

## Perceptual Narrowing of Linguistic Sign Occurs in the 1st Year of Life

Stephanie Baker Palmer and Laurel Fais  
*University of British Columbia*

Roberta Michnick Golinkoff  
*University of Delaware*

Janet F. Werker  
*University of British Columbia*

Over their 1st year of life, infants' "universal" perception of the sounds of language narrows to encompass only those contrasts made in their native language (J. F. Werker & R. C. Tees, 1984). This research tested 40 infants in an eyetracking paradigm and showed that this pattern also holds for infants exposed to seen language—American Sign Language (ASL). Four-month-old, English-only, hearing infants discriminated an ASL handshape distinction, while 14-month-old hearing infants did not. Fourteen-month-old ASL-learning infants, however, did discriminate the handshape distinction, suggesting that, as in heard language, exposure to seen language is required for maintenance of visual language discrimination. Perceptual narrowing appears to be a ubiquitous learning mechanism that contributes to language acquisition.

Human infants demonstrate an impressive set of abilities at birth that positions them perfectly for the successful acquisition of the complexities of human language. Neonates prefer listening to speech over equally complex, nonspeech sounds (Vouloumanos & Werker, 2007), and can discriminate languages from different rhythmical classes (Nazzi, Bertoni, & Mehler, 1998). In addition, very young infants are sensitive to a wide range of phonetic distinctions, including not only those contrasts used in the native language but also non-native contrasts that the infants have never before heard. First demonstrated in the early 1970s for both English-learning (Eimas, Siqueland, Jusczyk, & Vigorito, 1971; Trehub, 1976) and Kikuyu-learning (Streeter, 1976) infants, this finding has now been replicated for additional language contrasts (for reviews, see Gerken & Aslin, 2005; Saffran, Werker, & Werner, 2006). The broad-based linguistic sensitivities of young infants are then rapidly tuned across the 1st year of life to just those categories used in the native language.

Although there is some evidence of improvement as a function of experience (Kuhl et al., 2006; Narayan, Werker, & Beddor, 2010; Polka, Colantonio, & Sundara, 2001), the most commonly reported pattern of perceptual learning involves maintenance of the distinctions heard in the native language (Best, McRoberts, LaFleur, & Silver-Isenstadt, 1995; Bosch & Sebastián-Gallés, 1997; Werker & Tees, 1984), and decline in discrimination performance of those phonetic contrasts not heard. This pattern of "perceptual narrowing" (Lewkowicz & Ghazanfar, 2009; Pons, Lewkowicz, Soto-Faraco, & Sebastián-Gallés, 2009; Scott, Pascalis, & Nelson, 2007) is seen not only for consonant and vowel segments but also for linguistic tone (Mattock & Burnham, 2006). Indeed, this pattern of change extends beyond phonetic perception to many different domains, including audiovisual speech perception (Lewkowicz & Ghazanfar, 2006; Pons et al., 2009), preference for human speech (Vouloumanos, Hauser, Werker, & Martin, 2010), perception of rhythm in music (Hannon & Trehub, 2005), and face perception (Pascalis, de Haan, & Nelson, 2002).

There is a perceptual narrowing for visual speech as well. At 4 and 6 months of age, infants are able to discriminate the change from French to

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Correspondence concerning this article should be addressed to Janet F. Werker, Department of Psychology, University of British Columbia, 2136 West Mall, Vancouver, BC V6T1Z4, Canada. Electronic mail may be sent to [jwlab@psych.ubc.ca](mailto:jwlab@psych.ubc.ca).

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English (and vice versa) when they watch videos of silent talking faces, whereas by 8 months of age, they can no longer do so unless they are growing up bilingual, experiencing both English and French. At this age, monolingual English infants fail (Weikum et al., 2007). Experience with the two languages is essential for maintaining sensitivity to the visual facial information that distinguishes the two languages.

Perception of sign languages, a form of language that is exclusively visual spatial, also reveals perceptual narrowing. Just as they show a preference for speech over nonspeech, young infants show a preference for signs over gestures. When viewing the head, torso, and hand of an adult female producing either short signed sentences or mimed gestures of a particular activity, infants aged 6 months show a preference for watching the signs over the gestures. By 10 months of age, this preference is no longer evident in hearing infants (Krentz & Corina, 2008), suggesting that the decline in preference may be attributable to lack of exposure to sign language, leading to attenuation of a natural perceptual bias.

Even more unanticipated is the finding that infants not exposed to a sign language show categorical discrimination of signs just as they show enhanced discrimination at natural language

category boundaries for some acoustic-phonetic distinctions. In a recent article, Baker, Golinkoff, and Petitto (2006) showed that human infants discriminate sign continua according to natural linguistic boundaries. They tested infants on a contrast that native adult signers of American Sign Language (ASL), but not hearing adults, perceived categorically, that is, the [5]-[flat-0] contrast (see Figure 1). Native adult signers placed the boundary between the handshapes perceived as [5] and those perceived as [flat-0] at the location used across natural sign languages, that is, between Steps 5 and 6 (Baker, Idsardi, Golinkoff, & Petitto, 2005). In the infant study, Baker et al. (2006) tested hearing infants of 4 and 14 months on their discrimination of pairs of stimuli from this continuum that either crossed the natural sign boundary (i.e., Steps 4 and 7), or were perceived as being within the same category (e.g., Steps 1 and 4). At 4 months of age the infants showed enhanced discrimination of the pair of stimuli that crossed the natural sign boundary, whereas by 14 months of age, they performed like the hearing adults, showing no difference in discrimination for the two types of pairs. These results were taken as evidence that human infants are born with enhanced discrimination around natural linguistic category boundaries not only in heard,

