Language Acquisition

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hlac20

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Published online: 18 Jun 2013.

To cite this article: Tania S. Zamuner (2013) Perceptual Evidence for Young Children's Developing Knowledge of Phonotactic Probabilities, Language Acquisition, 20:3, 241-253, DOI: 10.1080/10489223.2013.796951

To link to this article: http://dx.doi.org/10.1080/10489223.2013.796951

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Perceptual Evidence for Young Children’s Developing Knowledge of Phonotactic Probabilities

Tania S. Zamuner
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Phonotactic probabilities and children’s speech production have been investigated widely, in both children with typical language development and children with phonological delay. Research has also documented infants’ sensitivities to phonotactic probabilities in infant speech perception, using methodologies that measure infants’ listening preferences. However, few studies have examined phonotactic probabilities in speech perception past the first year of life with children who are already producing language. Two-year-old Dutch-learning children were tested on their ability to perceive segmental contrasts in nonwords composed of high and low phonotactic probabilities, controlled for word-onset and word-offset position. Analogous to previous results from production, results from perception indicated that segmental contrasts that were presented in high phonotactic probability environments were perceived more accurately than the same contrasts presented in low phonotactic probability environments. Children did not show differential perception of contrasts based on word position. The implications of the findings are discussed with respect to frequency-based effects in phonological acquisition.

1. INTRODUCTION

Many studies have investigated the acquisition of phonotactic knowledge. Despite the recurring observation that phonotactic probabilities have an influence on the accuracy of children’s speech production, few studies have examined phonotactic probabilities in children’s speech perception beyond infancy. This study investigates whether parallel to the production findings, young children are better at perceiving segmental contrasts that occur in high phonotactic probability environments, compared to the same segmental contrasts presented in low phonotactic probability environments, controlled for word-onset and word-offset position. An effect of phonotactic probabilities in early speech perception would demonstrate a progression from frequency-based sensitivities seen in infant speech perception as measured by infants’ listening preferences to children’s later perception skills in a task that implicates lexical representations. Given that young children are already producing language, this would support the hypothesis that a perceptual learning mechanism partly forms the foundation for frequency-based effects in children’s production accuracy.

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Starting in infancy, studies have investigated the development of phonotactic knowledge. Phonotactics refers to the legal sequencing of sounds in a language (Hill 1958). For example, words in English may not begin with /ŋ/, but this sound does occur word finally, as in tongue. The restriction against /ŋ/ in word-initial position is not universal, however, as other languages permit /ŋ/ to occur in word-initial position. Infant studies have looked at a range of phenomena in the development of phonotactic knowledge (Friederici & Wessels 1993; Jusczyk, Friederici, Wessels, Svenkerud & Jusczyk 1993; Sebastián-Gallés & Bosch 2002) and the learnability of phonotactic patterns (Chambers, Onishi & Fisher 2003; Seidl & Buckley 2005). Infants in these studies have ranged from 4 months to 16.5 months, with the majority of studies focusing on infants between 9 to 11 months of age. A very small subset of studies has looked at infants’ knowledge of phonotactic probabilities, which emerges around 9 months of age (Jusczyk, Luce & Charles-Luce 1994) and the role of phonotactic probabilities in word segmentation (Mattys & Jusczyk 2001). Also see work by Hay, Pelucchi, Graf Estes & Saffran (2011), which found that 17-month-old infants were better at learning new word-object associations when infants were first familiarized to passages in which the labels occurred as sequences with high statistical coherence. Phonotactic probabilities refers to the statistical likelihood that a sound or sequence of sounds will occur in a given environment. An example of a high phonotactic probability nonword is /kis/ and a low phonotactic probability nonword is /zidz/ (taken from Jusczyk et al. 1994:642). While these nonwords both contain English phonemes, there is a greater likelihood that a word of English will begin with /k/ than /z/ or that the sequence /ki/ will be found in this position than /zi/. In Jusczyk et al. (1994), English-learning 9-month-old infants but not 6-month-olds displayed a listening preference for lists of nonwords composed of high-phonotactic probabilities over low-phonotactic probabilities. Note that the methodology in Jusczyk et al. (1994) measured infants’ listening preferences for nonwords, where there were no external referents; thus, one cannot be sure of the lexical status of these nonwords to the learners. In sum, studies on the acquisition of phonotactics show that within the first year, infants have some knowledge of the patterns of sounds in the ambient language. What learning strategy or mechanism can account for these findings has yet to be determined; infants may be acquiring specific knowledge about the frequency of sounds patterns in a given language, or they may be acquiring more abstract phonotactic knowledge that can be characterized as patterns abstracted across the learner’s lexicons.

