The shift in infant preferences for vowel duration and pitch contour between 6 and 10 months of age

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Abstract

This study investigates the influence of the acoustic properties of vowels on 6- and 10-month-old infants' speech preferences. The shape of the contour (bell or monotonic) and the duration (normal or stretched) of vowels were manipulated in words containing the vowels /i/ and /u/, and presented to infants using a two-choice preference procedure. Experiment 1 examined contour shape: infants heard either normal-duration bell-shaped and monotonic contours, or the same two contours with stretched duration. The results show that 6-month-olds preferred bell to monotonic contours, whereas 10-month-olds preferred monotonic to bell contours. In Experiment 2, infants heard either normal-duration and stretched bell contours, or normal-duration and stretched monotonic contours. As in Experiment 1, infants showed age-specific preferences, with 6-month-olds preferring stretched vowels, and 10-month-olds preferring normal-duration vowels. Infants' attention to the acoustic qualities of vowels, and to speech in general, undergoes a dramatic transformation in the final months of the first year, a transformation that aligns with the emergence of other developmental milestones in speech perception.

Introduction

Infants do not come into the world empty-handed – they begin life with 3 months of in utero experience of speech. What they hear there might be segmentally impoverished owing to the low-pass filter characteristics of the mothers' womb, but it is rich in prosodic information (Ockleford, Vince, Layton & Reader, 1988). Accordingly, newborns show a preference for their mother's voice over a stranger's (DeCasper & Fifer, 1980), and for their native language over a language from a different rhythm group (Mehler et al., 1988; Moon, Panneton Cooper & Fifer, 1993), even when presented with intonation-only versions. Infants are also born with certain sensitivities: they attend to syllabic in preference to non-syllabic utterances (Moon, Bever & Fifer, 1992); to the number of syllables in a sequence, but not to the number of phonemes (Bijeljac-Babic, Bertoncini & Mehler, 1993); and at 2 months can discriminate syllables (tap, pat) better than non-syllables (tsp, pst) (Bertoncini & Mehler, 1981). Thus, it seems that infants are born with a bias to attend to the periodic portions of the speech signal that carry prosodic and vowel information over the broadband structure of consonants (Cutler & Mehler, 1993). In accord with this periodicity bias, language-specific attunement occurs earlier for vowels than for consonants (Kuhl et al., 1992; Polka & Bohn, 1996; Polka & Werker, 1994). Whereas very young infants discriminate native and non-native vowels alike (Polka & Werker, 1994; Trehub, 1976), by 6 months of age experience-related effects emerge, showing that phonetic categories become organized around native-language vowel prototypes, such that poor exemplars are assimilated into the vowel prototype (Kuhl, Williams, Lacerda, Stevens & Lindblom, 1992; Polka & Werker, 1994). It makes sense that vocalic segments are more germane in early infancy, considering that they carry most of the prosodic information that young infants use to process speech in the early months. Moreover, experience-related effects emerge for the prosodic components of speech: newborns distinguish their own language from another, but cannot discriminate between two non-native languages (Mehler et al., 1988) unless they are from different rhythmic classes (Nazzi, Bertoncini & Mehler, 1998). By 5 months, infants can make fine discriminations between their native speech and other languages from the same rhythmic class (Nazzi, Jusczyk & Johnson, 2000). It is not until 9 months of age, however, that infants begin to make distinctions between two rhythmically similar languages based on phonetic/phonotactic information, rather than relying solely on prosody to make such distinctions (Jusczyk, Friederici, Wessels, Svenkerud & Jusczyk, 1993). Furthermore, 9- but not 6-month-olds are able to integrate segmental and suprasegmental information (Morgan & Saffran, 1995). It just so happens that the language input used with young infants in the form of infant-directed (ID) speech...
is imbued with rich prosodic features – it has higher pitch, greater pitch modulation, more distinctive pitch contours, high affective salience, and slower speech rate compared with adult-directed (AD) speech (Fernald & Simon, 1984; Kitamura & Burnham, 2003; Stern, Spieker, Barnett & MacKain, 1983). Analyses of mothers' speech shows that, in addition to exaggerated prosodic features, ID vowels have exaggerated phonetic features in American-English, Australian-English, Japanese, Russian and Swedish, such that the corner vowels, /i/, /a/ and /u/, occupy a larger vowel space in ID than in AD speech (Andruski & Kuhl, 1996; Burnham, Kitamura & Vollmer-Conna, 2002; Kuhl et al., 1997). Furthermore, it has been shown that this enlarged vowel space is not merely a by-product of exaggerated prosody, because when ID speech is compared with the prosodically similar register used to talk to pets, only ID speech has exaggerated phonetic characteristics (Burnham et al., 2002). Moreover, when Liu, Kuhl and Tsao (2003) tested the effect of the degree of mothers’ vowel hyperarticulation on infant speech perception, they found that mothers’ vowel space area was correlated with their infant’s ability to discriminate a native consonant contrast. This evidence suggests that the more mothers hyperarticulate their vowels, the better infants discriminate native language speech contrasts.

