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Twelve-Month-Olds Know Their *Cups* From Their *Keps* and *Tups*

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Fourteen-month-olds are sensitive to mispronunciations of the vowels and consonants in familiar words (N. Mani & K. Plunkett (2007), *Journal of Memory and Language*, 57, 252; D. Swingley & R. N. Aslin (2002), *Psychological Science*, 13, 480). To examine the development of this sensitivity further, the current study tests 12-month-olds' sensitivity to different kinds of vowel and consonant mispronunciations of familiar words. The results reveal that vocalic changes influence word recognition, irrespective of the kinds of vocalic changes made. While consonant changes influenced word recognition in a similar manner, this was restricted to place and manner of articulation changes. Infants did not display sensitivity to voicing changes. Infants' sensitivity to vowel mispronunciations, but not consonant mispronunciations, was influenced by their vocabulary size—infants with larger vocabularies were more sensitive to vowel mispronunciations than infants with smaller vocabularies. The results are discussed in terms of different models attempting to chart the development of acoustically or phonologically specified representations of words during infancy.

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INTRODUCTION

Over a decade ago, Stager and Werker (1997) published a provocative finding suggesting a nonstraightforward link between the infant phonological and lexico-phonological system. Their claim was that infants had limited access to the phonological code representing the words in their lexicons, such that 14-month-olds were unable to learn two words simultaneously that sounded similar to one another, e.g., *bih-dih*. This result was surprising since it was known that between 6 and 10 months of age, infants become attuned to the phonological repertoire of their native language (Kuhl, Williams, Lacerda, Stevens, & Lindblom, 1992; Werker & Tees, 1984). Given the depth of this early phonological knowledge, it became important to understand the factors that restricted infants from gaining adequate access to their native phonological code.

One approach suggested that inadequate specification was a product of the sparseness of the infant vocabulary (the developmental hypothesis; Charles-Luce & Luce, 1990). This infant-centric approach suggested that the small number of words known to infants resulted in few minimal pairs—e.g., *cat-hat*. The remaining words in the infant lexicon could, therefore, be discriminated holistically, and did not require infants to encode all the phonemes in words (or for that matter, any phonemes, e.g., *book-doll*). As the child's vocabulary expanded and further detail was required to discriminate the newly incorporated similar-sounding words, the lexical system is reorganised to represent the phonological detail in words (Lexical Restructuring Model; Metsala & Walley, 1998).

An alternative position suggests that vocabulary size does little to influence segmental level specification—rather, it is infants' familiarity with the word that improves the level of acoustic-phonological detail associated with the word (the familiarity hypothesis). Barton (1976) reports a correlation between greater phonological specificity (or more adult-like representations) and infants' familiarity with a word. Unlike the developmental hypothesis, the familiarity hypothesis does not support a qualitative difference between infant and adult phonological representations, at least for words learned early in life, i.e., more familiar words.

In support of the familiarity hypothesis, a number of recent studies using the Intermodal Preferential Looking task (Golinkoff, Hirsh-Pasek, Cauley, & Gordon, 1997) have found that infants as young as 14 months of age display a robust sensitivity to vowel and consonant mispronunciations of familiar words (Bailey & Plunkett, 2002; Ballem & Plunkett, 2005; Mani & Plunkett, 2007, 2008a; Swingley & Aslin, 2000, 2002). While this does not provide conclusive evidence against the holistic approach (i.e., the mispronunciation could still be detected at the word-form level), it suggests, at the very least, that there is enough acoustic-phonological detail in infants' early lexical representations to trigger detection of a mispronunciation of a familiar word—the lexical representations of words in the infant lexicon are not underspecified.

Testing younger infants provides a further perspective on the contrast between the familiarity and developmental hypotheses outlined above. Twelve-month-olds do not know as many words as older children: Infants in the current study knew an average of 50 words compared to 94 words at 14 months and 284 words at 18 months (Mani & Plunkett, 2007). Furthermore, the infant lexicon incorporates few minimal pairs—Communicative Developmental Inventory (CDI) data collected from parents in the current study revealed that infants at this age know an average of 3.85 minimal pairs (i.e., two words that differ from each other by not more than one phoneme, through either addition, deletion, or substitution of a phoneme). According to the developmental hypothesis, it would be surprising to find sensitivity to mispronunciations at this age, given the developmental level of these infants and the sparseness of minimal pairs in their vocabulary.

Typically, previous literature on phonological specificity (Mani & Plunkett, 2007, 2008a; Swingley & Aslin, 2000, 2002; Werker, Fennell, Corcoran, & Stager, 2002) has examined the developmental hypothesis by looking at the correlation between vocabulary size and infants' sensitivity to mispronunciations. In keeping with the developmental hypothesis, Werker et al. (2002) report finding such a correlation at 17 months (but see Mani & Plunkett, 2007, 2008a; Swingley & Aslin, 2000, 2002 who do not find a similar correlation). By contrast, according to the familiarity hypothesis, 12-month-olds should show sensitivity to vowel and consonant mispronunciations, as long as the words are sufficiently familiar to them, irrespective of their vocabulary size.

Infants on the cusp of acquiring a lexicon will only just have learned the consonantal repertoire of their language, while having had a more prolonged mastery of the vowels in their language. The native language vocalic repertoire is acquired earlier (6 months; Kuhl et al., 1992) than the consonantal range (10–12 months; Werker & Tees, 1984). This developmental difference might have direct consequences for the specificity of the 12-month-olds' lexico-phonological system and result in infants failing to show sensitivity to consonant mispronunciations, while displaying sensitivity to vowel mispronunciations.

Current research is undecided about the relative salience of vowel and consonant mispronunciations. Nespor, Pena, and Mehler (2003) argue that vowels play an important role in contrasting the prosodic characteristics of speech, while consonants appear to be more crucial to the lexico-phonological system. This theoretical perspective is supported by research findings showing that infants can not simultaneously learn two words differing by a single vowel, while successfully learning two words that differ by a single consonant (Havy & Nazzi, 2009; Nazzi, 2005; Nazzi, Floccia, Moquet, & Butler, 2009; Nespor et al., 2003).

In contrast to Nespor and colleagues, Fikkert (in press) argues that vowels are more accurately perceived compared with consonants. Fikkert finds that for 14-month-olds, the place of articulation of a word is defined by the vowel and not the consonant. Fikkert's data, from 14-month-olds, is consistent with earlier work finding that adults and preschoolers alike are more sensitive to vowel changes than to consonant changes in words (Bond, 1954; Gerken, Murphy, & Aslin, 1995). Mani and Plunkett (2007) find a symmetry in infants' sensitivity to mispronunciations of the vowels and consonants in familiar words at 18–24 months of age.

