, $p < .01$) (Plural = 2.12 (SD = 1.46), Chance 1.33 (SD = 0.00)).

The second set of analyses looked at children's comprehensive knowledge of voicing alternations. A repeated-measures ANOVA was used with Voicing (voiceless or voiced) and Number (singular-to-plural or plural-to-singular) as within-subjects factors, and Age (2 1/2 year-olds or 3 1/2 year-olds) as the between-subjects factor. Results of the mean scores are given by subjects (F1) in Table 2 and by items (F2) in Table 3.

Table 2: Subjects analyses, with mean number of correct responses (out of 2) for correct responses from non-words with /t/ and /d/, by singular-to-plural and plural-to-singular. Responses are broken down by age. Standard deviations are in parenthesis.

	Subjects analysis			
	Singular-to-Plural		Plural-to-Singular	
Age	t	d	t	d
30-32	1.5 (0.71)	1.17 (0.71)	1.33 (0.97)	1.00 (0.84)
42-44	1.4 (0.63)	1.13 (0.74)	1.00 (1.00)	0.86 (0.74)

Table 3: Items analyses, with mean number of correct responses (out of 1) for correct responses from non-words with /t/ and /d/, by singular-to-plural and plural-to-singular. Responses are broken down by age. Standard deviations are in parenthesis.

	Items analysis			
	Singular-to-Plural		Plural-to-Singular	
Age	t	d	t	d
30-32	0.77 (0.92)	0.55 (0.24)	0.70 (0.06)	0.53 (0.17)
42-44	0.70 (0.16)	0.58 (0.18)	0.51 (0.09)	0.42 (0.20)

Based on the analyses, there was a main effect of Voicing by subjects ($F1(1, 31) = 5.38$, $p = .03$) and by items ($F2(1, 6) = 10.36$, $p = .02$). Fourteen subjects performed better when the non-word had /t/, compared to seven subjects that were better when the non-word had /d/. There was no main effect of Number (($F1(1, 31) = 2.55$, $p = .12$) ($F2(1, 6) = 2.04$, $p = .20$)), and no main effect of Age (($F1(1, 1) = 1.00$, $p = .33$) ($F2(1, 1) = 3.02$, $p = .13$)). There was also no interaction between Num x Age (($F1(1, 31) = 0.28$, $p = .60$) ($F2(1, 6) = 0.70$, $p = .43$)), between Voicing x Number (($F1(1, 31) = 0.06$, $p = .81$) ($F2(1, 6) = 0.19$, $p = .68$)), or between Voicing x Age (($F1(1, 31) = 0.34$, $p = .57$), ($F2(1, 6) = 1.10$, $p = .33$)).

3. Discussion and Conclusion

In this study, children were tested on their comprehensive knowledge of voicing neutralization and morpho-phonological alternations between singular and plural non-words. There were three goals to this experiment.

The first goal was to assess children's knowledge of the singular-plural distinction in comprehension. Previous research has shown that children as old as 5 years have difficulty positing singulars from plural non-words, and often give plural responses for a singular (Zamuner et al., in prep). We found that children were able to correctly identify singulars and plurals, i.e. their responses were above chance. Thus, based on the results from our comprehension study, children's difficulty with the singular-plural distinction seems to be limited to production tasks that require children to posit novel singulars. This fits with results from Zamuner et al. where children were also tested on how they produce singulars and plurals for real words. Here, children had no difficulty in producing the appropriate forms.

The second goal was to examine children's comprehensive knowledge of singulars and plurals of non-words that have no surface alternation (those with /t/) as compared to those which do have surface alternations (those with /d/). Interestingly, although children performed above chance at picking the correct singulars or plurals, there was still a difference between the items that exhibited no surface alternation and those that did, i.e., *slatten* [slɑtən] – *slat* [slɑt] was comprehended better than *sladden* [slɑdən] – *slad* [slɑt]. This suggests that non-words with a surface alternation were more difficult to process than non-words with no surface alternation.

Furthermore, we found the asymmetry reported in production also in comprehension. Not only are children worse at positing singulars from plural non-words which result in a surface alternation (Zamuner et al., in prep.), and not only are children hesitant to extend alternating patterns to non-words in production (Kerkhoff, 2004), but children also show the same reluctance to accepting novel alternating forms in comprehension. This suggests that children's difficulty with processing alternating forms might stem from their

inability to relate the non-identical forms, at least for novel words. In this sense, the data suggest that Paradigm Uniformity or stem-to-stem faithfulness guides children, because words that do not alternate have an advantage in both comprehension and production.

Another possibility is that children were more likely to regard the alternating non-words as mono-morphemic. Under this account, when children were presented with the non-word *sladden*, they would be more likely to perceive this word as a singular mono-morphemic form. While this is a possibility, we find no reason for why children would be more likely to treat *sladden* as more mono-morphemic than *slatten*. Non-alternating words of both forms exist in the language. For example, the words *water* 'water' and *ridder* 'knight' are both mono-morphemic, but their lexical frequencies are highly similar, as indicated by a frequency count in the CELEX lexical database (Baayen, Piepenbrock & van Rijn, 1993)[3].

Furthermore, we did not find evidence for the claim that the acquisition of phonotactics patterns may aid the acquisition of morphological alternations (cf. Hayes, 2004). Thus, these results do not support the view that the 'restructuring' of underlying representations (e.g. /bɛd/) from an earlier underlying form /bɛt/ (upon learning alternating plurals), is aided by the previously acquired rule of final devoicing.

The last goal was to determine whether there were developmental differences in children's comprehension of singulars and plurals, and of alternating and non-alternating forms. We found no significant differences in children's knowledge of these patterns between 2 1/2 and 3 1/2 years-of-age.

Research has repeatedly found that children acquire more frequent language structures before less frequent structures, across phonology, morphology, syntax and semantics. Following this logic, one predicts that the relative ease with which children learn phonotactics and morpho-phonological alternations across languages will differ according to their relative frequency and predictability (Bittner, Dressler & Kilani-Schoch, 2003). Studies by Zamuner (in prep.) and Kerkhoff (in prep.) analyzed morpho-phonological voicing alternations in a corpus of spoken Dutch including child-directed speech (see van de Weijer, 1998) and in a corpus of mother-child dialogues from when the child was 1;6 until she was 6;0 (CHILDES, van Kampen corpus, van Kampen, 1997), respectively. The analyses determined how many words in the corpora do not alternate (as in 2a) as compared to the number of words in which underlying voiced stops alternate on the surface between voiceless and voiced (as in 2b). Results from these analyses show that in both corpora, there are more non-alternating types (2a) than alternating types (2b) in the input. Assuming that

[3] Counting only mono-morphemic nouns with intervocalic /t/ and /d/ preceded by short and long vowels (i.e. mirroring the experimental non-words), there are more types with /d/ (72 vs. 61), but more tokens with /t/ (952 vs. 833).

these corpora are representative of the Dutch language, Dutch learners do not hear many alternating forms in the input. In other words, children's attention is not drawn to the patterns that cue morpho-phonological alternations.

Future research exploring the relative frequency of these patterns in different word categories in Dutch is on-going in our lab. We hope that these studies, combined with acquisition data from a variety of languages, will help determine what principles and mechanisms underlie the acquisition of contrast neutralization and morpho-phonological alternations across languages.

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