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Cross-Linguistic Differences in the Perception of Dorsal and Coronal CV-Combinations: Evidence from English and Dutch

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1. Introduction

Very few studies to date have tested whether young children prefer to listen to words that they can produce, or whether young children might recognize preferred word forms faster (although see Majorano, Vihman & DePaolis, 2013). In this study, we set out to explore potential links between patterns found in early speech production, and early word recognition. We will start to explore the possible units of representation in young children's familiar words, and specifically, whether we can find evidence for influence of a larger unit than the segment in early recognition of familiar words, namely a syllabic or CV-unit. To address this issue, we will focus on the perception of place of articulation within the word-initial CV unit in children's early words.

When children produce their first words, these are predominantly monosyllabic, and often consist of a CV syllable. It has been argued that children's early production patterns – both in babbling and early words – favor particular CV patterns (Davis & MacNeilage, 1995). Three sets of preferred CV co-occurrences have been reported in children's early production in many different languages (Davis, MacNeilage & Matyear, 2002; Kern & Davis, 2009; Kern, Davis & Zink, 2010): (1) *Labial* consonants with *central* vowels, (2) *Coronal* consonants with *front* vowels and (3) *Dorsal* consonants with *back* vowels. These patterns are argued to be based on speech-motor factors and are considered to be very basic to the speech production system. Therefore, they should not be language-specific (MacNeilage, Davis, Kinney & Matyear, 2000). However, although for the large majority of languages including English these three CV co-occurences are reported, they have not been found in a few languages, including Dutch (Kern, Davis & Zink, 2010).

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In this study we investigate the potential for *perceptual* advantages for CV-combinations corresponding to reported prevalent patterns in production; and if there are, whether there is evidence for this to be language-specific or not? To investigate these questions, we compare early word recognition in Dutch- and English-learning children. Dutch and English are both Germanic languages which share many phonological characteristics. They have a similar set of stop consonants, containing /p, b, t, d, k/. The Dutch phonemic inventory lacks the voiced stop [g] and thus contains a smaller set of dorsal sounds: however, both Dutch and English children show the common process of fronting (Ingram 1974), producing target dorsal stops as coronal stops, for example as in 'kip' *chicken* produced as 'tip' (Fikkert & Levelt, 2008) or 'kiss' produced as 'tis' (Inkelas & Rose, 2003). The vowel systems in both languages contain front unrounded vowels (aka "coronal vowels") and back rounded vowels (aka "dorsal vowels") although it is important to note that Dutch also has front unrounded vowels (aka "labial vowels").

Despite these similarities, observations from early child language production also show important differences between English and Dutch. First, as mentioned above, Dutch-learning children do not show the preferred CV-combination of labial consonants with central vowels in babbling (Kern, Davis & Zink, 2010) or early words (Fikkert & Levelt, 2008); rather Dutch children predominantly produce labial consonants with back (rounded) vowels (Levelt, 1994; Fikkert & Levelt 2008). Fikkert and Levelt (2008) reported that in their earliest word productions, Dutch children produce either all-labial or all-coronal sound patterns (in line with earlier work by Menn (1978), who also argued for one place of articulation per word in the earliest lexicon). Fikkert & Levelt argued that the CV-combinations in early Dutch words share their Place of Articulation (PoA) features: words are either complete labial, i.e. consist of a labial consonant followed by a back rounded vowel, or completely coronal, i.e. consist of a coronal consonant followed by a front unrounded vowel. Dorsal-initial words are rare amongst Dutch children's first words, but if they occur at all, they tend to consist of a dorsal consonant followed by a back rounded vowel. Finally, another difference between patterns found in early production in the two languages is consonant harmony: While both Dutch- and English-learning children exhibit patterns of coronal consonant harmony in early words, English but not Dutch children have been reported to produce words with dorsal consonant harmony (*goggy* for *doggy*) (e.g. Pater & Werle, 2003, although see Kim & Davis, 2015 – English; Tsuji, Dijkstra, Benders, Mazuka & Fikkert, 2015; Levelt, 1994 - Dutch).

Given the fact that CV co-occurences have been attested more robustly in English than in Dutch for both babbling and first words and stronger evidence for consonant harmony has been found in English, we will explore whether the CV unit might also play a more important role in perception of early words in English than Dutch, or whether Dutch and English children show similar perceptual patterns in early word recognition. In this study we manipulate the pronunciation of familiar words to gain insight into the factors that influence word recognition.