Beyond demonstrating infants’ listening preferences to different phonotactic patterns, research has also looked at the role of phonotactics in lexical acquisition. Recently, Graf Estes, Edwards & Saffran (2011) showed that at 18 months, infants learning English can learn nonwords that conform to English phonotactics (dref, sloob), but do not learn nonwords with illegal phonotactic patterns (dlef, sroob). Similarly, MacKenzie, Curtin & Graham (2012) found that English-learning 12-month-olds map novel labels to objects when the labels conform to English phonotactics, but not if the labels violate English phonotactic patterns. Again, only a few studies have specifically controlled phonotactic probabilities when examining lexical acquisition. For example, MacRoy-Higgins, Schwartz, Shafer & Marton (2013) tested 2-year-old children on their phonological representations for trained nonwords that were controlled for either high or low phonotactic probabilities, using a preferential looking task (a subset of the research is reviewed here). MacRoy-Higgins et al. (2013) found significantly different looking times between correctly produced, trained high phonotactic probability nonwords compared to mispronunciations (e.g., /red/ mispronounced as /red/ and /k-v/ mispronounced as /p-v/). There were no significantly different looking times between correctly produced and mispronunciations on trained
low phonotactic probability nonwords (e.g., /zetf/ mispronounced as /detf/ and /giq/ mispronounced as /dig/). Note that the mispronunciations that occurred in the different phonotactic probability environments were not the same. Thus, while it is possible that the effects were driven by the phonotactic probabilities of the stimuli, the findings may also have been driven by other factors, such as the acoustic saliency of the different feature contrasts in the high versus low phonotactic probability environments. In the current study, the same segmental contrasts were embedded in different phonotactic probability environments, which provide a more controlled examination of phonotactic probabilities and perception. Other key research is work by Storkel (2001), who looked at how children (aged 3;2 to 6;3, mean age 4;6) integrate phonological and semantic information in newly formed lexical representations. Using a three-alternative forced-choice task, Storkel found that children learning English were better at learning the associations between novel referents and high phonotactic probability nonwords (/wæt/) than the associations between novel referents and low phonotactic probability nonwords (/gim/). These studies provide the first evidence for learners’ sensitivities to phonotactic probabilities in lexical acquisition.

In production, many studies have documented that children starting at age two exhibit greater production accuracy for high phonotactic probability nonwords compared to low phonotactic probability nonwords (Coady & Aslin 2004; Coady & Evans 2008; Messer, Lessman, Boom & Mayo 2010; Munson, Edwards & Beckman 2005; Zamuner 2009; though see Sosa & Stoel-Gammon 2012 for a study looking at variability in the production of real words). This finding has been argued to stem from phonological and lexical representations, phonological working memory, speech perception, motor planning, and/or articulation (Coady & Evans 2008). Two potential learning mechanisms that may drive this production effect have recently been discussed: perceptual learning and articulatory practice (Plante, Bahl, Vance & Gerken 2011; Richtsmeier, Gerken, Goffman & Hogan 2009). These accounts are rooted in the learner’s input and output frequency. Frequent patterns are heard more often and produced more often by children, and these perception- or production-based experiences are reflected in learners’ language representations as more robust acoustic-auditory and/or articulatory motor representations. To control for confounding effects of input frequency and articulatory practice, Richtsmeier et al. (2009) and Plante et al. (2011) experimentally manipulated the amount of children’s exposure to nonwords with low and high phonotactic probabilities. They found that English-learning four-year-old children were better at producing nonwords with high phonotactic probabilities; moreover, that children were also better at producing nonwords that were more frequently presented during an initial familiarization phase. These findings support the hypothesis that perceptual learning mechanisms at least partly drive the production effect.

