Universal Constraints on the Discrimination of Place of Articulation? Asymmetries in the Discrimination of 'paan' and 'taan' by 6-month-old Dutch Infants

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In the course of their first year of life, babies are claimed to change from universal listeners into language-specific ones: Around the age of eight to ten months they start perceiving consonantal contrasts language-specifically (e.g. Werker & Tees, 1984; Kuhl, 2004). Our study investigates whether six-month-old Dutch infants discriminate differences in Place of Articulation in the novel word form *paan* (labial-initial) when produced as *taan* (coronal-initial), and vice versa. The received opinion in the literature on infant speech perception is that six-month-olds are able to discriminate *paan* from *taan* as well as *taan* from *paan*. Generative linguistic theories, by contrast, predict an asymmetry between labial and coronal stops, based on the assumption that coronals are unmarked, and hence may remain unspecified. The change from *paan* to *taan* – i.e. from marked to unmarked – is noticed, but the reverse (from unmarked to marked) is not. To test this, we used a recently developed procedure; the Hybrid Visual Habituation Procedure (Houston, Horn, Qi, Ting & Gao, 2007). We tested 24 six-month-old Dutch infants. Our results show an asymmetry in perception: The difference between average looking times of infants who were habituated on *paan* and those who were habituated on *taan* is significant for the alternating trials, during which the *paan*-infants showed longer average looking times than the *taan*-infants. This difference was not found for the non-alternating trials, during which the average looking times of the *paan*-infants were shorter than those of the *taan*-infants.

1. Introduction

Children's first year of life seems to be crucial for the acquisition of linguistic skills in later years (Tsao, Liu & Kuhl, 2004; Molfese & Molfese, 1985; 1997). In the infant speech perception literature it is generally assumed that before eight to ten months of age, infants are able to discriminate most if

not all consonantal contrasts used in the languages of the world. They start out as what Kuhl called 'universal listeners' and (only) start paying more attention to contrasts that are exploited in their mother tongue in the second half of the first year (Werker & Yeung, 2005; Kuhl, 2004). There are already numerous studies on this topic, but not all studies have controlled for possible asymmetries: Many studies report on discrimination from marked to unmarked, e.g. 'ba' to 'pa' or from 'ba' to 'da', but they have not always tested (or reported) the reverse direction. Furthermore, speech perception data show rather intriguing results. For example, while eight- and fourteen-month-old infants perform quite well at discriminating certain phonological contrasts of meaningless words ('bih' vs. 'dih'), they are not able to distinguish the same contrasts when learning meaningful words (Stager & Werker, 1997). As discrimination was no problem for eight- and fourteen-month-old infants, our a priori expectation was that the six-month-old infants in our study would also be able to discriminate word forms with differences in Place of Articulation, as in the novel word form *paan* (with a word-initial labial stop) versus *taan* (with a word-initial coronal). Both *paan* and *taan* are pseudo-words, but the contrast is functional in Dutch words, as shown by the minimal pair 'pak' and 'tak' ('packet' and 'branch').

From a generative linguistic point of view, markedness is expected to influence the acquisition of Place of Articulation features. An old argument for the marked status of labials is based on early word production. Jakobson (1941/1968) claimed that the first contrast to be acquired is between (marked) labial and (unmarked) non-labial stops. In the book *The special status of Coronals* (edited by Paradis and Prunet, 1991) various arguments for the unmarked status of coronals are given for different phenomena, languages and language users, including children (Stemberger & Stoel-Gammon, 1991). Recently, De Lacy (2006), Rice (2007) and Dresher (2009) have argued for a markedness hierarchy in which labial is more marked than coronal, the latter being the least marked Place of Articulation. Markedness is often reflected in asymmetrical patterns of phonological behavior (Dresher, 2009). Asymmetries have also been found in acquisition, for example, in the mispronunciation detection tasks by fourteen- and seventeen-month-olds testing children's recognition of newly learned words (Fikkert, 2010) and in the recognition of well-known words (Van der Feest, 2007; Van der Feest & Fikkert, under review), where a change from labial to coronal is noticed, but a change from coronal to labial is not. These researchers argued that labial stops are specified with a marked feature [labial] in the mental phonological representations of words, whereas coronal stops remain unspecified. In pure discrimination tasks children are able to discriminate labial and coronal stops (Stager & Werker, 1997; Fikkert, 2010), hence infants are able to perceive the contrast in the acoustic signal; yet, they do not use these details for word recognition.[1]

