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REPORT

Preference for language in early infancy: the human language bias is not speech specific

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Abstract

Fundamental to infants' acquisition of their native language is an inherent interest in the language spoken around them over non-linguistic environmental sounds. The following studies explored whether the bias for linguistic signals in hearing infants is specific to speech, or reflects a general bias for all human language, spoken and signed. Results indicate that 6-month-old infants prefer an unfamiliar, visual-gestural language (American Sign Language) over non-linguistic pantomime, but 10-month-olds do not. These data provide evidence against a speech-specific bias in early infancy and provide insights into those properties of human languages that may underlie this language-general attentional bias.

Introduction

In the first year of life, well before they are able to understand, let alone produce, speech, infants are actively attending to the sounds in their environment that hold linguistic information and becoming experts at recognizing, discriminating, and categorizing those speech sounds (see Jusczyk, 1997). An underlying theme in many theories of language development is that a general interest in paying attention to the language spoken around them over other non-linguistic environmental sounds is crucial for the development of infants' analysis of their native language (Gould & Marler, 1987; Jusczyk & Bertoncini, 1988).

A variety of studies have documented early speech preferences: 4-month-olds have been found to prefer speech to silence and white noise (Columbo & Bundy, 1981), and 9-month-olds prefer human singing to instrumental music matched in melody or a repeated tone (Glenn, Cunningham & Joyce, 1981). More recently, Vouloumanos and Werker (2004) found that 2- to 7-month-olds prefer spoken words to complex sine-wave analogues of the same words. Sine-wave speech tokens preserve much of the complex temporal and prosodic information found in speech within a similar range of frequencies without retaining the distinctly biological quality of true speech. This latter study provides some of the best evidence for human infants' preference for speech over highly complex, yet non-linguistic acoustic stimuli.

To date, research investigating infants' attraction to language largely have been studies of hearing infants acquiring spoken languages. Thus it is unclear whether this attraction to speech reflects a bias towards human language in general, or rather a more limited interest in the salient acoustic properties of speech. Indeed, the nature of the critical properties of the signal that serve to capture infants' attention is not known. In addition, given infants' extensive pre- and post-natal exposure to speech this bias may simply reflect an interest in a highly familiar stimulus (DeCasper, Lecanuet, Busnel & Granier-Defferre, 1994). Thus it is important to determine whether this attraction to speech reflects a bias for human language in general, or rather reflects a more limited interest in the salient and highly familiar acoustic properties of speech. Evidence in support of the existence of a general language bias would predict that hearing, speech-exposed infants would also show a preference for a completely unfamiliar language expressed in a visual-gestural modality, such as the naturally occurring signed languages of the deaf.

American Sign Language (ASL) is a naturally occurring visual-manual language of the deaf that is used in the United States and parts of Canada. Two decades of research have shown unequivocally that signed languages are naturally evolving, linguistically complex, and fully productive instances of human language (Klima & Bellugi, 1979). Importantly, infants (both hearing and deaf) exposed to ASL from birth acquire sign language along the same developmental timeline as infants acquiring a spoken language (Meier & Newport, 1990; Meier, 1991; Newport & Meier, 1985; Petitto, Holowka, Sergio, Levy & Ostra, 2004; Petitto & Marentette, 1991).

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For infants unfamiliar with sign language, experimental exposure to ASL can provide a means to explore the robustness of an early language preference independent of mechanisms specific to auditory processing. Moreover, it allows us to control for the confounding factor of early experience with speech that may be influencing infants' apparent bias for language over non-linguistic stimuli.

In addition, with these controls in place, we may garner further insights into the 'language-general' to 'language-specific' shift in the processing of linguistic stimuli (Werker & Tees, 1984; Kuhl, Williams, Lacerda, Stevens & Lindblom, 1992). During the first year of life, infants learn which parts of the signal to attend to and process and which parts should be ignored. This trend is robustly illustrated in the decline of abilities that occurs as infants become specialized in processing their native language. A group of seminal studies have demonstrated that 6–8-month-old infants are able to discriminate between consonant contrasts that are meaningful to both their native language and unfamiliar foreign languages. By about 10 months, this generalized sensitivity disappears, and like adults, infants are only able to distinguish between those consonant contrasts that carry distinctive meaning in their native language (Best, McRoberts & Sithole, 1988; Eimas, 1975; Trehub, 1976; Werker, Gilbert, Humphrey & Tees, 1981; Werker & Tees, 1984).[1] This shift seems to occur earlier for acquisition of vowels; by 6–8 months, infants show a commitment to preserving the 'best instances' of vowel sounds in their native language by reducing discrimination between such prototypes and close neighbors (Bosch & Sebastian-Galles, 2003; Kuhl *et al.*, 1992).

These results are paralleled by another important group of studies that has mapped infants' gradually more sophisticated sensitivity to linguistic properties in general, and a more sophisticated preference for the specific properties of their native language. Infants begin life with a global preference for the prosodic structure of the language spoken around them compared to a foreign language (Mehler, Jusczyk, Lambertz, Halsted, Bertoncini & Amiel-Tison 1988) and an ability to discriminate two foreign languages that have sufficiently different prosodic structure (Nazzi, Bertoncini & Mehler, 1998). At 6 months, infants better recognize the reoccurrence of spoken passages in their native language that use prosodic markers correctly than passages that do not (Nazzi, Kelmer Nelson, Jusczyk & Jusczyk, 2000). By 9 months, infants have a more specialized preference for the phonotactic and stress-pattern information of their native language (Jusczyk, Cutler & Redanz, 1993; Jusczyk, Frederici, Wessels, Svenkerud & Jusczyk, 1993; Jusczyk, Luce & Charles-Luce, 1994; Sebastian-Galles & Bosch, 2002; Turk, Jusczyk & Gerken, 1995). Thus, along with a decline in the ability to distinguish phonemic information of non-native languages, the preference for the sound patterns of an infant's native language becomes more subtle and fine-tuned.

