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PAPER

11-month-olds' knowledge of how familiar words sound

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Abstract

During the first year of life, infants' perception of speech becomes tuned to the phonology of the native language, as revealed in laboratory discrimination and categorization tasks using syllable stimuli. However, the implications of these results for the development of the early vocabulary remain controversial, with some results suggesting that infants retain only vague, sketchy phonological representations of words. Five experiments using a preferential listening procedure tested Dutch 11-month-olds' responses to word, nonword and mispronounced-word stimuli. Infants listened longer to words than nonwords, but did not exhibit this response when words were mispronounced at onset or at offset. In addition, infants preferred correct pronunciations to onset mispronunciations. The results suggest that infants' encoding of familiar words includes substantial phonological detail.

Introduction

Language learning begins in infancy with both phonological and lexical development. Early phonological development has been shown clearly in studies revealing that over the course of the first year, infants' discrimination of speech sounds begins to align with the phonology of their native language, leading infants to disregard many phonetic distinctions that their language does not use (e.g. Werker & Tees, 1984; Kuhl, Williams, Lacerda, Stevens & Lindblom, 1992; Best, 1994; Polka & Werker, 1994; Cheour, Ceponiene, Lehtokoski, Luuk, Allik, Alho & Näätänen, 1998). These results are usually interpreted as suggesting that infants learn to perceive speech in terms of a language-specific set of phonetic categories (e.g. Kuhl, 1995).

Lexical development also begins in the first year, as infants begin to extract and learn recurring sequences of speech that often correspond to words. For example, Jusczyk and Hohne (1997) played infants stories in which several words were used frequently. Two weeks later, infants' memory for these frequent words was tested in the laboratory. Infants showed a preference for listening to the familiar words rather than a set of similar foil words. These children were only 8 months old, suggesting that by the end of the first year, infants may have amassed a substantial lexicon of word forms based upon their exposure to language (Swingley, 2005).

It seems natural to suppose that when infants begin to learn these word forms, they put their developing phonetic categories to use. As a result, the early lexicon should be composed of words that may be recognized when heard again, and differentiated from similar-sounding words. Unfortunately, efforts to test this prediction have yielded mixed results that depend upon the ages of the children tested, the nature of the words examined, and the tasks employed (e.g. Fennell & Werker, 2003; Hallé & de Boysson-Bardies, 1996; Stager & Werker, 1997; Swingley & Aslin, 2000, 2002). The substantial variability in outcomes across these studies has contributed to a re-examination of the role of early phonological learning in the acquisition of the lexicon (e.g. Beckman & Edwards, 2000; Metsala & Walley, 1998). The goal of the present series of experiments was to test the level of phonological specificity present in 11-month-olds' representations of familiar words.

Current views on early lexical representation are diverse. Many theoretical phonologists assume that children's 'underlying' representations (as distinct from their spoken forms) are like those of adults, a view described as 'the standard assumption' by Dinnsen, O'Connor and Gierut (2001; see also Smolensky, 1996). On this view, children's phonological knowledge may be described using the same discrete categories – features, segments and so forth – used to describe adults' knowledge, and most of children's deviant pronunciations are said to

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result from constraints on children's ability to produce word-forms that have been correctly perceived. On the other hand, a number of psychologists have noted that young children's performance on word learning tasks is often poor, even when the task does not require children to talk (e.g. Stager & Werker, 1997). Furthermore, performance frequently depends on phonological variables like the probability of speech sounds appearing in a particular sequence (e.g. Storkel, 2001). These results have been interpreted as evidence that many of children's early words lack phonological detail, and that complete phonological specification emerges only with substantial growth in the child's vocabulary and with the learning of sets of similar-sounding words in early childhood (Metsala & Walley, 1998; Walley, 1993; Storkel, 2002). Walley (1993), for example, suggested that a child's early phonological knowledge of the word *cap* might consist of a single phonological feature, '+labial' (p. 293; see also Ferguson & Farwell, 1975; Waterson, 1971).

A number of previous studies have attempted to evaluate infants' knowledge of words, but the pattern of results to date is complex. In one such study, $7\frac{1}{2}$-month-olds were familiarized to a list of repeated isolated words (e.g. *dog . . . dog . . . dog . . .*). Then infants were tested for a preference for listening to a passage containing the familiarized word several times, or to a similar passage containing a nonfamiliarized word (Jusczyk & Aslin, 1995). Preference was tested in the infant-controlled *Headturn Preference Procedure*. In this procedure, infants are played speech stimuli only as long as they continue to fixate a flashing light. Fixation times are compared for trials on which infants hear speech of one sort (e.g. passages containing familiarized words) and trials presenting speech of another sort (passages containing nonfamiliarized words). In Jusczyk and Aslin (1995), infants listened longer to familiarized-word passages than to the other passages, indicating that they had remembered the words and recognized them in sentences. This effect was *not* found in a second experiment, in which infants were first familiarized with mispronunciations of the passage words (e.g. *bog . . . bog . . . bog . . .*). The contrasting outcomes in the two experiments suggested that infants were able to encode sufficient phonetic information in familiarized words to recognize them in sentences, without 'false-alarming' to variants of the words. The same overall result was subsequently found in a study testing recognition (or the lack thereof) of words with altered *offsets* (Tincoff & Jusczyk, 1996). In this study, infants familiarized to words like *daub* did not respond preferentially to the passage containing *dog*.

While these results imply some degree of phonetic detail in trained words, their generalizability is uncertain. Infants were tested immediately after familiarization with the words, a procedure that may overestimate infants' long-term memory for word-forms. In addition, the familiarization consisted of many isolated repetitions of the words from a single speaker and in a carefully controlled experimental situation, conditions that may tend to inflate performance relative to infants' ordinary exposure to words.

Two previous studies with 11-month-olds tested infants' knowledge of words they were likely to be familiar with based on natural exposure. Hallé and de Boysson-Bardies (1996) presented French infants with lists of isolated bisyllabic words such as *bonjour* ('hello') and *canard* ('duck'), and words relatively unlikely to be familiar, such as *caduc* ('obsolete') and *busard* ('harrier'). Infants preferred the familiar words, replicating a previous study (Hallé & de Boysson-Bardies, 1994). However, infants also preferred the familiar words when those words were mispronounced by altering the voicing or place of articulation of the initial consonant (e.g. pronouncing *bonjour* as *ponjour* or as *vonjour*). In addition, infants showed a nonsignificant tendency to prefer familiar words altered by changing the manner of articulation of the second syllable's onset consonant (*bonjour* as *bongour*). An additional series of experiments yielded no apparent preferences for correct pronunciations over these mispronunciations. Only complete excision of the initial consonant (*bonjour* as *onjour*) quashed infants' preferences for mispronounced words over unfamiliar words. These results suggest that infants can recognize mispronounced versions of familiar words, at least for some mispronunciations. Hallé and de Boysson-Bardies suggested that early lexical representations may have a 'global format', underspecified enough to match correct forms and the tested mispronunciations equally.

