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Journal of Memory and Language 51 (2004) 173–189

Journal of Memory and Language

www.elsevier.com/locate/jml

Preference and processing: The role of speech affect in early spoken word recognition

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Received 29 October 2003; revision received 26 April 2004
Available online 28 May 2004

Abstract

Infants prefer to listen to happy speech. To assess influences of speech affect on early lexical processing, 7.5- and 10.5-month-old infants were familiarized with one word spoken with happy affect and another with neutral affect and then tested on recognition of these words in fluent passages. Infants heard all passages either with happy affect or with neutral affect. Contrary to initial expectations that positive affect would facilitate word recognition, younger infants recognized familiarized words only when affect *matched* across familiarization and testing. Older infants displayed a more mature pattern of word recognition, recognizing words across variations in affect regardless of the direction of change when the task was somewhat simplified. However, younger infants continued to be limited by affective matching in the simplified task. Early processing advantages thus do not necessarily follow listening preferences. Rather, infants' early lexical representations appear to be dominated by covarying properties of experienced exemplars, whether or not these are ultimately relevant for lexical distinctions.

Keywords: Infants; Spoken word recognition; Vocal affect; Preference

Recognizing spoken words in fluent speech is a formidable task. In a matter of milliseconds, the listener must identify which of possibly thousands of known words has occurred, a feat that entails locating the beginnings and ends of words in the speech stream and reformatting the incoming signal to optimize the efficiency of recognition. This task is even more daunting for infants, who must acquire the skills needed for segmentation, representation, and identification of words even as they are struggling to parse and comprehend what has been said. Thus, it is entirely natural that infants' initial capacities for spoken word recognition are quite limited. At six months, infants' recognition of words in fluent speech is limited to highly familiar items, such as their own names (Mandel-Emer, 1997). By 7.5 months, English-learning infants may be able to segment and recognize both newly familiarized monosyllables (Jusczyk & Aslin, 1995) and bisyllables (Jusczyk, Houston, & Newsome, 1999), but only if those bisyllables conform to the predominant strong–weak stress pattern of English. At nine months, infants segment monosyllables recurring in passages only if the sequences of sounds at their beginnings or ends conform to high probability word-initial or word-final sound sequences (Mattys & Jusczyk, 2001). Before the end of the first year, many of these restrictions have been overcome; for example, by 10.5 months, infants can recognize both weak–strong and strong–weak bisyllables (Jusczyk et al., 1999).

Complementing many of these early limitations on spoken word recognition are patterns of infants' speech preferences. At 4.5 months, infants prefer to listen to

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doi:10.1016/j.jml.2004.04.004

their own names over stress-matched foils (Mandel, Jusczyk, & Pisoni, 1995). English-learning infants at nine months prefer to listen to lists of strong–weak words rather than weak–strong words (Jusczyk, Cutler, & Redanz, 1993). At the same age, infants demonstrate preferences for native over non-native words that are distinguished by phonotactic and phonetic information (Jusczyk, Friederici, Wessels, Svenkerud, & Jusczyk, 1993) and for words exemplifying high-probability, rather than low-probability sound sequences within the native language (Friederici & Wessels, 1993; Jusczyk, Luce, & Charles-Luce, 1994).

In light of the finding that infants show processing advantages for preferred patterns in segmentation and recognition tasks, it is straightforward to conjecture that these phenomena are causally linked (Jusczyk, 1997): infants' attention is drawn to those forms or aspects of speech that they prefer, and these are thus processed more thoroughly and receive more detailed or more enduring representations in memory. If this conjecture is correct, it should hold not only for patterns specific to the native language, but for other listening preferences as well, including language-general or even non-linguistic properties of speech. In this article, we investigate whether processing advantages are associated with one salient feature of speech for which infants display an early and persistent preference: positive affect.

In contrast to preferences for language-specific properties of speech, such as probabilistic phonotactics or metrical stress patterns, which typically begin to emerge around the middle of the first year, preferences for certain non-linguistic aspects of speech are evident quite early in development. For example, newborns prefer their mother's voice to that of other females (DeCasper & Fifer, 1980) and, more generally, female voices to male voices (Fifer & Moon, 1988). Within a given talker, very young infants typically prefer infant-directed speech (IDS) to adult-directed speech (ADS) (Cooper, Abraham, Berman, & Staska, 1997; Cooper & Aslin, 1990; Fernald, 1985; Werker & McLeod, 1989). Infants also prefer positive vocal affect to negative or neutral vocal affect (Kitamura & Burnham, 1998; Papousek, Bornstein, Nuzzo, Papousek, & Symmes, 1990; Singh, Morgan, & Best, 2002a). It seems likely that, given processing advantages for other preferred aspects of speech, infants may likewise be better at parsing and comprehending speech from highly familiar talkers or speech that they hear in infant-directed register. Here, we focus on whether infants' preference for positive vocal affect influences the manner in which they process input speech, specifically by facilitating spoken word recognition.

Responses to positive vocal affect are observable shortly after birth. At two days, infants can discriminate at least four different vocal emotions (happiness, sadness, anger, and neutral emotion; Mastropieri & Turkewicz, 1999), suggesting that they may derive information about intonational properties of emotional expression prenatally. In fact, prenatal exposure to vocal emotion may provide infants with some of the earliest sound-meaning mappings, as maternal vocal emotional expression is accompanied by physiological changes indicative of emotional arousal, such as changes in respiration, muscle tone, or cardiovascular activity. These autonomic changes shape the intonational properties of vocal expression (Scherer, 1986), allowing the fetus to learn the acoustic correlates of emotional activity by association (Mastropieri & Turkewicz, 1999). Over the first few months, infants consistently display more eye-opening responses to happy vocal stimuli (Haviland & Lelwica, 1987; Mastropieri & Turkewicz, 1999). At four months, when infant-controlled procedures can be used to test preferences more sensitively, infants listen longer to stimuli with positive affect than to stimuli with negative or neutral affect (Papousek et al., 1990). By five months, infants smile in response to positive vocal affect (Fernald, 1993; Werker & McLeod, 1989).

Infants' preference for positive vocal affect persists at least through the first half of the first year (Kitamura & Burnham, 1998; Singh et al., 2002a, 2002b). Recent findings have shown that preferences for positive emotion in the voice account for infants' well-known preference for IDS. When speech affect and register (IDS/ADS) are independently manipulated, infants' preference is primarily guided by positive vocal affect and secondarily by other components specific to IDS register, such as heightened pitch or expanded pitch range (Kitamura & Burnham, 1998). Moreover, infants' preference for positive vocal affect appears to outweigh their preference for other aspects of IDS. When presented with lexically and syntactically matched happy ADS and neutral IDS, infants prefer the former to the latter (Singh et al., 2002a, 2002b). Together, this pair of studies suggests that infant-directed register and positive emotion are often conflated in reports of IDS preference: although both attract infants' attention, positive affect is the primary determinant of infants' listening preference.

Vocal affect expression has been documented as a precursor to linguistic expression both in the evolution of the species and the development of the individual (Bloom, 1990; Darwin, 1872). Infants are capable of expressing themselves using affective prosody from birth, and they use these vocal cues to communicate information about their internal state prior to the onset of productive language (Bloom, 1990; Lewis, 1936). Similarly, many other mammalian communication systems incorporate perceptually salient vocal cues to signify motivational or intentional processes. Positive affect attracts the attention of conspecifics and elicits an approach reaction from others, as it typically emanates from a non-threatening source or caregiver (Darwin, 1872). Thus, vocal affect has clear communicative significance. Furthermore, infants are sensitive to acoustic correlates of vocal affect before they have knowledge about the structure of their native language.

