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New Insights Into Old Puzzles From Infants' Categorical Discrimination of Soundless Phonetic Units

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For 4 decades, serious scientific debate has persisted as to whether infants' remarkable capacity to detect and categorize phonetic units is derived from language-specific mechanisms or whether this capacity develops out of general perceptual mechanisms. The heart of this controversy has revolved around whether the young human brain is specialized to detect the underlying contrasting patterns in language or whether it simply processes general auditory perceptual features of sound that, over time, become utilized for language learning. This article takes a novel look at this question by using soundless phonetic units from a natural signed language as a new research tool. Research finds that 4-month-old *hearing* infants categorize *soundless phonetic* units on the basis of linguistic category membership, whereas 14-month-old infants fail to do so—thereby exhibiting the identical initial capacity and classic developmental shift in infant categorical discrimination of native and nonnative (foreign language) phonetic units in speech. These results suggest a novel testable hypothesis: Infants may begin life with the capacity to detect specific patterned units with alternating contrasts unique to natural language organization and to categorize them on the basis of linguistic category membership.

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Out of the chaos of sights and sounds in our world, all infants discover the finite set of phonetic units that forms the basis of their specific native language by around 10 months of age. For 4 decades, heated scientific debate has centered on how infants come to have this remarkable capacity. Some have argued that this capacity reflects the neural superiority of the human brain to process specific properties of natural *language,* whereas others have argued that this capacity is built up from mechanisms of general *perception.* Here we take a new look at this decades-old puzzle by examining hearing, English-exposed infants' discrimination of nonnative (foreign language) phonetic units that are articulated on the hand in natural signed language. The use of soundless phonetic units allows us to pull apart whether infants have only discrimination for sound, or for language, be it from the mouth or on the hands. The use of two ages (4 and 14 months) that straddle the developmental time when nonnative contrasts in speech are first discriminated and then not discriminated gives us a window into whether the same developmental processes are at work when nonnative phonetic units are on the hands, as well as new insights into the universal nature of these processes in development.

In their landmark study, Eimas, Siqueland, Jusczyk, and Vigorito (1971; see also Eimas, 1975) showed that English-learning infants between the ages of 1 and 4 months had differential discrimination abilities for synthetic speech stimuli along a voice onset time continuum. Infants were reliably better at discriminating two stimuli that were from different sides of the adult phonetic category boundary than they were for two stimuli that were from within the same phonetic category. This differential discrimination of phonetic contrasts in relation to a phonetic boundary suggested the exciting possibility that infant speech discrimination may be "categorical," that is, based on the infant's tacit comparison of a given perceived phonetic unit with a specific linguistic–phonetic category.

Findings along these lines were indeed replicated many times (for a review, see Aslin, 1987). Infants under 6 months demonstrate an initial "language general" capacity to discriminate many of the phonetic contrasts in the world's languages, including both native and nonnative oral phonetic contrasts (Dehaene-Lambertz & Pena, 2001; Werker, Gilbert, Humphrey, & Tees, 1981; for a review, see Jusczyk, 1997). However, by 10 to 12 months of age, infants begin to perform like adults and discriminate only their native language phonetic contrasts—as if their initial open capacity had, over development, become restricted to (or neurologically tuned to) the specific language contrasts present in their environment (Best, McRoberts, LaFleur, & Silver-Isenstadt, 1995; Cheour et al., 1998; Polka & Werker, 1994; Rivera-Gaxiola, Silva-Pereya, & Kulh, 2005; Werker & Lalonde, 1988; Werker & Tees, 1984, 1999).