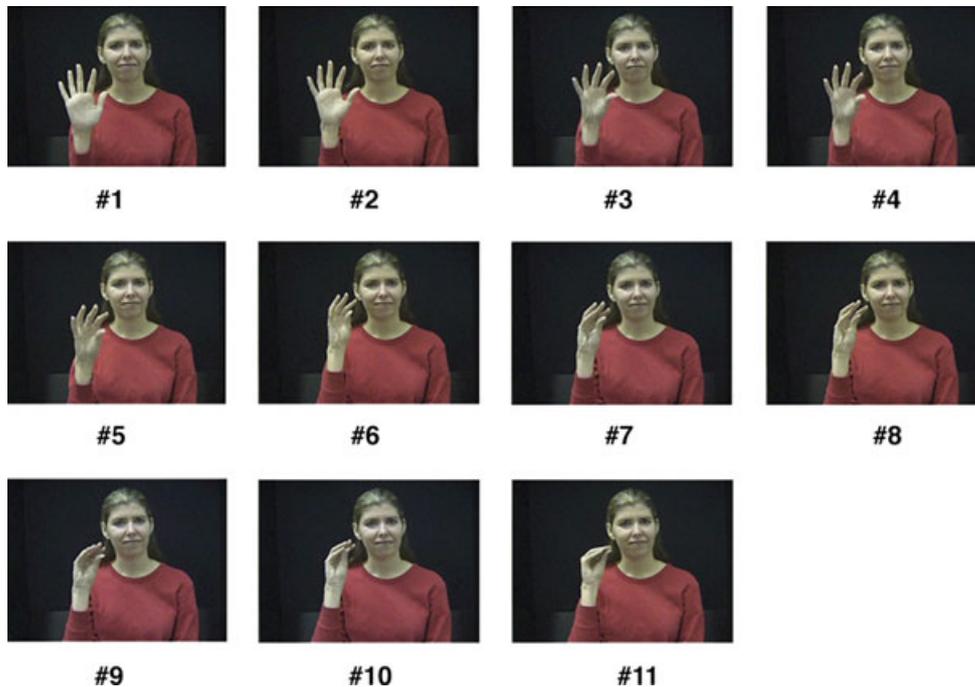


Figure 1. Steps of the handshape continuum from [5], top left, to [flat-0], bottom right.

Note. Although these are shown here as black-and-white, static representations, they were presented to infants in color and in motion—as in American Sign Language.

but also in seen, languages. Moreover, it was suggested that just as listening experience is required to maintain discrimination of speech sound contrasts, viewing experience may be required to maintain discrimination of natural signed contrasts.

Although it is intriguing to find evidence consistent with the notion that experience tunes sign language perception in the same way that it tunes perception of other linguistic stimuli, the fact that older hearing infants fail to perceive visual linguistic signs along natural boundaries is only half of the story. It is also crucial to show that continued experience with the contrast does indeed allow older, sign-learning infants to discriminate the contrast. Thus, in the current work, we tested infants growing up with sign language (specifically, ASL) to determine whether they maintain the sensitivity to the natural linguistic boundaries in sign that is present in young hearing infants.

It is essential to establish that the decline in discrimination performance of 14-month-old infants reported by Baker et al. (2006) is not simply a methodological or procedural artifact. In the testing situation used in that work, infants were shown the face and torso of a woman with her hand held up to the side of her face, signing. Some research suggests that as social cognition develops, visual attention to faces increases over the 1st year of life; 3-month-old infants' viewing patterns when observing a cartoon including faces is better predicted by visual salience than by the location of faces, while that of 9-month-old infants is better predicted by the location of faces (Frank, Vul, & Johnson, 2009). Given the increasing interest in faces, it might be the case that the older infants actually could discriminate the signs, but they looked at the face of the woman rather than at her hand, and thus they did not accrue enough exposure to the handshapes during the habituation phase to allow the familiarization needed to demonstrate discrimination, that is, to lead to a novelty preference in the test phase. The use of an eyetracker in this study allowed us to characterize infants' gaze direction more precisely in order to investigate this issue.