Over the past three decades evidence has been accumulating for the advantages of the ID mode of communication: ID speech has been shown to have attentional (Fernald, 1985; Panneton Cooper & Aslin, 1990; Werker & McLeod, 1989), emotional (Fernald, 1984; Kitamura & Burnham, 1998; Singh, Morgan & Best, 2002), social (Kitamura & Burnham, 2003; Snow, 1977, 1989) and linguistic (Karzon, 1985; Kemler Nelson, Hirsh-Pasek, Jusczyk & Wright Cassidy, 1989; Lui, Kuhl & Tsao, 2003) benefits for the infant. Even newborn infants have a proclivity to listen to ID over AD speech (Panneton & Aslin, 1990), and it is well established that infants still prefer ID to AD speech at around 4 months of age (Fernald, 1985).

Just what is it about ID speech that infants find so attractive? Both fundamental frequency and vocal affect have been implicated. Fernald and Kuhl (1987) used sine-wave analogues of ID speech to show that the acoustic dimension of fundamental frequency (F0) accounted for ID preferences, not its amplitude or duration patterns. However, when the mean F0 was matched in two samples of ID speech, 6-month-old infants were found to listen longer to ID speech with high than with low positive emotion, but showed no preference when emotion was matched and F0 varied (Kitamura & Burnham, 1998). Similarly, 6-month-olds listen longer to happy than to neutral speech, whether it is presented in the ID or the AD speech register (Singh et al., 2002).

Although there is firm evidence for ID speech preferences (Fernald, 1985; Hayashi, Tamekawa & Kiritani, 2001; Panneton Cooper & Aslin, 1990) and its associated positive affect (Kitamura & Burnham, 1998; Panneton, Kitamura, Mattock & Burnham, 2006; Singh et al., 2002), there is more recent evidence indicating that these preferences are modified as the infant develops. First, it has been shown that infants’ preference for ID over AD speech shows a U-shaped function over age. Hayashi et al. (2001) found that infants aged 4 to 6, and 10 to 14 months of age paid more attention to ID than to AD speech, whereas a group aged 7 to 9 months did not respond differentially to the two speech types. Second, 4- and 8-month-olds exhibit unique patterns of responsiveness to both the tempo and the positive affect in ID speech. Panneton et al. (2006) showed that at 4 months infants pay more attention to speech with slowed tempo, whereas by 8 months they prefer normal-tempo speech, and that the preference for ID speech with high positive affect shown at 4 months dissipates by 8 months (Panet, et al., 2006).

Mothers also modify F0 and affective intent in their speech over the first 12 months of life. For instance, mean-F0 tends to be highest in speech to 6-month-olds, lower in speech to 12-month-olds, and most restrained in speech to newborns (Kitamura & Burnham, 2003; Stern et al., 1983). Interestingly, Kitamura and Burnham (2003) found that pitch characteristics are considerably dampened in speech to 9-month-olds in comparison with speech to 6- and 12-month-olds. This dampening of pitch in speech to 9-month-olds corresponds to a dampening of positive vocal affect around this age. Thus, over the first year of life mothers tend to accentuate different types of affective intent – comforting in the first few months, approving around 6 months, and by 9 months utterances become most directive, and least approving. More recently it has been shown that infants show corresponding age-related preferences for these affective intent types. That is, when infants are presented with three types of affective intent – comforting, approving and directive – 3-month-olds look longer to hear comforting utterances, 6-month-olds look longer to hear approving utterances, and 9-month-olds look longer to hear directive utterances (Kitamura & Lam, 2009; Lam & Kitamura, 2006). These results indicate that infants’ preferences for the acoustic concomitants of these ID affective intent types transform over the first year.