Vocal affect is predominantly encoded by fundamental frequency (F_0) and energy (Murray & Arnott, 1993; Scherer, 1986; Williams & Stevens, 1972). Across talkers, vocal affect can be reliably labeled using F_0 contours (Scherer, 1986; Williams & Stevens, 1972). With respect to positive affect specifically, in Banse and Scherer's (1996) analysis of the cues predictive of emotion judgments, judgments of joyful happiness were based on the proportion of high frequency energy in the spectrum, mean F_0, and F_0 range, in order of decreasing weight. Increases in each of these parameters, relative to neutral, were judged to be critical carriers of happiness or elation in speech.

Given the salience of vocal affect in infant-directed speech and the extent to which it guides infants' attention to speech, one might expect that infants would find it easier to recognize words that they encounter in a happy voice than those they encounter in a neutral voice. Such a finding would mirror results found in studies of emotional intensity on adult word recognition, in which word naming in adults is facilitated when a happy or sad emotional state is induced in the participant beforehand (Niedenthal, Halberstadt, & Setterlund, 1997). Similarly, findings from event-related potential and fMRI studies show that words presented in emotionally charged contexts undergo more extensive processing than those presented in neutral contexts and activate additional areas of the brain relative to emotionally neutral sentences (Buchanan et al., 2000; Maratos, Dolan, Morris, Henson, & Rugg, 2001; Maratos, Morris, Dolan, & Rugg, 2000; Mitchell, Elliott, Barry, Cruttenden, & Woodruff, 2003). In addition, recognition memory is enhanced even for words simply bearing emotional content compared with those that are relatively neutral in adults, as measured by event-related potentials (Dietrich et al., 2000, 2001). Together, these studies indicate that the effects of vocal emotion occur at very early stages of speech processing and persist through adulthood.

The goal of the present set of studies was to determine whether infants' preference for positive vocal affect does indeed facilitate spoken word recognition. Adapting the procedure developed to investigate spoken word recognition introduced by Jusczyk and Aslin (1995), we familiarized infants with words in either happy or neutral affect. This was a within-subjects variable, so that each infant heard one happy word and one neutral word during familiarization. Infants were then presented with those words embedded in passages along with novel passages. For any individual infant, passages were presented either entirely in happy affect or entirely in neutral affect. Facilitative effects of positive vocal affect could arise during both familiarization (i.e., words spoken with happy affect might be more thoroughly encoded and therefore more easily retrieved later) and during recognition testing (i.e., passages spoken with happy affect might be attended to more closely, increasing the likelihood that familiarized words will be retrieved). If infants' listening preferences are causally linked to abilities for processing speech, a prediction follows straightforwardly: infants should be best at detecting and recognizing words that are familiarized in happy affect and later presented in happy passages. Conversely, infants should be worst at recognizing words spoken in neutral affect during both familiarization and recognition.

Such a finding relating infants' speech processing to a preference for a non-linguistic aspect of their language input would not be unprecedented. For example, infants' preference for IDS is accompanied by early processing advantages for this register. In a study exploring infants' processing of uninterrupted versus interrupted prosodic units, Hirsh-Pasek et al. (1987) found that six-month-olds listened longer to passages with uninterrupted intonational phrases (roughly, clauses). Further investigation revealed that infants' ability to discriminate interrupted and uninterrupted intonational phrases held for IDS only (Kemler Nelson, Hirsh-Pasek, Jusczyk, & Wright Cassidy, 1989). To date, however, no studies have investigated whether such general preferences interact with the development of the lexicon.

One recent set of studies has investigated the role in early word recognition of a non-linguistic property of speech for which no preference is evident. Houston and Jusczyk (2000) investigated infants' sensitivity to talker identity during word recognition. In studies with 7.5-month-old infants, who are just beginning to segment and recognize newly familiarized words in fluent speech, talker gender was varied across familiarization and recognition phases of the experimental session. These studies revealed that 7.5-month-old infants preserve information about talker characteristics in memory: infants failed to recognize the same word spoken by individuals of different genders. A follow-up study showed that infants at this age were not able to recognize words when familiarization and recognition stimuli were spoken by talkers of the same gender but with highly dissimilar voices (Houston, 2000). These findings are consistent with studies demonstrating that adults automatically integrate talker-specific information (such as gender) with phonetic detail during word recognition (Knösche, Lattner, Maess, Schauer, & Friederici, 2002) and store this type of information in memory even though it is lexically irrelevant (Bradlow, Nygaard, & Pisoni, 1999; Goldinger, 1996, 1998). In adults, talker changes may reduce the efficiency with which adults process incoming speech. However, for young infants, talker changes can altogether eliminate recognition of new tokens of familiar words.

Houston and Jusczyk's findings give rise to an alternative prediction in our studies. If infants, in the initial stages of word recognition, form lexical representations that preserve the phonetic and acoustic detail of encountered tokens, they might treat happy and neutral tokens as different words and only equate those tokens that are spoken in the same affect. In this case, we would expect a matching effect, similar to that observed with changes in talker gender, in which young infants recognize words familiarized in happy affect only in happy passages, and words familiarized in neutral affect only in neutral passages.

Experiment 1

In this study, following a procedure similar to that used by Jusczyk and Aslin (1995), 7.5-month-old infants were familiarized with two words, one in neutral affect (*neutral familiarization word*) and another in happy affect (*happy familiarization word*). Infants then heard passages with sentences containing the familiarized words (*familiar passages)*, as well as comparable passages containing non-familiarized words (*unfamiliar passages*). Affect of recognition passages was manipulated as a between-subjects variable. Across infants, the words used for familiarization, and hence which passages contained familiarized and non-familiarized words, were counterbalanced.

Given such counterbalancing, infants' discrimination of familiar versus unfamiliar passages provides evidence that they have retained memorial representations of familiarized words and recognized those words when they recurred in fluent speech. Most often, discrimination has been manifest by familiarity preferences—infants listen longer to familiar passages (DeCasper & Spence, 1986; Houston & Jusczyk, 2000; Jusczyk & Aslin, 1995; Jusczyk et al., 1999; Mattys & Jusczyk, 2001). However, due to an incompletely understood set of factors including age, stimulus complexity, amount of familiarization, delay between familiarization and test, test context, and so forth, results of preference studies may flip from familiarity to novelty (Aslin & Mehler, 2002). Thus, in some studies, infants' discrimination of familiar versus unfamiliar speech stimuli has been manifest by novelty preferences (e.g., Gómez, 2002; Höhle & Weissenborn, 2003; Marcus, Vijayan, Bandi Rao, & Vishton, 1999; Saffran, Aslin, & Newport, 1996).

Participants

Forty full-term, English-exposed 7.5-month-olds participated in the study (17 males and 23 females), recruited from Rhode Island Department of Health records. Mean age of participants was 34 weeks (range = 31 weeks, 4 days to 36 weeks). Data from 15 additional infants were not included for the following reasons: inattention or crying (4) and disconnected wire (11).

Stimuli

Stimuli consisted of four monosyllabic words and four six-sentence passages.[1] One word (*bike*) and the corresponding passage were identical to that used in Jusczyk and Aslin (1995). The other three words used there (*cup*, *feet*, and *dog*) were replaced with items judged less likely to be familiar to young infants (*hat*, *tree*, and *pear*), and novel passages containing these items were created. All passages are shown in the Appendix. When recording the stimuli, the speaker, the mother of an infant, was asked to use infant-directed speech for all tokens and to address her infant throughout the recording session.

For familiarization stimuli, 60 tokens of each word were recorded. During half of the recordings, the speaker was asked to smile and incorporate happiness or excitement into her voice. During the remaining half, she was asked to sound relatively neutral. She was also encouraged to introduce as much prosodic variation as possible within each of the two sets of stimuli (happy and neutral) without compromising the intended affect. For each word type, the experimenter (L.S.) selected 25 recordings for each affect that were judged to be the most clear and convincing exemplars of positive and neutral affect.

