Acquisition of Voicing Alternations

Annemarie Kerkhoff[1]
Utrecht University

1. Introduction

Morpho-phonological alternations are central to phonological theory, but little is known about how they are acquired. Acquiring alternations amounts to dealing with variation in a morpheme's shape depending on its morphological context. It is generally assumed that children start with an initial stage of phonotactic learning, after which morphology is acquired, i.e. the analysis of words into meaningful units or morphemes. In Optimality Theory (Prince and Smolensky 1993), alternations occur when two or more output forms share a single input form, the lexical or underlying representation. Hence, alternating forms are characterised by a lack of faithfulness to the underlying form of a morpheme. It is not fully understood how children store lexical items and represent the relationship between their contextual variants. Moreover, it is unclear whether early lexical representations differ from those of adults. Here, the various models of morphological processing, such as 'dual-route' models (e.g. Baayen et al. 1997) or 'whole word' models (e.g. Bybee 1995) will not be addressed. It is assumed that although words may be stored as wholes in the first stage of learning, the child will notice the semantic overlap between alternants and arrive at a more abstract lexical representation at a later stage. There are generally two types of alternations, which may be associated with different ages of acquisition. Phonologically conditioned alternations (assimilation, schwa insertion, cluster reduction) are assumed to be acquired early (Bernhardt & Stemberger 1998). MacWhinney (1978) reports that English schwa insertion was optionally applied as early as 2;10. The second type of alternation is lexically conditioned (without clear phonological motivation) and is assumed to be acquired late (Bernhardt & Stemberger 1998). These include alternations associated with suppletive allomorphy and inflectional and derivational morphology.

In this paper we will be concerned with the acquisition of the Dutch voicing alternation, which is of the phonologically conditioned type. The alternation is caused by the cross-linguistically common process of final devoicing (e.g. [bɛt] ~ [bɛdən] *beds*). Crucially, the underlying voice specification of the final segment of the singular stem can only be deduced on the basis of alternations, which poses a

problem for acquisition. Deriving singulars from newly heard plurals seems a fairly straightforward task given the phonotactic knowledge gained in infancy. In mapping a novel singular onto a plural however, the child must undo the neutralising effect of final devoicing. If only the singular's surface form is known, the plural may contain either a voiced or an unvoiced consonant. To derive the phonological properties of a plural on the basis of a singular, children may assume several strategies. For instance, a child might always opt for a non-alternating form when presented with a novel form (e.g. [kɛt] ~ [kɛtən]). Alternatively, the choice for one of the possible realisations ([kɛtən] or [kɛdən]) might be random, based on the characteristics of phonologically similar words in the lexicon, or based on phonological generalisation.

The various strategies for novel word formation and the predictions that follow from them will be discussed in section 2. The experiment that was carried out to test these predictions was a 'wug-test' in which children were asked to pluralise non-words. This experiment will be described in section 3, followed by the results in section 4 and the conclusions in section 5. First, the voicing alternation and its distribution in Dutch are discussed in the next section.

1.1 The Dutch voicing alternation

Although voicing is distinctive for obstruents in Dutch, the contrast is neutralised in syllable-final position, resulting in coda devoicing. In stems whose final obstruent[2] is underlyingly voiced, final devoicing results in voicing alternations, i.e. the voicing contrast surfaces in inflected forms. This is illustrated in (1) below for the nominal plural, which is formed by attaching a suffix /ə(n)/[3] to the stem. Note that there is no rule of intervocalic voicing, as shown in (1b). Underlying [voice] specifications are contrastive to a certain extent, as there are some 21 minimal pairs in Dutch that differ only in the underlying [voice] specification of the stem.