These studies provide contrasting perspectives on infants' sensitivity to vocalic and consonantal changes to words. One way to resolve these apparently conflicting findings might be to investigate whether these differences stem from the subsegmental rather than the segmental level, i.e., are there differences in the degree of infants' sensitivity to different kinds of vocalic (i.e., vowel height, backness, and roundedness) and consonantal changes (i.e., place of articulation, manner, and voicing)? Mani, Coleman, and Plunkett (2008) report that 18-month-olds are more sensitive to mispronunciations of vowel height, and vowel backness, compared with mispronunciations of vowel roundedness, suggesting that height and backness are well specified in Southern British English (see Curtin, Fennell, and Escudero, 2009, for similar results with Canadian English). This is unsurprising, since specification of vowel roundedness is relatively redundant due to the strong correlation between vowel backness and roundedness in English. Knowledge of this redundancy would, however, require sufficient exposure to the vocalic and consonantal repertoire of the infants' native language. It is possible, therefore, that younger infants may be sensitive to a broader range of vowel mispronunciations than the 18-month-olds tested in Mani et al.

To explain the pattern of infants' sensitivity to different kinds of vowel mispronunciations (i.e., height, backness, and roundedness), Mani et al. (2008) suggested that the acoustic characteristics, rather than featural differences of the mispronunciations could have driven the pattern of infants' responses in their study—height mispronunciations were the most acoustically salient compared with backness and roundedness mispronunciations. Likewise, Curtin et al. (2009) find that infants are more sensitive to greater acoustic changes compared to greater phonological changes to vowels. Despite lacking sufficient exposure to their native language phonology, younger infants may display sensitivity to the acoustic differences between mispronunciation types and so discriminate only the acoustically salient mispronunciation types presented to them.

In a similar vein, based on analysis of infants' looking behavior following voicing changes to words, other research indicates that 20-month-old French (Havy & Nazzi, 2009) and Dutch (Van der Feest, 2007) infants appear to be less sensitive to voicing changes to consonants compared to place of articulation changes. Havy and Nazzi (2009), citing Clements (2005) point out that a smaller proportion of the world's languages have voicing changes (83.4%) compared with place (98.7% for labial/coronal, 99.6% for coronal/dorsal, and 98.7% for labial/dorsal). These results suggest that the infants should be less sensitive to voicing changes than to the other consonant mispronunciations presented to them. However, White and Morgan (2008) report that 19-month-old English infants are sensitive to place, manner, and voicing changes on onset consonants. Clearly there are many differences between these studies including language, methodology, and precise age. A systematic manipulation of the characteristics of words that are familiar to infants at the outset of vocabulary development should help clarify this diverse range of findings.

The current study, therefore, presents a comprehensive analysis of the amount of phonetic or phonological detail associated with early lexical representations, around the time these lexical items enter the infants' vocabulary. In addition to testing infants' sensitivity to vowel and consonant mispronunciations of the same words, we examine the phonetic or phonological specification of the vocalic or consonantal segments by presenting infants with a range of vowel and consonant mispronunciations.

Note that some previous studies have examined infants' sensitivity to mispronunciations of words at younger ages (7.5 and 11 months of age) using the Preferential Listening task (e.g., Jusczyk & Aslin, 1995; Swingley, 2003). We believe that the current study extends this work in two important ways. First, earlier studies have not covered the range of vowel and consonant mispronunciations tested here. Second, it is unclear whether preferential listening studies tap into the lexical status of the mispronounced words to the extent that preferential looking tasks do, as there is no requirement in listening studies that infants identify a referent or activate any meaning representations for a given word form. For example, Jusczyk and Aslin (1995) reported that 7.5-month-olds respond to accurate pronunciations of familiar words, but not mispronunciations, even when these words are not likely to have lexical entries. More specifically, if infants' display sensitivity to a mispronunciation of *cup* as *tup*, having been presented with the sound /tʌp/, then we can not be sure whether this sensitivity is based on their having heard the sequence of sounds /k/, /ʌ /, /p/ more often than /t/, /ʌ/, /p/, or whether they recognize *tup* as a mispronunciation of *cup*. Preferential looking tasks, on the other hand, trigger infants' representation of the correct pronunciation of a word (by presenting infants with an image of the object associated with a word), and can, therefore, assess infants' response to a mispronunciation of the same word in the presence of the object association. As was demonstrated by Stager and Werker (1997), the presence of the object association can alter infants' sensitivity to phonological patterns (as displayed in their nonlexical checkerboard task), and it is precisely this lexically motivated sensitivity that we aim to assess in the current study. If we hope to investigate the phonological specificity of lexical representations, then we must ensure that the task attempts to access the lexical representation under examination.

METHOD

Participants

The participants in this experiment were 66 infants at 12 months of age (*M* age = 12.25 months, range = 11.4–12.76 months). Of these, 35 were presented with vowel mispronunciations and 31 were presented with consonant mispronunciations. Fifteen additional infants were tested but were excluded due to fussiness, parental interference, or experimenter error. All infants had no known hearing or visual problems and were recruited via the local maternity ward. Infants came from homes where British English was the primary language in use.

Stimuli

The speech stimuli were produced by a female speaker of British English in an enthusiastic, child-directed manner. The audio recordings were made with a solid-state compact flash card recorder in a sound-treated, recording booth. The audio stimuli were digitized at a sampling rate of 44.1 kHz and a resolution of 16 bits and spliced using Goldwave v. 5.10 (Newfoundland, Canada). The auditory stimuli presented to infants were nine monosyllabic (CVC) nouns taken from the British CDI (Hamilton, Plunkett, & Schafer, 2000)—words were judged to be known to around 50% of 12-month-olds according to the British CDI norms. For the vowel mispronunciations, three of the nine words were mispronounced as a 1-feature height mispronunciation, three were mispronounced as a 1-feature backness mispronunciation, and three resulted in a 1-feature roundedness mispronunciation. Due to restrictions on the number of possible single feature changes resulting in legal English vowels, not all words could change in all of the features to yield all kinds of mispronunciations. Similarly, for onset consonant mispronunciations, three words resulted in 1-feature place mispronunciations, three words resulted in 1-feature voicing mispronunciations, and three words resulted in 1-feature manner mispronunciations. In addition, we presented infants with three filler trials to consisting of images of familiar objects (*bunny*, *shoe*, *spoon*)—this was done to avoid a bias toward infants hearing a greater proportion of mispronunciations compared to correct pronunciations. We ensured that there was no systematic difference in the duration of the correct and mispronounced labels, $t(9) = .23, p > .5$.