Recognition stimuli consisted of sentences containing the target words (*bike*, *hat*, *tree*, and *pear*). Within each passage, the target word appeared twice each in initial, medial, and final sentence positions (see Appendix). The speaker was asked to commit each sentence to memory and recite it to her infant in infant-directed speech. For half of the recordings, she was asked to convey positive affect and smile during speech production. She was then asked to record the same passages in a neutral voice. Each sentence was recorded twice.

Several measures were undertaken to ensure that the stimuli captured the appropriate emotion and register. Each token was first rated by naïve adults to identify those that most effectively communicated positive and neutral affect. Ten adult native English speakers were asked to rate each of the 50 exemplars per word on a 7-point Likert scale ranging from neutral (1) to happy (7). The 15 tokens of each word type that received the highest and lowest scores were selected as happy and neutral tokens, respectively. The same adults were asked to rate all sentence tokens, of which there were a total of 96. The tokens rated closer to the end-point values were

[1] Examples of stimuli may be downloaded at www.cog.brown.edu/~morgan/stimuli/affectwordrecognition.zip.

Table 1
Acoustic analyses of words: means and (*SD*)

	Mean F_0	Min F_0	Max F_0	F_0 range	Duration
Happy	321.4 (41.9)	216 (59.8)	392.1 (44.1)	10.3 (4.82)	433.5 (90.3)
Neutral	158.4 (6.4)	141.6 (9.2)	184.2 (14.2)	4.6 (1.9)	456.6 (64.9)

Note. Mean, minimum, and maximum F_0 in Hertz, F_0 range in semitones, and duration in milliseconds.

Table 2
Acoustic analyses of sentences: means and (*SD*)

	Mean F_0	Min F_0	Max F_0	F_0 range	Target word duration	Sentence duration	Speech rate	% Energy >1 kHz
Happy	286.6 (30.5)	149.7 (56.2)	478 (24.2)	20.1 (5.2)	404.5 (88.9)	2293.5	298.3	31.9
Neutral	153.6 (31.2)	90.1 (15.6)	194.8 (9.5)	13.3 (7.4)	398.5 (68.7)	2314.8	299.7	17.8

Note. Mean, minimum, and maximum F_0 in Hertz, F_0 range in semitones, durations in milliseconds, and speech rate in milliseconds per syllable.

chosen, yielding 24 happy sentences and 24 neutral sentences. Each selected word/sentence was rated within 2 points of the end-point rating. The mean rating for selected happy word tokens was 6.28 ($SD = .64$) and the mean rating for selected neutral word tokens was 1.87 ($SD = .83$). The mean rating for selected happy sentence tokens was 6.25 ($SD = .79$) and for selected neutral sentence tokens was 1.70 ($SD = .82$).

The selected utterances and words were then acoustically analyzed. As described previously, two of the primary acoustic correlates of vocal affect are mean F_0 and F_0 range (Banse & Scherer, 1996). Each of these was measured for happy and neutral words and sentences. An additional measure was calculated for sentences, the proportion of high frequency energy in the spectrum (Banse & Scherer, 1996; Scherer, 1986). Perhaps due to increased tension in the vocal tract and buccal muscles, happy speech tends to have "brighter" timbre than does neutral speech. A higher proportion of the total energy is expected to reside at higher frequencies of the spectrum (>1 kHz) for happy speech relative to neutral speech. In addition, duration was measured for words and sentences (target word in sentence and entire sentence) and speech rate was measured for sentences. Peak amplitudes of words and phrases were equated across stimuli.

Acoustic measures for all words are shown in Table 1. For individual words, minimum and maximum F_0 were higher in happy words relative to neutral words, $t(59) = 9.39$, $p < .0001$ and $t(59) = 33.58$, $p < .0001$, respectively. Mean F_0 was higher in happy words than in neutral words, $t(59) = 29.55$, $p < .0001$. Pitch range (in semitones) of happy words also exceeded that of neutral words, $t(59) = 15.18$, $p < .0001$. However, there was no difference in the relative durations of happy and neutral words.

For sentences, happy tokens had higher F_0 minima and maxima compared with neutral tokens, $t(23) = 8.96$, $p < .0001$ and $t(23) = 25.93$, $p < .0001$, respectively. In addition, pitch was higher and more variable in happy sentences relative to neutral sentences, as indexed by F_0 mean and range, $t(23) = 25.47$, $p < .0001$ and $t(23) = 21.88$, $p < .0001$, respectively.[2] Finally, our analyses revealed a higher proportion of high-frequency energy in happy sentences than in neutral sentences, $t(23) = 7.40$, $p < .0001$, consistent with previous acoustic profiles of happy and neutral speech (Banse & Scherer, 1996; Scherer, 1986). Values for each measure are shown in Table 2. The duration of happy sentences did not differ significantly from the duration of neutral sentences, indicating that speech rate did not differ significantly across affect. In addition, the durations of the target words within the carrier sentences did not differ between happy and neutral passages.

During familiarization, infants heard citation form tokens of two words. Half of the infants heard the words *bike* and *hat* while the other half heard *tree* and *pear*. For each infant, one word was heard in happy affect and the other in neutral affect. The words used as familiarization stimuli and the assignment of affect to words were counterbalanced across subjects. As a result of this design, across subjects each item served every possible role (happy familiarization word/neutral familiarization word/unfamiliar word). During recognition testing, infants heard passages containing all four words. As a result of counterbalancing, familiar passages for some infants were unfamiliar to others and vice versa. Half of

[2] These measures were similar to those obtained by Singh et al. (2002a, 2002b). That work also included sad sentences, which in IDS were as variable in pitch as happy sentences. Infants preferred happy to neutral passages, but also neutral to sad passages. Thus, infants' preference is not simply for higher pitched, melodious speech over lower pitched, monotonous speech but rather is due to the complex of prosodic and spectral cues signaling happy affect.

the infants heard passages spoken with happy affect; the remaining half heard neutral passages.

Apparatus

Testing was conducted in a three-walled testing booth within a sound-treated laboratory room. Each beige pegboard wall of the booth was 120 cm wide. A chair was positioned at the open end of the booth where the parent sat with the infant on his/her lap. The infant sat approximately 110 cm from the front of the booth. Advent loudspeakers were located behind both side walls of the booth. At the infants' eye level, 86 cm above the floor, a yellow light was mounted on the front wall. Each of the side walls had a similar green light at the same level. A Panasonic CCTV video camera (model WV-BP330) was mounted behind the testing booth 12.3 cm above the yellow light. In a separate control room, a Panasonic monitor (WV-5410) was connected to the video camera in the testing booth. The participants were displayed on the monitor in the control room, where the experimenter judged infants' looking, pressing buttons on the mouse of a Windows computer to control the custom experimental software. The computer was equipped with a Sound-Blaster compatible soundboard connected to a Yamaha amplifier. Speech stimuli were set at conversation level (75 dB) using a Realistic sound level meter.

Procedure

Infants were tested using the headturn preference procedure (HPP) (Kemler Nelson et al., 1995). The infant was seated on the parent's lap facing the yellow light. The parent listened to instrumental music over Bose aircraft-quality noise-cancellation headphones to mask the stimuli. Each trial began with the yellow light flashing until the experimenter judged that the infant fixated on the flashing light. At that point, this light was turned off and one of the green side lights began to flash to attract the infant's attention to the side. Side of presentation was randomized across trials, so that all stimuli occurred on both sides. After the infant turned to look at the flashing green light, the speech stimuli for that trial began to play. The sound continued to play and the green light remained on for the duration of the infant's fixation on the light. Each trial continued until the infant looked away for 2 s, or until 30 s of looking time had been accumulated during that trial. If the infant looked away, but then looked back within two seconds, the trial continued. If the infant's looking time was below 2 s, the trial was repeated with a new randomization of the trial stimuli; otherwise, the procedure advanced to the next trial.