(1) a. /bɛd/ → [bɛt]   *bed*   /bɛd/ + ən → [bɛdən] *beds*
    b. /pɛt/ → [pɛt]   *hat*   /pɛt/ + ən → [pɛtən] *hats*

The main mechanism for plural formation in Dutch is the addition of an /s/ or /ə(n)/ suffix. The choice between two productive suffixes depends on the phonological characteristics of the preceding phoneme (cf. Booij 1995). It has been claimed that the use of functionally appropriate plural forms occurs between the ages of 2;7 and 3;1. Irregular forms (i.e. those undergoing stem vowel changes) remain difficult throughout primary school (Schaerlakens 1987). It is expected that plurals involving voice alternations pattern with these irregular forms to some extent. Words that are frequent in their plural form are presumably acquired early

---

[2] This process applies to labial and coronal obstruents (/p/, /t/) as well as fricatives (/f/, /s/). Velars do not have a voiced cognate in Dutch. In this study, fricatives are not considered, as the voiced/voiceless distinction is thought to be less relevant for fricatives than for stops, as evidenced by word-initial realisations and the small set of minimal pairs (see Ernestus, 2000).
[3] Pronunciation of final [n] is optional.

and rote-learned as unanalysed forms (e.g. [hɑndən] *hands*). Let us now turn to the distribution of voicing alternations in Dutch, which will be used to investigate possible effects of analogy later.

1.2 Distribution of voicing alternations

The distribution of forms with an underlying [voice] specification is not entirely unpredictable. The probability that a neutralised obstruent is underlyingly voiced is governed by a number of factors, the most important of which are place of articulation of the stem-final obstruent and quality of the preceding vowel (Ernestus and Baayen 2001).

For the present study, all orthographic wordforms ending in [ə], (including [ər], [əl] and [ən]) were retrieved from the CELEX lexical database (Baayen et al. 1995) and were restricted to the following environments: a. three types of rhyme (short vowel V_, long vowel V:_ and a vowel followed by a nasal VN_); and b. two types of final obstruent (alveolar T and labial P). Note that 'P' stands for /p/~/b/ alternations and 'T' for /t/~/d/ alternations. All complex and simplex forms in the nominal, verbal and adjectival paradigm were included. For all environments under consideration, the distribution of alternating wordforms was determined by computing the frequencies of an underlyingly voiced final segment as a percentage of the summed type or token frequencies of all forms (i.e. both alternating and non-alternating). This measure can be taken to reflect the probability for a final obstruent to be voiced, see Table 1 below. In a study by Ernestus and Baayen (2001a) a similar measure was used, defined in terms of the segments of the final rhyme according to a CART analysis of Dutch monomorphemic stems. However, the measures used in the present study were restricted to precisely those environments that were used in the experiment.

	Type			Token		
	P	T	Total	P	T	Total
V_	22%	14%	18%	72%	51%	60%
V:_	0%	42%	31%	0%	48%	43%
VN_	0%	47%	37%	0%	83%	80%
	12%	36%	28%	47%	56%	54%

Table 1: Probability of voicing based on frequency of Dutch wordforms

Table 1 shows that overall, roughly a third of all types and half of all tokens in Dutch alternate. There are several other important observations to be made on the basis of this distribution. First, there is a labial-alveolar split for contexts following long vowels and nasals, which I will call 'lexical gap' environments. Thus, for complex forms such as plurals and infinitives, there is a /b/-gap which does not occur in segmentally similar monomorphemic stems. Put differently, p ~ b alternations only occur after short vowels. Second, the token frequency of p ~ b alternations is much higher than its type frequency, which is mainly due to the high frequency of a single alternating form [hɛp] ~ [hɛbən] 'to have 1st sg / pl'. This allows for testing the different effects of type vs. token frequency. Third, most t ~ d

alternations occur in the vowel-nasal context, although the relative ranking between the short and long vowel environment differs for type and token frequency. This distribution will be taken to reflect children's input, as there is no evidence that child directed speech would reveal a different pattern.

2. Strategies of word formation

Let us now turn to what will happen if a child is confronted with a novel (*wug*) form such as [kɛt] and is asked to form a plural. A first prediction is that any voicing alternations that occur are randomly distributed across environment. Three other options will be outlined below.