In the following studies we examine speech exposed infants' preference for linguistic and non-linguistic stimuli in the visual-manual modality: American Sign Language and fluent pantomime. Both ASL and pantomime represent fluent biological actions that contain movements of both arms, varied configurations of hand shapes, and dynamic facial expressions. However, ASL is a hierarchically compositional system of conventionalized signs that are structured according to linguistic rules (Klima & Bellugi, 1979; McNeill, 2000; Stokoe, 1999; Stokoe, Casterline & Croninberg, 1965; Valli & Lucas, 1996). Pantomime, while communicative and complex, does not have linguistic structure (Klima & Bellugi, 1979). We hypothesize that the 6-month-old infants will show a preference for linguistically based sign language over non-linguistic pantomime. However, we predict that the 10-month-olds, who have a more narrowed interest in the linguistic properties of their native spoken language, will show no preference.

Study 1

Method

Thirty-four 6-month-old (24 weeks) and 37 10-month-old (42 weeks), full-term, hearing infants were tested in a paired-comparison preferential looking paradigm. Each infant was held by an experimenter standing in front of two TV monitors: one monitor played a native deaf female signer signing adult-directed American Sign Language descriptions of situational scenarios (e.g. waiting for the bus in the rain, going to the store to get groceries); the other monitor displayed the same woman performing everyday pantomime sequences (e.g. frying an egg, putting on make-up) (see Figure 1). Both the sign language and the pantomime made use of a variety of one- and two-handed hand configurations, facial expressions, and direction of eye gaze (see Stimuli Feature Analysis for detailed comparisons of the stimuli).

The experiment comprised six trials. A trial was created by matching and time locking a group of two or three signed scenarios with two or three pantomime sequences (range, 40–55 s, mean length 45.33 s). There were 5-second breaks between trials, and a 2-minute break mid-experiment. Trial order and stimulus location (right or left monitor) were counterbalanced, resulting in six different versions of the stimulus tapes. The experiment lasted a total of 6 minutes.

The dependent variable of interest was the number of seconds the infants looked at each monitor. The infants' eye movements were videotaped and coded off-line. The first 40 seconds of each of the six trials were coded,

[1] Interestingly, recent studies have found evidence that some infants retain sensitivity to non-native contrasts through the first year of life at neural and behavioral levels (Rivera-Gaxiola, Silva-Pereyra & Kuhl, 2005; Kuhl, Stevens, Hayashi, Deguchi, Kiritani & Iverson, 2006).

Figure 1 *Split screen display of full signal stimuli: American Sign Language is on the left and pantomime is on the right.*

resulting in a potential of 240 seconds of coded looking time per infant.

Results

The infants' looking times were analyzed using a repeated measures ANOVA with Age (6 months, 10 months) as the between-subjects factor and Stimuli (ASL, pantomime) and Side (left, right) as within-subject factors. The analysis revealed a main effect of Stimuli: the infants looked significantly longer at the ASL than to the pantomime, $F(1, 69) = 4.865$, $p < .05$ (M ASL = 101.51 s, M pantomime = 92.07 s), and a main effect of Side: there was an overall preference for the left monitor, $F(1, 69) = 6.765$, $p < .05$ (M left = 102.04 s, M right = 91.65 s). However, the interaction between Stimuli and Age was not significant, $F(1, 69) = 1.072$, $p = .304$, nor were there any other interaction effects.

Our interest in the well-documented patterns of language-general language-specific shifts in linguistic processing (see introduction) provided motivation for investigating attentional preferences in the two age groups separately. Separate repeated measures 2 (Stimuli: ASL, pantomime) × 2 (Side: left, right) ANOVAs revealed that the 6-month-olds significantly preferred the ASL over the pantomime, $F(1, 33) = 4.608$, $p = .039$ (M ASL = 113.85 s; M pantomime = 99.71 s), but showed no side preference, $F(1, 33) = .853$, $p = .363$ (M left = 110.56 s, M right = 103.18 s). There was an interaction between stimuli type and side, $F(1, 33) = 4.302$, $p = .046$, reflecting a preference for the left side when watching the pantomime (M left = 52.7 s, M right = 47.0 s), but no side preference for watching the sign language (M left = 57.9 s, M right = 55.9 s). However, the 10-month-olds showed no significant preference for either type of motion, $F(1, 36) = 1.205$, $p = .280$ (M ASL = 90.78 s, M pantomime = 84.43 s), but they did prefer watching the right monitor to the left monitor $F(1, 36) = 10.866$, $p = .002$ (M left = 74.27, M right = 101.00 s). There was no interaction effect.