An additional motivation for the current work is that there is one published report that indicates, counter to the work of Baker et al. (2006), that young hearing infants are not able to discriminate handshape in sign. Wilbourn and Casasola (2007) tested infants of 6 and 10 months of age on their ability to discriminate several parameters of difference in sign, including handshape. In a habituation paradigm, these infants discriminated a change in *location* of the handshape, but they did not show

evidence of discriminating a change in the *shape* of the hand, in contrast to the findings reported by Baker et al. On the basis of these findings, Wilbourn and Casasola argue that infant attention to handshape may be a later appearing ability, one that is induced by experience with sign. An important distinction between the two sets of studies is that different handshapes were tested. Baker et al. tested infants on an 11-step continuum that varied in the openness of the handshape, whereas Wilbourn and Casasola used a pair of hand shapes that differed in the orientation of some of the fingers (all upright vs. the middle three fingers down). Moreover, it had been established for the handshape contrast tested by Baker et al. that signing adults perceived the handshapes categorically (Baker et al., 2005); whether this would also be true of the sign shape contrast used by Wilbourn and Casasola is unknown. Finally, the infants tested by Wilbourn and Casasola were 6 and 10 months old, thus different ages than those tested by Baker et al. It is not known at what age sensitivity to the linguistic use of the hands declines in hearing infants. Nonetheless, the failure to find handshape discrimination in infants by Wilbourn and Casasola invites another test of the claim of the prior Baker et al. study.

The current study was designed to address all these issues. We tested hearing infants of 4 and 14 months, as well as an additional group of primarily older infants who were learning ASL as a natural language in the home. As in the Baker et al. (2006) study, we predicted that hearing infants of 4 but not 14 months would discriminate the signed contrast along natural boundaries. In addition, we predicted that the new group of infants who were learning ASL as a natural language in the home would discriminate the signed contrast along natural boundaries even after the end of the 1st year of life. To examine the question of whether any changes in discrimination performance seen across age resulted from a decline in sensitivity to the natural linguistic boundary or instead from an increase in social responsiveness with a shift in looking from the hands to looking at the face between 4 and 14 months of age, we tested the infants using an automated eyetracker so that we could record detailed changes in eye-gaze pattern in order to determine what proportion of the testing time infants spent focused on the hand and what proportion on the face.

Although previous work has used a habituation design (Baker et al., 2006; Wilbourn & Casasola, 2007) in which infants are first shown one instance repeatedly and then tested on their detection of a

new stimulus, we used an alternating–nonalternating preference task in which discrimination is measured by differences in looking time to two trial types (Best & Jones, 1998; Mattock, Molnar, Polka, & Burnham, 2008; Maye, Werker, & Gerken, 2002; Teinonen, Aslin, Alku, & Csibra, 2008; Yeung & Werker, 2009; Yoshida, Pons, Maye, & Werker, 2010). In *nonalternating* trials, a single token is presented over and over, for example, A<sub>1</sub> A<sub>1</sub> A<sub>1</sub> A<sub>1</sub>. In *alternating* trials, two different tokens, either both from within the same category, for example, A<sub>1</sub> A<sub>2</sub> A<sub>1</sub> A<sub>2</sub>, or each from different categories, for example, A<sub>1</sub> B<sub>1</sub> A<sub>1</sub> B<sub>1</sub>, are presented. It is expected that if infants can discriminate the two categories, they will show differential looking to the alternating versus the nonalternating trials. The alternating and nonalternating trials are each presented multiple times, allowing for a more stable estimate of discrimination than in a habituation–switch design where there are only two test trials. Moreover, in our use of this design, discrimination is tested immediately without requiring the long period of familiarization required prior to test trials in habituation designs.

## Method

### Participants

Participants were divided into two groups: nonsigning (NS) infants and ASL-learning infants. The NS were 32 (16 boys) healthy, full-term, hearing, speech-exposed infants, further divided into groups of 16 infants at each of two ages: 4 months (mean age = 4 months 21 days, range = 3 months 23 days–5 months 7 days) and 14 months (mean age = 14 months 25 days, range = 13 months 23 days–15 months 4 days). Another 8 children (3 boys, 5 girls; mean age = 15 months 5 days, range = 5 months 12 days–21 months 24 days), were bilingual ASL-English infants who were exposed to ASL at least 40% of the time on a daily basis (based on parental reports). Table 1 offers a full description of the ASL infants' age at testing and language exposure. Note that we use the term *ASL infants* to denote that group of infants exposed to sign as a full natural language as one of their two languages; the term does not imply that the infants themselves used ASL. Nor does the term imply that the infants learned "baby sign"; these infants were all learning ASL from fluent adult signers. Eight additional NS infants were excluded due to fussiness ( $n = 6$ ) or failure to look during two of four trials for a given trial type ( $n = 2$ ). The ages of the NS infants were

Table 1  
*Bilingual ASL-English Infants' Age and Language Exposure*

Age at test	Gender	Deaf parent	Age of exposure		% English	% ASL
			English	ASL		
1;9,24	F	Neither	14 months	14 months	50	50
1;1,20	F	Father	Birth	Birth	20	80
0;5,12	M	Mother	Birth	Birth	30	70
1;2,27	F	Mother	Birth	Birth	30	70
1;3,4	F	Father	Birth	6 months	50	50
1;2,27	M	Father	Birth	Birth	60	40
1;4,27	F	Father	Birth	5 months	50	50
1;7,16	M	Mother	Birth	Birth	60	40

Note. ASL = American Sign Language.

chosen to match the ages of the infants in the Baker et al. (2006) study. The ASL infants were selected to be older than the young group of NS infants and as close in age as possible to the older NS infants. This resulted in a group of ASL infants that included one 5-month-old and seven infants as old as or older than those in the NS 14-month group. The NS infants were recruited from the maternity ward of the British Columbia Women and Children's Hospital in Vancouver, British Columbia, and comprised the broad cross-section of ethnicities and social classes that characterizes Vancouver. Parents were contacted by phone to see if they would be interested in participating. The ASL infants were recruited from the local deaf community in Vancouver, British Columbia. Human subject research guidelines were followed.