2.1 Paradigm Uniformity

First, a strategy of paradigm uniformity or stem to stem faithfulness (cf. Benua, 1997; Bernardt & Stemberger 1998; Burzio 1998; Kenstowicz 1998; Steriade 2000) might lead children to match the singular's voicing value in the plural, producing non-alternations only (e.g. [hɔnt] ~ *[hɔntən] *dogs*). It has been noted by several authors that children produce sequences that are illegal in the target language in the interest of maintaining a non-alternating paradigm. An example involving flapping in American English is provided by Bernhardt and Stemberger (1998). They describe a child who from 2;0 to 3;8 realised taps in monomorphemic words invariably as [d], as in [waːdoʊ] *water*. However, taps in bimorphemic words were realised either as [t] or [d], depending on which appeared in other inflected forms. Hence, the child produced *[ˈsɪtɪŋ] for [ˈsɪɾɪŋ] on the model of [sɪt]. Another example is reported in Kazazis (1969) who provides data from Marina, a four-year-old learning Greek. The sequence *[xe] (velar consonant before front vowel) was innovated in the course of regularizing the verbal paradigm: thus [ˈexete] 'you-pl. have' (adult [ˈeçete]) was produced on account of [ˈexo] 'I have'. To account for these effects within Optimality Theory, output-to-output correspondence constraints have been proposed (McCarthy 1998; Hayes 1999) which require a surface form not to deviate from the surface form of its morphological base, rather than from its underlying representation. These constraints are presumably ranked a priori high (i.e. at the top of the hierarchy) by children acquiring language.[4]

A theory of Paradigm Uniformity predicts that overgeneralisations of voicing in non-words (e.g. [kɛt] ~ [kɛdən]) or errors such as *[pɛdən] will not occur in children's productions. A weaker version of this prediction is that voicing alternations will occur less often than would be expected on the basis of overall lexical frequency.

---

[4] Note however that Dutch words that are mainly heard in their plural form (such as [hɑndən] *hands*) are never realised as *[hɑnd] in the singular, showing that paradigm uniformity may be overruled by final devoicing in Dutch.

2.2 Analogy

Children may also exploit their knowledge of distributional probabilities of voicing (cf. Cutler & Carter 1987). Under this view, the language-learning child is assumed to be sensitive to the similarity structure in the data and word formation proceeds according to similarity- or exemplar-based analogy. Hence, the formation of a new word is determined on the basis of all phonologically similar words in the lexicon (Skousen 1989, Daelemans et al. 1994). In this approach, paradigmatic structure is given a much greater weight than in traditional rule-based theories. It is important to note that even in a rule-based account, analogical effects are predicted to occur when subjects are asked to inflect non-words. Since non-words do not have a lexical representation, the underlying [voice]-specification of the final segment cannot be retrieved from the mental lexicon. A symbolic morphological rule (add –ən) could be preceded by analogical processes that assign a [voice] specification to the final obstruent of the non-word. This specification may correspond to the underlying [voice]-specification of the final obstruents in some gang of phonologically similar words. Ernestus and Baayen (2001a) found that the proportion of stems in a gang with final voiced obstruents correlated with the proportion of participants interpreting the final obstruents of pseudo-verbs as voiced ($r_s = 0.50$). It is unclear to what extent type and token frequency play a role, but it is generally assumed that type frequency is the most important consideration in word formation (Bybee 1995).

Importantly, an analogy-based strategy could result in alternating forms for non-words or overgeneralisations of voicing. The distribution of these alternating forms would then be expected to mirror the distribution of these forms in Dutch. Hence, it is expected that no alternations will occur in lexical gap environments. Moreover, analogy to single high-frequency items might lead to frequency effects within environments. Results may also reveal effects of analogy to simplex forms.

2.3 Phonological Generalisation

A third possibility is that children postulate phonological generalisations, mirroring cross-linguistically common natural processes such as postnasal or intervocalic voicing. These processes could be phonetically motivated but might also reflect innate knowledge. For instance, postnasal voicing is widespread in the world's languages and is found to occur in child language (Kager 1999). Pater (1999) proposes a constraint against nasal plus voiceless obstruent sequences, which is arguably grounded in articulatory mechanisms that facilitate voicing throughout a nasal-plus-obstruent cluster. Intervocalic voicing is another candidate for phonological generalisation, and has also been reported to occur in child language. Bernhardt and Stemberger (1998) describe a child (4;0) who realised all intervocalic /t/'s and /d/'s as [d], and argue that this is a case of plateauing of the feature [+voice] from the neighbouring vowels. An early rule of intervocalic or intersonorant voicing is likely to be phonologically motivated (Stampe 1969; Hayes 1999, Kager 1999).