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[1] There are various explanations for the discrepancy that infants discriminate the same sounds in a discrimination task but not in a word recognition task: some claim that this is

Researchers have accounted for asymmetries by assuming underspecification in phonological representations, in which unmarked feature specifications are not represented, but marked features are. If representations are underspecified, perceived features in the acoustic signal can never mismatch with features that are not represented: i.e. a perceived labial will not mismatch a coronal (whose unmarked Place of Articulation feature is not specified in the lexical representation), and hence both a perceived labial and a perceived coronal are 'good enough' matches to the stored representation. The reverse is not true: a perceived coronal feature in the signal mismatches the stored features labial for labial-initial words. Hence, *taan* is not a good enough match for *paan* and the difference is noticed. However, the question is: When do children start building phonological representations? Can phonological representations exist without a link to meaning representations?

Our study aimed to investigate the origin of Place of Articulation asymmetries: Are they the result of learning based on the language input, or are they due to universal markedness constraints, and hence 'free', in the sense that no learning is involved? In case of universal markedness constraints, we may expect markedness to influence very early speech perception (Jusczyk, Smolensky & Allocco, 2002): i.e. before children learn to listen to language with a bias towards the native language consonant inventory. As mentioned above, children start to be less sensitive to non-native consonantal contrasts from about eight months old (Werker & Tees, 1984; 1999). Therefore, we wanted to test children of a younger age, when they are assumed to be 'universal listeners'.

If universal markedness constraints play a role and influence early perception, the hypothesis would be that an asymmetry in perception would occur: a change from (marked) *paan* to (unmarked) *taan* will be easier to detect, than a change from unmarked *taan* to marked *paan*. If, however, children are able to perceive any contrast used in the world's languages, and speech perception is still 'universal', i.e., no learning of language specific contrasts of Place of Articulation has taken place yet, we expect them to be able to discriminate both *paan* from *taan* and vice versa.

Recently, Nazzi, Bertoncini & Bijeljac-Babic (2009) reported a perceptual labial-coronal effect emerging between six and ten months of age using a head-turn-preference procedure: while the six-month-olds showed no preference, the ten-month-old French babies preferred to listen to forms in which a labial stop precedes a coronal stop (PT) over coronal-labial forms (TP), ignoring intervening vowels. They account for this finding in terms of frequency: in French, labial-coronal words have a higher frequency compared to coronal-labial words. The ten-month-olds are sensitive to this distributional information;

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due to task demands (e.g. Werker, Fennell, Corcoran & Stager, 2002); others argue that this is due to the fact that words are stored with abstract phonological representations (Fikkert, 2010). This discussion is not immediately relevant for our study, although we will return to this issue when discussing the implications of our data.

however, the six-month-olds are not (yet) sensitive to language-specific word patterns. This study shows a preference for labial-coronal versus coronal-labial in ten-month-olds, implying that they are able to perceive the difference. However, the fact that six-month-olds do not have a preference, does not tell us whether they are able to discriminate the two types of words.

To test the perception of consonantal contrasts in six-month-old infants, a switch-task is often used: Infants are habituated to one member of the contrasting pair (for example *bin*), while in the test phase the looking times to the same form as played in the habituation phase (*bin*) is compared to the contrasting member, i.e., the switch condition (*din*). If children notice the switch, they will dishabituate, and look longer to *din* (switch) than to *bin* (same). Although the experiment is simple and straightforward, disadvantages of this task are the high dropout rate and the fact that only very limited data are measured for each participant; hence only group results are obtained. We therefore decided to use the recently developed Hybrid Visual Habituation Procedure (HVHP; Houston et al., 2007). It is a combination of the traditional same/switch procedure (Best, McRoberts & Sithole, 1988; Polka & Werker, 1994); the oddity paradigm (Picton, Alain, Otten, Ritter & Achim, 2000), in which subjects are frequently presented with a 'standard' stimulus and infrequently to a 'deviant' stimulus; and the stimulus alternation preference procedure (Best & Jones, 1998), in which infants for example are familiarized with 'pah' repetitions and tested with two trials of 'pah-bah' alternations and two trials of 'pah' repetitions. According to Houston and colleagues, the HVHP is a robust methodology for assessing discrimination in individual infants and obtaining more measuring points. The dependent variable is the infant's looking time to the screen during the test phase.