This procedure has successfully been used to investigate perception of word-initial place of articulation (Altvater-Mackensen, Van der Feest & Fikkert, 2014; Swingley & Aslin, 2000; Van der Feest & Fikkert, 2015). We compare the perception of correctly and mispronounced dorsal- and coronal-initial words, where dorsals were mispronounced as coronal, and vice versa. In addition, we take the nature of the following vowel into account. We tested whether words with an initial coronal consonant followed by a front vowel, such as *table* (preferred pattern) are recognized faster than words with a coronal consonant followed by a back vowel, such as *doll* (non-preferred pattern), and similarly for words with a dorsal consonant followed by a back vowel, such as *cup* (preferred pattern) versus words with a dorsal consonant followed by a front vowel, such as *cat* (non-preferred pattern), as we will explain in detail in the Method section below.

We tested recognition of these different word types in English- versus Dutch-learning toddlers between 24 and 26 months of age. Similar effects in English versus Dutch would provide more support for the influence of general speech-motor constraints on early perception. However, from a phonological perspective based on early production and input patterns, representations of dorsal-coronal contrasts could be different in English and Dutch, which may lead to early perceptual differences in word recognition.

2. Method

2.1 Participants

Thirty-two 24- to 26-month-old children participated. Half (16) were Dutch-learning children (10 male; mean age 25 months, 3 days) and were tested in the Dutch condition, and half (16) were American-English learning children tested in the English condition (7 male; mean age 25 months, 6 days). All participants were monolingual and had no history of hearing issues or speech-language delays.

2.2 Stimuli, Apparatus and Procedure

The *visual stimuli* for both conditions consisted of photographs of familiar objects presented on a large screen, which were all edited to be similar in size and brightness. All target words were chosen from the Mac-Arthur Bates CDI list: words from both conditions were reported as early-acquired on the CDI version in Dutch (Zink & Lejaegere, 2002) as well as English (Fenson et al., 1993), and were expected to be familiar to 24-month-olds. This was confirmed by asking the parents after the experiment if their children knew the target words. All participants reportedly knew all target words. Test items always appeared on the screen side by side with a distractor item that started with the same initial consonant. The side on which the labeled target object appeared was counter-balanced across trials – the same two objects always appeared together.

All *auditory stimuli* were recorded in the same sound proof room, with a sampling rate of 44.100 Hz. The sentences were all spoken in an infant-directed voice, and were of the structure *"Kijk eens naar de / Look at the [target]!"* On each trial, the sentence was followed by a 750ms pause and a second phrase *"Vind je hem mooi? / Do you like it?"* or *"Kun je hem vinden?/ Can you find it?"*. On each test trial the two objects appeared immediately, and audio started exactly 2.5 seconds later. Each test trial lasted exactly 6.5 seconds.

In both the Dutch and English condition, participants heard correctly or incorrectly pronounced versions of the target words, which were each presented once in the first and once in the second half of the experiment (32 trials total). Of the 16 different critical test trials, on 4 trials one of two coronal-initial targets was correctly pronounced (e.g. 'tijger' *tiger*), on 4 trials these targets were pronounced with a place of articulation mispronunciation ('kijger'). On another 4 trials one of two dorsal-initial targets (e.g. 'cup') was correctly pronounced, on 4 trials these were mispronounced (e.g. 'tup'). Crucially, CV combinations in all test words were carefully controlled: Words in both languages contained universally 'preferred' (P) versus 'non-preferred' (NP) CV combinations. Mispronunciations of the initial consonant changed the structure of the target words from having a preferred to a non-preferred structure, or vice versa. (e.g. *tijger* 'tiger' (P) changing to *kijger* (NP) or *cup* (P) to *tup* (NP)). Table 1 gives an overview of all test items in the Dutch and English conditions. After every 6 trials, short animations of a bouncing duck, flying bird or a fish swimming across the screen accompanied by simple (non-speech) sound effects were played to maintain children's interest in the movie.

Table 1. Dutch and English test words: Target words were coronal- or dorsal-initial followed by either a *preferred vowel* (dorsal+back vowel; coronal+front vowel – white cells) or a *non-preferred vowel* (dorsal+front vowel; coronal+back vowel – grey cells).