This approach predicts that overgeneralisations of voicing will show a decline in acquisition. Importantly, a strategy of phonological generalisation might result in a different distribution of voicing alternations for non-words than the distribution

actually found in the ambient language. Overextension of postnasal or intervocalic voicing might even lead to alternations in lexical gap environments, i.e. in those contexts where alternations are not attested in Dutch.

3. Experiment

To test these predictions, a wug-test (Berko, 1958) was carried out in which children were asked to pluralise phonotactically legal non-words. Words were also included, to test knowledge of the alternation and elicit possible overgeneralisations.

3.1 Subjects

A total of 59 children (36 girls and 23 boys) participated in the experiment. Subjects were divided into three age groups. Children in the first age group (n = 26) attended day care, their ages ranged from 2;9 to 4;0. The second (n = 18, ages 4;1 - 6;2) and third group (n = 15, ages 6;9 - 7;8) were in separate elementary school classes. Subjects were tested in an isolated room in the school.

3.2 Stimuli and design

The stimuli set consisted of 24 non-words (e.g. [kɛt]) and 20 high-frequency words, 12 of which were non-alternating (e.g. pɛ/t/ *hat*) and 8 of which were alternating (e.g. bɛ/d/ *bed*). The set of non-words was constructed to mirror the six environments under investigation, in order to determine the effect of rhyme (V_, V:_, VN_) and final obstruent (P, T). The non-words were chosen in such a way that neither of the two possible 'inflected' forms was an existing Dutch word. In each category, one non-word was added that in its alternating 'plural' form was an existing simplex word of Dutch (with frequency above zero), differing from one of the other non-words only in its onset (e.g. [mɪt] ~ [mɪdən] *middle)*. This was done to test whether analogy to an existing form may prevent or promote the formation of an alternating plural. A set of 26 mono- and polysyllabic filler items was also added. The list of items was constructed in such a way that non-words were separated by fillers or words ending in a different obstruent. Alternating forms did not directly precede non-words. The lists were presented to subjects in two opposite orders. For the full set of experimental stimuli see the results in table 7 below.

3.3 Procedure

To elicit plurals of non-words, pictures of fantasy animals were presented to the child in a PowerPoint slide show. A recorded version of each non-word was inserted, to ensure that all subjects heard the same stimulus. To this end, a recording was made of a female speaker who read the list of non-words aloud, making sure there was an audible release. The stimuli were recorded in a soundproof room by means of a DAT-recorder Aiwa HD S100 and a Sony microphone ECM MS957. The recordings were stored as .wav files (sample rate: 48 KHz) on a laptop by means of the speech analysis package Praat (Boersma 1996). Upon presentation of the first picture, the recorded non-word was played at least twice, in a sentence

context provided by the experimenter ("This is a …"). The child was encouraged to repeat the stimulus. A second (identical) picture then appeared on the screen, upon which the experimenter would prompt the child to form a plural ("Now there are two. There are two…?"). To elicit plurals of existing words, children were shown pictures in the same way and encouraged to first name the stimulus. The test sessions were tape-recorded, and the plural forms supplied by the child were transcribed later.

3.4 Comparison with frequency distribution

To enable a more direct comparison between CELEX frequency and the experimental data, probability of voicing was computed based on the type and token frequencies of precisely those rhymes that were used for the experimental stimuli (i.e. yielding 9 different rhyme categories per obstruent). Probability of voicing was computed in the same way as described above for the overall frequency measure. The results (see table 2 below) illustrate that the high token frequency of the V_P category is due to one rhyme only. A similar frequency count that was based on combined frequency (i.e. complex and simplex forms taken together) was also performed, yielding a total of 4 different frequency measures (differing in token vs. type and complex vs. combined frequency). These measures, reflecting probabilities of voicing, were taken as independent variables. Other independent variables in the analysis are final obstruent and rhyme. The dependent variable (percentage of voiced responses) was measured over the total number of valid responses, treating other responses as missing data.