Visual stimuli were computer images of the nine words created from photographs judged by three adults (the authors and an independent observer) as typical exemplars of the labeled category. These images were paired with nine yoked distracter images whose labels began with the same onset consonant, whose names were likely to be familiar to around 50% of infants at this age. The use of identical onsets for target and distracter precludes the infants from using onset consonant information to identify targets in the vowel mispronunciation condition or onset consonants in the consonant mispronunciation condition.

Procedure

All infants sat on their caregiver's lap during the experiment facing a projection screen. Auditory stimuli were presented through two loudspeakers located immediately above the screen. Two cameras mounted directly above the visual stimuli recorded infants' eye movements. Synchronized signals from the two cameras were then routed via a digital splitter to create a recording of two separate time-locked images of the infant.

Each infant was presented with 12 trials—three filler trials and nine experimental trials (see Table 1). In each trial, infants saw an image of two familiar objects, side by side, for 5 sec. The labels for both objects began with the same onset consonant. Infants were then presented with either correct pronunciations or mispronunciations of the label for the target image, inserted after the carrier phrase "Look!" The onset of the target word began halfway into the trial at 2,500 msec. The onset of the target word divided the trial into a pre naming and post naming phase. Object preference during the pre naming phase provides an online baseline estimate against which to evaluate target preference during the post naming phase of the trial.

For vowel mispronunciations, infants were presented with three correct pronunciations, two height mispronunciations, two backness mispronunciations, two roundedness mispronunciations, and three filler trials. For consonant mispronunciations, infants were presented with three correct pronunciations, two place of articulation mispronunciations, two voicing mispronunciations, two manner of articulation mispronunciations, and

TABLE 1

Stimuli Presented to Infants

Target Label	*Vowel Change*	*Type*	*Acoustic Characteristics of Change*	*Consonant Change*	*Type*	*Distracter*
Ball	Bul	Height	195	Mall	Manner	Book
Bath	Bɔθ	Round	155	Dath	Place	Bus
Cat	Cɑt	Back	227	Gat	Voice	Keys
Cup	Kɛp	Back	205	Tup	Place	Car
Dog	Dɑg	Round	152	Tog	Voice	Duck
Doll	Dʌl	Round	166	Goll	Place	Door
Foot	Fɔt	Height	175	Voot	Voice	Phone
Hand	Hʌnd	Back	208	Thand	Manner	Hair
Milk	Mɛlk	Height	202	Bilk	Manner	Mouth

three filler trials (identical to the filler trials used in the vowel mispronunciation condition). Filler trials were introduced so that infants were presented with an equal number of correct pronunciation and mispronunciation trials overall (six each), although filler trials were not analyzed (since they were never presented as mispronunciation trials).

The shared onset consonant between target and distracter labels ensures that infants' responding to the vowel-mispronounced word is not driven by the onset mismatch between the distracter label and the heard label, as would be the case if the distracter and target label did not share the onset consonant. Through the shared onset consonant, we ensure that the distracter is as likely a candidate as the target until the presentation of the mispronounced phoneme in both consonant- and vowel-mispronounced words. This task, therefore, provides an earlier cue to the detection of consonant-mispronounced words than vowel-mispronounced words, since the onset consonant mismatch is presented earlier, and in a more salient location, than the word-medial vowel mismatch.

On the other hand, infants may begin to show a preference for the target when presented with the vowel of the consonant-mispronounced word, due to overlap between the rhyme of the consonant-mispronounced word and target label (*cup-tup*). For vowel-mispronounced words, infants need to wait until the coda consonant before recognizing the greater overlap between the vowel-mispronounced words and the target label (*cup-kep*). Even though the vowel-mispronounced word also maintains a two-phoneme overlap with the target label, the onset consonant is also consistent with the distracter label, so only one phoneme overlaps exclusively with the target label. Therefore, it might be easier for infants to accept the consonant-mispronounced word as a suitable label for the target than the vowel-mispronounced word, thereby making infants more sensitive to vowel mispronunciations than consonant mispronunciations.[1] While it remains unclear whether the current task may advantage either vowel or consonant mispronunciations, we know of no other way to compare 12-month-olds' sensitivity with vowel and consonant mispronunciations of familiar words using Intermodal Preferential Looking. This situation is further exacerbated by the fact that 12-month-olds know no vowel-initial imageable nouns.

Infants never heard both a correct and an incorrect pronunciation of the label for the same object. Nor were correct and incorrect pronunciations repeated within subjects. Previous research has demonstrated that repetition of trials can modulate mispronunciation sensitivity such that infants exhibit such sensitivity on the original trial, but not on the repeated trial (Ballem & Plunkett, 2005). Within infants, target images appeared equally often to the left and to the right. Likewise, correct and incorrectly pronounced words identified left and right targets equally often. Across infants, image pairs appeared equally often with correct pronunciations and mispronunciations. Order of presentation of trials was randomised.

A digital-video scoring system was used to assess visual events on a frame-by-frame basis (every 40 msec). This technique enabled tracking of every single eye fixation. For analysis, we use the Longest Look measure (LLK) and the Proportion of Target Looking measure (PTL). LLK is the difference between infants' single longest fixation at the target or familiar image (t) and distracter (d), i.e., $t - d$. A systematic positive value for this difference can be interpreted as a measure of the infants' sensitivity to the association between the heard label and the familiar image. The PTL measure calculates the amount of time infants spent looking at the target (T) over the amount of time infants spent looking at the target and distracter ($T + D$) in order to determine the proportion of time infants spent looking at the target. The infants' sensitivity to the association between the heard label and familiar image is examined by determining whether this proportion is significantly above chance (.5). The dependent variable in all analyses is the effect of naming which is the difference in either measure in infants' preference for the target from the pre- to the post naming phase (Post naming [PTL/LLK] − Pre naming [PTL/LLK]). Note that, on average, infants make 3.38 saccades during a 5-sec trial in our experimental procedure. Only those trials in which infants fixated both the target and the distracter in the pre naming phase of the trial were included in the analysis. This exclusion criterion resulted in the elimination of 22% of trials in the vowel mispronunciation condition and

[1]Our thanks to an anonymous reviewer for highlighting this important issue.

18% of trials in the consonant mispronunciation condition. We use this exclusion criterion to help eliminate trials where infants are not on task, based on the assumption that our participants are exploring the full visual array to identify potential matches between image and label.