	DUTCH		**ENGLISH**	
	Front V	**Back V**	**Front V**	**Back V**
Dorsal C	kip ('*chicken*') kikker ('*frog*')	koe ('*cow'*) kaas ('*cheese'*)	cat keys	cup car
Coronal C	teen('*toe'*) tijger ('*tiger'*)	tong ('*tongue')* tafel '*table')*	table tiger	duck doll

Participants in the Dutch condition were tested in Nijmegen, the Netherlands; participants in the English condition were tested in Austin, Texas, USA. During the 5-minute test phase of the experiment, all participants sat on their parents' lap in a sound-attenuated darkened room in front of a large screen (75 inch Sony LCD Projection Data Monitor - Dutch condition; 32 inch Macintosh screen - English condition). Throughout the experiment, caregivers listened to music mixed with speech over headphones and were instructed not to speak to their child or point at the screen. The audio was played over external speakers, and a concealed video camera (Sony CVX-V18NSP – Dutch condition; Sony EVI-D100 – English condition) located directly below the screen recorded the participants' face close-up).

2.3 Coding and Analyses

Children's eye movements were coded off-line by trained coders using the SuperCoder program (Hollich, 2005). For each 40ms frame of the silenced video, the coders indicated whether the child was looking at the left picture, the right picture or away from the screen. The beginning and end of each test-trial was clearly indicated on the video by a change in background light. The coder was blind to target side and test order. Codings by two different coders of ten percent of the data were compared to determine coder reliability. The mean agreement between coders was 95%.

A difference score was computed for each trial. To calculate the difference scores, we calculated the ratio (of the sum of the total time subjects looked at the screen) of fixations to the target object during a two-second window starting 365ms *after* target word onset (e.g., Swingley & Aslin, 2000). We then compared this with the ratio of fixations to the target during a window of 2 seconds *before* target word onset (when the pictures were shown in silence), during the same trial, to evaluate the effect of the auditory stimulus for each individual trial. All Figures in the Results sections depict these difference scores (see e.g., Quam & Swingley, 2010 for a similar use of difference scores). Trials on which the subject did not look at the screen for at least 400 ms in each of the two windows of analyses were excluded from the analyses (excluding a total of about 8% of trials across all subjects). All children included in the analyses (in both conditions) ended up being attentive to at least 25 of the 32 test trials (not including fillers).

3. Results and Discussion

In order to investigate Dutch and English children's recognition of familiar coronal and dorsal words with different CV-combinations, the difference scores calculated for each of the 32 participants were entered into a four-way mixed design ANOVA, with condition (English, Dutch) as between-subjects factor, and pronunciation (Correct, Mispronounced), word- type (Coronal-initial, Dorsal-initial) and CV-combination (Preferred, Non-Preferred) as within-subjects factors. The 2 x 2 x 2 x 2 ANOVA showed significant main effects of condition ($F(1,60 = 5.0$, $p = .03$) and of CV-combination ($F(1,60 = 4.1$, $p = .04$). There were also significant two-way interactions between word-type and pronunciation ($F(1,60 = 4.1$, $p = .04$) and CV-combination and pronunciation ($F(1,60 = 4.3$, $p = .04$). Finally, there were significant three-way interactions between condition, word-type and CV-combination ($F(1,60 = 3.9$, $p = .048$), and between condition, word-type and pronunciation ($F(1,60 = 6.4$, $p = .01$). No other main effects or interactions were significant. These outcomes indicate that children's recognition of coronal- and dorsal-initial words was influenced by the language they are learning, and depended on the exact CV sound pattern of the target words. Given our design and predictions, we proceeded to investigate these three-way interactions by analyzing the Dutch and English conditions separately.

3.1 Dutch

To further investigate the effects of CV combinations in coronal- and dorsal-initial familiar words, we next ran a 2 x 2 x 2 ANOVA for the children in the Dutch condition, with pronunciation (Correct, Mispronounced), word-type (Coronal-initial, Dorsal-initial) and CV-combination (Preferred, Non-Preferred) as within-subjects factors. This showed a marginally significant interaction between word-type and CV-combination ($F(1,30 = 3.8$, $p = .05$) and a marginally significant three-way interaction between pronunciation, word-type and CV-combination ($F(1,30 = 3.7$, $p = .05$). Figure 1 illustrates the difference scores (target fixations before versus after target word onset) for the Dutch condition.