A second study used the same methods to test English-learning 11-month-olds (Vihman, Nakai, DePaolis & Hallé, 2004). Infants heard familiar bisyllabic words that were correctly pronounced, mispronounced at word onset (e.g. *dirty* as *nirty*), or mispronounced at the onset of the second syllable (e.g. *dirty* as *dirny*). These words were contrasted with lists of presumably unfamiliar words (e.g. *budget*). Infants preferred correct pronunciations over unfamiliar words, but did not show this preference for words mispronounced at onset, showing that infants detected changes in onset consonants' manner of articulation. The comparison of words mispronounced in the second syllable and unfamiliar words yielded an interesting twist: infants preferred the mispronounced words, suggesting weak phonological encoding. However, this effect was carried by the trials in just the second half of the experiment; in the first half, infants showed no preference. Vihman *et al.* speculated that infants in this condition may have had some difficulty in recognizing the mispronounced words, leading to the emergence of a preference for the mispronounced words over the unfamiliar words only after relatively greater exposure to them during the study. On this interpretation, English-learning 11-month-olds know the first consonants of both syllables of bisyllabic words well enough to be measurably impaired in word recognition when those consonants' manner of articulation is altered.

The latter result prompted Vihman *et al.* (2004) to reanalyze the earlier data from French infants. This reanalysis showed that French infants' preference for words with altered onset consonants (with the mispronunciations achieved by altering the manner of articulation) over unfamiliar words was carried entirely by the second half of the experiment. Thus, English-learning infants appeared to recognize words with manner-mispronounced *medial* consonants, but only late in the experiment, while French-learning infants appeared to recognize words with manner-mispronounced *onset* consonants, but again only late in the experiment. This difference between first and second halves of the experiment was not found when correctly pronounced words were contrasted with unfamiliar words. Vihman *et al.* proposed a modified interpretation of the initial French data, in which infants' representations are not underspecified with respect to initial consonants. The difference between the French and the English data may be understood with reference to the differing stress systems of the two languages. In French, accent tends to be placed on the final syllable of bisyllabic words; in English, stress tends to be placed on the initial syllable. In both languages, children showed the 'late recognition of mispronounced words' results when a manner-of-articulation mispronunciation changed the onset of an unstressed syllable. When mispronunciations changed onsets of stressed syllables, by contrast, recognition was more likely to be blocked.

The present experiments extended these studies of infants' phonological encoding of familiar words in two ways. First, both onset and offset consonants were probed. Studies of adults' perception of onset and coda (offset) consonants generally show an advantage for onsets, possibly because the acoustic cues specifying onsets are clearer (Redford & Diehl, 1999). The more distinct realization of onsets in speech might result in better specification of onsets than codas in infants' lexicons. Another reason to suspect that infants may represent less detail in codas comes from a functional asymmetry in the word recognition process: because words are interpreted as the speech signal unfolds, early parts of words exercise more constraint on the interpretation of the heard word than do later parts of words (Marslen-Wilson & Welsh, 1978; Marslen-Wilson, 1987; Swingley, Pinto & Fernald, 1999). Indeed, because children know few words that differ only in their codas, successful word recognition relatively rarely depends on identifying the coda (De Cara & Goswami, 2002). This might lead infants to attend to codas less than onsets.

A second extension of the present experiments concerned the experimental materials. The two previous investigations of infants' responses to segmental mispronunciations consistently modified a particular phonological feature in generating the mispronounced stimuli: voicing or manner of articulation in Hallé and de Boysson-Bardies (1996), and manner only in Vihman *et al.* (2004).[1] In the Vihman *et al.* study of manner changes, for example, more than half of the mispronunciations involved exchanges of stops for nasals and vice versa (e.g. *dinner* to *ninner*), and the remainder were nearly all exchanges of stops and fricatives (e.g. *tickle* to *sickle*). Using a consistent change of this sort has the advantage of simplicity: we may say that infants were sensitive to variation in manner of articulation. However, it is possible that these manner changes were more salient than other changes that might be tested, and therefore risked overestimation of infants' sensitivity to phonological substitutions.

The ideal approach would be to use the least salient phonological substitutions possible in the language, so that if infants detect those changes it may be assumed that they would also detect more salient changes. The problem is that there is no adequate database from which to make well-grounded inferences about salience to infants. For example, children's spoken substitutions may be driven by articulatory rather than perceptual factors. Adult confusion matrices are normally generated by adding noise to speech, which may mask some cues more than others (and salience to adults may differ from salience to infants). Generalization from a trained sound to variants (using a conditioned headturning procedure, for example) could provide the right sort of infant data, but testing enough contrasts to yield a complete confusability table is not practical. Given these considerations, it seems most appropriate to test infants' lexical knowledge using a range of stimuli. In the present study, rather than using changes corresponding to a single type of phonological feature, changes were selected so as to minimize their estimated salience simply according to our intuitions. Most of the phonological substitutions tested were place substitutions. A more detailed description is given below.

Five experiments were conducted. All participants were Dutch-learning 11-month-olds. Experiment 1 tested infants' preference for correct pronunciations of familiar words relative to a set of matched unfamiliar or nonce words, thereby providing a baseline from which to compare infants' preferences when given deviant pronunciations of familiar words. Experiment 2a compared

[1] Vihman *et al.* also manipulated lexical stress in additional experiments.

mispronounced familiar words and unfamiliar words; Experiment 2b compared familiar words and mispronounced words. Mispronunciations in Experiments 2a and 2b involved changes in words' onsets. Experiments 3a and 3b were analogous to 2a and 2b, but tested mispronunciations in words' offsets.

Experiment 1: words versus nonwords

Experiment 1 was conducted to confirm the efficacy of our implementation of the headturn preference procedure (HPP; Kemler Nelson, Jusczyk, Mandel, Myers & Turk, 1995) by demonstrating infants' preferences for familiar words over unfamiliar words. Eleven-month-old infants were presented with lists of isolated spoken words on some trials (the Familiar-word condition), and lists of isolated nonwords or unfamiliar words (the Nonword condition) on other trials. Infants controlled the duration of their listening to the sounds on each trial by continuing to fixate a flashing light to their left or right: as long as they fixated the light, a computer was instructed to continue playing the speech stimuli on that trial. According to the logic of the HPP, fixation duration reflects listening preference. Based on past research (Hallé & de Boysson-Bardies, 1994; Vihman *et al.*, 2004), preference for familiar words was expected.