RESULTS

Vowel mispronunciations

Figure 1 presents the effect of naming using the PTL measure for the correct pronunciations and different vowel mispronunciations presented to infants. The pattern of results suggests that infants displayed an effect of naming (i.e., increase in preference for the target from the pre- to the post naming phase) following only correct pronunciations, and not following any of the mispronunciations (height, backness, or roundedness). Further statistical analysis confirmed this to be the case. As not all words could be mispronounced in all three ways, we ran univariate analyses of variance (ANOVAs) to compare infants' performance in the four conditions (correct pronunciations, height, backness, and roundedness mispronunciations) presented to them. The ANOVA confirmed a near-significant effect of pronunciation type using both LLK, $F(3, 125) = 2.53$, $p = .06$, $\eta^2 = .06$, and PTL measures, $F(3, 125) = 2.25$, $p = .08$, $\eta^2 = .05$. Furthermore, as univariate analyses can sometimes inflate the size of the effects, we ran multi variate analyses to confirm the pattern of results. This reduced the number

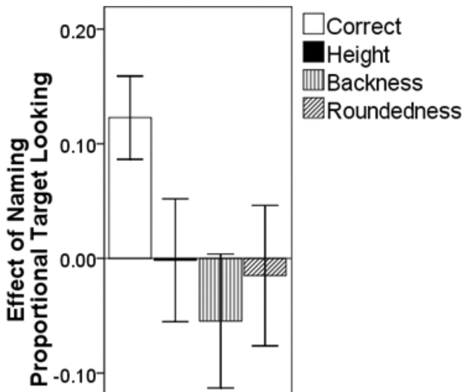

Figure 1 Infants' sensitivity to vowel mispronunciations (means and *SE*). Error bars reflect 1 *SE*.

of subjects considerably, as each subject needed to participate in all conditions. As in the univariate analyses, we found a significant main effect of pronunciation type (PTL: $F[3, 20] = 3.67$, $p = .02$, $\eta^2 = .35$; LLK: $F[3, 26] = 3.21$, $p = .04$, $\eta^2 = .32$). In order to avoid any possible confounds caused by the univariate analyses, the effect was examined by items: A repeated measures ANOVA confirmed a significant effect of pronunciation type (PTL: $F[1, 8] = 6.82$, $p = .03$, $\eta^2 = .46$; LLK: $F[1, 8] = 14.16$, $p = .006$, $\eta^2 = .63$). We then analyzed whether there was a significant difference in infants' performance following correct pronunciations and the three mispronunciation types.

There was a significant difference in infants' performance between correct pronunciations and height mispronunciations (LLK: $t[64] = 2.38$, $p = .02$; PTL: $t[64] = 1.96$, $p = .05$), correct pronunciations and backness mispronunciations (LLK: $t[66] = 2.64$, $p = .01$; PTL: $t[66] = 2.61$, $p = .01$), and correct pronunciations and roundedness mispronunciations (LLK: $t[63] = 2.24$, $p = .028$; PTL: $t[63] = 1.99$, $p = .05$). In addition, there was a significant effect of naming following correct pronunciations (LLK: $t[34] = 3.68$, $p = .001$, PTL: $t[34] = 3.37$, $p = .002$), but not following height (LLK: $t[30] = -.32$, $p = .7$; PTL; $t[30] = -.03$, $p = .9$), backness (LLK: $t[32] = -.82$, $p = .4$; PTL: $t[32] = -.93$, $p = .35$), or roundedness mispronunciations (LLK: $t[29] = -.45$, $p = .6$; PTL: $t[29] = -.24$, $p = .8$). There was no difference in infants' performance between height and backness mispronunciations (LLK: $t[62] = .39$, $p = .6$; PTL: $t[62] = -.66$, $p = .5$), backness and roundedness mispronunciations (LLK; $t[61] = .21$, $p = .8$; PTL: $t[61] = -.46$, $p = .64$), and roundedness and height mispronunciations (LLK: $t[59] = .15$, $p = .8$; PTL: $t[59] = .16$, $p = .87$).

Acoustic analysis

As in previous research (Mani & Plunkett, 2008b; Mani et al., 2008), we also computed the acoustic characteristics of each mispronunciation presented to infants (the Euclidean distance between the spectra of the two vowels). We calculated the spectral energy at the midpoint of the steady state of the vowels of all the words presented to infants (correct and incorrect pronunciation). We then computed the difference between the spectra of the correct and incorrect pronunciations of the same word, using the formula

Acoustic characteristics of a mispronunciation are

$$\sqrt{\sum_{i=1}^{n} (C_i - M_i)^2}$$

where n is the number of samples (bits) at which the spectral energy is recorded (256), C is the spectral energy recorded at the midpoint of the vowel of the correct pronunciation of a word for each sample, and M is the spectral energy recorded at the midpoint of the vowel in the vowel mispronunciation of the same word. This difference indexes the acoustic characteristics of each mispronunciation token. We then examined whether there was a correlation between the acoustic characteristics of each mispronunciation and infants' sensitivity to the mispronunciations.

We found a significant difference in the acoustic characteristics of the three mispronunciation types, $F(2, 6) = 17.94$, $p = .003$. Post hoc comparisons confirmed that backness mispronunciations were acoustically more salient (i.e., more different from correct pronunciations) compared to height ($p = .05$) and roundedness mispronunciations ($p = .001$), and height mispronunciations were more salient comparedwith roundedness mispronunciations ($p = .01$). However, there was no correlation between the effect of naming and the differences in the acoustic characteristics of the mispronunciations presented to infants (LLK: $p = .9$; PTL: $p = .6$).

In addition, we examined whether infants were more sensitive to vowel mispronunciations where there were greater differences in the first and second formants of the vowels of correct and incorrect pronunciations. Measurements of the first and second formants were taken at the mid point of the steady state of the vowel using PRAAT software (Amsterdam, the Netherlands). Once again, there was no correlation between the effect of naming and the differences in the first ($r = -.12$, $p = .4$) and second formants ($r = .08$, $p = .6$) of the two pronunciation types.

Vocabulary analysis

There was no correlation between the effects of naming (i.e., difference in preference for the target from the pre- to the post naming phase) in each condition (i.e., correct pronunciations, height, backness, and roundedness mispronunciations) and receptive vocabulary size, as calculated from parental CDI reports (all ps $> .2$).