Discussion

The overall analysis indicated that while both types of stimuli proved interesting, hearing infants with no prior sign language exposure show an interest for American Sign Language over non-linguistic pantomime. These data indicate that an infant's bias toward language is not limited to spoken languages, but may extend to all possible forms of human language. While not indicated in the main analysis, post-hoc testing revealed that this effect was largely driven by the data from the 6-month-olds. When analyzed separately, the preference for sign language was not present in the 10-month-old infants. Though one must be cautious in interpreting a null finding, especially when it disappears when subjected to a pooled analysis, the nearly equal interest in both stimuli in the older infants may signal a *language-specific* interest in auditory languages over signed languages.

Stimuli feature analysis

How do the American Sign Language and pantomime differ? In a descriptive feature analysis of the ASL and pantomime stimuli (based in part on Klima & Bellugi, 1979) we looked at the number and frequency of different types of locations on the body and in space, movements of the arms and hands, handshapes, and facial expressions. These analyses are quantitatively described in Tables 1, 2 and 3 and qualitatively described in Tables 4 and 5.

We quantified the occurrence of these properties across all trials (Table 1) and in an average 40-second trial (Tables 2 and 3). An interesting, though expected (see below), pattern emerged: the pantomime employed fewer types of handshapes, an equal variety of types of facial expression overall (including equal use of smiling), and more types of locations and movements compared to the signing. Only the difference in the use of handshapes reached significance ($p < .05$ for dominant hand[2]) with the model using 23 different handshapes in the ASL and only 16 in the pantomime (see Table 1). However, the signing used more types of all of these features *per trial*, although this difference was only significant in the numbers of handshapes in both dominant, $t(17) = 3.67$, $p < .005$ (M ASL = 11.10; M pantomime = 6.00), and

[2] For a right-handed signer, like our model, the dominant hand is the right hand and the non-dominant hand is the left hand. In American Sign Language, one-handed signs are performed with only the dominant hand. Two-handed signs involve either symmetrical movement and identical handshape in both hands, or the dominant hand performing an action while the non-dominant hand acts as an unmoving base with a less complex ('unmarked') handshape (see Baker-Shenk & Cokely, 1980; Battison, 1978).

Table 1 *Total number of types used by dominant hand across all trials by stimulus class*

Stimulus	Handshapes*	Face[a]	Location	Movement
ASL	23	24	16	20
Pantomime	16	25	27	26

[a] This includes the sum of all types of brow, eye, and mouth expressions combined.
* $p < .05$.

Table 2 *Average number of types of handshapes, locations, and movements per trial*

Variable	Stimuli	*M*	*SE*	Min	Max
Dominant hand					
Handshapes**	ASL	11.10	.98	8	15
	Pantomime	6.00	.97	2	12
Locations	ASL	9.50	.79	7	16
	Pantomime	7.22	1.28	3	15
Movements	ASL	12.50	.70	9	16
	Pantomime	10.22	1.18	6	18
Non-dominant hand					
Handshapes*	ASL	7.20	.85	3	11
	Pantomime	4.00	.58	1	7
Locations	ASL	6.30	.97	3	13
	Pantomime	5.33	1.07	1	11
Movements	ASL	7.40	.69	3	10
	Pantomime	6.56	.77	3	11

* $p < .05$.
** $p < .005$.

Table 3 *Average number of types of facial movements per trial*

Variable	Stimuli	*M*	*SE*	Min	Max
Mouth*	ASL	7.50	.54	5	10
	Pantomime	4.78	.92	1	8
Brows	ASL	3.00	.26	2	4
	Pantomime	2.67	.33	1	4
Eyes	ASL	4.40	.37	3	7
	Pantomime	5.00	.53	3	8
Eye contact*	ASL	4.10	.66	1	8
	Pantomime	1.78	.74	0	7

* $p < .05$.

non-dominant hand, $t(17) = 3.03$, $p = .007$ (*M* ASL = 7.20; *M* pantomime = 4.00); mouth movements, $t(17) = 2.60$, $p < .05$ (*M* ASL = 7.50, *M* pantomime = 4.78); and eye contact, $t(17) = 2.03$, $p < .05$ (*M* ASL = 4.10, *M* pantomime = 1.78; see Tables 2 and 3).

Importantly, these differences are predictable given that ASL is an arbitrary linguistic system and pantomime is not (see Table 4). ASL has prescribed linguistic constraints, including a well-defined corpus of handshapes, movements and locations (Battison, 1974, 1978; Baker-Shenk & Cokely, 1980; Klima & Bellugi, 1979; Liddell, 1977; Stokoe *et al.*, 1965). These constraints are shaped both by the biological capabilities of the human body and by a need to remain fully visible to the

Table 4 *Qualitative differences between the full signal pantomime and ASL*

	Pantomime	ASL
Handshapes	Few handshape types Simple handshapes: e.g. broad (open hand) and compact (closed hand) variants	Multiple handshape types Complex handshapes: e.g. broad (open), compact (closed) and intermediate variants ('V' index and middle fingers open, ring and pinky fingers closed; 'F' index finger and thumbing touching, middle, ring and pinky finger open)
Location	Numerous on- and off-body locations (e.g. above head, below waist, behind body)	Adherence to limits of defined signing space (head to waist, directly in front of signer)
Movement	More movement types More undefined movement types Frequent repetitions of movements	Fewer movement types More defined movement types Limited number of repetitions
Eyes and brows	Eyes follow actions that model performs; eyes are not independent of actions	More eye contact with camera; actions are independentof eyes
Facial expression	Expressivity based on actions performed (e.g. frustration at trying to fix hair, satisfaction in finishing a task)	More rapid changes in mouth More varied movement in mouth