Method

Participants

Participants were 24 infants (12 boys and 12 girls) from monolingual Dutch-speaking homes. Their mean age was 346.0 days or about 11;11 (SD = 8.0 days, range 334–360). All parents reported that their infants had normal hearing. An additional 14 infants were tested but excluded from the analyses because they became fussy before all trials were completed ($n = 8$), because of equipment failure or experimenter error ($n = 5$) or due to parental interference ($n = 1$).

Stimuli

Test words consisted of 16 monosyllabic Dutch words for animals or body parts. Nonwords consisted of 16 monosyllables constructed by rearranging the sounds of the test words. In this rearrangement, onset consonants and consonant clusters remained as onsets (thus, the [sx] of *schaap*, 'sheep', was relocated to the nonword *schee*); likewise, codas and coda clusters remained as codas (thus, the [nt] of *mond*, 'mouth', appeared in the nonword *vaant*). This constraint resulted in one or two nonwords that were fairly similar to a tested familiar word (reducing the likelihood of finding a difference between words and nonwords); however, the procedure had the advantage of ensuring that any preferences for words could not have been driven by preferences for particular speech sounds or consonant combinations. Rearrangement of the consonants was done separately for the eight animal words and the eight body-part words. Although the 'nonwords' were sometimes real Dutch words, they were judged unlikely to be familiar to 11-month-olds. The words and nonwords (and the mispronunciations used in the remaining experiments) are listed in Table 1.

The stimuli were read by a female native speaker of Dutch in a sound-attenuating booth, and digitally recorded with a sampling rate of 48 kHz. The talker read

Table 1 *International Phonetic Alphabet transcription of the Dutch test stimuli used in each of the experiments, with an English gloss. Columns labeled* change *give a featural description of the difference between the correct pronunciation and the mispronunciation*

Familiar	English	Nonword	Onset-MP	Change	Offset-MP	Change
beːn	leg	baːs	deːn	place	beːm	place
beːʁ	bear	bøːs	deːʁ	place	beːx	place, voice
bœyk	tummy	bœyn	kœyk	place, voice	bœyp	place
eːnt	duck	eːp	eːnt	[no change]	eːŋk	place
hɑnt	hand	haːk	xɑnt	place	hɑŋk	place
haːʁ	hair	heːn	saːʁ	place	haːl	place, manner
hont	dog	hoʁ	font	place	hɑŋk	place
ku	cow	kus	xu	manner	ku	[no change]
mont	mouth	maːnt	nont	place	moŋk	place
nøːs	nose	nut	møːs	place	nøːf	place
paːrt	horse	pøːnt	daːrt	place, voice	paːrp	place
pus	cat	purt	tus	place	puf	place
sxaːp	sheep	sxeː	ʃaːp	place	sxaːf	place, manner
teːn	toe	toʁ	peːn	place	teːm	place
vɪs	fish	vaːnt	vɪs	manner	vɪf	place
vut	foot	veːnt	but	place, manner	vuk	place

Table 2 *Acoustic measurements for stimuli used in all experiments. MP is an abbreviation for 'mispronunciation'. Standard deviations are shown in parentheses. Durations are given in milliseconds, and frequency measures in Hertz*

Condition	Expt.	Duration	Mean F_0	Min F_0	Max F_0	Range F_0
Familiar	1, 2b, 3b	681 (143)	227 (38)	144 (39)	322 (55)	178 (53)
Nonword	1, 2a, 3a	644 (112)	222 (31)	159 (35)	292 (34)	146 (54)
Onset MP	2a, 2b	705 (124)	221 (37)	139 (56)	313 (50)	174 (65)
Offset MP	3a, 3b	684 (110)	220 (26)	142 (41)	304 (42)	162 (61)

the words using an infant-directed speech register and a moderately slow speaking rate. A summary of acoustic measurements for all reported experiments is presented in Table 2. As shown in the table, the stimuli overlapped substantially on these measures over all conditions, rendering superficial acoustic differences unlikely to drive infant preferences.[2] Durations of individual words ranged from 420 to 960 ms. Amplitudes of stimulus words were individually normalized using SoundEdit 16 on an Apple G4 computer.

The experiment consisted of 16 test trials. On each trial, a single soundfile was played, containing stimulus words separated by 1 s of silence. Half of the Familiar-word trials contained only animal words, while the other half contained only body-part words. Each soundfile consisted of 24 word tokens. To construct the soundfiles, the eight animal or body-part words (or the associated nonwords) were arranged in a random order, yielding a block of eight words. These words were then re-randomized to form a second block and a third block. The three blocks were strung together to form a continuous list of 24 words separated by pauses. This randomization procedure was followed eight times for each set of eight words (animal words, body-part words, and each set's associated nonwords), yielding a total of 32 soundfiles. Each infant heard half of these 32, making 16 trials. Soundfiles were about 40.3 s in duration, with a range of 39.1 to 41.7. (Infants rarely heard these soundfiles in their entirety.)

The test trials were arranged into eight separate experimental orders according to several counterbalancing constraints. In each order, experimental condition was quasirandomly sequenced so that consecutive runs of a given condition were limited to two trials. Thus, for example, infants never heard three consecutive real-word trials. Side of presentation (left or right) followed the same constraint with a different quasirandom ordering. For each stimulus order, a 'partner' stimulus order contained the same essential sequence but with the condition inverted, a counterbalancing measure intended to nullify any spurious condition preferences actually due to side bias, trial number or other structural features. Thus, if in one order the first trial consisted of familiar animal words, in another order the first trial consisted of nonwords derived by rearranging the speech sounds from the animal words.

An approximately equal number of infants were assigned to each order, balanced by sex. These counterbalancing constraints held for all studies. The entire procedure took about 4.5 minutes.

Apparatus

The experiment was conducted in a three-sided booth whose side walls were black plywood panels (2 m tall and 1.2 m wide) and whose back wall (1.3 m wide) was covered with black felt cloth. A 4 cm square array of green LEDs was centered on the back wall; a similar array of red LEDs was attached to each side panel at the open end of the booth, about 1 m above the floor. A loudspeaker was fixed to each side panel just below the red lights. Infants were recorded using a low-light videocamera positioned about 10 cm beneath the green lights.

Soundfiles were stored on a computer. The experimenter, situated behind the back side of the booth, watched the infant on a video monitor fed from the camera. A button box connected to the computer was used by the experimenter to initiate each trial and to record infants' looking.