The fact that this initial capacity to discriminate phonetic contrasts exists in all infants, but then is attenuated over development, has been uncontroversial. Instead, the *biological basis* of this capacity has been hotly debated. The early work suggested that infants were innately endowed with specialized mechanisms for phonetically segmenting and categorizing human language (for a review, see Jusczyk, 1997). Several lines of research have challenged the claim for a specialized mechanism for phonetic processing in young infants. The claim has been weakened by research showing that certain nonhumans also exhibit categorical discrimination (CD) for human speech sounds (Kluender, Diehl, & Killeen, 1987; Kuhl, 1981; Kuhl & Miller, 1975, 1978; Kuhl & Padden, 1982, 1983; Morse & Snowdon, 1975; Waters & Wilson, 1976) and by research demonstrating CD in infants for some nonspeech sounds (Jusczyk, Pisoni, Walley, & Murray, 1980; Jusczyk, Rosner, Cutting, Foard, & Smith, 1977). It has also been shown that both human infants and cotton-top tamarin monkeys can discriminate sentences from unfamiliar languages such as Dutch and Japanese when sentences are played forward but not backward (Ramus, Hauser, Miller, Morris, & Mehler, 2000). In addition, it has been shown that both human infants and cotton-top tamarins can discriminate between syllables that differed only in the frequency with which they occurred in streams of input speech (Hauser, Newport, & Aslin, 2001; Saffran, Aslin, & Newport, 1996). Further, the "perceptual narrowing" of speech discrimination that infants exhibit has also been shown to apply to the domain of face processing. Pascalis, de Haan, and Nelson (2002) found that younger infants could discriminate between individual human and monkey faces, whereas older infants and adults only showed evidence of discrimination of faces from their own species. Based on these findings, many researchers have rejected the view that infants have specialized mechanisms for linguistic–phonetic processing. Instead, it has been suggested that speech–language perception in young infants can be best explained by general *auditory* (perceptual) mechanisms also present in other species (Aslin, 1987; Jusczyk, 1985).

One intriguing reason for the persistence of this debate is that the empirical question has been *a priori* largely unanswerable. This is because most research to date has used sound and speech to test whether sound on the one hand, or speech on the other, is key to the infant's linguistic categorization capacity. As a result, it has been challenging for contemporary science to adjudicate between the specific-linguistic (phonetic) versus the general-auditory (perceptual) hypotheses; and, in particular, it remains unclear whether infants are analyzing the speech signal at an acoustic (nonlinguistic) or a phonetic (linguistic) level. There is a way around this, however. The existence of natural signed languages offers a new research tool to test a language processing hypotheses in *all* language users. Because signed languages do not occur in the auditory modality, they allow us to set aside the confound that occurs when using fundamentally sound-based stimuli to test hypotheses about the phonetic versus acoustic basis of early language processing.

A recent study by Baker, Idsardi, Golinkoff, and Petitto (2005) used soundless phonetic units on the hands from American Sign Language (ASL), called "sign-phonetic" units, to study (a) whether categorical perception (CP) is specific to sound and (b) whether CP in the manual modality is specific to sign language users. The general auditory account would predict that the capacity to perceive sign-phonetic units should be absent in deaf signers and, of course, absent in hearing nonsigners. By contrast, a linguistic-specific (phonetic) processing account would predict that the capacity to perceive sign-phonetic units categorically should be present in only deaf signers. In their study, one half of the participants were deaf ASL-signing adults, and the other half were hearing English-speaking adults (with no knowledge of ASL). Using both identification and discrimination tasks, all participants were presented with moving video clips showing soundless but nonetheless linguistic sign-phonetic units in ASL, which varied along a phonetic continuum as in speech studies (for precise methodological details, see Baker et al., 2005).

As would be predicted by the linguistic account, the deaf signers showed the classic pattern of CP for the sign-phonetic units as has been observed in hearing adults' CP of speech, whereas the hearing speakers who viewed the identical stimuli did not show this pattern. That the hearing adults did not show CP for ASL sign-phonetic units was predicted based on related literature involving the typical adult's inability to perform phonetic discriminations for nonnative–foreign speech contrasts. In this case, ASL sign-phonetic units were indeed foreign language phonetic contrasts for these hearing adult participants (and, of course, they were native language phonetic contrasts for the deaf participants).

Baker et al. (2005) further demonstrated that the findings from the deaf signers were neither compatible with hypotheses of general visual perception, nor, for obvious reasons, were they compatible with hypotheses of general auditory or acoustic perception (as, again, the participants were deaf individuals, and the phonetic units were silent; Baker et al., 2005; see also Emmorey, McCullough, & Brentari, 2003, who also found CP with deaf signing adults).