While frequency-based differences in perception have been noted in infancy (e.g., Jusczyk et al. 1994), few studies have documented frequency-based differences in perception with young children who have begun to produce language. An investigation of this later group is important because “it is possible that infant sensitivity to what is frequent in their input has little to do with the production effects seen in older children, for whom greater experience with language might support alternative learning strategies” (Plante et al. 2011:92). For example, as mentioned, Jusczyk et al.’s 1994 infant study does not necessarily implicate lexical representations. Despite the recurring observation that children’s productions show effects of phonotactic probabilities, studies have not examined children’s perception abilities in different phonotactic probability environments. While most production studies assume that children’s perception is accurate, research
also shows that children’s perception is not entirely adult-like (Nittooru & Studdert-Kennedy 1987; Slawinski & Fitzgerald 1998). For example, young children rely on different acoustic cues for consonant and vowel discrimination, and young children may not have as detailed representations (see review in Walley 2005). (Literature also suggests that early lexical representations may be overspecified or detailed, e.g. Houston & Jusczyk 2000; Singh, Morgan & White 2004). Another aim of the current study, therefore, was to investigate frequency-based differences in perception abilities in children who are beginning to produce language. Crucially, children in the current study are at an age at which frequency effects in production have been documented (Coady & Evans 2008).

The last goal of the research was to investigate frequency-based differences in children’s abilities to perceive segmental contrasts in different word positions: word-initial versus word-final position. Positional differences in learners’ perception and production development are motivated by a variety of factors. The universally unmarked syllable shape is CV, such that all languages permit segments in word-initial (onset) position, whereas some languages do not permit segments in word-final (coda) position (Blevins 1995; Clements & Keyser 1983; Greenberg 1978). From these cross-linguistic patterns, universal grammar theories of phonology such as Optimality Theory, predict that word-initial segments would be acquired before word-final segments, as children initially produce unmarked structures before producing marked structures (Levelt, Schiller & Levent 2000). Position-based differences may also emerge from children’s phonological and lexical representations. For example, in models that allows for exemplar-based representations such as the PRIMIR model (Processing Rich Information from Multidimensional Interactive Representations; Werker & Curtin 2005), context-sensitive or position-based representations for segments in word-initial versus word-final position could have an influence in children’s perceptual abilities. If representations are richer or more developed in word-initial position, children should be better able to perceive segmental contrasts in word-initial versus word-final position. More lexical contrasts are also made in word-initial position compared to word-final position in English, French, German, and Dutch (Ziegler & Goswami 2005); moreover, segments in word-initial position are produced more consistently and more often in canonical form compared to word-final position (Gow, Melvold & Manuel 1996; Greenberg, Carvey, Hitchcock & Chang 2003; Manuel 1991; Redford & Diehl 1999). In the language development literature, some studies have shown that infants are sensitive to patterns regardless of the word position (Friederici & Wessels 1993). Other studies have found that infants are better at detecting commonalities in word-initial position compared to word-final position (Jusczyk, Goodman & Bauman 1999), and studies with young children aged 4 to 5 years have found that mispronunciations of words are detected more often in word-initial position compared to word-final position (Cole 1981; Walley 1987). Conflicting findings have also been found in production, where some studies have found that the accuracy of children’s segmental production varies by word position (Beers 1995), whereas others have found that children are equally accurate at producing segments in different word positions (Zamuner 2009).