Procedure

Infants were seated on their parent's lap on a chair centered between the loudspeakers. When the infant appeared ready, the experimenter signaled the computer to start the green light, which flashed until the infant oriented to it. Then the green light was turned off, and the red lights on one of the side panels began to flash. (The side was prespecified in the trial order.) When the experimenter judged that the infant was looking at this side light, she signaled the computer to initiate playback of the soundfile for that trial. As long as the infant continued to fixate the light, the experimenter pressed a button on the response box, signaling the computer to continue playing the soundfile; when the infant looked away, the experimenter released the button. Each trial and the playback of the soundfile continued until the soundfile was completed (which occurred rarely) or until the infant looked away from the side light for 2

[2] This overlap may be quantified using a one-way ANOVA with four levels of condition. Such a test repeated for each of these acoustic measures never yielded a significant result (all $p > .30$).

consecutive seconds, terminating the trial. At this point the green central light began blinking, and the process was repeated. The infant's listening score for a given trial included only the time when he or she was judged to have been fixating the light; looking-away times were not included.

Once the experiment began, the experimenter and the parent wore closed-ear headphones that played an auditory masking sequence. The masking was intended to prevent the parent from inappropriately influencing the infant and the experimenter from introducing bias. The masking sequence was constructed by digitally concatenating the experiment's stimulus words, and then replicating and overlaying this sequence into several overlapping streams out of phase, creating a continuous, disordered babble containing phonetic characteristics identical to those in the actual stimuli. Overlaid on this babble was a sequence of popular songs performed with a backup band by either Elvis Presley or Charles Trenet (at the parent's option). The music was intended to amuse and relax the parents, while drawing their attention away from the speech materials.

On the day of their visit to the laboratory, parents were given a questionnaire listing the words tested in the study, and asked to estimate how often their infant heard each word, on a scale from 1 (never/once per week) to 3 (several times per day). The mean response (over words and infants) was 1.9 (subjects' SD = .31), corresponding to our label 'one time per day'. No participants were excluded on the basis of these questionnaires.

Reliability coding

To estimate the reliability of experimenters in making on-line judgments of infants' looking times, tapes of 20 infants' performance (across the 5 experiments) were digitized and coded frame-by-frame. Coders noted the onsets and offsets of infants' looking to the side lights. These looking durations were then compared to the same durations as measured on-line by the experimenter. The correlation between on-line and off-line scoring was computed for each subject. Over the 20 subjects, the mean correlation was .9971 (SD = .0043; range .981 to 1.000). Over all trials, the mean *absolute* difference between on-line judgment and off-line coding was 404 ms (SD = 418; median = 265). Off-line coders tended to indicate shorter looking durations (mean difference, 309 ms, median 233 ms). For each of the 20 subjects, the difference in looking times between the two conditions was computed both using the on-line observation data and off-line coding. These two observational methods yielded difference scores that varied by an average of less than 0.1 seconds (mean, 85 ms; SD, 117 ms; range 0 to 370 ms). The negligible differences in results using the two coding methods suggest that on-line evaluation was adequate for measuring infants' looking behavior.

Results and discussion

Mean listening times for the Familiar-word and Nonword conditions were computed for each infant by averaging over the trials for each condition. Across all 24 infants, mean listening times were 9.20 s (SD = 3.19) in the Familiar-word condition and 7.39 s (SD = 3.30) in the Nonword condition. Infants' longer listening to the familiar words was statistically significant (paired $t(23) = 2.93$, p (one-tailed) $< .005$). Listening time differences were not correlated with parental reports of infants' exposure to the words ($r = .010$, *ns*). Infants' preference for words over nonwords replicated previous findings (Hallé & de Boysson-Bardies, 1994, 1996; Vihman *et al.*, 2004), using Dutch infants and phonologically matched nonwords.[3]

Two of the following experiments tested whether infants would maintain this lexical preference when presented with mispronounced words and nonwords. If infants differentiate mispronunciations and correct pronunciations, their preference for words over nonwords should diminish or disappear when the words are mispronounced. One empirical prediction, then, is for a null result (i.e. no preference) when mispronunciations are compared with nonwords (Experiments 2a and 3a). On the other hand, if children do not differentiate correct and incorrect pronunciations, Experiment 1 should be replicated when the words are replaced with mispronunciations. Because one of the predictions was for a null result, a power analysis was conducted to evaluate the likelihood of replicating the effect found in Experiment 1 if the no-differentiation hypothesis were true.

For this analysis, the magnitude of the lexical preference effect and the population standard deviation of this effect were estimated from Experiment 1: 1.81 seconds (magnitude) and 3.03 seconds (standard deviation). Assuming an n of 24 and an alpha level of .05, the power to (re)detect this effect was estimated at .884; with an alpha level of .10, the estimated power was .944. These computations suggested that the likelihood of arriving at a null result by chance in Experiments 2a and 3a was small.

[3] Hallé and de Boysson-Bardies (1994, 1996) reported difference scores and also preference ratios (e.g. looking to words divided by total looking). In the present studies these dependent measures yielded the same results, so the more traditional difference measure is reported throughout.

Experiments 2a and 2b: onset mispronunciations

Experiments 2a and 2b tested infants' knowledge of the onsets of the familiar words used in Experiment 1. In Experiment 2a, infants' listening times to mispronunciations of the familiar words were compared with listening times to the nonwords of the first experiment. If infants have only vague, general knowledge of how words sound, subtle mispronunciations of words would be expected to be recognized as instances of those words by infants, leading to a listening preference similar to that found in Experiment 1. Alternatively, if infants have well-specified lexical representations, mispronounced words might not be recognized as instances of the familiar words from which they were derived, and as a result infants might not prefer mispronunciations to nonwords. In Experiment 2b, these mispronunciations were compared to the correctly-pronounced familiar words. If infants have well-specified lexical representations, correct pronunciations may be preferred over mispronunciations.

Method

The procedure varied from Experiment 1 only in the stimuli.

Participants

All participants in Experiment 2 were from monolingual Dutch-speaking homes and were reported by parents to have normal hearing. Experiment 2a tested 24 infants (11 girls) whose mean age was 352 days or about 11;17 (SD = 6.8 days, range 342–364). An additional five infants were tested but excluded due to fussiness. As in Experiment 1, parents were asked to estimate how often their child heard each of the tested words; responses were comparable (mean 1.83 out of 3; SD = .40). Participants in Experiment 2b were 24 infants (13 girls) whose mean age was 351 days (11;16, SD = 8.3 days, range 335–362). An additional nine infants were excluded due to fussiness ($n = 6$), parental interference (2) or experimenter error (1). Parents' responses on the word-use questionnaire averaged 1.74 out of 3 (SD = .37).

Stimuli

The Nonword stimuli used in Experiment 2a were the same as the Nonword stimuli used in Experiment 1, and the Familiar-word stimuli used in Experiment 2b were the same as the Familiar-word stimuli of Experiment 1. The Onset-Mispronunciation stimuli were recorded in the same session (by the same talker) as all other stimuli.