Planned two-tailed *t*-tests were conducted, comparing the difference scores of the Dutch children (depicted in Figure 1) to chance, or 0. Word recognition is indicated by an increase in target fixations (significantly different from 0) after target word onset, compared to when the pictures were watched in silence. For the Dutch condition, there was a significant increase in target fixations on all CP trials (coronal-P: $t(15) = 2.3$, $p = .03$; coronal-NP: $t(15) = 3.3$, $p = .004$; dorsal-P: $t(15) = 2.7$, $p = .02$ and dorsal-NP: $t(15) = 2.4$, $p = .03$), and also significant increases on MP trials for coronal-P ($t(15) = 2.0$, $p = .05$), and dorsal-NP ($t(15) = 4.0$, $p = .001$). Increase in looking time was not significant on coronal-NP ($t(15) = 1.0$, $p = .31$) and dorsal-P MP trials $t(15) = -0.45$, $p = .65$), indicating that the target words were not significantly recognized in those two conditions.

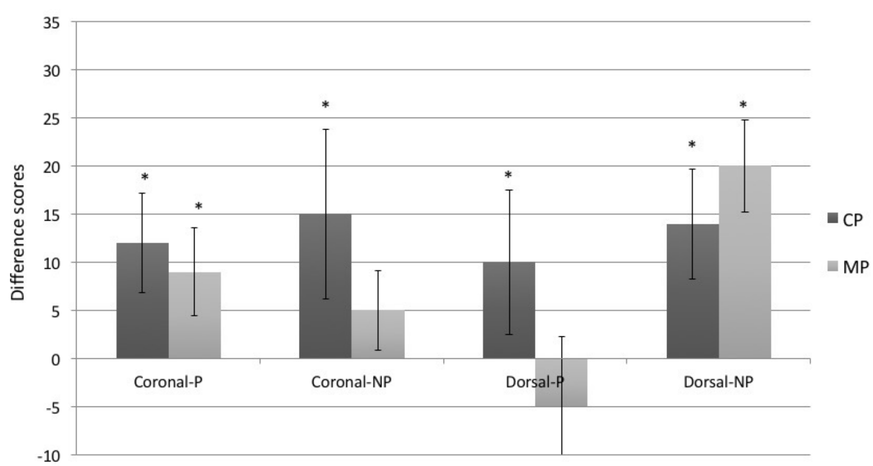

Figure 1 – Dutch Condition. Mean difference scores (target fixations, before versus after target word onset) and standard errors. Dark bars show correct pronunciations (CP), light bars place of articulation mispronunciations (MP), for the different word types (coronal-initial, dorsal-initial) and CV-combinations (Preferred (P), Non-Preferred (NP). Stars indicate significant differences from chance.

In sum, we do not find evidence for influence of (dis)preferred CV units in perception for Dutch. Results of the ANOVA and t-tests indicate that the Dutch children treated only changes in word-initial place of articulation of coronals and dorsals as mispronunciations when the word contained a back vowel. In other words, before front vowels, a mispronunciation of word-initial coronal and dorsal place of articulation does not hinder word recognition, possibly indicating a less-detailed representation of that word-initial consonant, which was true for both coronal- and dorsal-initial words. We will discuss possible reasons for this vowel influence in the General Discussion, and will argue that these results are compatible with previous phonological underspecification accounts (e.g. Fikkert, 2010).

3.2 English

For the children in the English condition, we also ran a 2 x 2 x 2 ANOVA with pronunciation (Correct, Mispronounced), word-type (Coronal-initial, Dorsal-initial) and CV-combination (Preferred, Non-Preferred) as within-subjects factors. There was a significant interaction between CV-combination and pronunciation (F(1,30 = 4.2, p = .04), and a marginally significant interaction between word type and pronunciation (F(1,30 = 3.7, p = .056). There were no significant main effects nor other significant interactions. This outcome indicates that children responded differently to the mispronunciations, depending on the CV-combination of the target words.

Planned two-tailed *t*-tests were also conducted for the English condition, comparing difference scores to 0 (see Figure 2 for a depiction of the difference scores). There was a significant increase in target fixations on all CP trials (coronal-P: $t(15) = 2.1$, $p = .05$; coronal-NP: $t(15) = 2.2$, $p = .04$; dorsal-P: $t(15) = 5.4$, $p < .0001$, and dorsal-NP: $t(15) = 3.1$, $p = .007$), and there were also significant increases on MP trials for coronal-NP ($t(15) = 3.9$, $p = .001$), and dorsal-NP ($t(15) = 3.2$, $p = .006$). Increase in looking time was not significant on coronal-P ($t(15) = 1.0$, $p = .32$) and dorsal-P MP trials $t(15) = 1.1$, $p = .27$), indicating the target words were not significantly recognized in those last two conditions.