Familiarization began with trials alternating between the two target words. Once the infant had exceeded 30 s of looking time with one word, all subsequent familiarization trials presented the alternate word. This modification of the HPP was instituted to ensure that differences in looking times during recognition testing could not be due to different amounts of familiarization with the two target words. When the infant reached 30 s of looking time with the second word, the test phase began.

Recognition testing consisted of four blocks of trials, each block containing one trial with each of the four passages. The order of passages within each block was randomized for each infant. In addition, the order of sentences within passages was also randomized on each trial. The test procedure was similar to the familiarization procedure, except that the side light continued to flash while infants were fixated on the light. As in the familiarization phase, if the infant continued to look at the light for 30 s, the trial ended automatically and the next trial began. Similarly, if the infant failed to look at the side light for at least 2 s, the trial was automatically repeated. A minimum criterion of 2 s was necessary to allow the infant to hear at least one token of the target word in a sentence.

Results and discussion

In our version of the HPP, familiarization trials with each stimulus type ended once the infant passed the familiarization criterion (30 s). This prevented infants from accumulating widely differing amounts of familiarization with one stimulus type versus another. While it is important that infants received comparable amounts of exposure to both types of familiarization tokens, one might expect that they would complete familiarization over fewer trials for happy words given their listening preferences for happy speech. However, a within-subjects analysis of familiarization trials showed no difference in the number of trials infants required with happy words ($M = 4.5$, $SD = 1.75$) versus neutral words ($M = 4.75$, $SD = 1.60$), $F(1, 39) = 0.64$, NS. There was also no difference in the amount of looking time per familiarization trial for happy words ($M = 8855$ ms, $SD = 3405$) versus neutral words ($M = 8190$ ms, $SD = 3614$), $F(1, 39) = 1.03$, NS. In previous studies, preferences for vocal affect were observed in continuous speech, rather than in isolated words (e.g., Fernald, 1993; Kitamura & Burnham, 1998; Singh et al., 2002a, 2002b). It remains unclear whether these preferences generalize to individual words, which may explain the absence of a difference in the distribution of familiarization times across trials in this study. Moreover, during familiarization, infants are becoming acquainted with the procedure as well as with the stimuli. It is possible that evidence of listening preferences does not surface during this period due to the fact that infants are mastering the contingency between the visual stimulus and the speech stimuli.

Results from looking times during recognition testing are shown in Table 3. A 3×2 mixed word type (happy familiarization, neutral familiarization, and unfamiliar) by test passage affect (happy, neutral) ANOVA revealed a significant main effect of word type, $F(2, 76) = 7.49$, $p < .01$, as well as a significant main effect of test passage affect, $F(1, 38) = 5.83$, $p < .05$. Collapsing across all three word types, infants listened longer to happy passages ($M = 8344$ ms, $SD = 2822$) than to neutral passages ($M = 6509$ ms, $SD = 1893$). Moreover, collapsing across both passage conditions, infants listened longer to the passages when they contained happy familiarization words ($M = 8754$ ms, $SD = 4770$) than when they contained unfamiliar words ($M = 7081$ ms, $SD = 2113$), $F(1, 38) = 5.19$, $p < .05$. There was no overall difference in looking times to passages containing neutral familiarization words ($M = 6445$ ms, $SD = 2768$) versus passages containing unfamiliar words, $F(1, 38) = 1.93$, NS. These results are consistent with infants' previously demonstrated preference for happy speech.

To assess infants' recognition of familiarized words in fluent speech, we calculated *recognition scores*, computed by subtracting infants' looking times to unfamiliar passages from looking times to familiar passages. Recognition scores are plotted in Fig. 1, which reveals quite different recognition patterns across the two test passage affect conditions. Therefore, to assess word recognition in each of these conditions, we conducted additional within-group analyses. These analyses revealed effects of *matching*: words were recognized in just those instances in which affect remained the same across familiarization and recognition testing.

Within the happy test passage condition, there was a significant recognition effect for happy familiarization words, $t(19) = 2.14$, $p < .05$. Thirteen of 20 infants had positive recognition scores for passages containing these words. However, there was no observed recognition effect for neutral familiarization words, $t(19) = -.13$, NS. Only 9 of 20 infants had positive recognition scores for passages with these words. Therefore, infants in the happy test passage condition recognized only words familiarized in happy affect.

Within the neutral test passage condition, there was no observed recognition effect for words familiarized in happy affect. Ten of 20 infants had positive recognition scores for passages containing happy familiarization words. However, infants in this condition had significant *negative* recognition scores for passages with neutral familiarization words, $t(19) = -2.27$, $p < .05$. Thirteen of 20 infants showed this effect. Infants in the neutral test passage condition recognized only words familiarized in neutral affect.

The directions of observed effects—a familiarity preference (positive recognition scores) with respect to happy words in happy passages, and a novelty preference (negative recognition scores) with respect to neutral

Table 3
Looking times to passages containing happy familiarization words, neutral familiarization words and unfamiliar words: means and (*SD*)

	Experiment 1			Experiment 2			Experiment 3			
	7.5-month-olds			10.5-month-olds			7.5-month-olds		10.5-month-olds	
	Word type			Word type			Word type			
	Happy	Neutral	Unfamiliar	Happy	Neutral	Unfamiliar	Neutral	Unfamiliar	Neutral	Unfamiliar
Happy test passages	10231 (5761.9)	7349.6 (2588.5)	7452.3 (2290.5)	9082.9 (4231.6)	7581.9 (3426.4)	7404.3 (3249.8)	8483.8 (3483.8)	8736.6 (2627.5)	5926.5 (2502.9)	7427.7 (1285.8)
Neutral test passages	7276.7 (2985.4)	5541.3 (2703.9)	6710.5 (1907.1)	9047 (4858.3)	4942.6 (1279)	6065.1 (2029.2)				

Note. All looking times are in milliseconds.

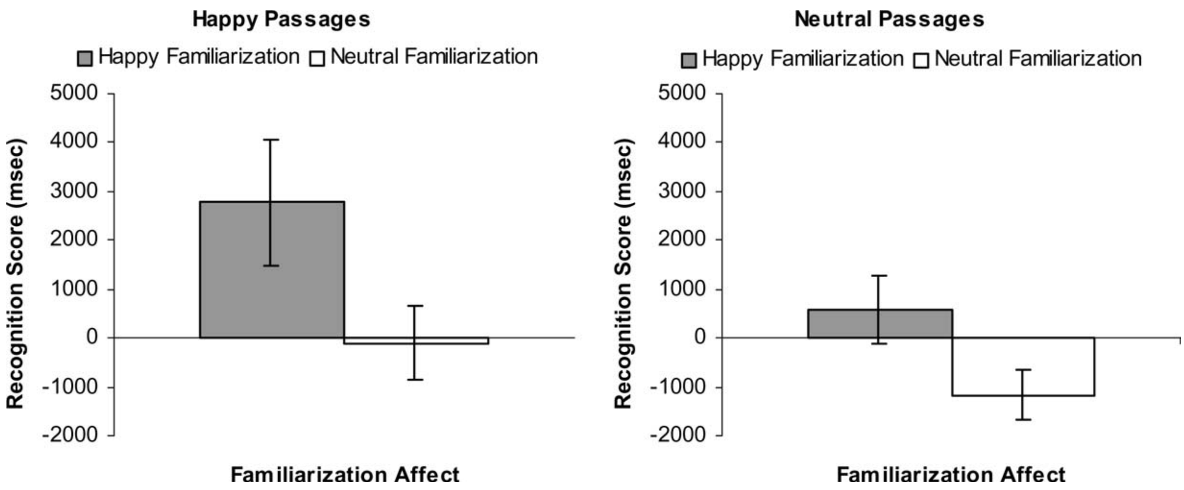

Fig. 1. Experiment 1: 7.5-month-olds' recognition scores for happy and neutral familiarization words.

words in neutral passages—were unexpected.[3] These were not clearly predicted by any of the factors noted earlier (age, familiarity, complexity). Items were counterbalanced and rotated among all possible roles (happy familiarization word, neutral familiarization word, unfamiliar word), so that the phonetic structures of words for which infants in the happy passage condition showed a familiarity preference were the same as those for which infants in the neutral passage condition showed a novelty preference. As Fig. 1 illustrates, the direction in which recognition of familiar items was manifest in this experiment is consistent with infants' listening preferences. This raises the possibility that the affect of the stimuli used may have governed the direction of infants' preference. After replicating these directional effects in Experiments 2 and 3, we will return to further consideration of this issue in the General discussion.