Table 5 *Qualitative differences between the pantomime and ASL in point-light form*

	Pantomime	ASL
Handshapes	–	–
Location	Numerous on- and off-body locations (e.g. above head, below waist, behind body)	Adherence to limits of defined signing space (head to waist, directly in front of signer)
Movement	More movement types More undefined movement types Frequent repetitions of movements	Fewer movement types More defined movement types Limited number of repetitions
Eyes and brows	–	–
Facial expression	–	–

addressee (Baker-Shenk & Cokely, 1980). As a result, in ASL we see extensive use of detailed handshape and movement information but limited locations in space so that the signs can be understood without shifting attention from the face of the signer. This results in a well-defined 'signing space', or the 12 specific locations on the body and in front of the body in which signs are allowed to be articulated in order to be well formed (Klima & Bellugi, 1979; Stokoe *et al.*, 1965).

Pantomime, on the other hand, is an intentional attempt to mimic everyday actions and while also constrained by the biological capabilities of the human body, does not require the same visual efficiency as a linguistic system and can make use of a larger field of articulation, and thus more varied locations and movement types. In the present study, for example, the model chose to employ only specific handshapes when she was pretending to hold an object. During the remainder of the time, she used more lax handshapes, such as when moving her hands from one location to the next. In addition, the model used all different parts of her body and space to represent the pantomimed sequences (including behind her back) and employed a greater variety of more undefined, broader, iconic movement types (e.g. upwards stroke), whereas the ASL made use of a smaller, more detailed, arbitrary corpus of movements types (e.g. symmetrical back and forth). Thus, in general, the pantomime makes use of more varied movement types and locations than the sign language, but lacks detailed handshape and movement information.

The small differences in mouth movement and eye contact between the ASL and pantomime can also be explained by the unique properties of each stimulus. While the most popular mouth expression was neutral for both types of stimuli, there was on average more varied mouth movement represented in an ASL trial than a pantomimed trial. This is likely due to the fact that the ASL requires a certain amount of mouth movement for well-formed signs (Baker-Shenk & Cokely, 1980), and does reflect some influence from the mouth formations used in spoken English.

For the vast majority of both the ASL and pantomime (80% of the time during the ASL and 91% of the time during the pantomime), the model did not make direct eye contact with the camera; rather she had an unfocused expression, or closed her eyes, likely because she did not feel that she was communicating with the camera. The relatively small amount of eye contact made in the pantomime is likely due to the fact that many of the pantomime sequences involved manipulating pretend objects in space and performing actions on those objects, which required the model to regularly move her eyes to follow the objects. This difference in eye contact, while small, is indeed provocative, given infants' remarkable sensitivity to small deviations in eye contact during social interaction (see General Discussion).

Finally, changes in state in the signing were based on the constantly shifting and completely arbitrary formation of linguistic elements, whereas the pantomime employed more iconic redundancy in order to mimic everyday motions (e.g. brushing hair, stirring soup). Thus, the full signal pantomime, while featurally rich in many ways, did not demonstrate the constraints necessary for a complex, hierarchically based, linguistic system. It is likely that the uniquely complex linguistic properties, especially the relatively high amplitude information carried in the hands and face, were particularly salient to the infants in Study 1. (See Hildebrandt, 2003, for a more detailed discussion of the Stimuli Feature Analysis.)

Study 2

In order to investigate the possible contribution of the hand and mouth changes and eye contact to the observed preference for ASL, we presented a new set of 6-month-olds ($N = 51$) with a point-light version of the sign and pantomime stimuli. The point-light technique, a common method used to capture movement information in complex biological stimuli, was used to render the sign and pantomime into visual patterns of small moving lights. In this transformation only the joints of the arms and torso are illuminated, so that the infants can see the movement and location information, but not information provided by the hands and face (see Figure 2).

Method

The stimuli were created by filming the same model performing the same stories and mime sequences as in Study 1 in a dark room while wearing 12 'grain-of-wheat' lights attached to her forehead, chest, and the major joints of her torso (see Figure 2). Previous studies

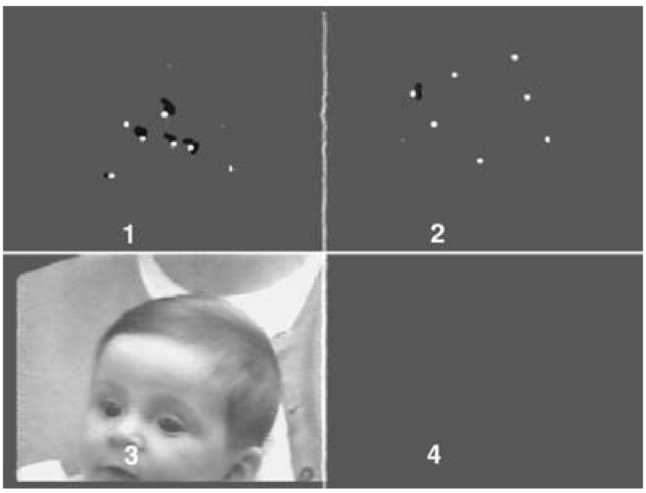

Figure 2 *Split screen display of point-light stimuli: American Sign Language is on the left and pantomime is on the right.*

have shown that 3-month-old infants prefer the point-light displayed movement of a human to randomly moving point-lights (Bertenthal, Profitt & Cutting, 1984; Fox & McDaniel, 1982). Importantly, studies have also shown that adult deaf signers are able to categorize ASL point-light stimuli along linguistic dimensions (Poizner, 1983).