To summarize, based on the standard infant speech perception literature infants in the prelinguistic stage of language development, i.e. before eight months of age, are predicted to show symmetrical looking behavior: we expect them to notice a shift from labial to coronal and vice versa. An account based on universal markedness of Place of Articulation features predicts an asymmetrical looking behavior, where the change from labial to coronal is noticed, but not vice versa. Our interest is in answering the question: What will six-month-olds do? As part of a longitudinal study on the development of early perception and production, we carried out an experiment investigating whether six-month-old Dutch infants discriminate minimally different non-words starting with a labial stop and words starting with a coronal stop.

2. Method
2.1. Participants

Twenty-four six-month-old infants from Dutch-speaking families were recruited from the subject pool of the Baby Research Centre in Nijmegen and tested individually. The data of twenty of these children were included in the analyses (mean age = 6;16 months; range: 6;01-7.03; 8 girls, 12 boys). The data

of the four additional infants were not included, due to problems with the video recording (1), crying (1) or no habituation (2). All infants passed a newborn hearing screening and had no history of recurrent acute or chronic middle-ear infections.

2.2. Stimuli

The visual stimulus consisted of a dynamic checkerboard pattern presented full screen on a 192 cm diagonal Sony LCD Projection Data Monitor. The visual stimulus was combined with auditory stimuli (described below) into a movie. The movie was played of a digital video player. The auditory stimuli were made up of two non-words: *paan* and *taan*. Audio recordings of these tokens were made in a sound-proof booth. A female native speaker of Dutch recorded several tokens of these two non-words in infant-directed speech. Each trial consisted of thirty tokens and, including pauses between the tokens, the duration per trial was 54 seconds. For the habituation phase seven tokens of *paan* or seven tokens of *taan* were used. For the test phase the same tokens as during the habituation phase were used, as well as seven new tokens of *paan* and *taan*. The test trials consisted of either alternating (*paan-taan-paan* etc., or *taan-paan-taan* etc.), or non-alternating sequences (*paan-paan-paan* etc., or *taan-taan-taan* etc.). The *paan* and *taan* tokens were controlled for duration and intonation.

2.3. Procedure and apparatus

After an informal play session during which the procedure was explained to the parent, children were seated on their parent's lap facing the screen. The experiment took place in a sound-insulated room, in a three-sided enclosure which was 2m tall, 1.3m wide and 1.2m deep. The parent and child sat on the open end of this enclosure. The speech stimuli were played over the television's speakers. Children were videotaped onto a DV cassette (using a Sony DV cassette recorder SR-40P), with a digital video camera (Sony CVX-V18NSP). The camera was placed 30cm below the screen, hidden by a black curtain with an opening for the lens. The spotlights in the room were dimmed to a preset criterion. Parents were instructed not to speak or interact with their child during the experiment, and wore Sennheiser Noisegard headphones during the entire experiment. The parents heard music mixed with random sentences (that were taken from unrelated experiments) over the headphones, so that they were unable to hear the sound of the movie and could not hear at what moment the child was presented with auditory stimuli.

The dependent variable in this experiment was the infant's looking time at the screen during the test trials. To catch the infant's attention, an attention getter (a flashing light) started playing on the screen. As soon as the baby looked to the screen, the next trial started playing. The experiment was infant-controlled: if the infant looked away for more than two seconds, the current trial stopped and the attention getter started playing again.