### Stimuli

The stimulus items from Baker et al. (2006) were used for this experiment. Similar to the phonemes of spoken languages, whose realizations can vary continuously by one feature (e.g., voice onset time), signed languages also have units whose realizations can vary continuously by one feature. The handshape contrast pair [5]–[flat-0] varies by the feature [aperture] (how open or closed the handshape is). Deaf, but not hearing, adults exhibit a consistent discrimination boundary for these handshapes (Baker et al., 2005). The dynamic stimuli used were taken from the stimuli in the 11-step continuum used by Baker et al. (2006), consisting of the two endpoints ([5] and [flat-0]; see Figure 1) and nine intermediate variants. From this continuum, we selected four handshapes: One handshape was chosen on either side of the adult boundary (Steps 4 and 7), and corresponding within-category hand-

shapes were chosen (Steps 1 and 4, and Steps 7 and 10) for the test stimuli. The handshapes were articulated by a native deaf signer, always shown full-face, who rotated her hand slightly about the vertical axis formed by her arm. Thus, the handshapes were presented moving in real time, fully consistent with the essential nature of linguistic, ASL signs (see Baker et al., 2006, for full stimuli details).

### Procedure

Infants were tested in a dimly lit room and were seated on their parent's lap approximately 24 in. from a 17-in. color Tobii 1750 system CRT eyetracker at eye level. The Tobii monitor's adjustable arm allowed for the monitor's position to be accommodated to each infant, thereby enabling accurate capture of the infant's eye gaze. Parents were instructed to close their eyes so as not to influence their infant's behavior. A low-light video camera was placed on a table just below the Tobii monitor in order to record the session and also to allow the experimenter to view the infant through a television monitor on the other side of a divider covered in black fabric, separating the experimenter from the infant.

The eyetracker was calibrated for each individual infant following the calibration routine provided by Tobii. Calibration was checked by displaying an attention-getter sequentially at five points on the screen (four corners, center). The infants' point of gaze had to be directed to within  $0.5^\circ$  of the center of the attention-getter stimulus for the calibration point to be accepted, and calibration points were repeated until this criterion was reached.

The procedure was monitored and controlled by the experimenter using a HP Pavilion computer running Clearview software (version 2.5.1; Tobii Technology, Danderyd, Sweden). The computer also recorded eye movement data as  $x$ - $y$  coordinates of the infant's point of gaze, at 50 Hz, as well as the timing of each stimulus onset and offset. The captured co-ordinates were saved to a unique file for each subject.

Because Tobii Clearview software is not suited to contingent looking time methodologies, an alternating-nonalternating paradigm was used (Best & Jones, 1998; Mattock et al., 2008; Maye et al., 2002; Teinonen et al., 2008; Yeung & Werker, 2009; Yoshida et al., 2010). In a within-subjects design, each infant saw a total of 12 handshape trials interspersed with 12 attention-getters. Each trial consisted of a series of four handshape tokens that were either identical or from the same or different categories. Trials were

of three types. In the four *nonalternating control* (control) trials, infants saw four identical tokens of the same handshape: one trial each of the handshape at Steps 1, 4, 7, and 10 of the continuum (see Figure 1). In the four *alternating within-category* (within-category) trials, infants saw an alternation of two handshape pairs from the same category. That is, they saw two trials that alternated Steps 1 and 4 and two trials in which Steps 7 and 10 alternated (the order of each pair and within a pair was counterbalanced across participants). In the four *alternating across-category* (across-category) trials, handshapes on either side of the category boundary were shown: The handshape from Step 4 alternated with the handshape from Step 7. In two of these trials, Step 4 came first, and in two trials, Step 7 came first. The order of the 12 trials was semirandomized across infants. A trial consisted of a still image of the onset of the first handshape presented for 500 ms, followed by the moving presentation of that handshape displayed for 4 s, and then a still image of the offset of the handshape displayed for 500 ms. This pattern of still-moving-still was presented four times in each trial (see Figure 2).

Trials began with an attention-getter consisting of a colorful moving object paired with an engaging nonlinguistic sound; one of three such attention-getters was played between trials in order to bring the infant's gaze back to the monitor.

## Results

### Looking Time

We examined the looking time data to verify our predictions, namely, that 4-month-old hearing (NS) infants would discriminate the natural sign boundary, while 14-month-old hearing (NS) infants would not. Furthermore, our analysis of the looking time data allowed us to test the hypothesis that this decline in discrimination is due to lack of experience with the use of handshape as a linguistically significant parameter, by comparing the behavior of the hearing 4- and 14-month-olds with that of the ASL infants, who do continue to receive such experience.