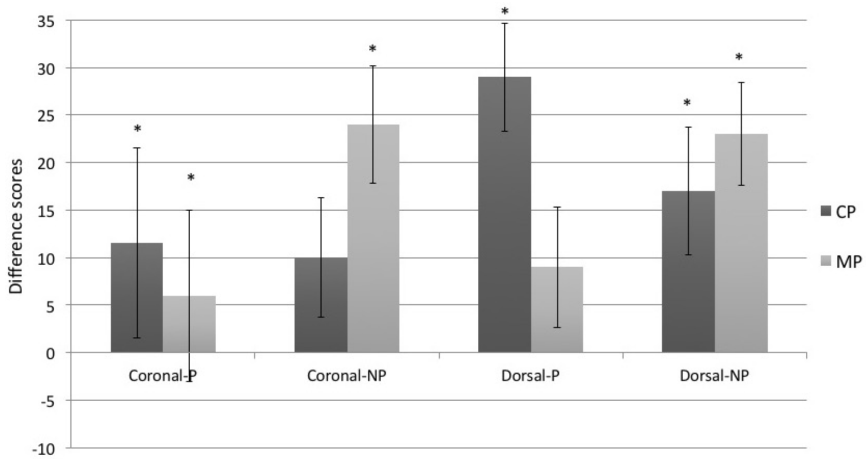

Figure 2 – English Condition. Mean difference scores (target fixations, before versus after target word onset) and standard errors. Dark bars show correct pronunciations (CP), light bars place of articulation mispronunciations (MP), for the different word types (coronal-initial, dorsal-initial) and CV-combinations (Preferred (P), Non-Preferred (NP). Stars indicate significant differences from chance.

The patterns of results we found in the English condition were different from the Dutch condition. The English-learning children reacted differently to the mispronunciations depending on the CV-combination of the target words. Word recognition was only hindered when place of articulation was mispronounced in coronal-initial words containing front vowels (Coronal-P) and in dorsal-initial words with back vowels (Dorsal-P), or in other words, only when preferred CV-combinations were changed to non-preferred combinations. This response pattern is consistent with children's speech production patterns in English (Davis et al., 2002). On words with a non-preferred CV structure, a mispronunciation of word-initial place of articulation did not hinder word recognition.

4. General Discussion

The current study sheds new light on the question of how patterns attested in speech production may be related to perception of early familiar words. We considered place of articulation in word-initial consonant-vowel combinations as a potential unit of perception during word recognition. We addressed this issue by investigating word recognition in Dutch- and English-learning children, languages we selected on the basis of different patterns attested for these language in early speech production (e.g. Davis et al., 2002). For both groups of children in our experiment, we found that the vowel in the word-initial CV-combination influences word recognition when the place of articulation of only the word-initial consonant is mispronounced. However, we also find different patterns for the two languages.

For the Dutch-learning children, mispronunciations of word-initial place of articulation hindered word recognition *only* before back vowels when the word-initial target consonant was either coronal or dorsal. Word recognition was not hindered by a place of articulation consonant mispronunciation on target words containing front vowels.[1] In contrast, the English-learning children detected word-initial consonant mispronunciations only on coronal- and dorsal-initial words with *preferred* consonant-vowel combinations, meaning words with coronal C + front V, and dorsal C + back V. Word recognition for the English-learning children was only hindered by a word-initial place of articulation mispronunciation when a preferred CV-combination was changed into a non-preferred combination (and not when a non-preferred CV-combination was changed to a preferred combination). These results provide evidence for potential CV 'units' in perception of early familiar words in English only. Patterns of response by the English children indicate a much more deeper-engrained influence of preferred CV-structure in English, where the CV co-occurence pattern is also retained in adult speakers production output (MacNeilage et al., 2000).