Taken together, the evidence suggests that young infants pay close attention to particular acoustic and/or affective properties transmitted via the vocalic segments in the speech signal, and that these cues are modified over the first year. Furthermore, it has been shown that they are linguistically beneficial for the infant. For instance, Karzon (1985) found that 1- to 4-month-olds can only discriminate the polysyllabic sequences /malana/ versus /marana/ when spoken with stress on the middle syllable typical of ID speech, but not with more monotonic intonation. In addition, it is suggested that ID prosodic cues are particularly beneficial to early infant speech perception, as the exaggerated features assist infants to segment the speech stream (Theissen, Hill & Saffran, 2005), and to parse clauses (Hirsh-Pasek et al., 1987; Kemler Nelson et al., 1989). Indeed, 6- to 7-month-old infants discriminate...
the vowels /i/ as in heed and /u/ as in hid better when the F0 contour is shaped than when it is monotonic (Trainor & Desjardins, 2002). There is undoubtedly an underlying affective basis to ID speech, at least in the early part of the first year, and it is possible that this supports, and even motivates, language development.

The above findings point to a two-fold function for the exaggerated prosody in ID speech, and with it certain acoustic properties in vowels. On the one hand, F0 excursions aid aspects of speech perception and speech processing (Karzon, 1985; Kemler Nelson et al., 1989; Theissen et al., 2005), and on the other, they convey positive affect (Papousek, Papousek & Symmes, 1991; Stern, Spieker & MacKain, 1982; Kitamura & Burnham, 2003), which is shown to attract and maintain infant attention around 6 months of age (Kitamura & Burnham, 1998; Singh et al., 2002). Thus, it is proposed that certain acoustic features in ID speech are used to attract infants' attention to those aspects of the speech signal that aid language acquisition. If this is the case, then it might be expected that the exaggerated acoustic properties in ID speech will be more attentionally salient when experience-related effects for vowels emerge around 6 months of age (Kuhl et al., 1992; Polka & Werker, 1994) than at 10 months of age, when infants are attuning to consonantal (Werker & Tees, 1984) and phonotactic (Jusczyk et al., 1993; Morgan & Saffran, 1995) information in their native language.

Exaggerated pitch contours are one candidate for attracting infant attention (Breazeal & Aryananda, 2002; Katz, Cohn & Moore, 1996; Slaney & McRoberts, 2003). Around 80% of ID speech to very young infants is made up of rising, falling and bell-shaped contours (Fernald & Simon, 1984). The use of these contours is determined to some extent by the context. For example, rising contours are generally used to gain infant attention when the infant is looking away; bell-shaped contours to reward and maintain infant attention; and falling contours to soothe a fussy infant (Papousek, Papousek & Symmes, 1991; Stern, Spieker & MacKain, 1982). In the current study, bell-shaped contours are used because their rewarding nature is known to hold infant attention.

In this study, 6- and 10-month-old infants' attention to contour shape is examined by presenting infants with words in which the vowels have either a bell-shaped or a monotonic contour. It is expected that 6-month-old infants will listen longer to words with an exaggerated contour than to those with a monotonic contour. The results for 10-month-olds should follow emerging evidence of a decrease in positive vocal affect in the production of ID speech at around 9 months of age (Kitamura & Burnham, 2003), and infant behavioral data indicating that there is a decrease in attention to ID speech, and to some of its features around the same time (Hayashi et al., 2001; Kitamura & Lam, 2009; Panneton et al., 2006). Thus, it is expected that 10-month-olds will show a preference for monotonic over bell-shaped contours.