We then divided infants into low and high vocabulary groups based on the median vocabulary size of the infants tested (= 56). Infants with a reported vocabulary size under 56 were in the low vocabulary group ($n = 16$), and those with a vocabulary size above 56 were in the high vocabulary group ($n = 19$). Univariate analyses with pronunciation type (correct, height, backness, and roundedness) as a fixed factor and vocabulary group as a covariate revealed a significant main effect of vocabulary group, $F(1, 121) = 3.98$, $p = .04$, $\eta^2 = .03$, and a near-significant effect of pronunciation type, $F(3, 121) = 2.36$, $p = .07$, $\eta^2 = .05$, on infants' responding as

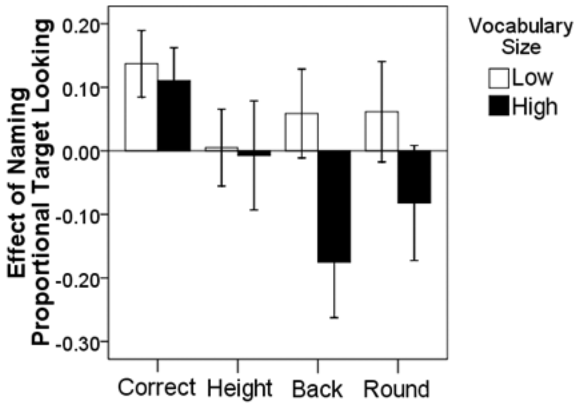

Figure 2 Infants' sensitivity to vowel mispronunciations—high and low vocabulary groups (means and *SE*). Error bars reflect 1 *SE*.

shown in Figure 2. We, therefore, reexamined the influence of pronunciation type separating the two vocabulary groups. There was a significant main effect of condition on naming in the high vocabulary group, $F(3, 64) = 2.96$, $p = .039$, $\eta^2 = .1$, but not in the low vocabulary group, $F(3, 57) = .3$, $p = .7$. Note that this was not due to infants in the low vocabulary group not knowing the words presented to them as there was a significant effect of naming following correct pronunciations in both vocabulary groups (low = $t[15] = 2.62$, $p = .019$; high = $t[18] = 2.14$, $p = .04$). Rather, as Figure 2 indicates, the difference stems from the patterns of responding to backness mispronunciations in the two vocabulary groups. There was a smaller mispronunciation effect following backness mispronunciations in the low vocabulary group than in the high vocabulary group, $t(31) = 2.14$, $p = .04$.[2] There were no differences between the two vocabulary groups in the effects of naming following any of the other pronunciation conditions (correct, $p = .7$; height, $p = .9$; and roundedness, $p = .2$). For the low vocabulary group, there was no significant difference between correct pronunciations and any of the mispronunciation types (*p*

[2]Note that infants' responding to the backness condition in the high vocabulary group tends toward distracter looking (PTL: $p = .063$; LLK: $p = .07$). One possible explanation for this finding is that this may have been caused by some infants not knowing the name of the distracter image in all trials, thereby making this task more similar to White and Morgan (2008). The limitations of the 12-month-old lexicon make it difficult to test infants on pairs of distracter-target items whose labels begin with the same consonant and with which 12-month-olds are also robustly familiar. Therefore, the impact of vocabulary size on infants' pattern of responding should be treated with caution and requires further examination before stronger conclusions can be reached.

[height] $= .1$; p [backness] $= .3$; p [roundedness] $= .4$). By contrast, for the high vocabulary group, there was a significant difference between correct pronunciations and backness ($p = .006$) and roundedness mispronunciations ($p = .07$), but not height mispronunciations, although this was near-significant using LLK ($p = .07$).

We also separately examined whether infants' responding to the two vocabulary groups correlated with the acoustic characteristics of the mispronunciations. As with the overall analyses reported above, there was no correlation between infants' sensitivity to mispronunciations and increase in vocabulary size in either low ($p = .4$) or high vocabulary groups ($p = .6$).

Finally, we examined whether infants displayed the same pattern of responding when we considered only those items (i.e., target items) that parents reported their infants as knowing. This eliminated 21.4% of all trials. As was found in the main analyses reported above, there was a significant main effect of pronunciation condition, $F(3, 201) = 2.86$, $p = .03$, and a significant effect of naming following only correct pronunciations ($p = .02$), but not following height ($p = .9$), backness ($p = .15$), or roundedness ($p = .86$) mispronunciations.[3] This suggests that the patterns of results reported are not an artifact of the level of infants' familiarity with the words presented to them.

In summary, 12-month-old infants appear to be equally sensitive to all three kinds of vowel mispronunciations presented to them: height, backness, and roundedness mispronunciations, while not displaying sensitivity to variation in the acoustic characteristics of the different mispronunciations presented to them. Moreover, in keeping with the developmental hypothesis, we found that infants with larger vocabularies were more sensitive to some of the vocalic changes presented to them compared to infants with smaller vocabularies.

Consonant mispronunciations

Figure 3 presents the effect of naming for the correct pronunciations and different consonant mispronunciations presented to infants. The pattern of results suggest that infants displayed an effect of naming (i.e., increase in preference for the target from the pre- to the post naming phase) following correct pronunciations and voicing mispronunciations, but not following

[3] As this analysis only included those items that parents reported their infants knowing, there was considerable loss of data, which meant that this analysis had to be conducted on unaggregated data (as has been done with younger age groups in earlier studies; (Mani & Plunkett, 2007; Swingley & Aslin, 2002).

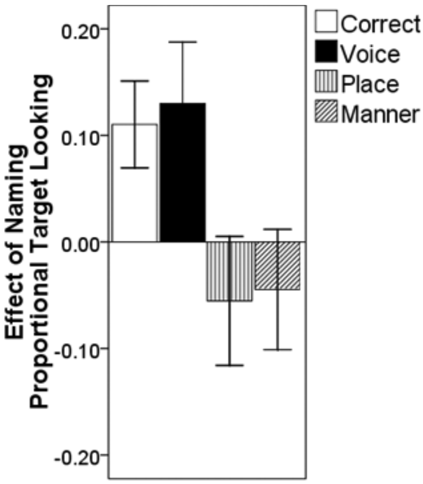

Figure 3 Infants' sensitivity to consonant mispronunciations (means and *SE*). Error bars reflect 1 *SE*.

mispronunciations involving place and manner of articulation. As with the vowel mispronunciations, we ran univariate ANOVAs to compare infants' performance in the four conditions presented to them. The ANOVA confirmed a significant effect of pronunciation type using both LLK, $F(3, 120) = 2.57$, $p = .05$, $\eta^2 = .07$, and PTL measures, $F(3, 120) = 3.28$, $p = .02$, $\eta^2 = .07$. This effect was near-significant by items (LLK: $F[1, 8] = 4.45$, $p = .06$, $\eta^2 = .35$; although PTL: $F[1, 8] = 1.03$, $p = .3$). This pattern of results was confirmed using multi variate analyses. A repeated measures ANOVA revealed a significant effect of pronunciation type using both PTL, $F(3, 27) = 3.61$, $p = .02$, $\eta^2 = .3$, and LLK measures, $F(3, 27) = 2.96$, $p = .05$, $\eta^2 = .27$, indicating a significant difference in infants' performance between the four pronunciation types.