The preferential looking procedure and statistical analysis for Study 2 were identical to Study 1. Fifty-one 6-month-old infants (24 weeks) were tested in this procedure.

Results

While overall the infants were less interested in the point-light stimuli than the full signal displays, a significant difference in looking time between the ASL and pantomime emerged (see Figure 3). In this study, a 2 (Stimuli: ASL, pantomime) × 2 (Side: left, right) ANOVA revealed that the infants demonstrated a preference for the pantomime motion over the sign language, $F(1, 50) = 5.299$, $p = .026$ (*M* ASL = 70.63 s; *M* pantomime = 79.28 s). There was no side preference, $F(1, 50) = .014$, $p = .907$, (*M* left = 74.71 s; *M* right = 75.20 s), nor was there an interaction effect, $F(1, 50) = 1.327$, $p = .255$.

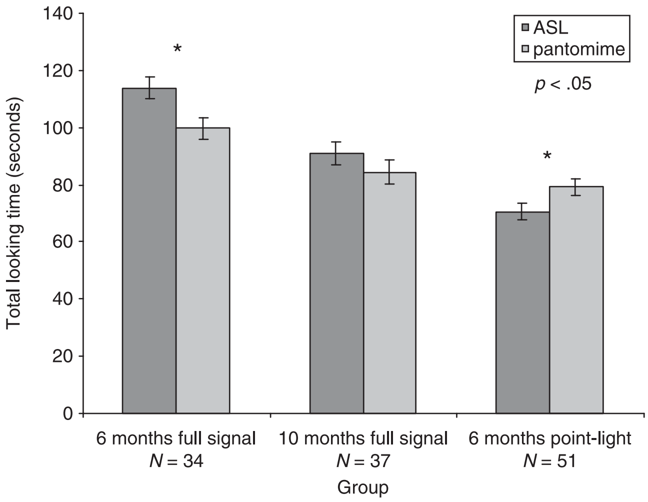

Figure 3 *Percent of total looking time of full and point-light stimuli in seconds by group.*

Discussion

In Study 1, we showed that 6-month-old infants preferred sign language stimuli over non-linguistic pantomime. In Study 2, we reduced the information in the signal by presenting point-light representation of the sign sentences and pantomime sequences. This experimental manipulation preserved the global movement properties of the stimuli, while eliminating the local featural information. Under these conditions we now observe that the 6-month-old infants showed a significant interest in the pantomime over the signing. These results suggest that the relatively local featural information carried by the hands and face, characteristic of naturalistic signing, are likely sources of salience for the infants. When this information is absent, the greater inventory of movement trajectories of the pantomime may capture the infants' attention.

General discussion

Spoken language research has demonstrated that infants show a predilection for paying attention to language over other sounds in their environment. However, it is unknown whether the preference shown for language reflects a bias specific to speech or to human languages in general. Further, it is unclear what effect a lifetime of exposure to speech, both pre- and post-natally, has on the manifestation of the speech bias. In Study 1, we demonstrate that 6-month-old hearing infants with no prior exposure to a sign language nevertheless prefer to look at sign language compared to highly interesting and complex, but non-linguistic, pantomime sequences. These data strongly suggest that infants' attentional preference to language is not limited to spoken languages.

In the 10-month-olds' data, we see a change in this preference; overall, this group of infants showed a reduced preference between the sign language and the pantomime. Given the well-documented shifts in organization of perceptual space in the first year of life, reflected in a decline in sensitivity to non-native phonemic contrast (Werker *et al.*, 1981; Werker & Tees, 1984), and an increased preference for the prosodic and phonotactic patterns of their native language (Jusczyk *et al.*, 1993; Jusczyk *et al.*, 1993; Jusczyk *et al.*, 1994; Mehler *et al.*, 1988; Turk *et al.*, 1995), it is possible that the 10-month-old infants may have lost (or are in the process of losing) sensitivity to the linguistic patterns of ASL, a non-native language. This honed interest in the language (and perhaps modality) that they have had the most experience with may result in an appreciation for ASL and pantomime as equally interesting complex biological motion.

Another possible explanation for a decreased interest in the sign language in the 10-month-olds is that the older infants may have a rudimentary ability to parse the pantomime sequences into intentional actions and have a more sophisticated appreciation for the pantomime as an attempt to communicate. Thus, the attention to the pantomime may not reflect an inability to discriminate these types of action, but may reflect a newly sophisticated social-cognitive ability, in effect equalizing the looking time between compelling linguistic stimuli and compellingly interpretable and potentially communicative stimuli. Baldwin and colleagues (Baldwin, Baird, Saylor & Clark, 2001) have found evidence to suggest that 10-month-old infants are able to parse human actions, presumably a fundamental precursor for further understanding of the underlying intentions of actors. In the realm of word learning, Namy and colleagues (Namy, 2001; Namy, Campbell & Tomasello, 2004; Namy & Waxman, 1998) found that 18-month-old infants accept iconic (pantomimic) and arbitrary (more sign-like) labels embedded in spoken language routines for novel objects, suggesting that the window for accepting potential object labels in the visual-gestural modality remains open and flexible into early childhood.