Vowel duration is also investigated, as it is a likely contender for attracting infant attention. Besides evidence showing that young infants pay attention to speech with slowed tempo (Panneton et al., 2006), there is a linguistic conflation with this attentional proclivity. In adult speech, there is a tendency for prolonged vowels to reach their target frequencies more often than shorter vowels, which tend to centralise or undershoot the target (Lindblom, 1963; Moon & Lindblom, 1994). In ID speech it is possible that this effect underpins the hyperarticulation of the corner vowels, as the duration of the corner vowels is greater in ID than in AD speech (Burnham et al., 2002). Again, it seems that vowels serve a dual purpose, as the preference for slow speech by young infants may be based on a sense of comfort imparted by slowing the speech rate (Kitamura & Burnham, 2003), but it could also accommodate early cognitive limitations for processing speech information. Thus, it is expected that 6-month-olds will pay more attention to stretched than to normal-duration vowels, and that more developmentally advanced 10-month-olds will prefer normal to stretched vowels.

**General method**

In order to examine whether infants' attention to words is governed by vowel duration or F0 contour, two experiments were conducted with infants aged 6 and 10 months. The shape of the F0 contour was either bell-shaped with high F0 range, or monotonic with low F0 range, while duration of the vowel was either normal or stretched to twice its normal duration. This resulted in four stimulus types: (1) normal-duration bell contours, (2) normal-duration monotonic contours, (3) stretched-duration bell contours, and (4) stretched-duration monotonic contours.

The four stimulus types were combined, so that in Experiment 1 (contour shape) infants heard either (i) normal-duration bell and monotonic contours in Condition A, or (ii) stretched bell and monotonic contours in Condition B; and in Experiment 2 (vowel duration) infants heard either (i) normal and stretched bell contours in Condition A, or (ii) normal and stretched monotonic contours in Condition B.

**Participants**

Parental questionnaires indicated that infants were full-term, healthy at the time of testing, had no hearing difficulties, and came from Caucasian middle-income families. Infants were not included if they were considered inattentive, that is, if the total duration of fixation of both targets (as a percentage of total presentation time) was less than 40%.

**Vowel stimuli – recording and selection**

The vowel stimuli were spoken by a female speaker who produced multiple tokens of four familiar words containing the vowels /i/ in ‘bee’ and ‘sheep,’ and /u/ in
The female speaker produced the word tokens with and without a distinctive bell-shaped F0 contour; that is, one exemplar set had high F0 range, and the other had low F0 range. Spectrograms showing the harmonic movement typical of steady-state and bell contours are shown in Figure 1. Mean F0, duration and range were measured using Praat (Boersma & Weenink, 2005). Stimulus selection was based on matching the starting F0 period and duration of the vowels in the high F0 range and low F0 range sets. The acoustic measures of F0 (mean and range) and the duration for normal and stretched vowels are shown in Table 1. There were 16 bell-shaped and 16 steady-state exemplars; that is, 4 bee, 4 sheep, 4 goose and 4 shoe stimuli in each set. For each of the 32 exemplars of words, the vowel portion of the words (excluding the consonants) was doubled using SoundEdit. For presentation to the infants, 16 vowel stimuli of each of the four types (N = 64) were appended with a 500-ms gap between words.

Vowel stimuli – ratings of positive affect

Because it is well known that positive affect in speech is especially salient to young infants (Kitamura & Burnham, 1998; Singh et al., 2002), the 64 stimulus words were also rated for positive affect by 20 first-year psychology students from the University of Western Sydney. Participants were asked to rate the words using a scale that ranged from +4 to −4, where +4 represented very high positive affect, 0 represented neutral affect, and −4 represented very high negative affect. The mean ratings of positive affect are shown in Table 1. A within-participant (2) (duration) × (2) (contour) analysis of variance (ANOVA) revealed a significant main effect for contour, \( F(1, 19) = 114.6, p < .0001, \eta^2 = .86 \), but no significant main effect for duration, or for contour × duration interaction. Thus, the results indicate that adults perceive that the bell contours convey more positive affect than the monotonic contours, but that no difference in degree of positive affect is conveyed by normal- and stretched-duration vowels.