		P		T	
		Token	Type	Token	Type
V_	[ɔp]	0.023	0.233	[ɑt] 0.872	0.212
	[ɛp]	0.979	0.154	[ɛt] 0.104	0.115
	[ɑp]	0.031	0.226	[ɪt] 0.019	0.188
V:_	[eːp]	0.000	0.000	[aːt] 0.138	0.500
	[aːp]	0.000	0.000	[eːt] 0.420	0.385
	[oːp]	0.000	0.000	[oːt] 0.242	0.340
VN_	[ɛmp]	0.000	0.000	[ɔnt] 0.987	0.600
	[ɪmp]	0.000	0.000	[ɑnt] 0.775	0.591
	[ɔmp]	0.000	0.000	[ɪnt] 0.940	0.417

Table 2: Probability of voicing in experimental rhymes (complex wordforms)

4. Results

All stimuli were transcribed by the experimenter and rated by five additional independent transcribers. Stimuli were excluded if interrater agreement was below 75%; average agreement on the remaining alternating items was 92%. Results for words and non-words are discussed separately.

4.1 Words

Stimuli were transcribed and scored as either correct or incorrect. All children produced some alternating plurals correctly, notably the highly frequent forms [hɑndən] *hands* and [hɔndən] *dogs*. Regularisations of the type *[bɛtən] *beds* (i.e. in the direction of [-voice]*)* occurred in 37% of cases, and persisted well into the oldest age group. Interestingly, overgeneralisations of the type *[pɛdən] *hats* (i.e. in the direction of [+voice]) were also attested in 3% of cases. These forms also occurred in both lexical gap environments: *[lɑmbən] *lamps* (3;5) and *[aːbən] *monkeys* (3;4). Other responses included bare stems (i.e. repetition of the singular or null affixation) and s-plurals. Error percentages for all age groups are shown in table 3.

	All (n=59)	1 (n=26)	2 (n=18)	3 (n=15)
Age range		2;9 – 4;0	4;1 – 6;2	6;9 – 7;8
Overall error rate	17.1	21.7	13.2	16.6
Errors [-voice]	36.5	54.4	27.8	31.3
Errors [+voice]	2.4	3.2	2.6	0.7
Bare stems	1.4	1.8	1.7	0.0
S-plurals	0.9	0.3	2.2	0.0

Table 3: Error percentages for words

4.2 Non-words

17 children (29%) produced alternating plurals for some of the 24 non-words presented to them, ranging from one to seven per child. The total number amounted to 10% of all opportunities or 12% of inflected forms. Note that this percentage drops to only 3% of all forms when all subjects are taken into account. The category 'missing data' refers to null responses (no answer), rhyme changes (e.g. [klaːt] ~ [klaːpən]), real word substitutions ([taːp] ~ [taːkən] *tasks*) and diminutive plurals. Results for all subjects are summarised in table 4.

	All (n=59)		1 (n=26)		2 (n=18)		3 (n=15)	
Mean age			3;4		5;2		7;1	
Alternations	41	2.9%	21	3.4%	15	3.5%	5	1.4%
Bare stems	69	4.9%	40	6.4%	28	6.5%	1	0.3%
S-plurals	33	2.3%	8	1.3%	24	5.6%	1	0.3%
Missing data	123	8.7%	62	9.9%	54	12.5%	7	1.9%

Table 4: Responses non-words: absolute and relative numbers (% of total)

Results for the 17 children (10 girls and 7 boys) who produced alternations are shown in table 5 below, as percentages of the total number of forms (i.e. opportunities). In table 6, results are shown for each type of obstruent and rhyme. Results for each age group are summarised in tables 7 and 8. Voicing alternations were not randomly distributed across environments. Results for each item are shown in table 9, to be compared to the data in table 2 above.