It is likely that these two developmental processes (linguistic specialization and social cognition) are playing out in tandem during this time. The 10-month-old data may reflect a combination of factors: a decline of interest in the linguistic properties of a nonnative language, and an increased interest in the intentional and communicative properties of the pantomime.[3]

What is it about the sign language that is interesting to the 6-month-old infants? The detailed feature analysis of the stimuli revealed that the pantomime employed less eye contact, more types of hand and arm movement and body locations, similar numbers of facial movements, and fewer handshapes overall compared to the ASL.

While the difference in eye contact is small (20% of the time in the signing vs. 9% of the time in the pantomime, see Table 3), it is potentially important given that infants have been shown to be very sensitive to eye contact during social interactions (Hains & Muir, 1996; Lasky & Klein, 1979; Symons, Hains & Muir, 1998; Zeifman, Delaney & Blass, 1996). However, there is some question as to whether the infants regarded the videotaped stimuli as a true interaction. Importantly, there is evidence that in a non-communicative setting, infants do not show a preference for frontal eye gaze (Vecera & Johnson, 1995). In addition, if the eye contact was significant enough to draw the infants' attention, we might expect the 10-month-olds to show a stronger preference in the sign language.

Another explanation for the 6-month-olds' preference for ASL over the pantomime is that the sign language contains unique linguistic features that are not present in the complex and biological, but non-linguistic, pantomime (see Tables 4 and 5). Critically, the formational characteristics that we found in the Stimuli Feature Analysis make ASL 'language-like' in important and predictable ways. The analysis of the sign language confirmed that it followed many well-prescribed linguistic constraints established in past research, specifically given the well-defined corpus of handshapes, movements and locations available in ASL (Battison, 1974, 1978; Baker-Shenk & Cokely, 1980; Klima & Bellugi, 1979; Liddell, 1977; Stokoe *et al.*, 1965).

In the point-light study, however, where only the joints of the arms and torso were illuminated, it was the movement paths and spatial information that were preserved at the expense of quick modulations of the hands and face (see Table 5). It may be that in the context of the highly unfamiliar point-light displayed signal, more varied movement paths of the pantomime were more captivating to the infants than the more confined movements of the ASL.

Importantly, we suggest that attempting to reduce the signed stimuli to the point-light form might very well have stripped it of some of the very properties that make it so uniquely linguistic. The infants may have been no longer drawn to the signed stimuli because the salient properties of handshape and facial gestures were absent. Indeed, the information carried through these local transitory properties may be crucial in drawing the infants' attention to linguistic signals. It also possible that these, and other aspects of the signed signal such as prosodic markers, contribute to its overall structure such that the combination of all features is more salient than any given feature in isolation.

Consistent with these findings, it has been shown that in the realm of spoken language, 2- to 7-month-old infants maintain an interest in speech compared to sinusoidal speech tokens that lack short-term acoustic properties (Vouloumanos & Werker, 2004). And while we do not pair full-signal ASL with its point-light displayed counterpart, the studies here suggest that infants are preferentially attentive towards ASL compared to non-linguistic biological motion when in its full signal form, but not when it is reduced to point-lights.

Taken together, these data suggest that preference for language in early infancy is not speech specific, but rather reflects an interest in human language, spoken or signed. It seems that the rule-governed and frequently recurring transitions of local features, a critical property of human language, may be driving infants' attention for language (see also Aslin, Saffran & Newport, 1998; Fiser & Aslin, 2001; Kirkham, 2003; Kirkham, Slemmer & Johnson, 2002; Marcus, Vijayan, Bandi Rao & Vishton, 1999; Saffran, 2002; Saffran, Aslin & Newport, 1996; Saffran, Johnson, Aslin & Newport, 1999). It is likely that all languages in both modalities evolve in such a way that they are salient and learnable to humans (Christiansen & Dale, 2001; Hildebrandt & Corina, 2002; Saffran, 2002). Indeed, it may be this inherent perceptual salience of language that promotes further processing of the signal, and biases infants towards more sophisticated cognitive representations of it (see Banks & Ginsburg, 1983; Jusczyk, 1997). Finally, we have promising data to suggest that this broad interest may narrow, such that by 10 months, infants may no longer appreciate the linguistic qualities of a language in an unfamiliar modality.

[3] A powerful way to tease apart the possible contributions of linguistic specialization and social cognition would be to test infants whose native language is ASL. We might expect that infants who are exposed to ASL from birth from deaf, signing, parents may not lose interest in ASL over non-linguistic biological stimuli, despite an increased ability to parse and sequence pantomimed action. We are in the process of collecting data from this unique population and preliminary findings support this predicted pattern (Krentz, Klarman, Brinkley, Kuhl & Corina, 2007).

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References

Aslin, R., Saffran, J., & Newport, E. (1998). Computation of conditional probability statistics by 8-month-old infants. *Psychological Science*, **27**, 197–206.

Baker-Shenk, C., & Cokely, D. (1980). *American Sign Language: A teacher's resource text on grammar and culture*. Washington, DC: Gallaudet University Press.

Baldwin, D.A., Baird, J.A., Saylor, M.M., & Clark, M.A. (2001). Infants parse dynamic action. *Child Development*, **72** (3), 708–717.

Banks, M.S., & Ginsburg, A.P. (1985). Infant visual preferences: a review and new theoretical treatment. *Advances in Child Development and Behavior*, **19**, 207–246.

Battison, R. (1974). Phonological deletion in American Sign Language. *Sign Language Studies*, **3** (5), 1–19.

Battison, R. (1978). *Lexical borrowing in American Sign Language*. Silver Spring, MD: Linstok Press.