The experiment started with a habituation phase, followed by the test phase. During the habituation and test trials, a dynamic checkerboard was presented on the screen. In the habituation phase, the infant was auditorily habituated on either *paan* or *taan*. Once the infant reached the habituation criterion, the test phase began. This criterion was defined as a decrease in looking time to less than 65% of the average looking time in the last three trials compared to the preceding three trials. The habituation phase had a maximum length of twelve trials. In the test phase the infant was presented with a total of twelve test trials: four alternating trials (e.g. *paan-taan* sequences, when habituated on *paan*) and eight non-alternating trials (e.g. *paan-paan* sequences, when habituated on *paan*). The order of the test trials was randomized per condition. The participating infants were randomly assigned to one of the four conditions (five infants per condition). The conditions differed in type of habituation (*paan* versus *taan*) and test order (first test trial alternating versus non-alternating) (see Table 1). Immediately before and after the experiment, the infant was presented with respectively a pretest and posttest. In these trials the infant heard the non-word [ni:m] and saw a moving water wheel. Looking times in the pre- and posttest trials were used to determine the arousal and attention of the infant during the experiment.

The experiment was run on a Macintosh G3 desktop computer using the Habit software (Cohen, Atkinson & Chaput, 2000). The experimenter was blind to which audio stimulus was being presented as she was wearing headphones and hearing music intermixed with speech. She observed the infant via a hidden digital camera and controlled the experiment pressing a key whenever the infant looked at the screen (online coding). After the experiments had been carried out, the infants' looking times were also coded offline using SuperCoder (Hollich, 2003). These offline measurements were used for statistical analysis.

Table 1. Overview of different conditions during the experiment

Condition	1	2	3	4
Habituation	*paan*	*paan*	*taan*	*taan*
1st test trial	alternating (*paan-taan*)	non-altern. (*paan-paan*)	alternating (*taan-paan*)	non-altern. (*taan-taan*)
2nd test trial	non-altern. (*paan-paan*)	alternating (*paan-taan*)	non-altern. (*taan-taan*)	alternating (*taan-paan*)

3. Results

To analyze the data, average looking times were calculated for the alternating and non-alternating trials, per condition (1, 2, 3, 4) and type of habituation (*paan-taan*). A repeated-measures ANOVA showed no main effects for test trial or condition, which means there was no overall difference in looking times between the alternating versus the non-alternating trials. However, we found a significant interaction between type of habituation (*paan* versus *taan*) and test trial (alternating versus non-alternating) ($F(1, 19) = 7.936$; p =

.011; see Figure 1). The difference between average looking times of infants who were habituated on *paan* and those who were habituated on *taan* is significant for the alternating trials (t(18) = 2.163, p = .044; see * in Figure 1), during which the *paan*-infants showed longer average looking times (10.16 sec.) than the *taan*-infants (5.81 sec.), but this difference is not significant for the non-alternating (same) trials (t(18) = -.229, p = .822), during which the average looking times of the *paan*-infants were shorter (6.81 sec.) than those of the *taan*-infants (7.32 sec.). Furthermore we compared the infants' looking times during the pre- and posttest and found no significant difference.
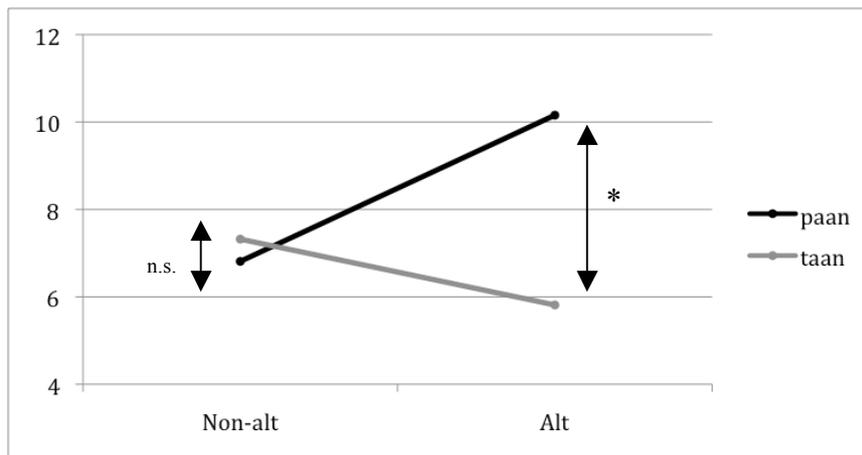

Figure 1. Interaction between habituation (*paan* versus *taan*) and test trial (non-alternating versus alternating trials). On the y-axis the average looking times in seconds are plotted. (*p <.05)

4. Discussion

There are several possible interpretations for the attested asymmetry. Firstly, the asymmetry between coronal- and labial-initial word forms could be due to frequency, suggesting a learning effect. On the other hand, the effect may be due to universal markedness, and hence is not a learning effect. Markedness can be grounded in phonetics (Hayes & Steriade, 2004), i.e. either in the perceptual system or the articulation system, or both. Infants may have a general preference for coronals. Or infants' perception could be influenced by their productions, i.e. early babbling patterns.