The evidence for CP in the deaf adults was noteworthy. The commonality across signing adults when processing soundless phonetic units and hearing adults when processing sound-based phonetic units suggested that phonetic identification and CD capacities are unique to *specific patterned units* at the core of human language structure rather than to mechanisms of general perception.

To further understand the basis for the capacity to detect, identify, and categorize phonetic units, in the present article, we study young hearing infants' discrimination of a nonnative soundless phonetic contrast in ASL. Our goal is twofold. First, we wish to learn whether young hearing infants treat soundless sign-phonetic units like any other nonnative phonetic units and demonstrate a capacity to categorically discriminate them. Second, we wish to determine whether this capacity attenuates as the infants grow older and are not exposed to sign language input. If the phonetic categorization capacity is based on linguistic mechanisms sensitive to specific patterns rather than sound, *per se,* then we hypothesized that very young hearing infants perceiving ASL *soundless* phonetic units should demonstrate the same CD and attenuation profile classically observed in other infants perceiving spoken language phonetic units.

Our test of infants' CD is fundamentally related to the concept of CP used in connection with adults, but it is also different in a subtle and important way. A widely accepted view in the language perception literature is that infants cannot be tested directly for CP because we cannot presuppose that they have established phonological categories. Instead, when testing infants, the most that can be attributed to them is a capacity to discriminate between phonetic units. This difference accounts for the fact that the field (and our study) used a measure of CD with infants. Further, like many other benchmark studies with speech–phonetic discrimination (e.g., Best, McRoberts, & Sithole, 1988; Jusczyk, 1985, 1997; Werker et al., 1981; Werker & Lalonde, 1988), we first established CP with adults (Baker et al., 2005) who were native users of the language, as they do have the linguistic categories for the contrasts. We used a strict interpretation of CP, and one that is commonly employed in the study of adult spoken language contrasts (Baker et al., 2005). For our infants, we used the exact same boundary and stimulus items used with the native deaf adult signers, testing whether our hearing infants would categorically discriminate the stimuli across the same boundary as native deaf adults do.

Therefore, in the present study, we specifically ask whether young hearing infants who have not been exposed to sign language categorize nonnative soundless phonetic units in sign language like they categorize nonnative phonetic units in spoken language.

METHODS

Participants

Participants were 32 (16 boys, 16 girls) healthy, full-term, hearing, speech-exposed infants (no sign language experience) divided into one of two age groups: 4-month-olds (age: $M = 4$ months, 9 days; range: 3 months, 20 days to 4 months, 21 days) and 14-month-olds (age: $M = 14$ months, 3 days; range: 13 months, 20 days to 15 months, 19 days). The ages were chosen based on developmental milestones: 4-month-olds were chosen to ensure sufficient development of the visual system (especially depth perception) for viewing the handshapes (Atkinson, 2000; Teller, 1997); 14-month-olds were chosen because this age group has been shown to no longer be able to discriminate nonnative speech contrasts (Best et al., 1995; Cheour et al., 1998; Werker & Lalonde, 1988; Werker & Tees, 1984, 1999). The names of the infants were obtained through local birth announcements in the Delaware and New Hampshire areas. Parents were first contacted by letter and then by telephone to see if they were interested in participating. Human Subjects research guidelines were followed.

Stimuli

Like spoken languages, all of the signs (identical to "words") and sentences in signed languages are built up from a highly restricted set of meaningless phonemic units that, in conjunction with the language-specific rules for combining them, makes up the languages' "phonemic inventory"; when produced, these surface forms make up the languages' phonetic units, and together, the phonetic inventory (e.g., Brentari, 1998, 2002; Emmorey & Corina, 1990; Emmorey et al., 2003; Kingston, 1999; Neville, 1991; Perlmutter, 1990). In the case of signed languages, phonetic units are produced on the hands (within a restricted set of locations, movements, and hand orientations). When produced in isolation, the restricted set of phonetic units in signed languages looks like a set of meaningless hand gestures, in the same way that the restricted set of phonetic units in spoken languages sounds like a set of meaningless sounds. Similar to the transition from the linguistic phonemes /ba/–/pa/ in spoken language, where the phonetic units [ba] and [pa] vary continuously by one feature, signed languages have linguistic phonemes that vary continuously by one feature and that have been categorically perceived by native deaf adult signers (Baker et al., 2005; Emmorey et al., 2003). The important implication for language processing is that only phonemic distinctions produce CP effects in adults. Therefore, a given sound or handshape must appear in the set of phones for a language (i.e., the set of all possible sounds or handshapes for a particular language), and it must also be a part of the phonemic inventory (i.e., the set of sounds or handshapes used for lexical contrast) to be considered contrastive in a language (Brentari, 1995, 1998; Corina & Sandler, 1993; Sandler, 1986, 1996; van der Hulst, 1995). The phonemic handshape contrast pair [5]–[flat-0] from the Baker et al. study was used here with the infants because those handshapes are formally contrastive within the phonological structure of ASL and are, therefore, treated as linguistic units by users of ASL.