The mispronunciations used for the Onset-Mispronunciation conditions of Experiments 2a and 2b involved alterations of the onset consonants of the target words. One of the test words (*eend*, 'duck') had no onset consonant and was pronounced the same way in both conditions. The alterations formed a phonologically heterogeneous set, though for the most part only one phonological feature was altered. Ten of the 15 mispronunciations involved a change in place of articulation (such as [n] for [m] or [d] for [b]). Transcriptions of the stimulus items are presented in Table 1.

Results and discussion

Mean listening times for each infant were computed for each condition as in Experiment 1. In Experiment 2a, mean listening times were 9.65 s (SD = 3.84) in the Nonword condition and 9.01 s (SD = 5.91) in the Onset-Mispronunciation condition. This difference was not significant (paired $t(23) = .75$, p (one-tailed) > .20), showing that infants did not prefer to listen to mispronounced versions of the familiar words over the nonwords.

The contrast with the results from Experiment 1 was confirmed by comparing between-condition difference scores found in Experiment 2a with those from Experiment 1. This difference was statistically significant ($t(46) = 2.32$, p (one-tailed) = .012), indicating that infants responded differently to correct pronunciations (relative to nonwords) and onset mispronunciations (also relative to nonwords).[4] Infants' difference scores were not correlated with parental estimates of exposure to the tested words ($r = .17$, *ns*).

Experiment 2b compared correct pronunciations and onset mispronunciations directly. Mean listening times were 10.07 s (SD = 4.09) in the Familiar-word condition and 8.94 s (SD = 3.59) in the Onset-mispronunciation condition. Infants' preference for the correctly pronounced words was statistically significant (paired $t(23) = 2.24$, p (one-tailed) = .018). Looking-time scores were not correlated with parental reports of exposure ($r = -.21$, *ns*).

Infants' preference for the correct pronunciations even in the context of a list including similar mispronunciations provides strong evidence for infants' knowledge of phonological detail in the onsets of familiar words. Because most of the mispronounced words differed from the correctly pronounced words by changes in one feature (primarily place of articulation; see Table 1), and all mispronunciations involved phonetically minor (though phonologically significant) changes, we may infer that infants' knowledge of familiar words includes more than

[4] This difference was also significant with looking-time proportions as the dependent measure; $t(46) = 3.39$, p (one-tailed) < .001.

just a vague, general sense of how the onset consonants should sound.

Experiments 3a and 3b: offset mispronunciations

Experiments 3a and 3b tested infants' knowledge of the offsets of familiar words. In Experiment 3a, infants' listening times to offset mispronunciations were compared with listening times to the nonce words of the first two experiments. In Experiment 3b, offset mispronunciations and correct pronunciations were compared directly.

Method

The procedure varied from Experiment 1 only in the stimuli.

Participants

All participants in Experiment 3 were from monolingual Dutch-speaking homes and were reported to have normal hearing. Experiment 3a tested 24 infants (12 girls) whose mean age was 350 days or about 11;16 (SD = 7.9 days, range 336–364). An additional 13 infants were excluded due to fussiness ($n = 11$), parental interference (1) or experimenter error (1). Parents' responses on the word-use questionnaire averaged 1.70 (SD = .34). Experiment 3b tested 24 infants (12 girls) whose mean age was 350 days or about 11;15 (SD = 7.4 days, range 335–361). An additional six babies were excluded due to fussiness ($n = 4$) or experimenter error ($n = 2$). Parents' responses on the word-use questionnaire averaged 1.97 (SD = .37).

Stimuli

The Nonword and Familiar-word stimuli were those used in the previous experiments. The Offset-mispronunciation stimuli were recorded in the same session as the other stimuli. Mispronunciations involved alteration of the final consonant or consonants of 15 of the 16 stimuli (the 16th, *koe*, 'cow', was not altered, having no coda consonant). Twelve changes involved place of articulation only. In four of these, the coda [nt] was changed to [ŋk]; in these cases, both the final and penultimate consonants were altered to conform to a phonotactic constraint disfavoring nonhomorganic sequences like [nk]. Stimulus transcriptions are presented in Table 1.

Results and discussion

In Experiment 3a, mean listening times were 8.85 s (SD = 3.38) in the Nonword condition and 8.99 s (SD = 4.89) in the Offset-mispronunciation condition. This difference did not approach significance (paired $t(23) = .26$, p (one-tailed) > .30), showing that infants did not prefer to listen to mispronounced versions of the familiar words over the nonwords. The contrast with Experiment 1 was confirmed by comparing subjects' condition difference scores in the two experiments. This difference was statistically significant ($t(46) = 2.03$, p (one-tailed) = .024).[5] Infants' listening-time differences were not correlated with parental report of word exposure ($r = .06$, *ns*).

Experiment 3b compared correct pronunciations and offset mispronunciations. Mean listening times were 9.02 s (SD = 3.74) in the Familiar-word condition and 9.07 s (SD = 3.71) in the Offset-mispronunciation condition. This difference did not approach significance ($t(23) = .08$, p (one-tailed) > .40). The correlation between listening-time differences and parental reports of exposure to the words was significant ($r = .476$, $p < .02$). However, this was largely due to two infants whose reported exposure and looking-time differences were both 1.96 or more standard deviations above the mean; without these two outliers, the correlation dropped to .11 (*ns*). Thus, as in the other four experiments, there was no strong evidence of a relationship between infants' responses and parental reports of exposure to the common words tested. In sum, Experiment 3b showed that infants did not prefer the correct pronunciations to the mispronunciations.

Vihman *et al.* (2004) found in two experiments that infants who showed an overall preference for mispronounced words over unfamiliar words in fact only displayed this preference in the second half of the experiment's test trials, as if infants only recognized the mispronounced words after multiple exposures. This result, coupled with the unexpected failure to find a correct-pronunciation preference in Experiment 3b, motivated a similar split-half analysis of the present series of experiments. If, for example, infants found the offset-mispronounced words harder to recognize than the correctly pronounced words, this might lead to early preferences for correct pronunciations masked by later recognition of offset-mispronounced words. However, the lack of difference between conditions was consistently found in both halves of Experiment 3a (a difference of .09 s in the first eight trials, and 0.18 s in the second eight). Similar analyses conducted for the other four experiments also

[5] An analysis using proportions rather than raw listening-time differences yielded the same result: $t(46) = 2.65$; p (one-tailed) = .005).

showed no systematic or significant split-half deviations from the overall pattern of results.[6]

The disappearance of the robust familiar-word preference (Experiment 1) when words were mispronounced at offset (Experiment 3a) suggests that Dutch infants do know how the ends of the tested words should sound; however, in the test directly opposing correct pronunciations and mispronunciations, infants failed to show a preference. Three explanations for this pattern of results may be advanced. First, it is possible that in fact infants are wholly unaware of the phonological specifications of the offset consonants of familiar words. This possibility is consistent with the results of Experiment 3b, in which infants showed no preference for correctly pronounced words over the same words with mispronounced codas. However, it does not help explain why infants in Experiment 3a failed to show a preference for mispronunciations over nonwords. If infants were indifferent to word-final mispronunciations, a replication of Experiment 1's robust lexical preference would be expected. Like Jusczyk and Aslin (1995), Hallé and de Boysson-Bardies (1996), Tincoff and Jusczyk (1996) and Vihman *et al.* (2004), we take significant interactions of the sort found in Experiments 1, 2a and 3a as evidence of infants' sensitivity to the distinction between correctly pronounced and mispronounced words.