Overall, these findings argue against a necessary relationship between listening preference and spoken word processing at 7.5 months. The fact that infants attend more to happy affect neither implies that they encode happy words in greater detail nor ensures that happy passages are privileged in segmentation tasks. Rather, infants recognize both positive and neutral targets; speech processing at this age appears to be more strongly influenced by affective similarity across tokens than by the affective valence of tokens. Similarity-based matching of the sort observed here is consistent with previous evidence that infants recognize tokens matching in talker gender or voice similarity (Houston, 2000; Houston & Jusczyk, 2000). Our results show further that infants may sometimes fail to recognize varying tokens of words even when they are produced by a single talker. At 7.5 months, infants' memorial representations incorporate factors that shape the physical forms of words, independent of whether these factors are lexically relevant in the native language.

[3] A pilot study using stimuli produced by a different talker, however, yielded a similar pattern of results.

Experiment 2

Ultimately, successful word recognition demands the capacity to disregard lexically irrelevant sources of variability, such as talker identity or affect, and to attend selectively to acoustic cues that are functionally significant in the native language. Languages of the world differ in the properties of speech that are assigned phonological significance. Therefore, infants have to master the phonological organization of their language in order to focus on linguistically meaningful cues in the input. The period from six to twelve months is characterized by an increasing sensitivity to language-specific features (Best, 1995). At the end of this period, infants' analyses of native language structure are evident at various levels of complexity, ranging from the composition of phonetic categories (Best, 1995; Werker & Tees, 1984) to the probabilistic composition of phrases (e.g., Morgan & Saffran, 1995). By 12 months, infants show more robust speech processing; they are no longer bound by statistically predominant cues in the input, but rather are able to encode and retrieve items even when they exemplify infrequent phonotactic patterns. Given this developing attunement to the native language, one might expect a similar transition in spoken word recognition. As infants develop awareness of the varying acoustic/phonetic forms that words can assume in their language, they should be better able to recognize words in spite of such variation.

When might infants realize that changes in vocal affect are not relevant to lexical identity and successfully recognize words in spite of changes in affect across tokens? In Houston and Jusczyk's studies examining effects of talker gender on early word recognition, infants at 10.5 months no longer showed a matching effect, recognizing words despite changes in talker gender. Here, we conducted a similar follow-up study with 10.5-month-old infants to see if they could disregard changes in affect across tokens.

Participants

Forty full-term, English-exposed 10.5-month-olds participated in the study (21 males and 19 females), recruited from Rhode Island Department of Health records. Mean age of participants was 46 weeks, 3 days (range = 43–49 weeks, 1 day). Seven additional infants were tested and data were discarded because of inattention or crying (6), non-English home environment (1).

Stimuli, apparatus, and procedure

Stimuli, apparatus, and procedure were identical to those in Experiment 1.

Results and discussion

As in Experiment 1, the number of trials infants required to complete familiarization did not differ between happy words ($M = 5.6$, $SD = 2.13$) and neutral words ($M = 5.1$, $SD = 2.06$), $F(1, 39) = 2.5$, NS. Moreover, the average length of familiarization trials did not differ for happy words ($M = 8291$ ms, $SD = 6980$) and neutral words ($M = 8020$ ms, $SD = 4763$). Infants received equivalent amounts of exposure to happy and neutral words and completed familiarization at equivalent rates for the two types of words.

Results from looking times during recognition testing are shown in Table 3. These data were analyzed in a 3×2 mixed word type (happy familiarization, neutral familiarization, and unfamiliar) by test passage affect (happy, neutral) ANOVA. This analysis revealed an overall main effect of word type, $F(2, 76) = 12.40$, $p < .0001$. As in Experiment 1, across both passage conditions, infants listened longer to passages containing happy familiarization words ($M = 9065$ ms, $SD = 4497$) than to unfamiliar passages ($M = 6735$ ms, $SD = 2758$), $F(1, 38) = 15.52$, $p < .0001$. There was no significant difference in infants' looking times to passages containing neutral familiarization words versus unfamiliar passages, $F(1, 38) = .754$, NS. There was no main effect of test passage affect and no interaction of word type and test passage affect. Although these findings appear similar to those of Experiment 1, a closer examination of recognition scores in each condition reveals some important differences (see Fig. 2).

Within the happy test passage condition, infants showed significant positive recognition scores for happy familiarization words, $t(19) = 2.12$, $p < .05$. Sixteen of 20 infants showed this pattern. For neutral familiarization words in happy passages, infants did not show significant recognition scores $t(19) = .17$, NS. Nine of 20 infants showed a negative recognition score for neutral familiarization items.

Within the neutral test passage condition, significant negative recognition scores were obtained for neutral familiarization words, $t(19) = -3.07$, $p < .01$. Fourteen of 20 infants showed this pattern. In the same condition, significant positive recognition scores also obtained for passages containing happy familiarization words,

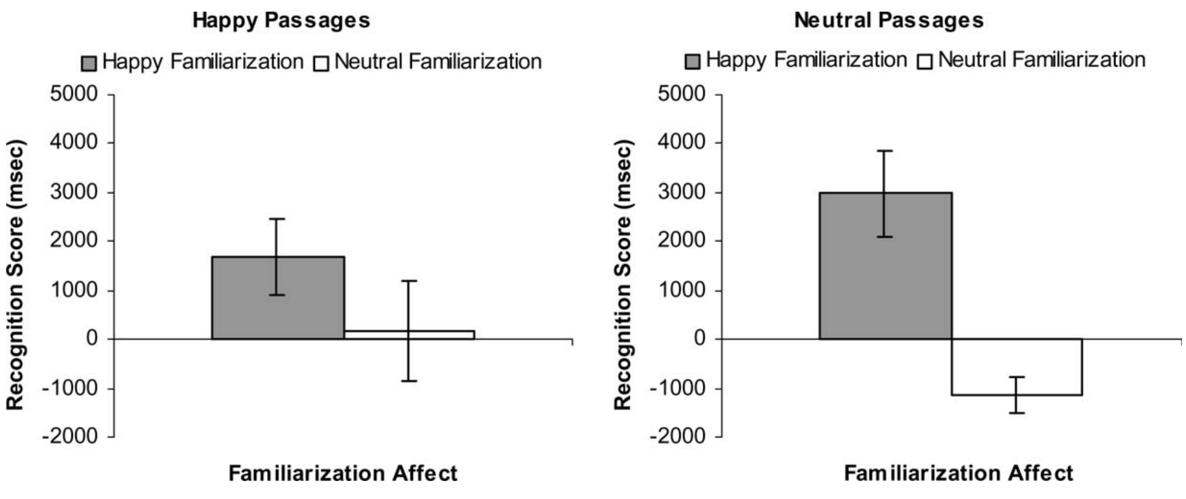

Fig. 2. Experiment 2: 10.5-month-olds' recognition scores for happy and neutral familiarization words.

$t(19) = 3.41$, $p < .01$. Sixteen of 20 infants displayed this pattern.

The right-hand side of Fig. 2 shows a unique combination of positive and negative recognition scores within subjects. Again, the direction in which infants express recognition of familiar items mirrors their perceptual preferences for happy and neutral affect. Happy affect is preferred over neutral affect in attentional tasks (Kitamura & Burnham, 1998; Singh et al., 2002a, 2002b). Similarly, for the processing tasks in both Experiments 1 and 2, happy words were preferred over unfamiliar words and neutral words were dispreferred relative to unfamiliar words. The bidirectionality of infants' recognition scores will be discussed in more detail in the General discussion.