The phonological structure of a sign consists of four components (often called *parameters*), which are roughly analogous to features: (a) *location,* or where the hand is located in relation to the body (e.g., head, chin, nose, chest); (b) *movement,* or how the hand moves in space (e.g., circle, arc, wiggle fingers); (c) *handshape,* the actual form of the hand itself (e.g., /5/, /A/, /G/); and (d) *orientation,* which is the direction the palm of the hand is facing in relation to the body (e.g., palm facing body, palm to side, palm out; Battison, 1978; Stokoe, 1960; Stokoe, Casterline, & Cronenberg, 1965). These four components simultaneously combine to produce a sign that has meaning. The components are regarded as separate despite their simultaneous combination because, as in oral language, there are minimal pairs in the language that differ by only one component (for examples of minimal pairs, see Brentari, 1995). The handshapes /5/ and /flat-0/ differ by the handshape feature and, thus, constitute a minimal pair similar to /ba/ and /pa/. (Although any of these parameters could be subjected to CP analyses, only location and handshape have been studied thus far; CP effects have only been found for handshape.)

Following standard phonetic continua with signed language that consist of two endpoints and 9 intermediate variants (e.g., Baker et al., 2005; Emmorey et al., 2003), we constructed an 11-step continuum for each of the sign-phonetic handshape contrasts for the ASL sign-phonetic units. To ensure that the sign-phonetic variants were *equidistant* along the continuum, we conducted a three-phase pilot test on 5 adult signers. In Phase 1, we identified the endpoint sign-phonetic handshapes of each continuum by taking anatomical measurements from the base of the palm to the tips of each finger for each participant while they produced the handshape. We then calculated the total distance between the endpoints and divided that distance equally among the nine intermediate variants (the range across all participants and sign-phonetic handshape continua was between 1.0 cm–1.2 cm). Finally, these measurements were mapped onto a template that the signer used as their guide for sign-phonetic handshape variant production in Phase 2. In Phase 2, signers used the template to form each of the 11 variants, which were videotaped and then each individual variant was made into a still image. In Phase 3, the signers made the natural movement of starting with the fully open endpoint and then closing the hand to fully closed endpoint in one continuous motion, at *normal speed,* and also in slow motion (00:22–00:24 sec and 01:07–01:11 sec, respectively). To ensure a standard interval that would produce a predictable sign-phonetic handshape change, the total time for each of the speeds of movement was calculated and then divided by 11 (1–2 frames and 4–5 frames, respectively).

Still images were made for each variant by advancing through the continuous motion clip at the given frame rate. These moving images were then compared to the template still images to be sure that the variants were the same across the continuum for all three sign-phonetic handshape continua and across all 5 signers. To be clear, all participants in the present study with infants, and all participants in our earlier study with adults (Baker et al., 2005), saw the identical moving stimuli; in each case, the stimuli were real-time moving images of a full-faced, native-ASL signing deaf woman producing the sign-phonetic variants. Figure 1(a) shows still frames taken from the real-time movies that were presented during the habituation conditions and test trials. Although the participants viewed them as real-time movies, they are shown here as still frames to aid the reader's comprehension. The two habituation handshapes were chosen based on the location of the native deaf signing adults' category boundary placement for the 11-step [5]–[flat-0] continuum in the Baker et al. study. One handshape was chosen on either side of the adult boundary (Steps 4 & 7), and corresponding within-category handshapes were chosen (Steps 1 & 10) for the test stimuli so that all handshapes were equidistant from each other.