A second, more likely possibility is that infants encode the phonological features that describe the coda consonants of familiar words, but that infants' preference for correct pronunciations over mispronunciations was obscured by lexical activation processes. As a mispronunciation like [teːm] (from [teːn], 'toe') is heard, for a substantial portion of the acoustic stimulus infants have no information indicating that the word they are hearing is in fact a deviant form. Infants do not need to hear a whole word for the word recognition process to begin – a conclusion supported by recent ERP results (Thierry, Vihman & Roberts, 2003; see also Mills, Coffey-Corina & Neville, 1997) and by eyetracking experiments with older children (Fernald, Swingley & Pinto, 2001; Swingley *et al.*, 1999). Thus, as each mispronunciation began, infants activated the real word from which it was derived. This might make preference differences between offset-mispronounced words and correctly-pronounced words harder to find than the same preference differences for onset-mispronounced words, even if infants know how both the onsets and offsets should sound.

For this account of the data to be complete, however, it is also necessary to explain why temporary activation of offset-mispronounced words failed to lead to a preference for those words over nonwords (Experiment 3a). Perhaps overall activation of offset-mispronounced words is too weak to drive a preference for such words over very similar nonwords, but is sufficient to obscure a preference for words over these mispronunciations. A related argument, first raised by Hallé and de Boysson-Bardies (1996), is that when infants hear correctly pronounced words, this primes those words enough to overcome the effects of mismatching consonants. An infant hearing a word like [vɪs] ('fish') may then be primed to hear the word *vis* again even when the word is mispronounced as [vɪf]. The same lexical priming would not be expected when nonwords are contrasted with mispronunciations. In addition, such priming should be weaker with onset mispronunciations, for which little lexical activation should occur (cf. the adult case, e.g. Allopenna, Magnuson & Tanenhaus, 1998; see also Monsell & Hirsh, 1998, for evidence of words priming offset mispronunciations of those words).

A third explanation for the contrast between Experiments 2b and 3b is that in fact infants' encoding of coda consonants is less secure or robust than their encoding of onset consonants. Infants may know the full phonological specifications of fewer words' codas, or infants may be less certain about the words they do know. As described in the introduction, this may be because codas are less distinctly pronounced (Redford & Diehl, 1999), or because incremental activation processes render coda consonants less informative than onset consonants in the word recognition process (Marslen-Wilson, 1987), leading infants to pay less attention to the ends of words. Differences in attention to onsets and codas have been found in other studies. For example, Jusczyk, Goodman and Baumann (1999) found that 9-month-olds had spontaneous preferences for lists of CVC syllables sharing their onset CV over lists of heterogeneous CVCs, but no preferences for CVCs sharing their offset VC. (Infant attention to such rhymes has been shown, however,

[6] In a further attempt to clarify the results of Experiment 3b, information about some participants' vocabulary size at about 16 months of age (mean age, 496 days; SD, 18 days) was collected using a Dutch version of the MacArthur Communicative Development Inventory (Words and Sentences; Fenson, Dale, Reznick, Bates, Thal & Pethick, 1994). Data from 17 of the 24 infants were available. The mean comprehension vocabulary size was 188 words (SD = 78) and the mean production vocabulary size was 34 words (SD = 24). Performance in Experiment 3b, computed as the difference in listening time to correctly pronounced words and mispronunciations, was correlated with comprehension vocabulary size ($r = .431$, $t(15) = 1.85$, p (one-tailed) $< .05$). The eight children with the larger vocabularies at 16 months showed a marginal preference for words over offset mispronunciations in Experiment 3b (1.79 s, $t(7) = 1.50$, p (one-tailed) $= .088$). This is consistent with other research showing positive correlations between infants' performance in speech perception tasks and later vocabulary size (Bernstein Ratner, Newman, Dow, Jusczyk & Jusczyk, 2004; Tsao, Liu & Kuhl, 2004). These data suggest that at least some children may distinguish between correctly pronounced words and offset mispronunciations, even if on the whole children did not.

using a conditioning procedure; see Hayes, Slater & Brown, 2000; see also Sebastián-Gallés & Bosch, 2002.) The procedure used in the present series of experiments relied upon infants' spontaneous preferences. Where differences in these preferences are found, we may infer differences in infants' processing. Though lack of preference is informative when it contrasts with strong preferences, it need not also imply that infants do not represent the contrasted distinction.

Thus, while Experiment 3a appeared to indicate that infants do not treat correct pronunciations and offset mispronunciations equivalently, there is reason to believe that infants' treatment of offset mispronunciations differs from their treatment of onset mispronunciations. It is difficult to say at present to what degree these differences are due to activation processes under way during the experiment, or to infants' possibly less robust phonological encoding of final consonants.

General discussion

In five experiments, Dutch 11-month-olds' reactions to words, mispronounced words and unfamiliar words were tested using the headturn preference procedure. Infants preferred familiar words over unfamiliar words; this preference evaporated when mispronunciations of words (at word onset or offset) were compared to unfamiliar words. In addition, infants preferred correct pronunciations of words over mispronunciations involving onset consonants but not offset consonants. Some evidence for a preference for correct pronunciations over offset mispronunciations was found, however, in a subset of infants with larger receptive vocabularies as measured several months later.

On the whole, these results support the conclusion of Vihman *et al.* (2004) that infants do learn the phonological specifications of the onset consonants of familiar words, at least for stressed syllables. (The evidence on unstressed syllables is mixed, as described above.) The present studies provided additional evidence supporting at least some knowledge of offset consonants, though this knowledge has proven to be more difficult to demonstrate clearly either because of less robust specification or timecourse effects that negate infants' spontaneous preferences.

Experiments in which infants reveal accurate perception of words extend the gap between perception and production and tend to disfavor perceptual accounts of children's unadultlike pronunciation. For infants to show a preference for correct pronunciations over mispronunciations, or to fail to exhibit an otherwise robust known-word preference when words are mispronounced, they must know at some level that the mispronunciations do not match the correct forms. This does not have to imply that the words' representational *format* is adultlike, because phonetic detail and representational form can, in principle, vary independently. It remains possible that infants have nonsegmental or 'holistic' lexical representations that are nevertheless detailed enough to allow detection of phonologically deviant pronunciations (see e.g. Beckman & Edwards, 2000). However, the fact that infants respond differently to correct and mispronounced forms is consistent with the possibility that by 11 months infants have begun to build a phonological system that will help distinguish lexical minimal pairs.