Ideally, the ASL infants would all have been 14 months and older, to match the older group of NS infants. However, ASL-learning infants proved to be a difficult population to recruit, and thus our group of 8 ASL infants includes 1 participant who was much younger than the age at which infants not receiving experience with ASL might be

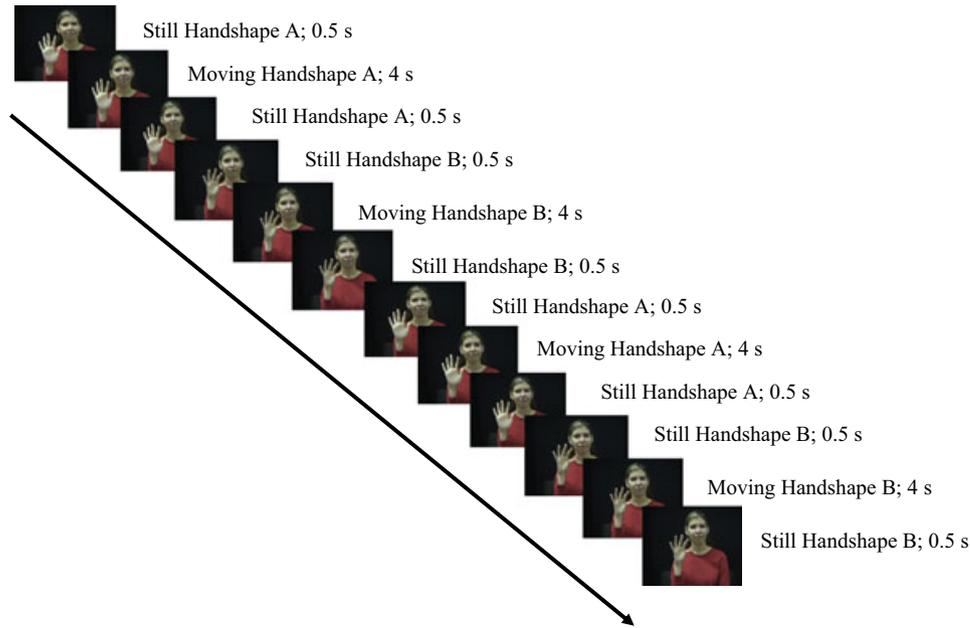


Figure 2. Trial schematic: Sample timing for a trial.

Note. Handshape A and handshape B refer to the different handshapes that were displayed during the alternating trials (both within-categories and across-categories); in the case of the nonalternating control trials, the same handshape was presented throughout the trial. Videos were presented in color.

expected to lose the ability to discriminate natural ASL handshape boundaries. To rule out the possibility that the overall success of the ASL group was driven by the inclusion of this single, 5-month-old infant, in addition to analyzing the data from all 8 of the ASL participants, we also analyzed the data from only the 7 ASL infants who were better matched in age to the 14-month-old NS infants, and we illustrate the latter results. As reported below, all results are equivalent in both sets of analyses.

Looking times were derived from the output of the eyetracker by summing across all measured fixations during each test trial interval. A repeated measures analysis of variance (ANOVA) with trial type (control, within-category, and across-category) as the within-subjects factor and group (4 months, 14 months, and ASL) as the between-subjects factor revealed a main effect for trial type,  $F(2, 74) = 5.57$ ,  $p < .01$ , but not for group,  $F(1, 37) = 1.77$ ,  $p > .05$ . Additionally, a two-way interaction effect was found for Trial Type  $\times$  Group,  $F(4, 74) = 9.55$ ,  $p < .001$ . When the data from the 5-month-old ASL participant was excluded, a repeated measures ANOVA with the factors trial type (control, within-category, and across-category) and group (4 months, 14 months, and ASL) also revealed a main effect for trial type,  $F(2, 72) = 5.23$ ,  $p < .01$ , but not for group,  $F(1, 36) = 1.66$ ,  $p > .05$ . Additionally, a two-way interaction effect was found for Trial

Type  $\times$  Group,  $F(4, 72) = 9.54$ ,  $p < .001$  (Figure 3). Thus, the groups showed differential discrimination performance for the handshape types.

Planned comparisons were conducted by group on the handshape trial types. For the NS 4-month-olds, looking time to the control trials was not significantly different from that to the within-category trials,  $F(1, 15) = 0.072$ ,  $p > .05$ , while looking time to the control trials was significantly different from that to the across-category trials,  $F(1, 15) = 10.96$ ,  $p < .01$ . For the NS 14-month-olds, looking time to the control trials was significantly different from that to the within-category trials,  $F(1, 15) = 7.02$ ,  $p < .05$ , while looking time to the control trials was not significantly different from that to the across-category trials,  $F(1, 15) = 0.538$ ,  $p > .05$ . It was not the case that the 14-month-olds simply preferred the more open handshape variants at one end of the continuum as opposed to the more closed handshapes at the other end of the continuum, since they spent almost exactly the same amount of time looking at both types of handshapes. Mean looking time to the trials with Steps 1 and 4 was 7.64 s ( $SD = 5.00$ ); mean looking time to the trials with Steps 7 and 10 was 7.50 s ( $SD = 3.50$ ).