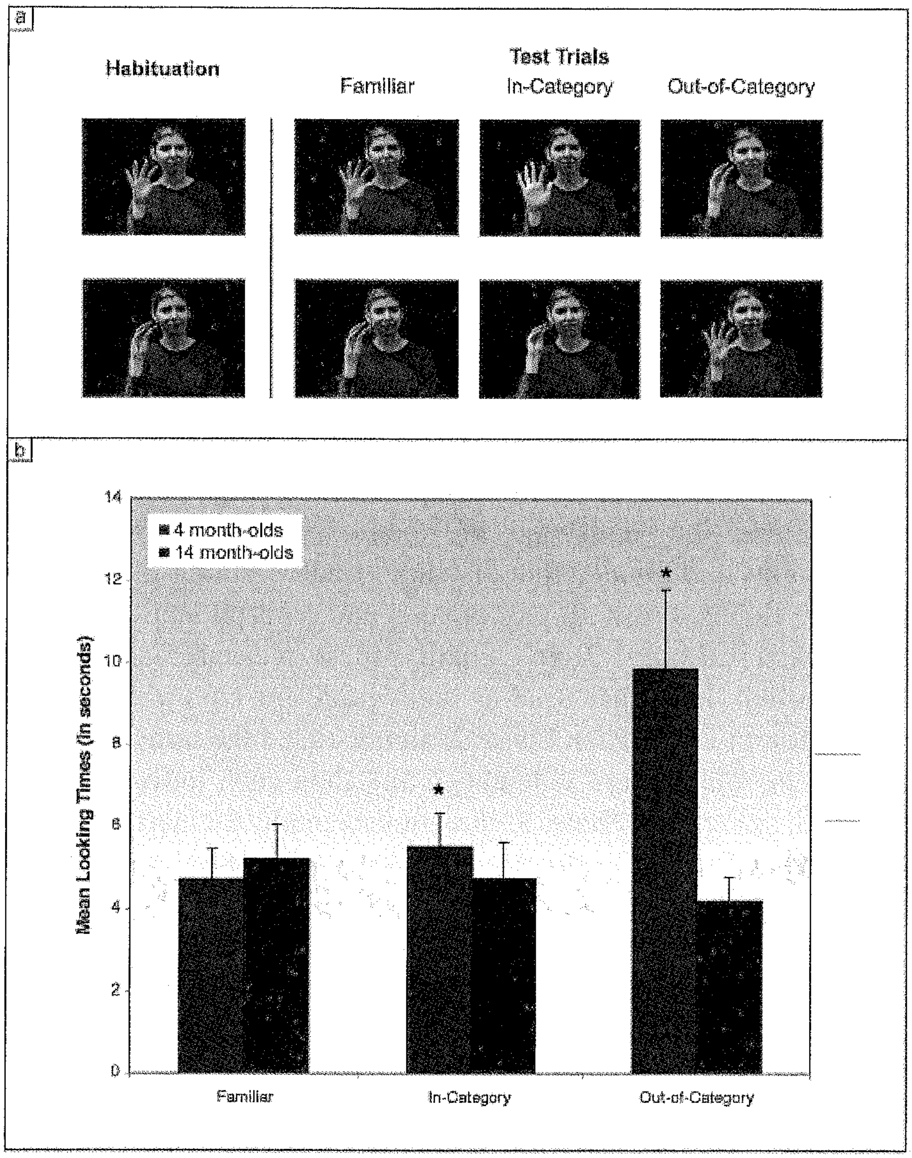

FIGURE 1 (a) Habituation and test stimuli. Shown on the left are still image examples of the real-time moving sign-phonetic units that were produced by a native deaf signer (always shown full face) and that all participants viewed in habituation; the top image is an American Sign Language (ASL) phonetic variant from the phonemic category /5/, and the bottom image is an ASL phonetic variant from the phonemic category /flat-0/. During the habituation phase, infants were habituated to movies of an ASL signer repeating one of these two phonetic variants. On the right are the test phonetic units (the Familiar stimulus is the exact same phonetic unit that the infant saw during the habituation phase; the In-Category stimulus is a phonetic variant from the *same* phonemic category as the phonetic unit that was used in the habituation phase; the Out-of-Category stimulus is a phonetic variant from a *different* category than the phonetic unit that was used in the habituation phase). The four stimulus items in the top row constituted one habituation condition, and the four stimulus items in the bottom row constituted a second habituation condition; infants were randomly assigned to one of these two habituation conditions. (b) Hearing infants' looking times and standard errors for each of the test trials for the test stimuli. Analyses revealed that only the hearing 4-month-olds looked significantly longer at the Out-of-Category trial compared to the In-Category trial, suggesting that they were discriminating the handshapes on the basis of linguistic–phonetic category membership just as infants do in speech. *$p < .032$, for In-Category versus Out-of-Category significance.

Procedure

Infants were tested in a dimly lit room, and all infants were seated on their parent's lap approximately 36 in. from a 17-in. color computer monitor that was 36 in. from the floor at eye level. Parents were instructed to close their eyes so as not to influence their infant's behavior. Black curtains were hung from the ceiling in front of the monitor and on both sides of the infants' viewing area to focus their attention on the monitor. A low-light video camera recorded the session through a small hole in the curtain below the monitor for later reliability coding. A second small hole just above the computer monitor allowed the experimenter to watch infant's eye gaze and to record looking times. The procedure was monitored, recorded, and controlled by the experimenter using a Macintosh G4 computer, and the experimenter was blind to what infants were seeing during each trial. The computer calculated infants' looking times and presented the events using the parameters explained below.