Table 1  The acoustic measures of fundamental frequency, duration and pitch range; and ratings of affect (normal and stretched) for both bell and monotonic contours associated with the vowels in the words goose, bee, shoe and sheep

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<td></td>
<td>F0 (Hz)</td>
<td>Duration (s)</td>
<td>Range (s)</td>
<td>Normal</td>
<td>Stretched</td>
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<tr>
<td>Goose</td>
<td>312</td>
<td>.75</td>
<td>314</td>
<td>1.70</td>
<td>1.74</td>
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<tr>
<td>Bee</td>
<td>308</td>
<td>.65</td>
<td>352</td>
<td>1.97</td>
<td>1.79</td>
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<tr>
<td>Shoe</td>
<td>307</td>
<td>.77</td>
<td>253</td>
<td>1.84</td>
<td>1.61</td>
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<tr>
<td>Sheep</td>
<td>332</td>
<td>.76</td>
<td>265</td>
<td>1.28</td>
<td>1.11</td>
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<tr>
<td>Mean</td>
<td>314</td>
<td>.73</td>
<td>296</td>
<td>1.70</td>
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Figure 1  Spectrograms of the word ‘bee’. An example of a monotonic contour is shown in (a), and a bell-shaped contour is shown in (b).

Although bell contours are typically used across several syllables in an utterance, single words were used in the current study to reduce the effect of utterance content on infant preferences. Furthermore, when bell contours are used it is the case that the peak of the contour tends to occur on the stressed word in the utterance (see Fernald & Mazzie, 1991).
speakers placed beside the monitors. A digital video camera, placed midline facing the infant, was connected to a video monitor in the control room and used by the experimenter to judge the infant's head and eye movements in real time. The sequencing of the experiment was controlled by SimulPrep software developed at MARCS Auditory Laboratories. To diminish parental influence, speech that had had all silences removed was played to parents using a Panasonic portable CD player, and AKG studio headphones.

Procedure
Each set of vowel exemplars was paired with the same visual target, one presented to the infants' left, and the other to their right. Thus, if infants fixated the left visual target they heard one set of vowel exemplars, and if they fixated the right visual target they heard the other set. Each infant received two familiarization trials and six test trials. Trials commenced when the infant attended the central screen for 2 seconds. Sessions began with two 20-second familiarization trials, during which each set of vowel exemplars played, irrespective of the infant's looking behaviour. The order of presentation in familiarization trials was counterbalanced so that half the infants heard one set of vowel exemplars first, and the other half of the infants heard the other vowel set first. In the test phase, there were six 20-second trials in which presentation of the vowel exemplars was contingent on the infants’ direction of fixation. Side of presentation was counterbalanced so that half the infants heard one set of vowel exemplars on the left side, and the other set of vowel exemplars on the right side, and this was reversed for the other half of the participants. During familiarization and test trials the infants’ head and eye movements were recorded by video camera, and observed on a video monitor in the adjacent control room. The experimenter used a computer keyboard to input the timing of the infant’s looking behaviour: the left arrow key was pressed when the infant looked to the left monitor; the right arrow key when the infant looked to the right monitor; and the down arrow key when the infant was fixating the central monitor between trials. No key was pressed when the infant looked elsewhere. Thus, the onset of fixation was defined by the infant looking at a monitor, and the offset by the infant looking away from a monitor. Offline coding of 25% of the collected data was conducted by a second observer. Inter-observer reliabilities showed correlations in Experiment 1 of \( r = .95 \) (Condition A), \( r = .98 \) (Condition B), and in Experiment 2 of \( r = .97 \) (Condition A) and \( r = .93 \) (Condition B).

Experiment 1: Bell- and monotonic-shaped vowels
In Experiment 1, contour shape (bell versus monotonic) was the within-participants factor, and duration (normal and stretched) was the between-participants factor. Therefore, infants in Condition A heard exemplars of \textit{normal-duration} bell and monotonic contours, whereas infants in Condition B heard \textit{stretched} bell and monotonic contours.