To summarize, this research examines the effect of phonotactic probabilities in young children’s perception skills in a task that implicates lexical representations. Second, it investigates whether parallel to the production findings, young children show sensitivities to phonotactic probabilities in a perception task. Lastly, it examines young children’s perceptual abilities in different word positions. Dutch-learning children were tested on their perception of segmental contrasts that were embedded in high and low phonotactic probability nonwords. The same segmental contrasts were tested in both word-initial and word-final position.
2. EXPERIMENT

2.1. Method

2.1.1. Participants

The participants were 34 Dutch monolingual children, between the ages of 2;2–2;8 ($M = 2;5,17$). Participants did not have a history of speech and/or hearing impairment, as determined by parent questionnaire. An additional 63 subjects were tested but not included in the analysis due to failing to pass the pretest (31), failing to complete the experiment (25), equipment error (2), experimenter error (3), parental interference (1), and for scores greater than two standard deviations from the mean (1). Children failed the pretest for a number of reasons such as not understanding the task, having a preference for choosing pictures on one side of the page, and choosing a picture before the experimenter asked for a specific picture. While the number of participants excluded is large (65%), it is not untypical for a study using this task with this age group. For example, in three separate experiments using a picture pointing task with children between 2;6 and 3;0, Skoruppa, Mani & Peperkamp (2013) report a 50% drop-out rate in each of their studies. A subset of children ($N = 26$) first completed a production task where they were tested on a subset of the nonwords used in the current study. Children’s receptive and expressive vocabulary scores were measured by the Dutch version of the MacArthur-Bates Communicative Development Inventory (N-CDI; Zink & Lejaegere 2002). Word position was a between-subjects factor, and children were randomly assigned to either word-position condition: initial ($N = 16$) or final ($N = 18$).

2.1.2. Materials

The stimuli consisted of 64 nonwords, controlled for phonotactic probabilities (high or low) and word position (initial or final). The phonotactic probabilities of the nonword stimuli were calculated using standards in the field (Vitevitch & Luce 1999). Thus, phonotactic probabilities were calculated on the log frequency weighted counts using both type and token counts, from a Dutch speech corpus that included adult, child, and infant-directed speech (Weijer 1998). Segments and biphone sequences were defined as high or low based on a median split. Phonotactic probabilities were controlled for both Segmental Positional Frequencies and Biphone Frequencies (high or low), and the average phonotactic probabilities of the nonword stimuli are provided in Table 1.

There were eight pairs of segmental contrasts /p-k, t-r, k-s, x-t, m-f, n-p, r-f, l-x/ (Table 2). Each segmental contrast occurred in the same phonotactic probability context and word position. This is illustrated with the stimuli for the segmental contrasts for /p-k/: initial low phonotactic probability environment (peem /pem/ vs. keem /kem/), initial high phonotactic probability environment (paat /pat/ vs. kaat /kat/), final low phonotactic probability environment (buup /bup/ vs. buuk /buk/), and final high phonotactic probability environment (miep /mip/ vs. miek /mik/). Nonwords were paired with nonce animals (Ohala 1999) that were depicted on small laminated cards with Velcro™ on the back. Materials were presented in a book containing the pretest and test trials.
TABLE 1
Mean Phonotactic Probabilities of Nonword Stimuli, by Word Position, in Low and High Phonotactic Probability (PP) Environments