These results show that older infants are generally better able to recognize words mismatched in affect than younger infants. To make a direct comparison between age groups, a $2 \times 2 \times 2$ ANOVA was conducted using matching status as a within-subjects factor and age and test passage affect as between-subjects factors. Recognition scores were used as the dependent variable in this analysis. There was a significant interaction of age and matching status, $F(1, 76) = 4.40$, $p < .05$. Further comparisons separated the data by test passage affect (a between-subjects factor), as the direction in which recognition was expressed led recognition scores in the two passage conditions to cancel each other in the overall comparison. For happy test passages, there was no interaction of age and matching status, $F(1, 38) = 1.18$, NS, but there was a main effect of matching status, $F(1, 38) = 11.88$, $p < .01$. Recognition scores for matched words were greater than those for mismatched words across both age groups. For neutral test passages, there was a marginally significant age by matching status interaction, $F(1, 38) = 3.55$, $p = .067$, indicating that the relationship between matching status and recognition is dependent on the age of the infant. There was also a main effect of matching status, $F(1, 38) = 21.56$, $p < .0001$, showing again that matched words were better recognized than mismatched words across both age groups.

This statistical comparison between age groups reveals that older infants are better able to recognize tokens that are mismatched in affect than are younger infants. However, older infants were not able to recognize mismatched tokens in both types of passages. Whereas happy familiarization words were recognized in neutral passages, neutral familiarization words were not recognized in happy passages. We had expected that evidence of recognition would have extended to neutral words presented in happy passages by 10.5 months. However, in this condition, the sample was evenly divided into those with positive versus negative recognition scores. Like the 7.5-month-old infants, older infants recognized neutral words only in neutral passages and failed to recognize them in happy passages.

One possible explanation for this effect might concern asymmetric allocation of attention to happy and neutral words during familiarization. If infants attended preferentially to happy words during familiarization, these words may have been encoded in greater depth, allowing for more robust recognition of these words. Alternatively, affectively charged speech is likely to be more variable than neutral speech, and the greater variability of happy tokens may have led to better recognition of these words. Differences in the variability of familiarization stimulus sets may lead to asymmetries in generalization (Mareschal, French, & Quinn, 2000), whereby familiarization with a more variable set leads to the formation of broader category, one that more readily admits dissimilar exemplars. Indeed, the acoustic analyses presented in Table 1 are consistent with this possibility; there were significantly larger pitch excursions within the happy set of tokens than within the neutral set.

Experiment 3

To determine whether older infants are indeed capable of recognizing neutral tokens that are later presented in happy speech, we conducted a follow-up to Experiment 2 in which the task was simplified by eliminating differences in word affect during familiarization. Infants were presented with both familiarization words in neutral affect, and heard all passages in happy affect. Although there remained a mismatch in affect across the two phases of the experiment, restricting familiarization affect to a single emotion (i.e., neutral) for both words eliminated any opportunity for happy (and more variable) familiarization tokens to usurp attention that infants would otherwise devote to neutral words and reduced the complexity of the task. If asymmetric attention during familiarization contributed to infants' failure to recognize neutral words in happy passages, 10.5-month-olds should now recognize the familiarized words. However, if restricted variability of the neutral familiarization items accounted for 10.5-month-old infants' inability to recognize neutral words in happy passages, they should still fail to recognize these words, even when the task is simplified. To ensure that simplifying the task demands alone do not allow 10.5-month-olds to recognize mismatched tokens, a group of younger infants was also tested using the simplified design. Other than limiting familiarization to two neutral words, the design of the experiment was identical to that of the previous two experiments.

Participants

Sixteen full-term, English-exposed 10.5-month-olds (7 males and 9 females) and 16 7.5-month-olds (11 males and

5 females) participated in the study, recruited from Rhode Island Department of Health records. The mean age of 10.5-month-old participants was 45 weeks, 4 days (range = 43 weeks, 3 days to 47 weeks, 5 days); the mean age of 7.5-month-old participants was 33 weeks (range = 32–34 weeks, 1 day). Data for six additional 10.5-month-olds and four additional 7.5-month-olds were collected and discarded due to failure to complete the session (7), computer error (1), and having two or more trials that constituted outliers (2). Outliers were trials in which the listening times departed from the subject's average listening times by at least two standard deviations.

Stimuli, apparatus, and procedure

The apparatus was identical to that of Experiments 1 and 2. As before, half the infants were familiarized with "bike" and "hat," and the other half were familiarized with "pear" and "tree." Due to a change in procedure subsequent to Experiment 2, infants in this experiment received 12 recognition trials.

Results and discussion

Results from looking times during recognition testing are shown in Table 3, and recognition scores are illustrated in Fig. 3. Older infants showed significant negative recognition scores, $t(15) = -2.17$, $p < .05$. Although infants at 10.5 months have some difficulty recognizing neutral familiarization words in happy passages, they are able to do so when task demands are simplified. As in Experiments 1 and 2, the direction of the recognition scores is consistent with infants' listening preferences: infants showed depressed looking times to sentences containing words familiarized with neutral affect.

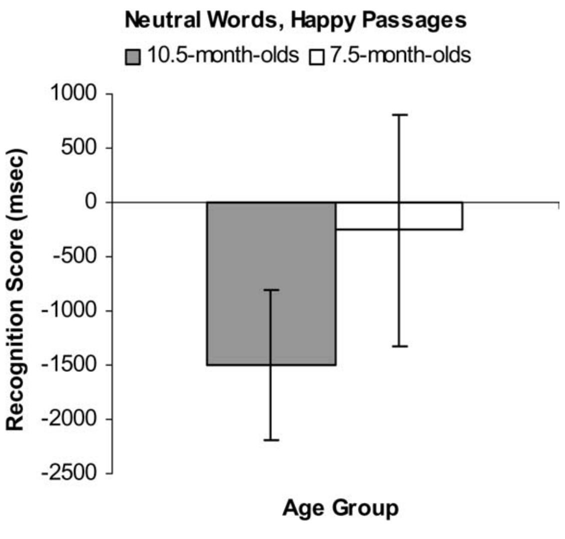

Fig. 3. Experiment 3: 10.5- and 7.5-month-olds' recognition scores for neutral familiarization words.

In contrast, younger infants did not display significant recognition of neutral familiarization words in happy passages, $t(15) = -.23$, NS. Unlike younger infants, who appeared to exhibit a reliance on affective matching regardless of task complexity, older infants can recognize affectively mismatched words, at least under certain circumstances. This difference in performance between the two age groups indicates that successful recognition on the part of the older infants is not simply due to the reduction in task complexity. Rather, older infants possess more mature word recognition capacities than 7.5-month-old infants, independent of task demands.

In conjunction with the findings from Experiment 2, in which 10.5-month-olds recognized happy words in neutral passages, the present demonstration that they can also generalize from neutral words to happy passages in this simplified procedure suggests that infants at 10.5 months are in a period of transition in which lexically irrelevant dimensions of tokens are becoming less important in lexical representation and processing.

General discussion

We began with the observation that infants prefer to listen to speech with positive vocal affect and the hypothesis that infants' selective attention, as indexed by their listening preferences, is causally linked to biases in their language processing. To assess this hypothesis, we conducted a set of experiments exploring the relation between vocal affect in the input and infants' spoken word recognition. Using the headturn preference procedure as adapted by Jusczyk and Aslin (1995) for studying word recognition, we familiarized infants with tokens of two different words. In Experiments 1 (7.5-month-olds) and 2 (10.5-month-olds), one word was spoken with happy affect, while the other was spoken with neutral affect. In recognition testing, infants heard passages containing the words with which they had been familiarized, along with passages containing non-familiarized words; individual infants heard all passages spoken with happy affect or spoken with neutral affect. A follow-up study, in which infants were familiarized with words spoken in neutral affect and tested on passages spoken with happy affect, was conducted to probe an asymmetry observed in Experiment 2. The results from all three experiments are summarized in Table 4.