Participants
A total of 96 infants participated in Experiment 1. The younger group consisted of 48 infants, and the older group of 48 infants. In Condition A, listening to \textit{normal-duration} bell and monotonic contours, there were 24 infants with a mean age of 26.0 weeks (range = 24.3–28.0 weeks; 10 females, 14 males), and 24 infants with a mean age of 42.2 weeks (range = 39.7–45.1; 13 females, 11 males). Data from 3 younger and 3 older infants were discarded because of inattentiveness. In Condition B, listening to stretched bell and monotonic contours, there were 24 infants with a mean age of 26.3 weeks (range = 23.7–28.3; 10 females, 14 males); and 24 older infants with a mean age of 42 weeks (range = 39.9–47.4; 12 females, 12 males). Data from 2 younger infants and 4 older infants were discarded because of infant inattentiveness.

Results and discussion
Mean fixations to bell and monotonic contours for both conditions by both age groups are shown in Figure 2. The dependent variable was fixation duration averaged across the six test trials as a function of stimulus type. Preliminary ANOVAs conducted to test the between-participants effects of side of presentation (left or right) and order of presentation in familiarization trials (bell first, monotonic first) on fixation duration to bell and monotonic contours showed no significant main effects,
or interactions for order, or side of presentation for either condition in either age group.

The main analysis consisted of a (2) × 2 × 2 ANOVA, with contour shape (bell, monotonic) as the within-participant variable, and duration (normal, stretched) and age (6, 10 months) as between-participants factors. The results revealed no significant main effects for contour, duration or age. Importantly, there was a significant age × contour interaction, \( F(1, 92) = 12.98, p < .0001, \eta^2 = .13 \), indicating that, irrespective of whether the speech samples were of normal or stretched duration, 6-month-olds listened longer to bell than to monotonic contours, whereas 10-month-olds listened longer to monotonic than to bell contours. Post-hoc two-tailed t-tests were conducted to test whether infants looked longer to bell or to monotonic contours in each condition. They revealed that 6-month-olds looked longer to normal-duration bell \( (M = 7.9) \) than to monotonic \( (M = 5.9) \) contours, \( t(1, 23) = 2.2, p < .04 \), in Condition A, and that there was a tendency for this age group to prefer stretched bell \( (M = 8.2) \) over stretched monotonic \( (M = 6.8) \) contours \( (p = .1) \) in Condition B. For 10-month-olds, there was no significant difference between looking times to normal-duration bell \( (M = 6.0) \) and monotonic \( (M = 6.9) \) contours (Condition A), but 10-month-olds showed a significant preference for stretched monotonic \( (M = 8.0) \) over stretched bell \( (M = 6.1) \) contours, \( t(1, 23) = 2.13, p = .04 \) (Condition B). The t-tests showed that younger infants preferred bell over monotonic contours only when both were of normal duration, and that older infants preferred monotonic over bell contours, but only when the vowels were stretched. These results indicate that infants’ contour preferences are dependent on the durational context in which contours are presented. However, the critical finding from this experiment is that 6-month-olds show an overall preference for bell-shaped contours, whereas 10-month-olds show the opposite pattern, preferring monotonic contours.

**Experiment 2: Normal- and stretched-duration vowels**

In Experiment 2, the within-participant variable was duration, and the between-participants factor was contour shape, so infants heard vowels with normal and stretched bell-shaped contours in Condition A, and normal and stretched monotonic contours in Condition B.

**Participants**

A total of 96 infants participated in Experiment 2. The younger group consisted of 48 infants, and the older group of 48 infants. In Condition A, listening to normal-duration and stretched bell contours, there were 24 younger infants with an average age of 26.0 weeks (range = 24.5–27.0 weeks; 12 females, 12 males), and 24 older infants with an average age of 42.3 weeks (range = 42.3–47.4 weeks; 12 females, 12 males). Data from another 3 younger and 4 older infants were discarded because of infant inattentiveness. In Condition B, listening to normal-duration and stretched monotonic contours, there were 24 younger infants with an average age of 26.5 weeks (range = 24.2–28.1 weeks; 12 females, 12 males), and 24 older infants with a mean age of 42.8 weeks (range = 41.04–46.0 weeks; 10 females, 14 males). Data from another 3 younger and 4 older infants were not included because of infant inattentiveness.