An infant-controlled habituation procedure (see Cohen, 1972, 1973) was used in which the infant had to look at the trial for a minimum of 1 sec for the look to count and had to look away for 1 sec to end the trial. Therefore, the intertrial interval was determined by the infant—hence, "infant controlled." Maximum trial length was 30 sec before the computer advanced to the next trial. The habituation phase continued until an infant's average looking time for 3 consecutive habituation trials was 50% or less than the average looking time for the first 3 habituation trials, or until an infant had received a maximum of 18 trials. Regardless of whether an infant habituated during the habituation phase, the infant proceeded to the test phase, with nonhabituators being identified in posttest analyses.

What infants actually saw while seated on their parent's lap was as follows: On a color computer monitor, they habituated to one of the two phonetic handshapes in ASL that were adjacent to the native signing deaf adult category boundary. Infants were then tested on three phonetic ASL handshapes (1 familiar, 1 novel but from the same category as habituation, and 1 novel from another category), the order of which was randomized and counterbalanced across participants. Following these three post-habituation test trials, a posttest recovery trial (in which infants saw a video of a smiling infant's face) followed the three test trials.

From the total number of infants run ($N = 66$), 32 were used and 34 were excluded for the following reasons: fussiness ($n = 9$), spitting up ($n = 1$), not habituating ($n = 11$), parental interference ($n = 5$), failure to recover ($n = 5$), experimenter error ($n = 2$), and failure to reattend ($n = 1$). Of the 32 infants who participated, interobserver reliability coding of the data was conducted on the standard sample size of 25% (Stager & Werker, 1997). Two independent blind coders recorded these infants' looking times by observing the taped sessions. Correlations between the times recorded by the original experimenter and the times recorded by the two coders were calculated, with an interobserver reliability of .98.

Results

Only habituators (those who met the 50% criterion by the 18th habituation trial) were used ($n = 32$). Nonhabituators either (a) reached the 18th habituation trial but did not meet the 50% criterion ($n = 6$); or (b) did reach the criterion, yet looked at least four times longer (i.e., more than 2.5 *SD* above the mean) at the familiar (control) trial during test than at the average of the last 3 habituation trials ($n = 5$).