<table>
<thead>
<tr>
<th>Measure</th>
<th>Initial Position</th>
<th></th>
<th></th>
<th>Final Position</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low PP</td>
<td>High PP</td>
<td>Low PP</td>
<td>High PP</td>
<td>Low PP</td>
</tr>
<tr>
<td>Segmental positional probabilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>.201 (.02)</td>
<td>.236 (.014)</td>
<td>.185 (.019)</td>
<td>.224 (.013)</td>
<td></td>
</tr>
<tr>
<td>Token</td>
<td>.196 (.019)</td>
<td>.229 (.014)</td>
<td>.187 (.013)</td>
<td>.237 (.008)</td>
<td></td>
</tr>
<tr>
<td>Bi-phoneme probabilities</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type</td>
<td>.002 (.003)</td>
<td>.019 (.006)</td>
<td>.003 (.004)</td>
<td>.011 (.007)</td>
<td></td>
</tr>
<tr>
<td>Token</td>
<td>.007 (.006)</td>
<td>.018 (.005)</td>
<td>.004 (.005)</td>
<td>.015 (.005)</td>
<td></td>
</tr>
</tbody>
</table>

Note. Standard deviations are in parentheses.

2.1.3. Procedure

Children were tested in a quiet room of the Kindertaal Lab (Child Language Lab) at the Radboud University Nijmegen. Children’s perception abilities were tested using a two-alternative forced-choice picture-matching task (2AFC). Children were first given six pretest trials. The first two trials tested children’s perception of pairs of known animal pairs (e.g., kikker ‘frog’ and aap ‘monkey’) and then four trials of pairs of phonologically distinct nonwords (e.g., taam and kep). The pretest familiarized children with the task and established whether children could follow instructions and attend to the task. Subjects had to score a minimal 5 out of 6 on the pretest trials to be included. Children were then presented with 16 test trials. Recall that word position was a between-subjects factor. Therefore, children in the word-initial position condition were tested on the eight pairs of initial low phonotactic probability nonwords and the eight pairs of initial high phonotactic probability nonwords, and vice versa for the children in the word-final position condition (see Table 2). The order of the stimuli was prerandomized, with four different lists for counterbalancing. Each child received a score out of 8 for correct responses on low phonotactic probability nonword pairs, and out of 8 for correct responses on the high phonotactic probability pairs.

The protocol for the pretest and test trials was the same. The experimenter showed children a book full of new and funny animals. The experimenter then introduced children to an elephant puppet (controlled by the experimenter) and explained that the elephant was very hungry and wanted to eat one of the two animals. Children were told to listen very carefully to the elephant. The experimenter first reviewed the names of the animals, e.g., “Dit is een kikker en dit is een aap” (This is a frog and this is a monkey). The elephant would then name the animal or nonce animal it wanted to eat, e.g., “een aap” (a monkey). Children removed an animal from the page and fed it to the elephant. Alternatively, children pointed to a picture and the experimenter removed it and fed it to the elephant. The elephant then said “Lekker, dank je wel” (Delicious, thank you). Children were given this feedback, regardless of whether they gave a correct or incorrect response. The experimenter was a native speaker of Dutch and naïve to the purpose of the study. Children’s responses were recorded by the experimenter. A subset of the data (50%) was checked off-line by the experimenter or author. There was 100% agreement between the online and off-line coding
### TABLE 2
Nonword Stimuli Contrasts, by Word Position and Target Segments, in Low and High Phonotactic Probability (PP) Environments

| Segments | Initial Position | | Final Position | |
|----------|------------------|------------------|------------------|
|          | **Low PP** | **High PP** | **Low PP** | **High PP** |
| p - k    | peem /pem/ | keem /kem/ | paa /pat/ | kaa /kat/ |
| t - r    | tup /typ/ | rup /typ/ | tan /tan/ | ran /ran/ |
| k - s    | keup /køp/ | seup /søp/ | kaan /kan/ | saan /san/ |
| x - t    | guf /xuf/ | tuf /tyf/ | ges /xes/ | tes /tes/ |
| m - f    | mup /møp/ | fup /fyp/ | mas /mas/ | fas /fas/ |
| n - p    | num /nym/ | pum /pym/ | nes /nes/ | pes /pes/ |
| r - f    | reup /röp/ | feup /føp/ | raa /ran/ | faa /fan/ |
| l - x    | loem /løm/ | goem /xøm/ | laa /lar/ | gaar /xar/ |
as to which picture children chose. In a few cases (3%), off-line coding suggested that the child might have already chosen the picture before the experimenter completed her question. Children’s responses on these trials were not included in the analyses.