**Results and discussion**

Mean fixation times of 6- and 10-month-old infants for normal-duration and stretched vowels are shown in Figure 3. Preliminary ANOVAs conducted to test the effects of side of presentation (left or right) and order of presentation in the familiarization trials (normal-duration first or stretched first) on looking times showed no significant main effects, or interactions for order, or side of presentation for either condition in either age group.

The main analysis consisted of a (2) × 2 × 2 ANOVA, with duration (normal-duration, stretched) as the within-participant variable, and contour shape and age as the between-participants factors. The results revealed a significant main effect for age, \( F(1, 92) = 11.28, p < .001, \eta^2 = .11 \), a significant contour × duration interaction, \( F(1, 92) = 5.8, p < .02, \eta^2 = .06 \), and, importantly, a significant age × duration interaction, \( F(1, 92) = 14.5, p < .0001, \eta^2 = .14 \). No other main effects or interactions were significant. The main effect for age shows that, as is typically found in developmental studies, 6-month-olds spent more time engaged with the stimuli than 10-month-olds, irrespective of duration or contour type.

![Figure 3](image-url)
The shape × duration interaction suggests that, averaged across age, infants preferred stretched (M = 7.4) over normal-duration (M = 5.9) vowel stimuli when the contours were bell-shaped (Condition A), whereas when both contours were monotonic, infants looked slightly longer to normal-duration (M = 7.0) than to stretched (M = 6.4) vowels (Condition B). As shown in Figure 3, the greater preference for stretched bell-shaped vowels seems to reflect the much stronger preference shown by 6- than 10-month-olds for this stimulus type, and the stronger preference by 10- than 6-month-olds for monotonic contours. More relevant to the current study is the significant age × duration interaction, which reveals that 6- and 10-month-olds have different looking patterns when listening to duralional differences in vowel stimuli. That is, irrespective of shape, the younger group paid more attention to stretched than to normal-duration vowel contours, whereas the older group showed the opposite fixation pattern, preferring normal-duration to stretched vowel stimuli. Post-hoc two-tailed t-tests for each condition at each age showed that 6-month-olds looked longer to stretched (M = 8.8) than to normal-duration (M = 5.8) bell contours, t(1, 23) = 4.2, p < .0001, but there was no statistical difference in fixation duration to stretched (M = 7.6) and normal-duration (M = 6.4) monotonic contours. Ten-month-olds showed the opposite effect: they looked significantly longer to normal-duration (M = 7.6) than to stretched (M = 5.2) monotonic contours, t(1, 23) = 2.7, p < .01, but showed equivalent looking times to normal-duration (M = 6.1) and stretched (M = 6.1) bell-shaped contours. In brief, the results of Experiment 2 show that younger infants prefer stretched to normal-duration vowels, and that older infants prefer normal-duration to stretched vowels, but only in the context of the favoured contour type. That is, 6-month-olds showed a preference for stretched over normal-duration bell-shaped contours, and 10-month-olds for normal-duration over stretched monotonic contours. Thus it seems that duration salience of bell-shaped contours has receded, and infants are in the midst of vowel attunement (Kuhl et al., 1992; Polka & Werker, 1994).

At 6 months of age, infants listen longer to vowel contours with high over low F0 range. Presumably, this occurs because infants are attracted to the greater affective salience of bell than of monotonic contours (see Table 1), a conclusion that is supported by evidence of 6-month-olds showing preferences for ID speech with high over low positive affect (Kitamura & Burnham, 1998), and for happy over neutral speech (Singh et al., 2002). In addition, Figure 1(b) indicates that the increase in pitch range causes the harmonics to move through the upper frequencies and separate the formant bands. The findings of Trainor and Desjardins (2002) suggest that the separation of the formant bands that accompanies this kind of pitch movement aids vowel discrimination. Of interest in the current study, however, is that this linguistic benefit is manifested in those features of ID vowels that attract and maintain infant attention, and that this attentional bias occurs at an age at which infants are in the midst of vowel attunement (Kuhl et al., 1992; Polka & Werker, 1994).

