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Sign Language Promotes Object Categorization in Young Hearing Infants

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ABSTRACT

Language has a powerful effect on the human mind: during the first year of life, spoken language boosts core cognitive capacities including object categorization. Here the researchers ask: Does signed language exert the same cognitive advantage? They asked whether hearing, 4- to 6-month old infants will learn a novel category if exemplars are labeled in American Sign Language. Results indicate that signed language supports object categorization for 4-month-old infants, but not for 5- and 6-month-olds. Additionally, this developmental pattern was not observed when category exemplars were paired with only pointing and eye gaze, suggesting that the cognitive boost of seeing sign language is specific to language, and not just about the presence of communicative cues. These findings underscore the critical role of language on learning in early development and emphasize the influence of infants' own language development on how they approach learning from novel communicative signals.

Sign Language Promotes Object Categorization in Young Hearing Infants

It is well established that language is fundamentally interwoven with human cognition from early in development. Well before infants begin to produce words themselves, hearing language - specifically labels, supports essential cognitive processes (Balaban & Waxman, 1997; Feigenson & Halberda, 2008; Ferguson & Lew-Williams, 2016; Ferry, Hespos, & Waxman, 2010; Fulkerson & Waxman, 2007; Xu, 2002). Language exerts powerful effects on cognition throughout the lifespan, and this early emerging link to cognition emphasizes its importance for cognitive development.

One critical example involves the process of object categorization. Infants who see a series of exemplars from a single category (a series of fish) paired with labels ('look at the modi") come to learn the category - they subsequently differentiate between a novel exemplar from the familiar category (a brand-new fish) and a novel exemplar from a novel category (a dinosaur) (Balaban & Waxman, 1997; Ferry et al., 2010; Fulkerson & Waxman, 2007). Importantly, not all sounds link to learning in this way – non-linguistic sounds such as sine-wave tones or backward speech do not support category learning for infants (Balaban & Waxman, 1997; Ferry, Hespos, & Waxman, 2013; Ferry et al., 2010; Fulkerson & Waxman, 2007). Nevertheless, other auditory signals, including non-native languages that are similar to their native language (German, for English Speaking infants) as well as non-human primate vocalizations (lemur calls), also support categorization for very young infants (Ferry, Hespos, & Waxman, 2013; Perszyk & Waxman, 2019). Together, the previous work suggests that there is a range of initially privileged signals that infants are willing to link to concepts in the world.

An important caveat this previous work is that it has focused exclusively on the role of *auditory* signals on infant category learning. And this raises an important open question: Are

these effects specific to the *auditory* modality, or might there be a more abstract representation of the types of signals that infants are willing to link to cognition? In other words, might the benefit of language on learning extend to signals in the visual modality as well? Here, we address this open question by asking whether hearing infants who have never before seen sign language will accept American Sign Language as a category marker, just as they do for spoken language.

American Sign Language (ASL) is a naturally occurring visual-manual language which shares all of the same linguistic features as spoken languages (Klima & Bellugi, 1979). Hearing or deaf infants exposed to sign language from birth reach the same linguistic milestones as hearing infants exposed to spoken language (Conlin, Mirus, Mauk, & Meier, 2000; Meier & Newport, 1990; Newport & Meier, 1985; Petitto & Marentette, 1991; Petitto, Holowka, Sergio, & Levy, 2004). This underscores the idea that infants are born primed to learn language, regardless of whether than language is spoken or signed.

Infants' initial openness to the communicative and linguistic potential of sign language persists for several months, even in the absence of exposure. At six months, hearing infants prefer sign language over pantomime (Krentz & Corina, 2008), similar to infants' known preference for spoken language over non-linguistic sounds (Vouloumanos & Werker, 2004) (Voloumanos & Werker, 2004). They also demonstrate sensitivity to linguistic features of sign language such as categorical perception (Baker, Idsardi, Golinkoff, & Petitto, 2005; Palmer, Fais, Golinkoff, & Werker, 2012) and the feature of sonoroity (Stone, Petitto, & Bosworth, 2018). These initial sensitivities, which are seen at 4-6 months, go away as hearing infants approach one year, suggesting that they lose their initial sensitivities to manual language as they tune specifically to their native language (spoken language).