For the ASL group, looking time to the control trials was not significantly different from that to the within-category trials,  $F(1, 7) = 0.025$ ,  $p > .05$ , while looking time to the control trials was significantly

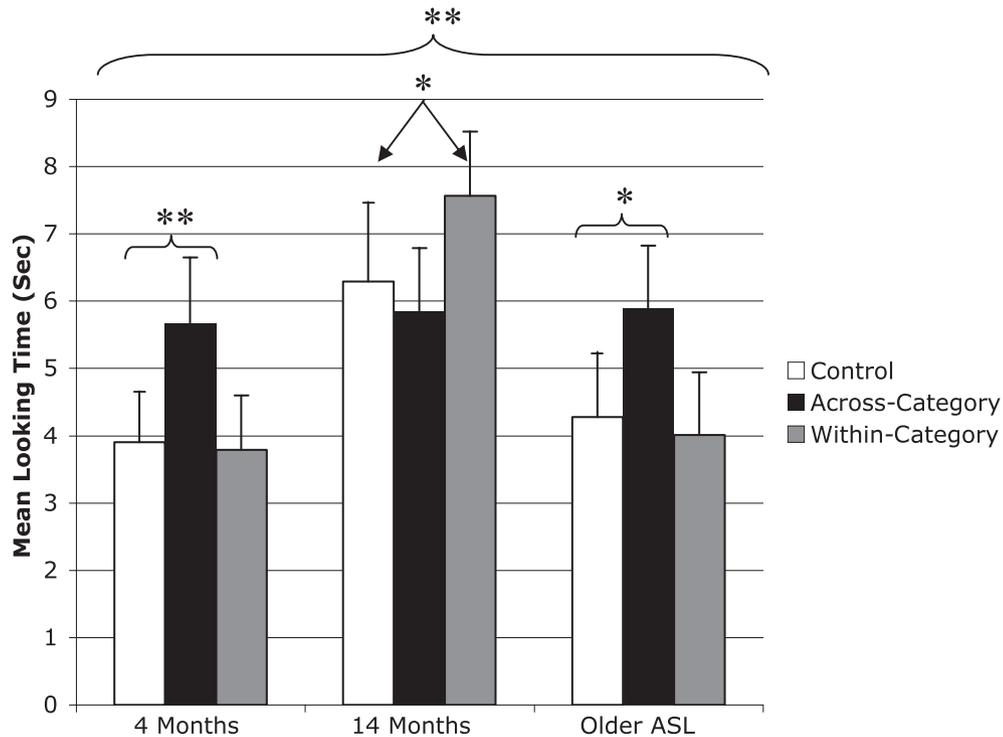


Figure 3. Mean looking times to handshape trial types for 4- and 14-month-old hearing infants and older ASL infants; bars represent 1 SE.

\* $p < .05$ . \*\* $p < .01$ .

different from that to the across-category trials,  $F(1, 7) = 12.74$ ,  $p < .01$ . When the 5-month-old ASL participant was excluded from the analysis, looking time to the within-category trials was still not significantly different from that to the control trials,  $F(1, 6) = 0.252$ ,  $p > .05$ , while looking time to the across-category trials continued to be significantly different from that to the control trials,  $F(1, 6) = 9.47$ ,  $p < .05$ .

These results indicate the ASL infants discriminated between the handshape types, looking significantly longer only to those handshapes that changed across a linguistic category boundary, displaying the same pattern of discrimination as native adult signers of ASL (Baker et al., 2005). Moreover, the NS 4-month-olds, who have no experience with ASL, showed discrimination performance identical to that of the ASL group, also discriminating only those handshapes from across a linguistic category boundary. The NS 14-month-olds looked longer at trials in which the handshapes changed within the *same* linguistic category, demonstrating that they are capable of detecting a change in the handshapes, but not in relation to a linguistic sign boundary. The performance of the 14-month-olds parallels the performance of the NS adults in the

Baker et al. (2005) study, who detected differences in the handshapes, but ones that did not correspond to linguistic sign category boundaries.

We also conducted Wilcoxon signed-rank tests to confirm our findings for looking times to control versus within-category trials and for control versus across-category trials. These results confirmed that a significant number of 4-month-old hearing infants looked longer to across-category trials than to control trials, but not longer to within-category trials than to control trials. A significant number of 14-month-old infants, on the other hand, looked longer to within-category trials than to control trials, but not longer to across-category trials than to control trials. Finally, like the 4-month-old infants, a significant number of ASL infants looked longer to across-category trials than to control trials (7 of 8,  $p < .05$ ), but not longer to within-category trials than to control trials (5 of 8,  $p > .05$ ). These results were not affected by the exclusion of the 5-month-old ASL participant (Table 2).

#### Eyetracking Data

One possible explanation for the differential performance of 4- versus 14-month-old infants is that

Table 2  
*Numbers of Infants Looking Longer to Within-Category and Across-Category Trials Than to Control Trials for All Three Groups*

	Looking longer to within-category trials than to control trials	Looking longer to across-category trials than to control trials
Four-month hearing	6/16 ( $p < .68$ )	13/16 ( $p < .007$ )
Fourteen-month hearing	12/16 ( $p < .03$ )	9/16 ( $p < .54$ )
Older ASL	4/7 ( $p < .73$ )	6/7 ( $p < .03$ )

Note. ASL = American Sign Language.

the older infants were more interested in social interaction than in looking at the hand and thus may have been looking at the signer's face (and not her hand), while the 4-month-olds were looking at the signer's hand. Thus, the difference in performance, both in our study and in the previous work by Baker et al. (2006), might simply have been a matter of *where* the infants were looking, and not maturation or experience. The eyetracking data in this study provide a definitive way of examining this question and have important implications for the interpretation of the infants' handshape discrimination performance.