2.2. Results

A repeated-measures ANOVA was used with Phonotactic Probabilities (high or low) as the within-subjects factor, and Position (initial or final) as the between-subjects factor. There was a significant effect of Phonotactic Probabilities, $F(1, 32) = 5.32, p < .05, \eta_p^2 = .14$. Children gave more correct responses in high phonotactic probability environments ($M = 6.47$, $SD = 1.48$) than in low phonotactic probability environments ($M = 5.77$, $SD = 1.64$). There was no significant main effect of position, $F(1, 32) = .19, p = .67$, and no significant interaction between phonotactic probabilities and positions, $F(1, 32) = .29, p = .59$. Figure 1 depicts the accuracy of children’s perception of segmental contrasts in different phonotactic probability environments and position in the word.

3. DISCUSSION

While many studies focus on phonotactic probabilities in production, to date, children’s perception abilities of segmental contrasts in frequent and infrequent phonotactic probability environments has been less explored. In the current study, an effect of phonotactic probabilities was found in perception: children were better at perceiving segmental contrasts embedded in high phonotactic probability environments than when the same segmental contrasts occurred in low phonotactic probability environments. This is similar to the literature on adult language processing, where an advantage in terms of speed and accuracy has been found for high phonotactic probability nonwords (Vitevitch & Luce 1998, 1999).
The current results are partly in line with MacRoy-Higgins et al. (2013), who found a significant difference in two-year-olds’ looking times to correct versus mispronunciations on high phonotactic probability trained nonwords. In the present study, however, even in the low nonword pairs, children were above chance in their ability to detect the segmental contrasts (see Figure 1), whereas in MacRoy-Higgins et al., no significant looking differences were found when trained nonwords with low phonotactic probabilities were mispronounced. This difference may be based on the methodologies: the present study used a two-alternative forced-choice picture-matching task (2AFC) between two nonwords, whereas MacRoy-Higgins et al. used a preferential looking task testing perception of correct versus mispronunciations of trained nonwords. It is possible that in the preferential looking task, children might have been able to detect mispronunciations of the low phonotactic probability trained nonwords (e.g., /zetf/ pronounced as /detf/), but yet still considered the mispronunciations as acceptable pronunciations of the target, resulting in no significant looking differences. Another main difference between the studies was the experimental stimuli: in the present study, the same segmental contrasts were used for the nonword stimuli; in the present study, the same segmental contrasts were used for the nonword stimuli in the high and low phonotactic probability environments. In MacRoy-Higgins et al., the segmental changes between the correct and mispronounced nonwords were different in the high and low phonotactic probability environments. If the segmental changes in the low phonotactic probability environments had lower acoustic saliency, this might explain why children did not show significant looking differences for the correct versus mispronunciations of nonwords. Lastly, the current study tested children who were a few months older and with a different language background than the children in the MacRoy-Higgins et al. study.

The current study also compared children’s ability to perceive the same segments in different word positions. No significant differences were found in children’s ability to perceive segmental contrasts in word-initial compared to word-final position, adding to the research that finds no effect of word position in children’s perception and production (Nazzi & Bertoncini 2009; Zamuner 2009). The lack of a position effect might reflect participants’ stage of development in the study, where the average age of participants was 2:5. Children may have already learned that word-final consonants make informative lexical distinctions. This idea is supported by data from children acquiring Dutch, who typically produce word-final consonants by this age (Fikkert 1994). It is also possible that position-based differences in perception may be found using more sensitive perception measures, such as the Intermodal Preferential Looking Procedure (Hirsh-Pasek & Golinkoff 1996). These paradigms allow for measurements of online processing by examining participants’ eye-movements as they look at a visual display. Thus, these paradigms allow for more implicit measures of children’s knowledge, compared to the 2AFC task, which requires explicit responses from children.