Bertenthal, B.I., Profitt, D.R., & Cutting, J. (1984). Infant sensitivity to figural coherence in biomechanical motion. *Journal of Experimental Child Psychology*, **37**, 213–230.

Best, C.T., McRoberts, G.W., & Sithole, N.M. (1988). Examination of the perceptual re-organization for speech contrasts: Zulu click discrimination by English-speaking adults and infants. *Journal of Experimental Psychology: Human Perception and Performance*, **14**, 345–360.

Bosch, L., & Sebastian-Galles, N. (2003). Simultaneous bilingualism and the perception of a language-specific vowel contrast in the first year of life. *Language and Speech*, **46** (2–3), 217–243.

Bosworth, R.G., Wright, C.E., Bartlett, M.S., Corina, D., & Dobkins, K.R., (2000). Characterization of visual properties of spatial frequency and speed in American Sign Language. *TISLR Proceedings*. Washington, DC: Signum Press.

Christiansen, M.H., & Dale, R.A.C. (2001). Integrating distributional, prosodic, and phonological information in a connectionist model of language acquisition. In *Proceedings of the 23rd Annual Conference of the Cognitive Science Society* (pp. 220–228). Mahwah, NJ: Lawrence Erlbaum.

Colombo, J., & Bundy, R.S. (1981). A method for the measurement of infant auditory selectivity. *Infant Behavior and Development*, **4**, 219–223.

DeCasper, A.J., Lecanuet, J.P., Busnel, M., & Granier-Deferre, C. (1994). Fetal reactions to recurrent maternal speech. *Infant Behavior and Development*, **17** (2), 159–164.

Eimas, P.D. (1975). Auditory and phonetic coding of the cues for speech: discrimination of the [r–l] distinction by young infants. *Perception and Psychophysics*, **18**, 341–347.

Fiser, J., & Aslin, R.N. (2001). Unsupervised statistical learning of higher order spatial structure from visual scenes. *Psychological Science*, **12** (6), 499–504.

Fox, R., & McDaniel, C. (1982). The perception of biological motion by human infants. *Science*, **218** (29), 486–487.

Glenn, S.M., Cunningham, C.C., & Joyce, P.F. (1981). A study of auditory preferences in non-handicapped infants and infants with Down's Syndrome. *Child Development*, **52**, 1303–1307.

Gould, J.L., & Marler, P. (1987). Learning by instinct. *Scientific American*, **256**, 62–73.

Hains, S.M.J., & Muir, D.W. (1996). Infant sensitivity to adult eye direction information. *Child Development*, **67**, 1940–1951.

Hildebrandt, U.C. (now Krentz, U.C.) (2003). An investigation of hearing infants' preference for American Sign Language and non-linguistic biological motion. *Dissertation Abstracts International: Section B: The Sciences & Engineering*, **64** (5-B), 2417.

Hildebrandt, U.C., & Corina, D. (2002). Phonological similarity in American Sign Language. *Language and Cognitive Processes*, **17** (6), 593–612.

Jusczyk, P.W. (1997). *The discovery of spoken language*. Cambridge, MA: The MIT Press.

Jusczyk, P.W., & Bertoncini, J. (1988). Viewing the development of speech perception as an innately guided learning process. *Language and Speech*, **31**, 217–238.

Jusczyk, P.W., Cutler, A., & Redanz, N. (1993). Preference for the predominant stress pattern of English words. *Child Development*, **64**, 675–687.

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

Jusczyk, P.W., Luce, P.A., & Charles-Luce, J. (1994). Infants' sensitivity to phonotactic patterns in the native language. *Journal of Memory and Language*, **33**, 630–645.

Kirkham, N.Z. (2003). The predictable nature of the perceptual environment as a guide for learning in infancy. *Dissertation Abstracts International: Section B: The Sciences and Engineering*, **64** (2-B), 984.

Kirkham, N.Z., Slemmer, J.A., & Johnson, S.P. (2002). Visual statistical learning in infancy: evidence for domain general learning mechanism. *Cognition*, **83**, 35–42.

Klima, E., & Bellugi, U. (1979). *The signs of language*. Cambridge, MA: Harvard University Press.

Krentz, U.C., Klarman, L., Brinkley, J., Kuhl, P.K., & Corina, D.P. (2007). Deaf and hearing infants' preference for American Sign Language and non-linguistic biological motion: The role of language exposure. Manuscript in preparation.

Kuhl, P.K., Stevens, E., Hayashi, A., Deguchi, T., Kiritani, S., & Iverson, P. (2006). Infants show a facilitation effect for native language phonetic perception between 6 and 12 months. *Developmental Science*, **9** (2), F13–F21.

Kuhl, P.K., Williams, K.A., Lacerda, F., Stevens, K.N., & Lindblom, B. (1992). Linguistic experience alters phonetic perception in infants by 6 months of age. *Science*, **255** (5044), 606–608.

Lasky, R.E., & Klein, R.E. (1979). The reactions of five-month-olds to eye contact of the mother and a stranger. *Merrill-Palmer Quarterly*, **25**, 163–170.

Liddell, S.K. (1977). An investigation into the syntactic structure of American Sign Language. Doctoral Dissertation, University of California, San Diego.