We then analyzed whether there was a significant difference in infants' performance following correct pronunciations and the three mispronunciation types. There was a significant difference between correct pronunciations and place mispronunciations (PTL: $t[60] = 2.26$, $p = .02$; LLK: $t[60] = 1.84$, $p = .07$), correct pronunciations and manner mispronunciations (PTL: $t[60] = 2.22$, $p = .03$; LLK: $t[60] = 1.62$, $p = .1$), but not between correct pronunciations and voicing mispronunciations (PTL: $t[60] = -.27$, $p = .78$; LLK: $t[60] = -.74$, $p = .45$). In keeping with this pattern of responses, there was a significant effect of naming following correct pronunciations (PTL: $t[30] = 2.71$, $p = .01$; LLK: $t[30] = 2.33$, $p = .02$) and voicing mispronunciations (PTL: $t[30] = 2.25$, $p = .03$; LLK: $t[30] = 2.24$,

$p = .03$), but not following place (PTL: $t[30] = -.91$, $p = .3$; LLK: $t[30] = -.68$, $p = .4$) or manner mispronunciations (PTL: $t[30] = -.7$, $p = .4$; LLK: $t[30] = -.33$, $p = .7$). In addition, there was a significant difference in infants' performance between voicing and place mispronunciations (PTL: $t[60] = 2.16$, $p = .03$; LLK: $t[60] = 1.93$, $p = .05$), voicing and manner mispronunciations (PTL: $t[60] = 2.11$, $p = .03$; LLK: $t[60] = 2.21$, $p = .03$), but not between manner and place mispronunciations (PTL: $t[60] = .13$, $p = .8$; LLK: $t[60] = .28$, $p = .7$).

Vocabulary analysis

There was no correlation between the effects of naming (i.e., difference in preference for the target from the pre- to the post naming phase) and receptive vocabulary size following correct pronunciations ($p = .5$), place ($p = .8$) and manner mispronunciations ($p = .9$). By contrast, there was a significant correlation between the effect of naming and vocabulary size following voicing mispronunciations ($r = -.35$, $p = .049$). There was a possibility that the correlation between sensitivity to voicing mispronunciations and vocabulary size might have been led by one of the data points, despite the fact that this item was not statistically an outlier (i.e., not more than two standard deviations from the mean vocabulary size). However, we found a marginally significant correlation, even when this item was excluded from the analysis ($p = .089$). Nevertheless, the weaker correlation cautions against strong conclusions regarding the influence of vocabulary size on infants' sensitivity to voicing changes.

As with the vowel mispronunciations, we divided infants into low and high vocabulary groups based on the median vocabulary size of the infants tested (=48). There were 16 infants in the low vocabulary group and 15 infants in the high vocabulary group. Univariate analyses with pronunciation type (correct, place, manner, and voicing) as a fixed factor and vocabulary group as a covariate revealed a significant main effect of pronunciation type, $F(1, 119) = 3.25$, $p = .02$, $\eta^2 = .07$, but not of vocabulary group, $F(1, 119) = 1.04$, $p = .3$). Unlike the vowel mispronunciations, there was no influence of vocabulary group (i.e., high or low) on infants' responding to consonant mispronunciations overall, although there was a mild suggestion of a split in infants' sensitivity to voicing mispronunciations in high ($M = .03$, $SE = .28$) and low vocabulary groups ($M = .23$, $SE = .31$), $t(29) = 1.77$, $p = .086$, also reflected in the correlational analysis.

Finally, we examined whether infants' displayed the same pattern of responding when we considered only those items that parents reported their infants as knowing. This eliminated 18.8% of all trials. As in the main analyses reported above, there was a near-significant difference between the four pronunciation conditions, $F(3, 179) = 2.39$, $p = .07$, and a significant effect of naming following correct pronunciations ($p = .04$) and voicing mispronunciations ($p = .012$), but not following place ($p = .46$) and manner mispronunciations ($p = .29$).

DISCUSSION

The current study was inspired by previous research suggesting that infants display sensitivity to vowel and consonant mispronunciations as early as 14 months of age (Mani & Plunkett, 2007; Swingley & Aslin, 2000, 2002). However, we hypothesized that as infants display comprehension of some words prior to this age, they may also display sensitivity to mispronunciations earlier than 14 months. We separately examined infants' sensitivity to vowel and consonant mispronunciations, in order to examine whether there were any differences in the role of vowels and consonants in constraining lexical recognition (Mani & Plunkett, 2007; Nazzi, 2005; Nespor et al., 2003). In addition, as previous research finds that 18- and 20-month-olds are less sensitive to some kinds of vowel (i.e., roundedness; Mani et al., 2008) and consonant mispronunciations (i.e., voicing; Havy & Nazzi, 2009; Van der Feest, 2007) compared to others, we examined whether our younger age group would display a similar lack of sensitivity to these less salient mispronunciations.

Vowel mispronunciations

Infants displayed an effect of naming for correct pronunciations (both by subjects and items and in high and low vocabulary groups), indicating that 12-month-olds were familiar with the associations between the target labels and images presented to them. Furthermore, infants displayed sensitivity to all three kinds of mispronunciations, i.e., height, backness, and roundedness. This suggests that, as early as 12 months of age, infants pay attention to the acoustic or phonological characteristics of the vowels in familiar words and demonstrates that vowels play an important role in lexical recognition very early in infancy.

The finding that 12-month-olds were sensitive to roundedness mispronunciations is of considerable interest, and contrasts with 18-month-olds' failure to detect roundedness mispronunciations of words (Mani et al., 2008). The latter result was explained by suggesting that vowel roundedness is a largely redundant feature in English, due to the high correlation between backness and roundedness and the low acoustic salience of roundedness changes.

Sophisticated performance in English infants, therefore, involves infants not noticing a roundedness mispronunciation. Twelve-month-olds' sensitivity to roundedness mispronunciations suggests that the early vowel system may not yet have fully attuned to the salience of the lexico-phonological cues in the native language.[4]

We also found that 12-month-old infants failed to show sensitivity to differences in the acoustic characteristics of the vowel mispronunciations. Clearly, this result should not be taken as discounting the contribution of acoustic information in guiding infants' responses, but rather suggests that any mispronunciation may be salient early in life. Later, with greater exposure to the sounds of words in their native language, some mispronunciations (such as the acoustically and phonologically less salient roundedness change) may become more or less discriminable than others. A comparable universal to language-specific shift has been observed in phonetic discrimination tasks, which is then fine-tuned toward phonologically or acoustically salient changes alone with greater experience (Werker & Tees, 1984).