Infants' preference for and sensitivity to sign language may map on to their inclination to view the signal as a potential link to categorization. But it is possible that whether or not hearing infants can process sign language as *language*, they may, at some point, learn that it is not *their* language, and therefore will not link it to learning. In fact, this seems to be the pattern observed with infants' approach to lemur calls. At 3-4 months infants are precocious learners, and hearing, English speaking infants show a learning boost from not only their native language, but lemur calls as well (Ferry et al., 2013). However, by 6 months, the benefit of lemur calls on categorization disappears, leaving only native language. Presumably, this change in infants' willingness to accept foreign signals as category markers has to do with their increasing exposure and tuning to their native language: as they refine and gain more experience with their native language, they tune out the links between foreign signals and categorization. An open question we ask here, is whether infants' tuning to their native language may also influence their openness to unfamiliar languages in the manual modality. This underscores the need to ask whether any initial inclination to accept sign language as a category marker may change with development, and may *decline* with age.

To test whether or not infants ever accept sign language as part of the range of signals that initially link to learning, we build upon previous work and use a design that presents category exemplars during familiarization, and novel exemplars - one from the familiar category and one from a novel category - at test. We chose to test infants within the range of 4 to 6 months, because we already have strong evidence that infants throughout this age range can succeed in this task, if category exemplars presented during familiarization are paired with infants' native language (spoken language). This age range will also allow us to determine whether there is developmental change in how infants approach the link between sign language

and categorization. By testing infants from 4 through 6 months, we will be able to determine whether the same narrowing of initially privileged signals that limits their openness to non-human vocalizations extends to sign language.

Finally, if we find that sign language supports object categorization, just like spoken language, then it begs one final question – it is truly about the *language*, or might the effects be driven exclusively by the presence of a communicating agent? If it is the case that non-linguistic pedagogical or communicative cues alone are driving learning, then we should expect to see that these cues, without the linguistic signal, should have the same effects. In fact, theories of natural pedagogy predict that pointing and eye gaze alone are markers of generalizable, kind-based inferences (Csibra & Gergely, 2009). Therefore, we also include a Point & Eye Gaze condition to test for this possibility.

Method

Participants

110 (final sample will include 120) full term infants were included in the current analysis: 39 four-month-olds (range 3.98-4.97, M=4.4, 24 females), 40 five-month-olds (range 5.0-5.95, M=5.4, 17 females) and 31 six-month-olds (range 6.0-7.01, M=6.6, 13 females). Within each age group half of the infants were randomly assigned to the Sign Language condition and half to the Point & Eye Gaze condition. An additional 16 infants (10 in Sign Language condition, 6 in Look and Point condition) were tested but then excluded for the following reasons: 7 infants (3 in Sign Language, 4 in Point & Eye Gaze) did not finish the study due to fussiness. Nine infants (7 in Sign Language, 2 in Point & Eye Gaze) were excluded due to computer malfunction. An additional 4 infants tested were replaced because of low attention during familiarization (>2 SD

from mean). Two infants tested were replaced for only looking at one image during the test phase. Families were given a book and t-shirt or $10 for participation. Participants were predominantly from white middle class families.

Stimuli

Familiarization

Familiarization video stimuli were developed by combining line-drawn images of dinosaurs or fish together with a video of a woman communicating. For each trial, a single animal from one of two categories (fish, dinosaur) appeared on the right or left bottom side of the screen. The category exemplar appeared alone for 2 seconds, after which a woman appeared in the top center. She clapped three times, and then glanced back and forth between the image and the camera. In the Sign Language condition she signed the phrase "LOOK MODI YOU SEE MODI?" in infant directed American Sign Language. In the Pointing & Eye Gaze condition the woman pointed and looked at the object. The number of gaze shifts and the total amount of time pointing was matched across the two conditions. This communicative episode occurred twice during each familiarization trial. Between instances of the communicative episode, the woman faded out of view, leaving the category stimulus to appear by itself. While the stimulus was alone, an audio file playing three claps occurred to ensure infant engagement. Each familiarization trial lasted 24 seconds.