To address the question of where the infants were looking, we established two areas of interest (AOIs): one comprising the signer's face and the other, her hand. A two-way AOI (face, hand)  $\times$  Group (4 months, 14 months, ASL) repeated measures ANOVA revealed no main effect for group,  $F(1, 37) = 1.49$ ,  $p > .05$ , indicating that all of the groups had comparable amounts of looking time. There was a main effect of AOI,  $F(1, 37) = 13.49$ ,  $p < .001$ , but no two-way interaction effect for AOI  $\times$  Group,  $F(2, 37) = 0.442$ ,  $p > .05$ , indicating that all of the groups looked significantly longer at the signer's face than at her hand. The results remained the same when the 5-month-old ASL participant's data were removed: There was no main effect for group,  $F(1, 36) = 1.36$ ,  $p > .05$ ; there continued to be a main effect of AOI,  $F(1, 36) = 14.14$ ,  $p < .001$ , but there was no two-way interaction effect for AOI  $\times$  Group,  $F(2, 36) = 0.585$ ,  $p > .05$  (Figure 4).

That the infants looked longer at the signer's face was not surprising, given the importance of the face for language, communication, and social interaction more generally, and the fact that the signer was filmed from a frontal, full-face angle, thereby making her face a prominent feature in the video clips. The more revealing finding was that although all three groups of infants looked longer at the face

than the hand, this was no more pronounced in the 14-month-old hearing infants than in the other two groups. The 14-month-olds did spend time looking at her hand, and in fact spent just as long looking at her hand as did the 4-month-olds and the ASL infants. This finding allows us to rule out an increased interest in faces, and hence a failure to look at the hand as an explanation for the difference in discrimination performance between the 4-month-olds and the 14-month-olds.

## Discussion

Our results show that 4-month-old NS infants and ASL infants looked significantly longer at across-category handshapes, but not within-category or control handshapes, indicating that they discriminate moving sign handshapes along the same boundaries as do native adult users of ASL. Conversely, NS 14-month-old infants looked significantly longer at the within-category handshapes, indicating that while they can detect differences between the handshapes, they do not discriminate the moving handshapes on the basis of linguistic boundaries. Furthermore, our work allows us to rule out a more trivial explanation of the lack of discrimination by the 14-month-olds having to do with the older group's allocation of attention.

These results provide the crucial evidence for perceptual narrowing in the visual modality. Without previous experience, young infants discriminate changes in a handshape used in natural sign languages according to the same boundary region as discriminated by adult signers. Our results show that sensitivity to linguistic sign is not present in older NS infants as it was in younger infants, and therefore it appears that sensitivity changes across age, diminishing in older infants unless those infants continue to be exposed to sign language. Moreover, the age-related changes seem to occur within the same relatively broad period as seen for many other aspects of perceptual narrowing. These results confirm and extend those of Baker et al. (2005), and provide further support for the proposition that the human mind is equally prepared to learn a signed language as it is to learn a spoken language, with initial perceptual sensitivities that are tuned to natural (in this case, signed) languages (Petitto, 1997).

This finding provides a hitherto missing piece of the picture of the developmental trajectory for the discrimination of native versus non-native contrasts

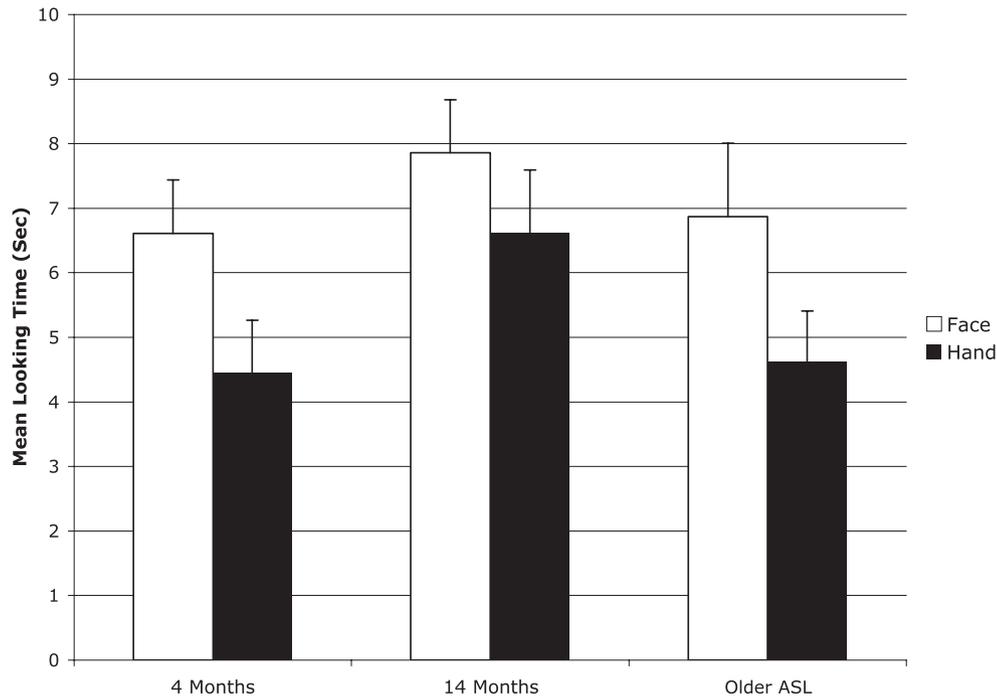


Figure 4. Mean looking times to signer's hand and face for 4- and 14-month-old hearing infants and older American Sign Language infants; bars represent 1 SE.