	All		1 (n=8)		2 (n=5)		3 (n=4)	
Alternations	41	10.0%	21	10.9%	15	12.5%	5	5.2%
Bare stems	22	5.4%	20	10.4%	2	1.7%	0	0.0%
S-plurals	4	1.0%	1	0.5%	2	1.7%	1	1.0%
Missing	42	10.3%	34	17.7%	2	1.7%	6	6.3%

Table 5: Results non-words for all age groups

	P		T		Total	
*V_*	8	14.3%	9	16.1%	17	15.2%
V:_	3	5.7%	5	9.1%	8	7.4%
*VN_*	0	0.0%	16	26.7%	16	13.3%
Total	11	6.5%	30	17.5%	41	12.1%

Table 6: Voicing alternations for each environment

	Group 1 (n=8)					
	P		T		Total	
*V_*	4	17.4%	4	16.7%	8	17.0%
V:_	3	13.0%	4	17.4%	7	15.2%
*VN_*	0	0.0%	6	27.3%	6	14.0%
Total	7	10.4%	14	20.3%	21	15.4%

Table 7: Voicing alternations for group 1 (mean age 3;5)

	Group 2 (n=5)						Group 3 (n=4)					
	P		T		Total		P		T		Total	
*V_*	3	15.0%	5	11.5%	8	15.4%	1	6.7%	0	0.0%	1	3.3%
V:_	0	0.0%	1	4.0%	1	2.0%	0	0.0%	0	0.0%	0	0.0%
*VN_*	0	0.0%	6	23.1%	6	10.9%	0	0.0%	4	25.0%	4	12.5%
Total	3	3.7%	12	15.6%	15	9.5%	1	2.2%	4	8.9%	5	5.6%

Table 8: Voicing alternations for groups 2 (mean age 5;5) and 3 (mean age 7;1)

	P		T	
*V_*	[xɔp]	0.000	[slɑt]	0.200
	[tɛp]	0.125	[kɛt]	0.250
	[dɑp]	0.154	[jɪt]	0.077
	[zwɑp]	0.308	[mɪt]	0.083
V:_	[de:p]	0.143	[kla:t]	0.200
	[ta:p]	0.071	[fe:t]	0.000
	[bo:p]	0.000	[kno:t]	0.000
	[xlo:p]	0.000	[zo:t]	0.167
*VN_*	[bɛmp]	0.000	[jɔnt]	0.313
	[kɪmp]	0.000	[flɑnt]	0.400
	[fɔmp]	0.000	[dɪnt]	0.250
	[tɔmp]	0.000	[xɪnt]	0.077

Table 9. Relative number of voicing alternations for each item

A univariate ANOVA with overall percentage of voicing alternations as dependent variable yielded an effect of Final Obstruent ($F(1) = 9,483$, $p<.002$) and an interaction between Final Obstruent x Rhyme ($F(2) = 5,645$, $p<.004$). This was due to the fact that more alternations were produced for T than for P, and no alternations were found in one of the lexical gap environments (VN_P). None of the children produced voicing alternations consistently in a certain environment. There was no effect of sex or list order. At first inspection, responses of the first age group seem to differ from those of the two older groups, as more voicing alternations were produced in the former, particularly after long vowels.

Nonparametric correlations were performed to assess the relationship between the distribution of children's responses (i.e. the percentage of voiced responses, computed over the total number of valid responses) and the probability of voicing based on CELEX frequency measures. As no interesting differences were found between the overall frequency measure (cf. table 1) and the one based on experimental rhymes, results for the latter are reported here. Results of the two older groups are combined for this analysis, to ensure an equal number of children per group.

Children's overall responses were found to be significantly correlated with token frequency of complex forms ($\rho = .616$, $p<.001$), type frequency of complex forms ($\rho = .558$, $p<.005$), token frequency of combined (i.e. complex and simplex) forms ($\rho = .467$, $p<.021$ and type frequency of combined forms ($\rho = .462$, $p<.023$). Results of the youngest age group ($n=8$) however did not yield significant correlations with any of the frequency measures, although a low correlation with type frequency of complex forms approached significance ($\rho = .395$, $p<.056$). The results of the two older groups taken together ($n=9$) correlated with all frequency measures again, but in the following order of strength of correlation: token frequency of complex forms ($\rho = .763$, $p<.000$), token frequency of combined forms ($\rho = .690$, $p<.000$), type frequency of combined forms ($\rho = .492$, $p<.015$) and type frequency of complex forms ($\rho = .485$, $p<.016$).