To ensure that test results were not due to fatigue, infants had to look at the posttest recovery trial at least 30% longer than their mean looking time to the three test trials. Infants' mean looking time for the three test trials was 6.72 sec ($SD = 3.84$, 4-month-olds) and 4.74 sec ($SD = 1.95$, 14-month-olds), and their mean looking time for the posttest recovery trial was 9.80 sec ($SD = 6.84$, 4-month-olds) and 14.71 sec ($SD = 6.84$, 14-month-olds). A 2 (group: 4-month-olds; 14-month-olds) × 2 (trial type: mean of test trials; recovery) mixed analysis of variance revealed a significant main effect for trial type, $F(1, 30) = 30.94$, $p < .001$. Thus, both age groups of infants looked significantly longer at the recovery trial than at the test trials; therefore, whatever results are obtained on the test trials cannot be attributed to an accumulation of fatigue over the course of the experiment.

The 4-month-old infants' mean looking time during the last three habituation trials was 5.73 sec ($SD = 2.97$), and the 14-month-olds' mean looking time during the last three habituation trials was 4.89 sec ($SD = 2.42$). For the Familiar, In-Category, and Out-of-Category test trials, the 4 month-old infants' mean looking time was 4.74 sec ($SD = 2.89$), 5.53 sec ($SD = 3.23$), and 9.89 sec ($SD = 7.75$), respectively; the 14-month-old infants' mean looking time was 5.23 sec ($SD = 3.29$), 4.76 sec ($SD = 3.54$), and 4.23 sec ($SD = 2.29$), respectively. Following the logic of Bertenthal, Haith, and Campos (1983), the Familiar trial was treated as a control condition for spontaneous recovery during test and as a comparison point for change trials. Planned comparisons ($\alpha = .05$) revealed that (a) both groups of infants habituated: Familiar trial versus last three Habituation trials, $F(1, 15) = 1.22$, $p > .287$ (4-month-olds); $F(1, 15) = .26$, $p > .615$ (14-month-olds). Further, (b) only the 4-month-olds looked significantly longer at the Out-of-Category trial compared to the In-Category trial, $F(1, 15) = 5.55$, $p < .032$; 14-month-olds: Out-of-Category trial compared to the In-Category trial, $F(1, 28) = .26$, $p > .616$, *ns* (see Figure 1[b]).

The 4-month-old infants looked significantly longer only at the handshape from a new linguistic category, whereas the 14-month-olds showed no preference for any of the handshapes. Therefore, the 4-month-old infants, and not the 14-month-old infants, categorically discriminated the phonetic handshapes across the same category boundaries as native signing deaf adults. This differential discrimination of phonetic units by age has an important correspondence with the Baker et al. (2005) study, as native signing deaf adults had CP for the phonetic handshapes from the [5]–[flat-0] continuum, whereas nonsigning adults did not.

DISCUSSION

The primary finding is that 4-month-old hearing infants looked significantly longer at Out-of-Category, but not at In-Category or control sign-phonetic, handshapes; this indicates that they discriminate sign-phonetic handshapes along the same category boundaries as native adult users of ASL (Baker et al., 2005). This pattern of results is similar to many findings with age-matched hearing infants regarding their capacity to discriminate nonnative phonetic units in speech. Conversely, 14-month-old infants did not look significantly longer at any of the sign-phonetic handshapes during test trials, indicating that they do not discriminate the handshapes on the basis of linguistic category membership. Because the habituation method is employed in many studies with children this age, including those from our lab, it is unlikely that their failure to discriminate between these handshapes can be blamed on their inability to function in this procedure (Best et al., 1988; Pulverman, Sootsman, Golinkoff, & Hirsh-Pasek, 2003; Werker, Cohen, Lloyd, Casasola, & Stager, 1998). The decline we observed in the capacity to discriminate nonnative sign-phonetic units by 14 months of age is precisely the same developmental shift as observed in other hearing infants at this age with speech stimuli.

These results precisely parallel the speech perception literature (e.g., Werker & Lalonde, 1988). Hindi-speaking adults have CP for contrasts in Hindi, whereas English-speaking adults do not; young, English-reared infants (6–8 months) categorically discriminate these same contrasts along the same category boundaries as Hindi adults. Older infants (11–13 months), however, no longer categorically discriminate between these contrasts. Therefore, there appears to be a developmental shift in discrimination abilities in infants with both nonnative spoken language phonetic units and nonnative sign language phonetic units. The interesting difference between this study and the spoken language literature, however, is that these young infants are able to categorically discriminate soundless phonetic units in a visual modality, without having had experience with a signed language.