Three primary conclusions emerge from the results of these experiments. First, the preference observed very early in development for speech with happy affect extends into the second half of the first year. Second, despite this early and persistent preference, there is no apparent advantage for recognition of words either initially familiarized with happy affect or later encountered in happy fluent speech. Third, in lieu of an advantage for

Table 4
Recognition of familiarized words

	7.5-month-olds		10.5-month-olds	
	Happy word	Neutral word(s)	Happy word	Neutral word(s)
Happy test passages	↑[a]	—[a,c]	↑[b]	—[b]/↓[c]
Neutral test passages	—[a]	↓[a]	↑[b]	↓[b]

Relative to baseline (passages with non-familiarized words): ↑, increased looking time; ↓, decreased looking time; —, no difference.
[a] Experiment 1.
[b] Experiment 2.
[c] Experiment 3.

happy speech, we observed an early advantage for recognition of words that occurred with the same affect in familiarization and recognition testing. Later in development, infants begin to recognize words even when the affect changes across familiarization and recognition. We take up each of these points in the following, focusing in particular on the circumstances that may govern whether preference and processing are causally linked and on the implications of the observed matching effect for the nature of early lexical representations and the mechanisms by which such representations develop.

Previous research has documented that preference for positive vocal affect is evident shortly after birth and continues through the first half of the first year (see Kitamura & Burnham, 1998; Singh et al., 2002a, 2002b; Trainor, Austin, & Desjardins, 2000). Our initial analyses focused on whether infants listened longer to happy stimuli versus neutral stimuli. In Experiment 1, 7.5-month-old infants listened significantly longer to happy passages than to neutral passages (a between-subjects difference). They also listened significantly longer to passages containing words familiarized in happy affect than to passages containing words familiarized in neutral affect (a within-subjects difference). This pattern of results is consistent with the presence of an ongoing preference for positive affect for both words and passages. In Experiment 2, 10.5-month-old infants showed no overall difference in listening times to happy passages versus neutral passages, but they did listen significantly longer to passages containing words familiarized in happy affect than to passages containing words familiarized in neutral affect. In the absence of any within-subjects comparison of listening times to happy versus neutral passages, we are reluctant to interpret these findings as indicating a decline in preference for positive affect between 7.5 and 10.5 months. However, as infants increasingly devote their attention to phonemic properties of speech, it would not be surprising to see affective prosody lose some of the power to compel attention that it possesses early in development.

Although overall listening behavior revealed a preference for happy speech, a different pattern of results emerges when we consider word recognition. In Experiment 1, 7.5-month-old infants recognized happy words in happy passages and neutral words in neutral passages; in Experiment 2, 10.5-month-olds recognized happy words in happy passages and both happy and neutral words in neutral passages; and in Experiment 3, 10.5-month-olds recognized neutral words in happy passages, whereas 7.5-month-olds again failed to do so. According to the hypothesis that happy affect would facilitate infants' spoken word processing, recognition ought to have been worst for neutral words in neutral passages. Our results clearly failed to comport with this prediction. Listening preferences are not always linked to processing advantages.

Direction of preference

Another novel finding in these studies concerns the fashion in which infants expressed recognition of familiarized words: this varied in conjunction with the affect of the familiarization words. Infants tended to show positive recognition scores for happy familiarization words, but negative recognition scores for neutral familiarization words. This bidirectionality in looking times is a robust finding, as it surfaced across all three experiments and across both age groups, as well as in pilot studies using happy and neutral stimuli produced by a different talker conducted prior to the present experiments.

The standard interpretation of differences in looking time in infant preference experiments is in terms of familiarity and novelty effects. Both types of effects are commonly observed in infant cognition tasks, and, as noted earlier, both have been observed in previous studies of early linguistic processing (e.g., in studies using HPP, Houston & Jusczyk, 2000 and Jusczyk et al., 1999 report familiarity effects, whereas Höhle & Weissenborn, 2003 report novelty effects). We review the three factors traditionally assumed to determine the direction of infant preference and then assess their influence in the present set of studies.

First, age is a reliable predictor of whether infants will express a novelty or familiarity preference. When other factors are equated, older infants typically show novelty preferences for stimulus sets that induce familiarity preferences in younger infants (Hunt, 1970; Wetherford & Cohen, 1973). However, age cannot explain our results because both types of effects were found within each of the two age groups tested. Second, familiarization time has been implicated as a predictor of novelty and familiarity preferences. Increasing familiarization time typically leads to novelty preferences, when other factors are controlled (Hunter & Ames, 1988; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982; Wagner & Sakovits, 1986). The familiarity and novelty preferences observed here could not have arisen from differences in familiarization time, however. In the current studies, overall familiarization time was carefully controlled across happy and neutral familiarization items. Furthermore, the rate of familiarization (amount of familiarization divided by the number of familiarization trials) did not differ significantly for happy and neutral familiarization words in any of the experiments here or for any age group. Third, increasing stimulus complexity can lead to familiarity preferences in tasks that typically produce novelty preferences (Hunter, Ames, & Koopman, 1983). Of course, the relevant measure is psychological, rather than physical complexity: stimuli that are psychologically more complex take longer to encode. Our acoustic analyses support the notion that happy stimuli may be physically more complex, in that they span greater ranges of frequency and duration measures. However, because infants are likely to have had more experience with happy IDS than with neutral IDS, there is no reason to believe that happy speech has greater psychological complexity. To the contrary, one might expect infants to be more adept at encoding happy speech given its prominence in their auditory world. Therefore, this explanation does not plausibly account for the directions of effects observed here.

In sum, familiarity preferences commonly arise when infants have not fully encoded stimuli. If infants are prevented from fully encoding stimuli as a result of young age, shortened familiarization time, or increased complexity, a shift from novelty to familiarity preference may occur. These traditional explanations for novelty and familiarity do not appropriately or adequately explain the direction of infants' preference in the present studies. For example, in Experiment 2, one group of infants had both significant positive recognition scores for happy familiarization words and significant negative recognition scores for neutral familiarization words. Simultaneously possessing a familiarity preference and a novelty preference is a logical impossibility, unless those preferences are defined with respect to the intrinsic characteristics of particular stimuli. However, if stimulus characteristics suffice to explain the pattern of preference, then references to "familiarity" or "novelty" are no longer necessary.

Typically, the stimuli used in studies of infant cognitive processing are carefully controlled for intrinsic appeal. Social significance or intrinsic appeal of stimuli are manipulated in studies of preference, not processing (DeCasper & Fifer, 1980; DeCasper & Spence, 1986; Mehler et al., 1988). This is the first study to test infants' abilities to *process* socially meaningful, non-phonemic aspects of the input in the service of language acquisition. The fashion in which infants manifest recognition of affective stimuli coincides with their perceptual preferences; this indicates that processing mechanisms are not altogether invulnerable to the effects of preference, even though they may not be impeded or facilitated by preferences. In short, we suggest that infants bring to the laboratory an intrinsic preference for affectively positive stimuli and an intrinsic dispreference for affectively neutral or negative stimuli. These preferences and dispreferences are reflected here in the patterns of infant looking times.