One explanation for this developmental change between 12 and 18 months implicates the variability of the acoustic characteristics of sounds. As these words are recently acquired, 12-month-olds may not have heard many varied tokens of these words (typically only from their immediate caregivers). Therefore, the representations of these words may be stored with fine acoustic detail, perhaps exemplar-based, such that deviations from the represented form are readily detected. The novelty of the word-object association may initially focus the infant to encode fine-grained acoustic-phonetic detail in representing familiar words. Later, with greater and more varied speaker and language experience, the representations of words may become robust enough to withstand some mispronunciations, such as the acoustically and phonemically nonsalient roundedness mispronunciations presented to infants in Mani et al. (2008). Indeed, recent work documenting the facilitating effect of speaker variability in word learning and phoneme recognition (Rost & McMurray, 2009) supports this interpretation, as does work on the pattern of infants' sensitivity to acoustically salient and non-salient phonemic contrasts (Narayan, Werker, & Beddor, 2009).

An additional perspective on this issue is provided by our finding of an influence of vocabulary size on infants' responding. Infants in the high

[4]It should be noted that the current study presented infants with different words compared to the items presented to the 18-month-olds in Mani et al. (2008). Of two roundedness changes presented to infants in Mani et al. (2008), one of them was identical (i.e., dog to /d?g/) and the other involved the same vowel change ([?] to [ʌ]), albeit in a different word. It is unlikely, therefore, that differences in the mispronunciation tokens presented to infants in the two studies played an important determining role in these divergent pattern of responses.

vocabulary group were more sensitive to vowel mispronunciations than infants in the low vocabulary group. This effect appeared to be driven by differences in infants' sensitivity to backness mispronunciations, but not height or roundedness mispronunciations. This finding dovetails with the approach outlined above. With larger vocabularies, infants are exposed to a larger range of their lexico-phonological repertoire allowing them to fine-tune their sensitivity to some already salient mispronunciations. Greater vocabulary experience also allows dissociations between the different vowel mispronunciations to become apparent. However, it is worth noting that larger vocabularies do not fine-tune 12-month-olds' sensitivity to the level of the 18-month-olds' performance in Mani et al. (2008), i.e., the higher vocabulary group continues to show sensitivity to roundedness mispronunciations. This is unsurprising, given the difference in vocabulary size between the average 18-month-old (284 words) and the average 12-month-old (high vocabulary group: 98). Further vocabulary experience may be required for infants' to show this degree of sensitivity to the structure of their native language lexico-phonological repertoire.

Consonant mispronunciations

Once again, infants displayed a robust effect of naming for correct pronunciations of words (by items and by subjects). Furthermore, infants displayed sensitivity to consonant mispronunciations of familiar words, replicating the findings of many previous studies (Bailey & Plunkett, 2002; Ballem & Plun-kett, 2005; Swingley & Aslin, 2000, 2002). This result was, however, dependent on the type of consonant mispronunciation presented to infants. Although infants were sensitive to place and manner of articulation mispronunciations, they showed an effect of naming for both voicing and correct pronunciations. This greater similarity in looking behavior to voicing mispronunciations and correct pronunciations replicates the findings of previous studies on older French and Dutch infants (Havy & Nazzi, 2009; Van der Feest, 2007). However, White and Morgan (2008) report that, unlike the 12-month-olds, 19-month-old English infants do not discriminate between different kinds of 1-feature consonant mispronunciations. Aside from the age of the infants, one explanation for the difference between the 12- and 19-month-olds implicates the novel image–familiar image pairing used in the White and Morgan study. It is possible that, in the context of a name-unknown image, the similarity of the mispronunciation to the familiar label may encourage the younger infants to ignore small 1-feature fluctuations in mispronunciation size, thereby not differentiating between different kinds of consonant mispronunciations.

Nevertheless, the finding that infants were sensitive to two of three types of consonant mispronunciations presented to them suggests that early representations of words are detailed enough for infants to detect many consonant mispronunciations of these words. The later acquisition of the native language consonantal repertoire does not appear to indiscriminately reduce the salience of consonant mispronunciations relative to vowel mispronunciations.

Comparing vowel and consonant sensitivity

An important aspect of the current study was to investigate whether there were any differences in infants' sensitivity to vowel and consonant mispronunciations. Previous research suggests a dissociation between infants' attention to vowels and consonants in lexical recognition (Havy & Nazzi, 2009; Nazzi, 2005; Nazzi et al., 2009; Nespor et al., 2003). The current study provides further clarification of this issue. First, we did not find any advantage for consonant mispronunciations over vowel mispronunciations in the current study, inasmuch as infants were sensitive to both vowel and consonant mispronunciations at 12 months of age. This result suggests that there may be few differences in the importance of vowels and consonants in guiding lexical recognition early in life.[5] One caveat to this conclusion is that the current task may advantage vowel over consonant mispronunciations, as discussed earlier (see Procedure). However, as noted earlier, given the absence of vowel-initial concrete nouns in the 12-month-old vocabulary, we know of no other way to compare infants' sensitivity to vowel and consonant mispronunciations of familiar words.

It is also possible that we do not find an advantage for consonant mispronunciations over vowel mispronunciations because of the relative salience of the acoustic content of vocalic over consonantal information. The longer duration of vowels (compared to consonants) may make vowel changes, as a group, more acoustically salient compared to consonant changes. Consequently, these 12-month-old infants may pay more attention toward vowel than consonant changes, thereby compensating for the disadvantaged medial position of the vowel in signaling a mispronunciation. It is worth noting, however, that in the absence of reliable acoustic measures of the difference

[5]One caveat to this conclusion comes from a limitation of the current study, which tested infants' sensitivity to different kinds of vowel and consonant mispronunciations on separate items. The structure of the English phonological space did not allow us to mispronounce all words in all possible ways. Indeed, these limitations also meant that we could only include three items per mispronunciation type (i.e., height or voicing) in the current study, which may also have implications on the strength of the conclusions drawn here.

between vowel and consonant mispronunciations, this account must remain speculative.

There were, however, some differences in infants' responding to vowel and consonant mispronunciations that might suggest differences in the representation and processing of these segments in early infancy. First, we found that infants were sensitive to the full range of vowel mispronunciations, but only a selection of the consonant mispronunciations presented to them. Second, we found a robust effect of vocabulary size on infants' responding to vowel mispronunciations, but not on consonant mispronunciations, suggesting a differential impact of language experience on sensitivity to vowel mispronunciations and consonant mispronunciations. Sensitivity to vowel mispronunciations appears to improve only with increased vocabulary size, while at 12 months sensitivity to consonant mispronunciations appears uninfluenced by increasing vocabulary size.