Frequency effect?

It might be the case that the asymmetry is caused by frequency. The standard view seems to be that frequent sounds are easier to discriminate than infrequent sounds, as for frequent sounds infants have formed a clear sound category. However, frequency can be defined in several ways: the overall token

or type frequency of a sound in the language, or the token or type frequency of a sound in word-initial position. There is strong evidence that there is little generalization over positions in early infancy: Zamuner (2006) showed that whereas 9-month-old infants are able to discriminate labial and dorsal stops in word-initial position, they fail to do so in word-final position. Therefore, we will only consider frequency in word-initial position. Whether infants generalize over sounds with the same Place of Articulation feature is an unanswered question, hence we report both the frequency of initial /p/ vs. /t/, and initial labials vs. coronals. It could also be that children store word patterns and hence we also compared labial-coronal (*paan*) word patterns to coronal-coronal (*taan*) (cf. Nazzi et al., 2009)

Based on an analysis of the Van de Weijer (1998) corpus, the only corpus of infant-directed input in Dutch, the following facts can be reported (Fikkert, Levelt & Van de Weijer, ms.). First, if we consider general token frequency measured over all word-initial consonants containing coronal and labial sounds (hence, generalized over different Manners of Articulation and voicing characteristics), the coronal Place of Articulation is more frequent than labial (36 vs. 25%). If we compare word-initial coronal stops with word-initial labial stops the difference become larger: 59% coronals vs. 18% labials. This includes function words, like demonstratives such as *deze* 'this' and *dat* 'that'. Based on a token count of word-initial /t/ and /p/, /t/ is more frequent than /p/ (t: 3482; p: 2033), but based on types the difference disappears (t: 223; p: 224). Finally, if one looks at frequency of word types, labial-coronal words are about as frequent as coronal-coronal words (20 vs. 23%). In brief, these data show that coronals may be slightly more frequent in word-initial position than labials based on token frequencies. In a type frequency count the differences are smaller. Although the evidence for a major role of frequency is rather weak, it seems that if frequency does play a role, coronals are more frequent, and hence, are expected to be easier to discriminate than labials. This, however, is not congruent with the attested asymmetry.

An alternative view may be that frequent sounds allow more variation, which leads to less detail in the representation of those sounds, which therefore are more difficult to discriminate. Anderson, Morgan and White (2003) found that 8.5-month-olds were worse in their performance in a discrimination task on the more frequent vs. the less frequent stop contrasts. However, they found no difference for the 6.5-month-olds. If the more frequent stops are more difficult to discriminate than the less frequent stops, labials should be easier to discriminate than coronals. This view would be compatible with the attested asymmetry, but seems neither compatible with the finding of Anderson et al. (their 6.5-month-old do not show a difference in discrimination) nor with the standard view on early infant perception, which assumes that frequency is beneficial for the establishment (and subsequent discrimination) of a sound category.

Universal markedness?

Our results show an asymmetry that is not compatible with the standard view on infant speech perception, according to which infants are considered to still be 'universal listeners'. However, the asymmetry found in this study is predicted under a linguistic view that assumes universal markedness constraints of Place of Articulation features: infants notice a change if they have established a representation for a marked form, i.e. the labial-initial form *paan*, and thus the change is one from (marked) labial to (unmarked) coronal, but not the other way around. This suggests that coronal and labial play a different role in the sound system from very early on, i.e. possibly before the children listen language-specifically to the consonantal system becomes language-specific.

The attested asymmetry has also been found in earlier work on word learning and in word recognition in older children (Van der Feest, 2007; Fikkert, 2010), as mentioned above. However, these asymmetries have been explained in terms of the nature of early phonological representations in the mental lexicon and would have been expected at the earliest around ten months of age when children start learning words. Asymmetries have not been reported for discrimination studies with young infants, where results show that the younger the infant, the better (, rather than worse,) their discrimination ability (Stager & Werker, 1997).