in visually presented language: By the end of their 1st year, infants, whether exposed to auditory-visual speech or visual language, are beginning to fine-tune their linguistic repertoires, and those infants receiving continued input of a contrast in their native linguistic context, whatever modality it is presented in, continue to discriminate the contrast. Although we have shown that exposure to a signed language in early infancy, before perceptual narrowing would typically take place, is sufficient to maintain the discrimination ability seen in early infancy, we do not know from this study whether exposure at a later age would be equally effective, or whether there is a sensitive period in early infancy when such exposure is required. An interesting follow-up to this study, then, would be to provide extensive exposure to NS 14-month-old infants to see if it is possible to reinstate sensitivity to ASL at this older age.

Using an eyetracker to gather gaze location information, we have also shown that patterns of looking at the signer's hand and face cannot account for our results: Fourteen-month-old NS infants looked at the hand of the signer just as much as did the NS 4-month-olds and the ASL infants. The older NS infants therefore had access to just as much information concerning handshape as did the NS 4-month-olds and ASL infants who did discriminate

the handshape contrast. The availability of eye-tracking data to reveal specific looking patterns in infants, both hearing and not, who are viewing linguistic sign opens up a new set of fascinating questions, beyond the scope of our work here, that will enrich our understanding of how infants process language, regardless of modality. Eyetracking data may reveal patterns in the dynamic timecourse and trajectories of gaze patterns in various populations and ages of infants as they watch and listen to speech. These patterns may indicate different strategies for the perception and integration of audio-visual speech information across development and modalities. This study makes innovative use of this approach to probe differences yielded by looking time data, in this case, to rule out the possibility that different gaze patterns, rather than lack of exposure to visual linguistic signs, underlie the differential performance of the 14-month-old NS infants. Results indicated that the 14-month-old infants' gaze pattern to face and hands was not different from that of the 4-month-old or the older ASL infants (Figure 4), and thus could not have been the cause of the difference in discrimination patterns for each group.

Finally, because both our results and those of Baker et al. (2006) show that young infants are, indeed, capable of discriminating at least some

handshapes, we suggest that discrimination of handshape per se cannot simply be a later developing ability, as suggested by Wilbourn and Casasola (2007). However, while our data show that young infants and ASL infants *can* demonstrate discrimination of handshape contrasts, it might yet be the case that contrasts involving different visual parameters have different acquisition trajectories. This is certainly the case in the auditory domain; recent work has shown that the acoustic salience of a contrast can affect infant perception of that contrast, modulating the effect of native language experience (Narayan et al., 2010; Polka et al., 2001). Narayan et al. (2010) tested English-hearing and Filipino-hearing infants on the *na-ma* and *na-nga* contrasts. Crucially, even young Filipino-hearing infants (4–5 and 6–8 months) whose language exposure included the latter contrast failed to discriminate the low-salience difference between *na* and *nga*. Narayan et al. interpret these findings as suggesting that the perceptual system in young infants is sensitive to acoustic differences in nasal consonants but that specific experience with acoustically very similar nasal consonants, such as *na* and *nga*, may be necessary to lead to above-threshold discrimination. Similarly, infants might be predisposed to detect differences in handshape in sign, but may require specific experience to establish sensitivity to some handshape differences that are particularly similar visually. We suggest that the contrast used in the work by Wilbourn and Casasola might have been analogously low in salience to the *na-nga* acoustic distinction, and thus difficult to discriminate without sufficient native language exposure. The handshape contrast used in our work, on the other hand, may have been analogous to the highly salient *na-ma* contrast tested by Narayan et al. which even very young (4–5 months) English infants could discriminate. Thus, the present findings, taken together with those of Wilbourn and Casasola, yield a more nuanced understanding of the developmental trajectory of the acquisition of handshape distinctions by infants exposed to ASL, suggesting a role for visual salience of the parameters marking these distinctions. Clearly, further work investigating the acquisition of different ASL handshape contrasts as well as different types of ASL contrasts is necessary to flesh out this understanding.

In summary, this study demonstrates that a pattern of perceptual narrowing occurs for the perception of linguistic sign. This pattern is similar to the perceptual narrowing of heard speech contrasts and other linguistic stimuli. The preparedness for

linguistic stimuli at birth, and the subsequent tuning as a function of experience, across both heard and seen speech, adds to the growing evidence that narrowing is a ubiquitous perceptual learning mechanism that contributes to the acquisition of the native language.

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