One explanation for this difference between consonants and vowels implicates the efficiency with which infants learn to encode these segments in early lexical representations. Given the considerable variability in their acoustic characteristics (Liberman, Delattre, Cooper, & Gerstman, 1954; Pisoni, 1973), vowel information may initially be stored on a token-by-token basis. Early words may be represented with exemplar-like fine-grained acoustic detail, such that infants display sensitivity to a broad range of vowel mispronunciations and any vowel mispronunciation is readily detected. Consonants, on the other hand, tend to be less variable in production, and can be more easily analyzed into their component features (acoustic or phonemic), such that infants discriminate between different kinds of consonant changes earlier than different kinds of vocalic changes. The differences between infants' sensitivity to vowel and consonant mispronunciations in the current study may, therefore, be explained by suggesting that the change from fine-grained acoustic-phonetic representations to broader phonemic representations of vowels may take place later than with consonants. This view is consistent with an exemplar-based approach that suggests that the initial representation of the word is consolidated on the basis of further experience with varied tokens of the word (Rost & McMurray, 2009).

This interpretation garners support from the suggestion that increasing vocabulary size appeared more influential in modulating infants' sensitivity to vowel mispronunciations compared to consonant mispronunciations. Although infants display sensitivity to both vowel and consonant mispronunciations, attention to vocalic detail may involve greater experience with words and greater exposure to different tokens of words. Once again, this may be due to the greater variability of the acoustic characteristics of vowel tokens in words compared to the stability of most consonant tokens. The one case for consonants where there was a suggestion that greater vocabulary size improves performance, i.e., voicing, is precisely the case where variability is well documented (Baran, Zlatin, & Daniloff, 1977; Kewley-Port & Preston, 1974; Macken & Barton, 1979; Sunberg & Lacerda, 1999). Note that in both cases, i.e., with vowels and voicing mispronunciations, greater vocabulary exposure did not result in superior performance, akin to the level of 18-month-old infants (Mani et al., 2008). As noted above, further vocabulary experience may be required for infants to show this degree of sensitivity to the structure of their native language lexico-phonological repertoire. Taken together, the current results appear to suggest that at the initial stages of word learning (i.e., at 12 months of age), greater familiarity with words leads to acoustically detailed representations of words, thereby explaining the difference between the high and low vocabulary groups responding to vowel mispronunciations. With greater and more varied vocabulary exposure (e.g., by 18 months of age), infants may develop phonologically detailed representations in tune with the phonological make-up of their native language.

Furthermore, we note that while there was a similar influence of vocabulary size on infants' responding to voicing and vowel mispronunciations, there were differences in the pattern of infants' sensitivity to voicing and vowel mispronunciations. In contrast with infants' robust sensitivity to vowel mispronunciations, infants were not sensitive to voicing mispronunciations. It is unclear, however, that increased variability in production of consonant voicing and vocalic cues results in both vowels and consonants being stored with fine-grained acoustic-phonetic detail. Even older French and Dutch infants and adults are less sensitive to voicing changes in words compared to other changes, suggesting that voicing changes may not be adequately salient in words even later in life. It is evident that the interaction between vocabulary size and token variability requires further experimental validation before more definite conclusions about infant phonological specificity can be drawn.

Phonological underspecification

The results of the current study have implications for theoretical models charting the specification of phonological detail in early lexical representations. The main divide in theoretical perspectives rests on whether there is a qualitative change in the representation of words from infancy to adulthood. Those arguing for a qualitative change suggest that words are represented holistically early in infancy—the density of infant lexicons is sufficiently sparse as to not require acoustically phonetically detailed representations of words (Charles-Luce & Luce, 1990). This implies that infants should not be sensitive to small mispronunciations of words until their lexicons are populated to a degree that requires further discrimination of acoustic or phonemic detail.

An alternative form of this hypothesis is evidenced in work by Werker and colleagues suggesting that although the underlying representations are phonemically detailed, infants may not be able to access these representations until later in life, when the cognitive demands of word learning do not constrain the level of infants' access to phonetic detail. As infants learn more words, they are able to generalize from word representations to phonemic representations, such that in tasks with fewer cognitive demands, infants are able to access these phonetically detailed representations (Werker & Curtin, 2005).

In keeping with Werker & Curtin's (2005) hypothesis, our results provide tentative support for the view that vocabulary size influenced infants' responding. Infants in the high vocabulary group were more sensitive to backness mispronunciations than infants in the low vocabulary group. However, there was a concern that infants in the high vocabulary group were mis-mapping the mispronunciations to the distracter label, raising doubts about the mental processes underlying this finding. Similarly, with consonant mispronunciations, there was a significant correlation between infants' sensitivity to voicing mispronunciations and increasing vocabulary size, although this correlation was only marginally significant upon excluding a single data point. Therefore, although these results provide support for this alternative form of the developmental hypothesis, further research is required to more systematically assess the manifestation of an influence of vocabulary size on infant sensitivity to mispronunciations.

An adaptation of the developmental hypothesis such that exposure to words (all words, not minimal pairs alone) can increase the salience of some mispronunciations would allow greater cohesion between the results of the current study and the developmental hypothesis. Indeed, some of the suggestions incorporated by PRIMIR would allow for vocabulary size to influence further phonemic specification (Werker & Curtin, 2005). According to PRIMIR the qualitative change between infant and adult representations of words rests on infants moving from early phonetic categories to later level phonemic categories. Early discrimination of vowel mispronunciations may, therefore, rest on infants' use of phonetic categories of speech. Later, infants may begin to rely on phonemic categories that have been extracted from early phonetic generalizations, at least for vowels. In addition, because the model encodes information at the phonetic, lexical, and phonemic levels, different tasks have access to different levels of representation. Simple cross-modal tasks that mimic natural speech processing (as in Mani & Plunkett, 2007, 2008a; Swingley & Aslin, 2000, 2002) may allow infants to access to all the information in the input, while more complex tasks (such as word learning or name-based categorization) can impose restrictions on the level of access infants have to the information in the input.

The current study confirms that, irrespective of whether this early sensitivity is phonetically or phonemically based, infants do pay attention to the acoustic or phonemic properties of vowels and consonants in words, such that infants display sensitivity to vowel and consonant mispronunciations of words. Two questions now remain: first, is there a qualitative change from infant phonetic perception to adult phonemic perception? This question has reached a stand-off in research on adult language processing—adult perception of phonemes in word recognition tasks appears to depend on the kinds of tasks used and whether these tasks specifically focus attention at the phonemic level. Perhaps a pertinent second question for future research is whether any such putative movement from phonetic to phonemic categories is more influenced by infants' familiarity with a word (i.e., with different tokens of the same word) or by the vocabulary size of the infants.

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