Tests of infants' spontaneous responses to stimuli that do or do not conform to the native language serve as a crucial complement to training studies examining infants' learning within the laboratory. Training studies are important because they can elucidate the conditions under which infants are likely to learn, thereby refining our understanding of the mental capacities that make language acquisition possible (e.g. Chambers, Onishi & Fisher, 2003; Gomez & Gerken, 1999; Jusczyk & Aslin, 1995; Stager & Werker, 1997). However, the external validity of training studies is not guaranteed; what infants learn in the laboratory, typically in a brief, concentrated exposure phase, may not reflect infants' true knowledge of language, acquired over their lifetime, in communicative interactions, amid the tumult of everyday experience. For this reason it is important to assess what infants know, and not only what they can learn in the laboratory.

This is a difficult task, because in evaluating infants' receptive knowledge of language, researchers are bound by significant methodological constraints that present their own generalization problems. In the headturn preference procedure, the most severe of these is that in most studies each infant provides what amounts to one data point per experiment. This precludes item analysis when more than one item is used in a single condition; in the present studies, it is not possible to know how many words were responsible for the effects, or which ones they were. Thus, it is appropriate to conclude that infants store phonological detail in enough words to drive their listening behavior, but this may not include all the words tested.

Infants' distinction of correctly pronounced and mispronounced words fits well with other early capabilities, including the learning of phonetic categories (e.g. Werker & Tees, 1984) and phonotactic regularities (e.g. Jusczyk, Friederici, Wessels, Svenkerud & Jusczyk, 1993). Slightly older children (14-month-olds) have been shown to respond differently to correct pronunciations and mispronunciations in a picture fixation task requiring children to link familiar spoken words and their meanings (Swingley &

Aslin, 2002; see also Fennell & Werker, 2003). Most perceptual studies of the phonological aspects of early word learning have only examined the encoding of word onsets, and the mixed results reported here on codas suggest that further empirical attention to other parts of words is necessary (e.g. Hallé & de Boysson-Bardies, 1996; Swingley, 2003; Vihman *et al.*, 2004). However, the preponderance of experimental data shows that infants begin learning the sound patterns of words in their language very early, well before they say words reliably. This learning is useful in its own right, as each word-form learned is the foundation for a new lexical entry. Learning word-forms correctly is also useful because the expanding stock of phonological forms in the vocabulary provides the database from which phonological generalizations are drawn – generalizations that themselves render further word discovery more efficient (Swingley, 2005).

Finally, it is important to be clear that these results (and other data showing significant decrements in recognition when words are slightly mispronounced) do not mean that the problem of interpreting speech is entirely solved in infancy. Young 1-year-olds have problems learning two phonologically similar object words (Werker, Fennell, Corcoran & Stager, 2002), encoding words' forms given few repetitions (Swingley, 2002) and recognizing words in sentence-medial position (Fernald, McRoberts & Swingley, 2001). The use of phonetic cues in identifying phonological categories only gradually approaches the adult pattern (e.g. Hazan & Barrett, 2000; Nittrouer, 1992; Parnell & Amerman, 1978). In spite of the many refinements 11-month-olds have yet to achieve in speech interpretation, however, infants can learn words with their phonological details intact.

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References

Allopenna, P.D., Magnuson, J.S., & Tanenhaus, M.K. (1998). Tracking the time course of spoken word recognition using eye movements: evidence for continuous mapping models. *Journal of Memory and Language*, **38**, 419–439.

Beckman, M.E., & Edwards, J. (2000). The ontogeny of phonological categories and the primacy of lexical learning in linguistic development. *Child Development*, **71**, 240–249.

Bernstein Ratner, N., Newman, R., Dow, K., Jusczyk, A.M., & Jusczyk, P. (2004, November). Infant speech segmentation ability predicts later language development. Paper presented at the 29th Annual Boston University Conference on Language Development.

Best, C.T. (1994). The emergence of native-language phonological influences in infants: a perceptual assimilation model. In J.C. Goodman & H.C. Nusbaum (Eds.), *The development of speech perception* (pp. 167–224). Cambridge, MA: MIT Press.

Chambers, K.E., Onishi, K.H., & Fisher, C. (2003). Infants learn phonotactic regularities from brief auditory experiences. *Cognition*, **87**, B69–B77.

Cheour, M., Ceponiene, R., Lehtokoski, A., Luuk, A., Allik, J., Alho, K., & Näätänen, R. (1998). Development of language-specific phoneme representations in the infant brain. *Nature Neuroscience*, **1**, 351–353.

De Cara, B., & Goswami, U. (2002). Similarity relations among spoken words: the special status of rimes in English. *Behavior Research Methods, Instruments, and Computers*, **34**, 416–423.

Dinnsen, D.A., O'Connor, K.M., & Gierut, J.A. (2001). The puzzle-puddle-pickle problem and the Duke-of-York gambit in acquisition. *Journal of Linguistics*, **37**, 503–525.

Fennell, C.T., & Werker, J.F. (2003). Early word learners' ability to access phonetic detail in well-known words. *Language and Speech*, **46**, 245–264.

Fenson, L., Dale, P.S., Reznick, J.S., Bates, E., Thal, D.J., & Pethick, S.J. (1994). Variability in early communicative development. *Monographs of the Society for Research in Child Development*, **59**(5), Serial Number 242.

Ferguson, C.A., & Farwell, C.B. (1975). Words and sounds in early language acquisition. *Language*, **51**, 419–439.

Fernald, A., McRoberts, G.W., & Swingley, D. (2001). Infants' developing competence in recognizing and understanding words in fluent speech. In J. Weissenborn & B. Hoehle (Eds.), *Approaches to bootstrapping: Phonological, lexical, syntactic, and neurophysiological aspects of early language acquisition* (Vol. I, pp. 97–123). Amsterdam: Benjamins.

Fernald, A., Swingley, D., & Pinto, J.P. (2001). When half a word is enough: infants can recognize spoken words using partial acoustic-phonetic information. *Child Development*, **72**, 1003–1015.

Gomez, R.L., & Gerken, L.A. (1999). Artificial grammar learning by 1-year-olds leads to specific and abstract knowledge. *Cognition*, **70**, 109–135.

Hallé, P.A., & de Boysson-Bardies, B. (1994). Emergence of an early receptive lexicon: infants' recognition of words. *Infant Behavior and Development*, **17**, 119–129.