One interpretation of these results may be that in Dutch, consonants and vowels are specified at the individual segmental level earlier than in English. If this is the case, this may be related to the fact that Dutch has two types of front vowels: rounded and unrounded, but only one type of back vowel (rounded). This means that in Dutch, there is no clear 1:1 relationship between the vowel system and place of articulation, whereas there is in English. This may also explain the attested lack of the prevalent CV-co-occurrences in Dutch babbling and early words: even at the earliest stages of speech production patterns are influenced by the more complex vowel system in the input of Dutch-learning children. In addition, in contrast with English, preferred CV co-occurrences were not found in adult Dutch in a dictionary analyses of different languages (MacNeilage et al., 2000). The exact patterns of CV co-occurences in the input young Dutch- versus English-learning children receive is a matter we aim to address in future studies.

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[1] Note that although here we did not discuss the results of coronal- versus dorsal-initial words into great detail, our findings are in line with previous studies that have investigated perceptual asymmetries in the perception of place of articulation in early words (Altvater-Mackensen, Van der Feest & Fikkert, Fikkert 2010; Tsuji, Mazuka, Cristia & Fikkert, 2015; Van der Feest & Fikkert, 2015, among others). In that work, we showed that there are asymmetries with regard to the perception of labial versus coronal sounds: a place of articulation mispronounciation of a labial-initial target always hindered word recognition. A place of articulation mispronounciation of a coronal-initial target, however, does not seem to hinder recognition. If we consider all coronal target words in the current study together, we also find no significant mispronunciation effects on coronal-initial target words. There are very few previous studies in which dorsal PoA was manipulated. Dorsals are considered special as they are generally produced much later than labials and coronals (Tsuji et al., 2015).

In addition to investigating the role of early input more precisely, longitudinal analysis of perceptual responses to CV combinations will be of interest for future research. For example, even though consonants and vowels may be represented separately earlier in Dutch, as we hypothesized above, it has also been argued that at earlier stages in development Dutch-learning children may have only one PoA represented per word: Dutch-learning 14-month-olds responded differently to a change in place of articulation in the name of a novel object depending on the vowel in that novel name (i.e. Fikkert (2010) showed they responded differently to changes between 'bon-'don' than to changes in 'bin'-'din').

However, even though we did not find evidence in the current experiment for influence of the CV unit in perception in the Dutch children, we did see influence from the vowel following the word-initial consonant: We found that word recognition in the Dutch condition was hindered only on words containing back vowels. On word-initial stops before front vowels, Dutch children seem to ignore the difference between coronal and dorsal stops. This finding is in line with theories that initially, words may be represented with one place of articulation, driven by the vowel. (Fikkert & Levelt, 2008; Menn, 1978). We found that word recognition was not hindered by place of articulation mispronunciations when the vowel following the word-initial consonant was front and unrounded (so-called "coronal vowels"), which have been argued to be underspecified for place of articulation (the word would in that case be specified as having a "neutral" place of articulation, e.g. Van der Feest & Fikkert, 2015; Lahiri & Reetz, 2002).

The results from the Dutch condition are also in line with phonetic accounts: before front vowels, coronals and dorsals are produced more similarly (i.e. a dorsal in front of a front vowel becomes more palatized, and thus more 'coronal-like', Ohalla, 1971). Therefore, the difference between dorsal and coronal may be more apparent in words containing back vowels. In the history of English, many dorsals have changed to become palatal consonants (compare for instance the English words *cheese*, *church* to the Dutch word *kaas*, *kerk* (Prokosch, 1939/2009), words which have shared origins). The existence of palatal consonants in English but not in Dutch may have rendered the contrast more salient in English than in Dutch.

To summarize, our results indicate that in both English and Dutch children's perceptual responses, the following vowel influences word recognition when the word-initial consonant of a familiar word is altered. In English, we found influence from the word-initial Consonant-Vowel combination, whereas in Dutch we found influence from the place of articulation of the following vowel (irrespectively of whether the word-initial consonant was coronal or dorsal). The findings from the English children may actually be considered more surprising than the findings from the Dutch condition, since we found such a strong effect of CV-combinations in perception. However, the items we chose in the experiment were based on patterns found in early speech production, and the results from the English children in particular indicate strong links between the perception of sounds in early words and attested preferred sound patterns in very early speech production. Future studies into the exact nature and extent of these links will provide more insight into the nature of early representations of sounds in words. It should be noted that these perception-production asymmetries might be important to take into consideration in chronologically older children who need clinical support to achieve age appropriate developmental speech patterns. Choices of clinical stimuli should ideally balance perceptual capacities reflected responses to in the input language as well as in production patterns observed early in acquisition of the child's ambient language sound system.

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