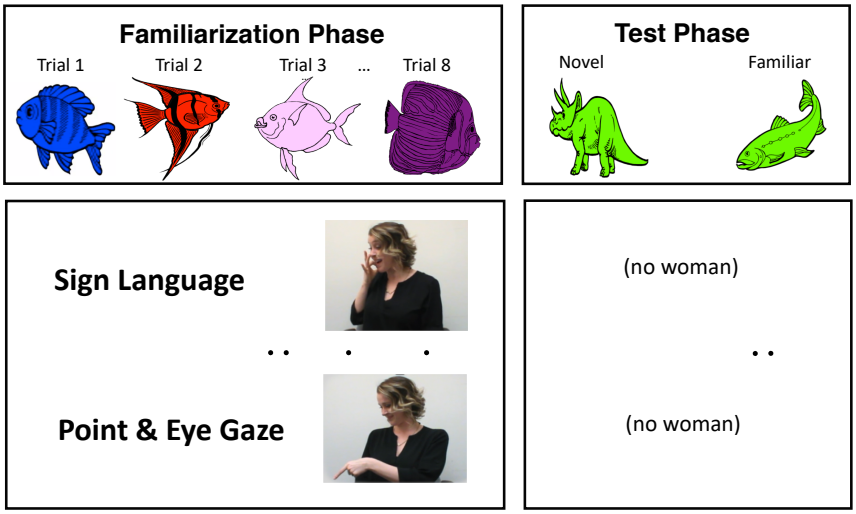
Test

Test videos presented two novel images side by side: one exemplar from the familiar category and one exemplar from the other (novel) category in silence, with no woman present.

Test videos lasted 20 seconds. See Figure 1 for examples of the stimuli used in Familiarization and test phases.

Figure 1

Examples of stimuli and design



Procedure

Infants sat on a caregiver's lap facing a large screen. A video camera hidden below the screen recoded infant looking behavior. Caregivers were given opaque glasses and were instructed not to talk to their infants or influence their attention in any way. Infants were presented with a familiarization phase followed by a test phase. The familiarization phase included eight trials showing eight distinct exemplars from a single category – either fish or dinosaurs. The test phase followed the familiarization phase. The side of first exemplar (right/left), stimuli type (fish, dinosaur), and location of novel and familiar category members at test (right/left) were counterbalanced, resulting in either unique orders.

Coding and Analysis

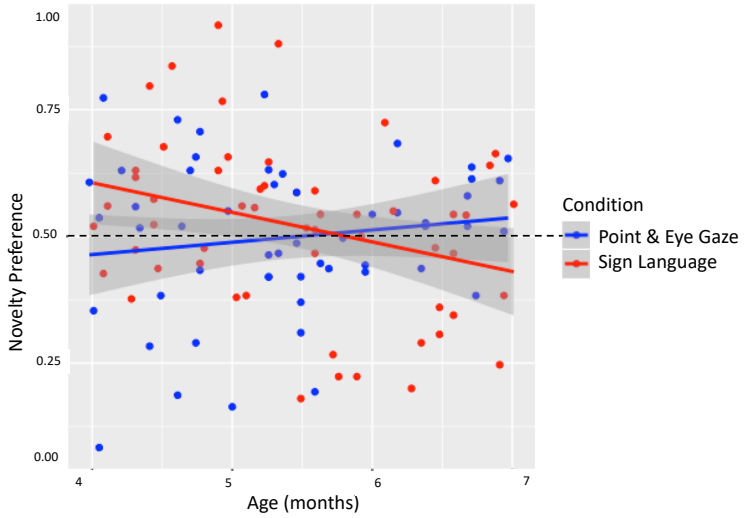
Videos of infant attention were coded frame-by-frame using the program supercoder, by trained coders blind to the hypothesis. For familiarization trials, coders determined whether infants were looking to the woman, the objects, or were off screen. For test trials they coded whether infants were looking to the right or left test image. As in previous work with this paradigm (Ferguson & Waxman, 2016; A. L. Ferry et al., 2013; Alissa L. Ferry et al., 2010; Perszyk & Waxman, 2016, 2019), a novelty preference score was calculated for each infant (accumulated time looking toward the novel test object/accumulated time looking toward both the novel and familiar test objects) based on infants' first 10 s of looking during test. All statistical tests reported used arcsine root transformations of novelty preference, however figures and text describe raw means for clarity. Preliminary analyses revealed no reliable effects of test image position, familiarization category, or participant gender (all p's > .3), further analyses collapsed across these factors.