Hallé, P.A., & de Boysson-Bardies, B. (1996). The format of representation of recognized words in the infants' early receptive lexicon. *Infant Behavior and Development*, **19**, 463–481.

Hayes, R.A., Slater, A., & Brown, E. (2000). Infants' ability to categorise on the basis of rhyme. *Cognitive Development*, **15**, 405–419.

Hazan, V., & Barrett, S. (2000). The development of phonemic categorization in children aged 6–12. *Journal of Phonetics*, **28**, 377–396.

Jusczyk, P.W., & Aslin, R.N. (1995). Infants' detection of the sound patterns of words in fluent speech. *Cognitive Psychology*, **29**, 1–23.

Jusczyk, P.W., Friederici, A.D., Wessels, J.M.I., Svenkerud, V.Y., & Jusczyk, A.M. (1993). Infants' sensitivity to the sound patterns of native language words. *Journal of Memory and Language*, **32**, 402–420.

Jusczyk, P.W., Goodman, M.B., & Baumann, A. (1999). Nine-month-olds' attention to sound similarities in syllables. *Journal of Memory and Language*, **40**, 62–82.

Jusczyk, P.W., & Hohne, E.A. (1997). Infants' memory for spoken words. *Science*, **277**, 1984–1986.

Kemler Nelson, D.G., Jusczyk, P.W., Mandel, D.R., Myers, J., & Turk, A. (1995). The headturn preference procedure for testing auditory perception. *Infant Behavior and Development*, **18**, 111–116.

Kuhl, P.K. (1995). Mechanisms of developmental change in speech and language. In K. Elenius & P. Branderud (Eds.), *Proceedings of the XIIIth International Congress of Phonetic Sciences* (Vol. 2, pp. 132–139). Stockholm: Stockholm University.

Kuhl, P.K., Williams, K.A., Lacerda, F., Stevens, K.N., & Lindblom, B. (1992). Linguistic experience alters phonetic perception in infants by 6 months of age. *Science*, **255**, 606–608.

Marslen-Wilson, W.D. (1987). Functional parallelism in spoken-word recognition. *Cognition*, **25**, 71–102.

Marslen-Wilson, W.D., & Welsh, A. (1978). Processing interactions during word-recognition in continuous speech. *Cognitive Psychology*, **10**, 29–63.

Metsala, J.L., & Walley, A.C. (1998). Spoken vocabulary growth and the segmental restructuring of lexical representations: precursors to phonemic awareness and early reading ability. In J.L. Metsala & L.C. Ehri (Eds.), *Word recognition in beginning literacy* (pp. 89–120). Mahwah, NJ: LEA.

Mills, D.L., Coffey-Corina, S., & Neville, H.J. (1997). Language comprehension and cerebral specialization from 13 to 20 months. *Developmental Neuropsychology*, **13**, 397–445.

Monsell, S., & Hirsh, K.W. (1998). Competitor priming in spoken word recognition. *Journal of Experimental Psychology: Human Perception and Performance*, **24**, 1495–1520.

Nittrouer, S. (1992). Age-related differences in perceptual effects of formant transitions within syllables and across syllable boundaries. *Journal of Phonetics*, **20**, 351–382.

Parnell, M.M., & Amerman, J.D. (1978). Maturational influences on perception of coarticulatory effects. *Journal of Speech and Hearing Research*, **21**, 682–701.

Polka, L., & Werker, J.F. (1994). Developmental changes in perception of nonnative vowel contrasts. *Journal of Experimental Psychology: Human Perception and Performance*, **20**, 421–435.

Redford, M.A., & Diehl, R.L. (1999). The relative perceptual distinctiveness of initial and final consonants in CVC syllables. *Journal of the Acoustical Society of America*, **106**, 1555–1565.

Sebastián-Gallés, N., & Bosch, L. (2002). Building phonotactic knowledge in bilinguals: role of early exposure. *Journal of Experimental Psychology: Human Perception and Performance*, **28**, 974–989.

Smolensky, P. (1996). On the comprehension/production dilemma in child language. *Linguistic Inquiry*, **27**, 720–731.

Stager, C.L., & Werker, J.F. (1997). Infants listen for more phonetic detail in speech perception than in word-learning tasks. *Nature*, **388**, 381–382.

Storkel, H.L. (2001). Learning new words: phonotactic probability in language development. *Journal of Speech, Language, and Hearing Research*, **44**, 1321–1337.

Storkel, H.L. (2002). Restructuring of similarity neighbourhoods in the developing mental lexicon. *Journal of Child Language*, **29**, 251–274.

Swingley, D. (2002, November). On the phonological encoding of novel words by one-year-olds. Paper presented at the 27th Annual Boston University Conference on Language Development. Boston, MA.

Swingley, D. (2003). Phonetic detail in the developing lexicon. *Language and Speech*, **46**, 265–294.

Swingley, D. (2005). Statistical clustering and the contents of the infant vocabulary. *Cognitive Psychology*, **50**, 86–132.

Swingley, D., & Aslin, R.N. (2000). Spoken word recognition and lexical representation in very young children. *Cognition*, **76**, 147–166.

Swingley, D., & Aslin, R.N. (2002). Lexical neighborhoods and the word-form representations of 14-month-olds. *Psychological Science*, **13**, 480–484.

Swingley, D., Pinto, J.P., & Fernald, A. (1999). Continuous processing in word recognition at 24 months. *Cognition*, **71**, 73–108.

Thierry, G., Vihman, M., & Roberts, M. (2003). Familiar words capture the attention of 11-month-olds in less than 250 ms. *Neuroreport*, **14**, 2307–2310.

Tincoff, R., & Jusczyk, P.W. (1996, July). Are word-final sounds perceptually salient for infants? Poster presented at the Fifth Conference on Laboratory Phonology, Evanston, IL.

Tsao, F., Liu, H., & Kuhl, P. (2004). Speech perception in infancy predicts language development in the second year of life: a longitudinal study. *Child Development*, **75**, 1067–1084.

Vihman, M.M., Nakai, S., DePaolis, R.A., & Hallé, P. (2004). The role of accentual pattern in early lexical representation. *Journal of Memory and Language*, **50**, 336–353.

Walley, A.C. (1993). The role of vocabulary development in children's spoken word recognition and segmentation ability. *Developmental Review*, **13**, 286–350.

Waterson, N. (1971). Child phonology: a prosodic view. *Journal of Linguistics*, **7**, 179–211.

Werker, J.F., Fennell, C.T., Corcoran, K.M., & Stager, C.L. (2002). Infants' ability to learn phonetically similar words: effects of age and vocabulary size. *Infancy*, **3**, 1–30.

Werker, J.F., & Tees, R.C. (1984). Cross-language speech perception: evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development*, **7**, 49–63.

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