Frequency-based differences in children’s production accuracy have been linked to a variety of sources: phonological and lexical representations, phonological working memory, speech perception, motor planning, and articulation (Coady & Evans 2008). While these frequency-based differences can be captured by children’s phonological representations, such as high and low frequency-based exemplar or abstract representations, how do these frequency-based differences in representations arise? Two possible sources are perceptual learning or articulatory practice (Plante et al. 2011; Richtsmeier et al. 2009). While the current findings do not discount articulatory practice as an additional mechanism for frequency-based differences in perception, the progression between early speech perception skills and later perception
skills supports the theory that a perceptual learning mechanism forms the foundation for frequency-based effects in children’s production accuracy or that minimally, both perceptual and production mechanisms are involved. This is further supported by the previous findings from Richtsmeier et al. (2009) and Plante et al. (2011), who found that children more accurately produced nonwords that were presented more frequently during an initial familiarization phase.

One potential drawback of the current study is the number of children who were excluded. These children may not have been as cognitively or linguistically developed as the children who successfully completed the experiment. Since children’s vocabulary scores were gathered based on the N-CDI (Zink & Lejaegere 2002), it was possible to compare vocabulary sizes between the children who did and did not complete the study. These comparisons did not find any differences between children’s receptive and expressive vocabulary scores, suggesting that they were a uniform group with respect to vocabulary size. Note also that the percentage of children who did not complete the task is not unusual compared to similar studies with the same-aged children (Skoruppa, Mani & Peperkamp 2013).

An interesting research question would be to further manipulate the types of segmental contrasts used in the perception task. For example, an examination of the stimuli in Table 2 shows that a variety of segmental contrasts were tested, which varied on their feature and acoustic dimensions. For example, /p-k/ contrasts place of articulation, whereas /n-p/ contrasts both voicing, place of articulation, and manner of articulation. Previous research using the Intermodal Preferential Looking Procedure has shown that infants demonstrate graded sensitivity to the number of feature changes between a target word and a mispronunciation of the target word. For example, infants show graded sensitivities to the word keys mispronounced with one feature change as teys, versus three feature changes as zeys (White & Morgan 2008). Given the restrictions on the creation of the stimuli in the present study (that the same feature contrast be presented in pairs of nonwords, embedded in both high and low phonotactic probability environments, and in both word-initial and word-final position), it was not possible to control for the number of feature changes between the pairs. An examination of children’s responses in the pairs with one, two, or three feature changes did not show any differences in their performance (one change: 69% accurate; two feature changes: 72% accurate; three feature changes: 68% accurate). As stated earlier, it is possible that another methodology might reveal differences in children’s performance based on the number of feature changes.

The current research is one of the first studies to demonstrate that phonotactic probabilities is a factor in young children’s perception of segmental contrasts: children who are already producing language are more accurate at perceiving the same segmental contrast when it occurs in a high phonotactic probability environment than in a low phonotactic probability environment. This finding shows a progression from perceptual sensitivities to phonotactic probabilities in previously reported studies with infants (Jusczyk et al. 1994) to later language development and adds to the growing research relating early perceptual knowledge to later language development (Kuhl, Conboy, Padden, Nelson & Pruitt 2005). To further address the issue of perceptual learning and articulatory practice, it would be informative to compare individual children’s performance on perception and production tasks. A positive relationship would provide further evidence that perceptual learning also contributes to the development of children’s speech production.
ACKNOWLEDGMENTS

This research was supported by The Netherlands Organization for Scientific Research grant 275-75-001 awarded to Tania S. Zamuner. Thanks to Katherine Demuth, Suzanne van der Feest, Paula Fikkert, Elizabeth Johnson, Erik Jan van der Torre, and Ellen Westrek for helpful comments and assistance.

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Submitted 26 March 2012

*Final version accepted 01 November 2012*