Results

The main analysis concerned whether there were differences in test novelty preference as a function of both condition (Point & Eye Gaze, Sign Language) and infant age. A condition by age analysis revealed a significant interaction ($F(1, 107) = 6.05$, $p = 0.02$) (See Figure 2). Within the Sign Language condition there was a significant negative effect of age on novelty preference ($B = 0.06$, $SE = 0.03$, $t = 2.42$, $p = 0.02$), whereas there was no effect of age in the Point and Eye Gaze Condition ($B = 0.02$, $SE = 0.03$, $t = 1.06$, $p = 0.29$).

Figure 2

Infant Novelty preference by age for both Conditions. Dotted line indicates chance performance



To further explore the effect of age on Novelty Preference in the Sign Language condition, infants were grouped into age bins (4.0-4.99, 5.0-5.99, 6.0-6.99). Four-month-old infants in the Sign Language condition were significantly above chance (M=0.60, SD = 0.15, t(19) = 3.01, *p* =0.007), demonstrating that, as a group, 4-month-olds successfully learned the category. This was not the case for 5- and 6-month-olds: 5-month-olds (M=0.48, SD = 0.17), t(19) =0.32, p=.75); 6-month-olds (M=0.46, SD = 0.16), t(16) = 0.93, p=.36). Four-month-old's average novelty preference was also significantly higher than both the 5- and 6-month-olds: 4 vs. 5: t(38) =2.24, p-value = 0.03; 4 vs 6: t(35) = 2.72, p = .009.

The effect of Sign Language on categorization cannot be attributed to overall attention during familiarization. There was no difference in attention between conditions during familiarization (*p*= 0.44), nor interaction with age (*p*= 0.94), and attention during familiarization did not predict novelty preference at test (*p*=.70).

Discussion

In this study, we examined whether infants' expectations that language links to learning extends beyond the auditory modality, and includes signals in the manual modality as well. We presented a series of category exemplars paired with ASL labels to hearing 4-6 month-old infants never before exposed to sign language. Four-month-olds successfully learned the category, but five and six-month-old infants did not. Together, with previous research (Balaban & Waxman, 1997; Alissa L. Ferry et al., 2010; Fulkerson & Waxman, 2007) this demonstrates two keys points. (1) Initially, infants are willing to accept *both* spoken and signed language as category markers. (2) The effects of sign language on category learning change with age. As hearing infants accrue more experience with their native language, sign language, they seem to be tuning out the link between foreign languages in the manual modality and learning processes. These findings underscore the critical role of language on learning in early development and emphasize the influence of infants' own language development on how they approach learning from novel communicative signals.

Although 5 and 6-month-olds did not show a category learning boost from signed labels, we do not think that they simply ignored the signer. Attention during the familiarization portion did not differ by age, suggesting that 5 and 6-month-olds were no less likely to attend to the familiarization compared to the 4-month-olds. Furthermore, previous research suggests that at six months hearing infants still prefer sign language to pantomime (Krentz & Corina, 2008) and are still sensitive to linguistic features of American sign language (Stone et al., 2018). Therefore, we might assume that the older infants in the age range understood that the woman was communicating with language. But whereas the 4-month-olds were willing to link this foreign

manual language to learning, 5 and 6-month-olds have narrowed their expectations, and are now reserving the link specifically to their native language, spoken language.

Finally, the effects of Sign Language on category learning at 4-months cannot be attributed to the presence of communicative cues, like pointing and eye-gaze, alone. Results from the Point & Eye Gaze condition were distinct from that of the Sign Language Condition. This suggests that the effects within the sign language condition are likely attributable to the presence of the linguistic signal itself.

These results demonstrate, for the first time, that the link between language and cognition in early infancy is not about spoken language, but rather includes language in a more abstract sense. These findings broaden what we know about infants' initial expectations about what counts as "language" and the functions of different types of language on learning.

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