5. Discussion

The results for words show that even the oldest children have not completely acquired the Dutch voicing alternation. Although the overall error rate does not decrease much with age, the youngest children produced more overgeneralisation errors in both directions (i.e. *[bɛtən] and *[pɛdən]).

To test predictions connected with strategies for new word formation, plurals of non-words were elicited. Results indicate that alternating responses were not randomly distributed. Further analysis suggests that a combination of factors is likely to play a role when children are confronted with a novel singular.

First, it seems that a strategy of paradigm uniformity cannot account for the fact that voicing alternations were produced for non-words ([kɛdən]). Likewise, overgeneralisations of voicing in words (*[pɛdən] *hats*) were not predicted to occur under this view. However, one could argue that an effect of paradigm uniformity was found for the majority of subjects, since only 27% of children produced alternating forms. Moreover, they only did so in 10% of all items offered to them, and never consistently in one environment. The fact that the overall percentage of

alternations was lower than to be expected on the basis of lexical frequency in Dutch lends further support to a strategy of paradigm uniformity.

Second, effects of analogy were investigated by measuring correlations between responses and probabilities of voicing based on CELEX frequencies. This revealed low but significant correlations. A frequency measure based on complex tokens seemed to yield the strongest correlation with the overall results, although differences between frequency measures may be too small to be meaningful.

However, systematic analogy cannot account for all findings. Crucially, voicing alternations for non-words occurred in a 'lexical gap' environment: p~b alternations after long vowels (e.g. [taːp] ~ [taːbən]). Overgeneralisation of postnasal voicing also occurred for words (e.g. *[lɑmbən] *lamps*). Since forms like this never alternate in Dutch, it is unclear how a strategy based solely on analogy could account for this result. When frequency of simplex forms is taken into account, one would expect voicing alternations to occur more often in the postnasal environment, since here both type and token frequency are higher than in the long vowel environment (due to words like [tɔmbə] *tomb*). In fact, no alternations for non-words occurred in this context, suggesting that analogy to simplex forms cannot account for the results. No effect of onset was observed either, i.e. children were not more or less likely to produce an alternating form for a non-word if that form resulted in an existing simplex word of Dutch (e.g. [jɪt] → [jɪtən] but [mɪt] → [mɪdən] *middle*).

Furthermore, no effects of the high token frequency of the V_P environment (due to [hɛp] ~ [hɛbən] *have*) was found for any age group. No within environment effects were observed at all, i.e. it was not the case that more alternations were produced for the non-word [tɛp] than for any other item in that environment, e.g. [dɑp]. This seems to support the observation by Bybee (1995) that the strength of a morphological pattern is related to its type frequency, i.e. that language learners abstract away from tokens.

Finally, the results indicate an interesting effect of age. Children in the youngest age group (with a mean age of 3;5) may be less sensitive to lexical frequency since their results did not correlate with the CELEX measures. Importantly, children in this age group produced the highest number of alternating forms for non-words as well as the highest number of overgeneralisation errors of the unexpected *[pɛdən] type. Furthermore, these children were reponsible for the lexical gap alternations that were produced. The occurrence of these unexpected voicing alternations can be accounted for by an analysis that posits an early (and false) rule of intervocalic voicing. Such a rule would be expected to disappear with time, as the child develops both the correct underlying representations and the correct grammar.

However, it is as yet unclear whether the intervocalic voicing observed is indeed categorical (i.e. phonological) in nature or whether it is a more gradual, phonetic effect. An acoustic analysis of the data is indicated for future research to determine to what extent the voicing contrast is identical across age groups and to correlate the stability of the prevocalic voicing contrast with the degree of alternations in children's elicited productions.

In conclusion, responses of the youngest group in particular show overextension of intervocalic voicing, indicating that young children may generalise from phonological knowledge. These results also suggest that effects of analogy are likely to become stronger in the course of acquisition.