It might be the case, just as in oral language, that the degree of CP of sounds varies by type of contrast. For example, neither affricates or fricatives (Ferrero, Pelamatti, & Vagges, 1982; Rosen & Howell, 1987) nor vowels (Abramson, 1961; Fry, Abramson, Eimas, & Liberman, 1962) are categorically perceived. Might we expect this to be true of signs as well? Further research must evaluate whether infants' ability to categorically perceive signs is also sensitive to the particular contrast being tested. Another issue is whether a gesture (such as a point), systemically varied as done here, would also elicit something that appeared to be CP. It might be the case that at some spot in the continuum of a nonexistent to a full point, when it is clear that the speaker is indeed pointing, infants would show discrimination. However, this asks a different question than the present study. The discrimination in the present study rests on silent, sign-phonetic segments that have no meaning in isolation. Although a gesture used by nonsigning people, such as a point, will likely have been observed by infants, points have meaning; perhaps not for 4-month-olds, but certainly for 14-month-olds (Franco & Butterworth, 1996). However, hearing infants are unlikely to have observed the use of such sign-phonetic segments used in a linguistic way, although they may have seen the actual handshapes in gestures produced by nonsigning people. Research from the literature on gesture has shown that the gestures hearing people produce along with their talk are qualitatively different from the signs that deaf signers produce (Goldin-Meadow, 2003; Goldin-Meadow, Mylander, & Butcher, 1995; McNeill, 1992; Singleton, Morford, & Goldin-Meadow, 1993).

The results obtained in this investigation occurred without the benefit of auditory information and yet look startlingly like results obtained with auditory stimuli. Could our present results be wholly derived from mechanisms of general perception, or could these results suggest the existence of mechanisms specific to natural language processing? Perhaps it is the case that infants are generally good at deducing patterns, which allows them to discriminate speech contrasts, nonlinguistic sound stimuli, colors, faces, visual patterns, and even signed language contrasts. Based on this view, the 14-month-olds' performance should have exceeded the 4-month-olds' performance. It did not. Only the 4-month-olds, unfamiliar with sign language, perceived these silent stimuli in a categorical manner.

Perhaps young infants are using general visual processing to categorize the sign-phonetic handshapes. However, their performance was constrained in a highly specific way that is not commensurate with general visual perception. Because the stimuli are equidistant from each other along a continuum, they each have the potential to be discriminated equally well, as if each handshape were a member of a separate category. Therefore, the differences between the stimuli, regardless of whether they are from the same category or across the category boundary, are of the same magnitude. Despite this fact, the 4-month-olds only discriminated the stimulus items that *crossed over* the category boundary, as was empirically defined in experiments with native deaf signing adults (Baker et al., 2005). The 4-month-olds performed in this fascinating way regardless of which category was the referent category ([5] or [flat-0]).

If the infants' discrimination capacity is not exclusively due to general perceptual processing, then we suggest that the ultimate answer will be revealed once we fully understand what is structurally invariant across both the spoken and the signed phonetic–syllabic unit. That the hearing infants' categorization of input stimuli across two different modalities (audition, vision) is highly similar (apparently treating both as linguistic units) teaches us that the infants are ignoring the modality differences. Possibly, infants are focusing instead on core underlying linguistic contrastive and temporal patterns at the heart of natural language phonology (Petitto, 2000, 2005, in press; Petitto, Holowka, Sergio, Levy, & Ostry, 2004; Petitto, Holowka, Sergio, & Ostry, 2001; Petitto et al., 2000).

These findings suggest that infants begin life with a remarkable capacity to detect and categorize phonetic units—regardless of whether they emerge from the mouth or on the hands. Furthermore, the parallel between the decline in discrimination at 14 months of age on these sign-phonetic segments and nonnative oral language phonetic contrasts presents a tantalizing picture of an infant poised to learn any natural language, regardless of modality. Only future research can provide the additional confirmatory data needed to strongly make these claims. In the meantime, however, it appears that in the absence of experience, 4-month-olds are indeed prepared to make categorical distinctions between phonetic units in languages that rely on the tongue and the hand.

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