At 10 months of age, the attentional and affective salience of bell-shaped contours has receded, and infants listen longer to monotonous contours, which convey relatively neutral vocal affect (see Table 1). Certainly, it has been shown that in mothers’ productions there is a reduced level of positive vocal affect in ID speech at 9 months compared with at 6 months of age (Kitamura & Burnham, 2003). Moreover, by this age, attunement to native-language vowel categories is more or less complete (Polka & Werker, 1994), and a new way of perceiving speech is emerging – infants are beginning to rely more on native-language phonetic and phonotactic, not prosodic, information (Jusczyk et al., 1993; Morgan & Saffran, 1995). Furthermore, they are undergoing a process of perceptual reorganization for native-language consonant categories (Werker & Tees, 1984). Under these conditions, infants may no longer need the exaggerated features of ID speech, and, indeed, the high level of positive affect in ID speech may disrupt infants’ attention to aperiodic segmental information.

The results of Experiment 2 show that infants aged 6 months prefer stretched over normal-duration vowels, but by 10 months of age they prefer normal-duration over stretched vowels. Previously, it has been shown that infants’ preferences for slowed speech diminish over the first year of life, that is, 4- but not 8-month-old infants prefer ID speech with slowed to normal tempo (Panneton et al., 2006), and here the findings for 8-month-olds extend to 10-month-olds. Furthermore, the preferences in Experiment 2 were not based on the level of positive vocal affect because normal and stretched vowels were rated similarly on this dimension. However, it is possible that younger infants are predisposed to vowels with increased duration because (1) slowed speech contributes to the regulation of arousal levels (Kitamura & Burnham, 2003; Panneton et al., 2006), and (2) longer vowels are more likely to reach their target frequencies than shorter-duration vowels (Moon & Lindblom, 1994). Again, a characteristic

Discussion

This study examined the developmental transition that occurs between the ages of 6 and 10 months in infants’ attention to F0 contours, and the durational cues typically found in the periodic portions of ID speech. On the basis of studies probing infants’ preferences for ID speech and prosody, it was anticipated that infants’ preferences for the more exaggerated features of ID speech would be present at 6 months, but have subsided by 10 months of age. That is, 6-month-olds would prefer bell-shaped contours, and stretched vowels, whereas 10-month-olds would prefer monotonic contours, and normal-duration vowels. The results support these predictions, showing a dramatic reversal in infant preferences for these features in the latter part of the first year.
feature of ID vowels appears to show a two-fold function as slowed speech modulates arousal levels and increases vowel intelligibility, both of which are of greater import to younger than to older infants.

Some interesting findings emerge from the individual experimental conditions. In Experiment 1, 6-month-olds’ preferences for bell, and 10-month-olds’ preferences for monotonic contours were manifested only when the contours were produced without the age-favoured durational cue, that is, in the normal-duration condition for 6-month-olds, and in the stretched-duration condition for 10-month-olds. However, in Experiment 2, younger infants’ preferences for stretched vowels, and older infants’ preferences for normal-duration vowels only occurred in conditions with the favoured contour type, that is, bell-shaped for 6-month-olds, and monotonic for 10-month-olds. These results indicate that infants process contour and durational cues differently, and that under certain conditions these two features compete with each other for attentional resources. The results of Experiment 1 show that the favoured durational cue detracts attention from the contour type, whereas the results of Experiment 2 show that the favoured contour type enhances attention to durational cues.

Overall, this study shows that young infants find exaggerations of intonation and duration attentionally salient, but by the end of the first year, when speech perception is undergoing reorganization, they prefer the exaggerated acoustic characteristics of vowels in ID speech to be more subdued. It has been argued that vowels, and the acoustic and phonetic information they carry, have special standing in infant speech perception (Cutler & Mehler, 1993), and, although this study does not directly test this, it does show that infants’ attention to the acoustic properties of vowels shifts dramatically in the first year, and that this shift corresponds to whether infants are attuning to vowels at 6 months or to consonants at 10 months of age.

Acknowledgements
This research was funded by the University of Western Sydney Research Grant Scheme (20211/80401). Thank you to Jennifer Lorenzo, who conducted a pilot study, to Stacey Kuan and Glenda Walter, who tested the infants, and to Denis Burnham and the anonymous reviewers for their insightful comments on the manuscript.

References


Received: 23 August 2007
Accepted: 9 June 2008
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