References

Baayen, R.H., Piepenbrock, R. and L. Gulikers (1995) 'The CELEX Lexical Database' CD-ROM), Linguistic Data Consortium, University of Pennsylvania, Philadelphia, PA.

Baayen, H., Dijkstra, T. & R. Schreuder (1997) 'Singulars and plurals in Dutch: Evidence for a parallel dual-route model'. *Journal of Memory and Language* 37, 94-117.

Berko, J. (1958) 'The child's learning of English morphology'. *Word* 14, 150-177.

Bernhardt, B.H. and J.P. Stemberger (1998) 'Acquisition of adult alternations', in: B.H. Bernhardt and J.P. Stemberger (eds.) *Handbook of Phonological Development*. San Diego: Academic Press, 635-666.

Boersma, P. (1996) 'Praat: doing phonetics by computer', ms. University of Amsterdam.

Booij, G.E. (1995) *The Phonology of Dutch*. Oxford: Oxford University Press.

Burzio, L. (1998) 'Multiple correspondence'. *Lingua* 104, 79-109.

Bybee, J. L. (1995) 'Regular morphology and the lexicon'. *Language and Cognitive Processes* 10, 425-455.

Cutler, A. and D.M. Carter (1987) 'The predominance of strong initial syllables in the English vocabulary'. *Computer Speech and Language* 2, 133-142.

Daelemans, W., Gillis, S. and G. Durieux (1994) 'The acquisition of stress, a data-oriented approach'. *Computational Linguistics* 20 (3), 421-451.

Ernestus, M. and R.H. Baayen (2001) 'Phonological interpretation of neutralized segments in unknown words'. ms. University of Nijmegen.

Ernestus, M. and R.H. Baayen (2001a) 'Choosing between the Dutch past-tense suffixes *–te* and *–de'*, in: T. van der Wouden and H. de Hoop (eds.), *Linguistics in the Netherlands* 2001. Amsterdam: Benjamins, 81-93.

Hayes, B. (1999) 'Phonological acquisition in Optimality Theory: the early stages'. *Rutgers Optimality Archive ROA* 327.

Kager, R.W.J. (1999) *Optimality Theory*. Cambridge Textbooks in Linguistics. Cambridge: Cambridge University Press.

Kazazis, K. (1969) 'Possible evidence for (near-)underlying forms in the speech of a child'. *CLS* 5: 382-388.

Kenstowicz, M. (1998) 'Uniform Exponence: exemplification and extension'. *ROA* 218.

MacWhinney, B. (1978) 'The acquisition of morphophonology'. Monographs of the Society for Research in Child *Development*, serial 174, vol. 34, nos. 1-2.

McCarthy, J.J. (1998) 'Morpheme structure constraints and paradigm occultation', in: M. Gruber et al. (eds.) *CLS 32, Part 2: The Panels*, Chicago Linguistic Society, 123-50.

Pater, J. (1999) 'Austronesian nasal substitution and other NC effects', in: R.W.J. Kager, H. van der Hulst and W. Zonneveld (eds.) *The Prosody-Morphology Interface*, Cambridge, Cambridge University Press, 310-343.

Prince, A. and P. Smolensky (1993) '*Optimality Theory: Constraint Interaction in Generative Grammar'*. Technical Report TR-2, Rutgers University.

Schaerlaekens, A.M. and S. Gillis (1987) *De Taalverwerving van het Kind*. Groningen: Wolters Noordhoff.

Skousen, R. (1989) *Analogical Modeling of Language*. Dordrecht: Kluwer.

Stampe, D. (1969) 'The acquisition of phonetic representations'. Bloomington: Indiana University Linguistics Club (1979).

Stemberger, J. P. & B.H. Bernhardt (1999) 'The emergence of faithfulness', in: B. Macwhinney (ed.) *The Emergence of Language*. New Jersey/London: Lawrence Erlbaum Associates.

Steriade, D. (2000) 'Paradigm uniformity and the phonetics-phonology boundary', in: J. Pierrehumbert & M. Broe (eds.) *Acquisition and the Lexicon: Papers in Laboratory Phonology V*. Cambridge: Cambridge University Press, 313-334.