Relationship between preference and processing

In this study, infants' processing of preferred stimuli was not facilitated. However, as discussed earlier, infants' processing biases for other properties of speech input, such as words with strong–weak stress or frequent phonotactic sequences, are complemented with preferences for such patterns. Why are these preferences associated with infants' processing while the preference for positive speech affect is not? One possibility is that the former pertain to language-specific properties of the speech signal, whereas the latter pertains to language-general or even non-linguistic properties, for example, intonation contours that may signal meaning even to a naive listener. Unlike salient properties such as affect, there may be no fundamental appeal of language-specific patterns for infants. Rather, infants' preference for language-specific properties of speech may be driven by the prior abstraction of subtle phonological patterns. For example, the appearance of a preference for frequent phonotactic patterns implies that some distributional analysis of segments has been completed. As a result, this type of preference may only arise as a consequence of extensive exposure to the native language. On this view, the direction of causality may be opposite to that which we suggested at the outset: the ease of processing frequent patterns may lead to familiarity preferences for these patterns. At this juncture the evidentiary record does not distinguish the possibilities. Preferences for language-specific properties of speech have been demonstrated both contemporaneously with such biases (in the case of frequent phonotactic patterns: Friederici & Wessels, 1993; Jusczyk et al., 1994; Mattys & Jusczyk, 2001), and at later ages than such biases (in the case of strong-weak bisyllables: Jusczyk et al., 1993; Jusczyk et al., 1999). Which of these reflects the true pattern cannot be determined because the data on infant spoken word recognition are sparse; as the record gets filled in, it will be come clearer whether processing biases lead to listening preferences or vice versa.

In contrast, preferred language-general or non-linguistic properties are likely to comprise perceptually prominent aspects of auditory input that serve to engage infants' attention prior to any linguistic analysis. Such preferences may include biases observed very early in development towards sound patterns such as musical consonance (Schellenberg & Trehub, 1996) or maternal voices (DeCasper & Fifer, 1980), as well as positive affect (Mastropieri & Turkewicz, 1999; Singh et al., 2002a, 2002b). Preferences for such properties may draw infants toward certain types of speech (or away from others). In some cases, these preferences may affect processing, as when cues to clause boundaries are exaggerated in IDS. However, in most cases, it is likely that these preferences may not by themselves generate useful and sophisticated strategies for identifying linguistic structure.

The nature of early lexical representations

What appears to be important for successful word recognition in early infancy is that tokens are similar to one another across familiarization and recognition testing. In this respect, our results parallel those of Houston and Jusczyk (2000), who found that 7.5-month-old infants familiarized with words from one talker failed to recognize those words when spoken by talkers of the opposite gender (or with dissimilar voices, cf. Houston, 2000). In a result usually interpreted as indicating early representational sophistication, Jusczyk and Aslin (1995) found that 7.5-month-olds familiarized with non-words like *tup* or *zeet* showed no preference for passages containing phonologically similar words like *cup* or *feet*. We suggest an alternative interpretation: these findings complement those of Houston and Jusczyk and the present results to indicate that infants' early lexical representations preserve acoustic and phonetic detail with such precision that variation, whether it be phonemic (as in the case of *tup* vs. *cup*) or non-phonemic (as in the case of happy *bike* vs. neutral *bike*), impedes their recognition of novel exemplars as familiar types.

These results from infants are reminiscent of those from studies of older children (Fisher, Hunt, Chambers, & Church, 2001) and adults (e.g., Bradlow et al., 1999; Church & Schacter, 1994; Goldinger, 1996; Luce & Lyons, 1998; Nygaard, Sommers, & Pisoni, 1995; Palmeri, Goldinger, & Pisoni, 1993), which provide evidence from both implicit and explicit memory tasks that older individuals retain token-specific details, such as talker identity, dialect, gender, coarticulation context, fundamental frequency, and emotional state. However, these studies indicating sensitivity to surface detail do not report the sort of matching effect observed with infants. Whereas surface form variation may tax processing resources in adults, it does not prevent us from recognizing familiar words altogether. Adults recognize dissimilar tokens as exemplifying the same lexical type, albeit with reduced efficiency, but infants appear to treat dissimilar tokens as though they are exemplars of different types.

It is possible, however, that these findings from infants, older children, and adults are all of a piece, except that reduction in efficiency of lexical access due to token variation has more catastrophic consequences for infants. This could arise if infants process speech less efficiently than adults. We noted at the outset that word recognition in fluent speech is subject to severe time constraints: given the ephemeral nature of speech, lexical access must succeed before the signal is so far downstream that backward interference disrupts recognition. If infants' processing is generally less efficient, then additional delays contributed by perceptual dissimilarity might cause recognition time to exceed the threshold imposed by the rate of incoming tokens, thus causing recognition to fail. Evidence demonstrates gradual increases in speed of speech processing across the second year (Fernald, Pinto, Swingley, Weinberg, & McRoberts, 1998); it is likely that this represents continuation of a trend from earlier in development.

The constraints to which early lexical representations are subject are unknown at present. It appears that infants' early lexical representations reflect covarying properties of experienced exemplars, whether or not these are ultimately relevant for lexical distinctions in the native language. What the range of these properties might be, however, is unclear. Perhaps infants only encode those surface details that may signal phonemic distinctions in some language (though not necessarily the native language). For example, differences in pitch contours may signal phonemic distinctions in tonal languages, and differences in segment duration are phonemic in many languages. To the extent that properties of affect mimic such differences, these might be encoded in early lexical representations. Alternatively, infants might encode only those surface details that are characteristic of human vocalizations. Or infants might begin with a representational mechanism in which *any* co-occurring characteristics of encountered tokens, regardless of their provenance, are encoded. Additional ongoing studies are probing the effects of surface form variations that are never phonemic, such as changes in amplitude, absolute shifts in fundamental frequency, or presence of extralinguistic noise, on early spoken word recognition.

In the experiments reported here, we exposed infants to words whose affect was held constant. If infants were instead exposed to words with varying affect, we would expect that they would be able to later recognize these words when they occurred in some novel affect. Indeed, results from Singh, Bortfeld, and Morgan (2002b) indicate that more variable familiarization does contribute to more robust recognition. Does such variability really characterize the speech that infants hear? One common property of IDS is that words (particularly nouns) are repeated in full form, rather than being replaced by proforms (Ferguson, 1964). Such repetitions, however, are not exact replicas; words appear in different syntactic and prosodic positions (Bernstein-Ratner, 1996) and with varying degrees of focal stress (Bortfeld & Morgan, 1999). This sort of variation, occurring within limited time frames, can help infants to learn which prosodic and paralinguistic properties of tokens are irrelevant to lexical identity, first, perhaps, with respect to specific lexical types, and later with respect to the entire lexicon. At 7.5 months, infants have not yet learned which properties of speech are or are not relevant for the determination of lexical identity, but by 10.5 months, infants are well along the road to doing so.

Acknowledgments

This work formed part of a doctoral dissertation submitted by L.S. to the Brown University Graduate School and was supported by a Dissertation Fellowship from Brown University to L.S. and a grant from the National Institute of Health (1 RO1 HD32005) to J.L.M. We thank Whitney Boon for conducting pilot research, Karen Rathbun, Lori Rolfe, and Nancy Allard for assistance in testing infants, and Cathi Best, Heather Bortfeld, Barbara Church, Katherine Demuth, Angela Friederici, Melanie Soderstrom, and an anonymous reviewer for comments on previous drafts.

Appendix. Passages used in recognition testing

Bike
His bike had big black wheels.
The girl rode her big bike.
Her bike could go very fast.
The bell on the bike was really loud.
The boy had a new red bike.
Your bike always stays in the garage.

Hat
She put on her hat to play in the snow.
The hat was soft and warm.
Her brother had knitted the hat.
The hat was blue and white.
She liked how the hat covered her ears.
Her friends also liked her hat.

Tree
The tree was a hundred years old.
The tree grew in the man's back yard.
He liked to look outside at the tree.
Hanging from the tree was a swing.
The man's grandchild played in the tree.
The leaves on the tree were yellow.

Pear
The juicy, green pear came from the basket.
The pear is her favorite fruit.
She wanted to eat the biggest pear.
The pear in the basket looked very good.
Next to the pear was an apple.
She ate the whole pear.

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