McNeill, D. (2000). *Language and gesture: Language, culture and cognition* (Vol. 2 of S.C. Levinson (Ed.), *Language,*

culture and cognition). Cambridge: Cambridge University Press.
Marcus, G.F., Vijayan, S., Bandi Rao, S.B, & Vishton, P.M. (1999). Rule learning by seven-month-old infants. *Science*, **283**, 77–80.
Mehler, J., Jusczyk, P.W., Lambertz, G., Halsted, N., Bertoncini, J., & Amiel-Tison, C. (1988). A precursor of language acquisition in young infants. *Cognition*, **29**, 144–178.
Meier, R.P. (1991). Language acquisition by deaf children. *American Scientist*, **79**, 60–70.
Meier, R.P., & Newport, E.L. (1990). Out of the hands of babes: on a possible sign advantage in language acquisition. *Language*, **66**, 1–23.
Namy, L.L. (2001). What's in a name when it isn't a word? 17-month-olds' mapping on nonverbal symbols to object categories. *Infancy*, **2** (1), 73–86.
Namy, L.L., Campbell, A.L., & Tomasello, M. (2004). The changing role of iconicity in non-verbal symbol learning: a U-shaped trajectory in the acquisition of arbitrary gestures. *Journal of Cognition and Development*, **5** (1), 37–57.
Namy, L.L., & Waxman, S.R. (1998). Words and gestures: infants' interpretations of different forms of symbolic reference. *Child Development*, **69** (2), 295–308.
Nazzi, T., Bertoncini, J., & Mehler, J. (1998). Language discrimination by newborns: towards an understanding of the role of rhythm. *Journal of Experimental Psychology: Human Perception and Performance*, **24** (3), 756–766.
Nazzi, T., Kelmer Nelson, D.G., Jusczyk, P.W., & Jusczyk, A.M. (2000). Six-month-olds' detection of clauses embedded in continuous speech: effects of prosodic well-formedness. *Infancy*, **1** (1), 123–147.
Newport, E.L., & Meier, R.P. (1985). The acquisition of American Sign Language. In D. Slobin (Ed.), *The cross-linguistic study of language acquisition. Vol. 1: The data*. Hillsdale, NJ: Lawrence Erlbaum Associates.
Petitto, L.A., Holowka, S., Sergio, L.E., Levy, B., & Ostra, D.J. (2004). Baby hands that move to the rhythm of language: hearing babies acquiring sign languages babble silently on the hands. *Cognition*, **93** (1), 43–73.
Petitto, L.A., & Marentette, P.F. (1991). Babbling in the manual mode: evidence for the ontongeny of language. *Science*, **251**, 1493–1496.
Poizner, H. (1983). Perception of movement in American Sign Language: effects of linguistic structure and linguistic experience. *Perception and Psychophysics*, **33** (3), 215–231.
Rivera-Gaxiola, M., Sliva-Pereya, J., & Kuhl, P.K. (2005). Brain potentials to native and non-native speech contrasts in 7- and 11-month-old American infants. *Developmental Science*, **8** (2), 162–172.
Saffran, J. (2002). Constraints on statistical language learning. *Journal of Memory and Language*, **47**, 172–196.
Saffran, J., Aslin, R.N., & Newport, E.L. (1996). Statistical learning by 8-month-old infants. *Science*, **274**, 1926–1928.
Saffran, J., Johnson, E., Aslin, R., & Newport, E. (1999). Statistical learning of tone sequences by human infants and adults. *Cognition*, **70**, 27–52.
Sebastian-Galles, N., & Bosch, L. (2002). Building phonotactic knowledge in bilinguals: role of early exposure. *Journal of Experimental Psychology: Human Perception and Performance*, **28** (4), 974–989.
Stokoe, W.C. (1999). Gesture to sign (language). In D. McNeill, *Gesture and language* (pp. 388–399). Cambridge: Cambridge University Press.
Stokoe, W.C., Casterline, D.C., & Croninberg, C.G. (1965). *A dictionary of American Sign Language on linguistic principles*. Silver Spring, MD: Linstok Press.
Symons, L.A., Hains, S.M., & Muir, D. (1998). Look at me: five-month-old infants' sensitivity to very small deviations in eye-gaze during social interactions. *Infant Behavior and Development*, **21** (3), 531–536.
Trehub, S.E. (1976). The discrimination of foreign speech contrasts by infants and adults. *Child Development*, **47**, 466–472.
Turk, A.E., Jusczyk, P.W., & Gerken, L.A. (1995). Do English-learning infants use syllable weight to determine stress? *Language and Speech*, **38**, 143–158.
Valli, C., & Lucas, C. (1996). *Linguistics of American Sign Language*. Cambridge, MA: Harvard University Press.
Vecera, S.P., & Johnson, M.H. (1995). Gaze detection and the cortical processing of faces: evidence from infants and adults. *Visual Cognition*, **2**, 59–87.
Vouloumanos, A., & Werker, J.F. (2004). Tuned to the signal: the privileged status of speech for young infants. *Developmental Science*, **7** (3), 270–276.
Werker, J.F., Gilbert, H.V., Humphrey, K., & Tees, R.C. (1981). Developmental aspects of cross-language speech perception. *Child Development*, **52**, 349–355.
Werker, J.F., & Tees, R.C. (1984). Cross-language speech perception: evidence for perceptual reorganization during the first year of life. *Infant Behavior and Development*, **7**, 49–63.
Zeifman, D., Delaney, S., & Blass, E.M. (1996). Sweet taste, looking, and calm in 2- and 4-week-old infants: the eyes have it. *Developmental Psychology*, **6**, 1090–1099.

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