The asymmetry found in six-month old infants raises a number of questions: When do children start building abstract phonological representations? Is discrimination driven by universal markedness constraints or are these constraints learned? It is possible that the learning of consonantal contrasts takes place earlier than previously assumed? If so, what drives learning if it is not frequency?

Preference for labial-initial words?

As was mentioned in the introduction, Nazzi and colleagues (2009) found a perceptual labial-coronal bias over coronal-labial forms for ten-month-olds, but not for six-month-olds. Their study tested whether infants had a preference for labial-coronal words, not whether they were able to discriminate labials and coronals. Although our experiment was not set up to test infants' preference, it nevertheless may be the case that if the infants in our study had a preference for either labial-coronal words or coronal-coronal words, this preference may be seen in the difference between the number of the habituation trials, or the looking time during habituation, in the *paan* vs. *taan* conditions. Therefore we looked at the average habituation times and number of trials per habituation: *paan* versus *taan*. The looking time and number of habituation trials in the habituation phase did not differ significantly for infants who were habituated with *paan* and infants who were habituated with *taan*: i.e. the number of habituation trials were 6.3 for *paan* versus 6.5 respectively for *taan* (n.s.) and the habituation time was 122.9 seconds for *paan* versus 127.2 seconds for *taan* (n.s.). Hence, from our experiment there is no evidence for a bias towards a

particular word form. To exclude the possibility of the asymmetry being caused by a preference for coronals, a preference experiment could be conducted.

Coronal preference?

Although the attested asymmetry could be explained by abstract underspecified lexical representations, it is also compatible with the view that there simply is a preference for coronals. Although we are not aware of a general bias towards coronals in perception, a possible explanation for such a bias could come from infants' early monosyllabic babbles, in which coronals are claimed to occur more frequently than labials (Locke, 1983). The six-month-olds we tested were in or around their babbling stage. For this reason they might have preferred coronals over labials in their production, and therefore have this preference in perception as well. This would be in line with our results of which could be argued that the infants show a preference for coronals.

Other data, however, show that infants start their babbling phase by producing consonant-vowel sequences mostly with labials (De Boysson-Bardies, 1999) and that disyllabic labial-to-coronal sequences are about 2.5 times more often used than coronal-to-labial ones (MacNeilage & Davis, 2000; Locke, 1983). Also when children start uttering their first words, they particularly often produce labial-initial words (De Boysson-Bardies, 1993, Fikkert & Levelt, 2008). MacNeilage and Davis (2000) report an intersyllabic preference for initiating words with a labial consonant followed by a vowel-coronal consonant sequence (LC), and similar results have been reported for Dutch (Fikkert & Levelt, 2009). Given the findings of Nazzi et al. (2009), showing an early preference for labials in perception and the preference for labial-initial early words, we would have expected a labial, rather than a coronal bias. However, that is not what we found. Our results clearly show that Dutch six-month-olds discriminate a change from labial to coronal, i.e. they seem to have a clearly marked labial stop, but not from coronal to labial, suggesting that the coronal stop is less well defined. This state of affairs is covered by our use of the term underspecification.

5. Conclusion

To conclude, our results clearly show that coronals are treated differently from labials and show an early asymmetry in speech discrimination. This could not easily be explained as a frequency effect, as the frequency differences are not substantial. Moreover, it would mean that high frequency sounds are less well discriminable, which is not compatible with the standard view. We also excluded an account based on a general perception preference for coronal: that explanation is not highly probable, as looking times to *taan* and *paan* did not differ in the habituation phase of the experiment. This also suggests that the six-month-old infants do not have a general preference for a certain word pattern at the age of six months (e.g. Nazzi et al., 2009).

Two possibilities remain to be explored: (a) the asymmetry could be due to innate constraints, which is a claim that is hard to test, or (b) the asymmetry could be based on early production patterns. There is some evidence that babbles and early words are frequently labial-initial. Therefore our future work will focus on early development in both production and perception. To understand the early asymmetry, a longitudinal study will be conducted in which infants will be tested at five, ten and fifteen months of age to track development in both production and perception.

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