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Social gating and pedagogy: Mechanisms for learning and implications for robotics

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ABSTRACT

It seems self-evident that human responsiveness to social input enhances learning, yet the details of the social forces at play are only beginning to come into focus. Recent research on language and cognitive development in preschoolers and infants illuminates mechanisms such as social gating and natural pedagogy, and specific ways in which they benefit learning. We review such advances and consider implications of this research for designing robotic systems that can harness the power of social forces for learning.

Open a text on children's development and one is almost certain to find, somewhere, William James' famous "blooming, buzzing confusion" (James, 1890, p. 462) attribution regarding infants' phenomenological experience. This is almost invariably followed by a statement that in some form denies the validity of James' way of conceiving of early experience, given the abundant evidence now documenting even tiny infants' skills for organized processing of the complex flow of sensory input. One among these skills – perhaps an especially powerful and heuristically valuable skill – is rarely mentioned in this context, however. This is the skill of sociality. Infants' experience is saturated with social interactions and social cues that have the potential to facilitate emotional, cognitive, and linguistic development. Fortunately for their learning's sake, infants typically are intensely responsive to all this social input. For example, face-like forms hold special fascination for them from birth (e.g., Johnson, Dzurawiec, Ellis, & Morton, 1991), and they are attuned to being the target of another's attention from at least as young as 3 months of age (e.g., Striano & Stahl, 2005). In this article we consider certain specific ways in which social cues help to organize learning in infancy and childhood. One of these is a phenomenon called "social gating" (e.g., Kuhl, 2007; Meltzoff, Kuhl, Movellan, & Sejnowski, 2009), in which learning is thought to be enhanced for information couched within social interaction. Another is the directly instructional; that is, pedagogy. Pedagogy appears to alter infants' and children's processing of events, leading to a learning trajectory that is both enhanced in certain respects and constrained in others (e.g., Bonawitz et al., 2009; Csibra & Gergely, 2006; Sage & Baldwin, unpublished manuscript; Topal, Gergely, Miklosi, Erdohegyi, & Csibra, 2008). Our goals for the article are twofold: first, to delineate theoretical differences between social gating and pedagogy, and in this context examine evidence currently available that speaks to the roles that social gating and pedagogy each play in early learning. Second, we will consider implications of such evidence for designing robotic systems with heightened social sensitivity.

1. Social Gating

Social gating – the idea that learners are especially attuned to information presented in a social context – potentially has broad implications for knowledge acquisition generally. However, ideas regarding the phenomenon of social gating have emerged in the context of accounting for language learning. Kuhl and colleagues articulated the hypothesis that linguistic information presented within a social context is particularly appealing to the learning system of the infant. This notion that social input widens the gate to detection and encoding of linguistic information seems plausible for several reasons. Language is a fundamental social activity, and it thus would not be surprising were language learning to be enhanced by social input. And of course, as we alluded to earlier, even tiny infants are known to be highly responsive to the social, preferring face-like stimuli, orienting to contingent interaction, displaying early skills for discriminating facial expressions of emotion, and the like (e.g., Hains & Muir, 1996; Johnson et al., 1991; Nelson, 1987). Language that accompanies salient social behavior might thus be expected to be especially appealing and enhanced in learnability. Moreover, social gating is known to operate in other species, such as in some bird species' acquisition of song. Similar to humans, there is thought to be a critical period for song learning in birds — around 50 days. Baptista and Petrinovich (1984) placed sparrows older than 50 days in cages where they could

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interact with a social tutor of their own subspecies, a different subspecies, or an alien species. All sparrows learned the song from their social tutor, suggesting that a rich social environment can extend the sensitive period for song learning in birds. Baptista and Petrinovich (1986) introduced alien songs to sparrows on videotape or via a live tutor. The sparrows only learned these songs when exposed to a live tutor. Eales (1989) determined that zebra finches need visual interaction with a tutor bird in order to learn a song. Zebra finches only exposed to tutor sounds did not learn the songs. In addition, Pepperberg (1994) exposed parrots to either audiotaped tutoring, videotaped tutoring, or live human tutors. Pepperberg proposed that input needed to be referential, contextually applicable, and interactive. In support of this notion, the parrots only showed learning from live tutors.

Kuhl and colleagues recently provided initial evidence documenting social gating in human language acquisition. Kuhl, Tsao, and Liu (2003) examined whether social factors affect 9-month-old infants' ability to learn from first-time exposure to a foreign language. Prior research had clarified that infants younger than about 6–8 months of age show categorical discrimination for the majority of consonant contrasts, regardless of whether these contrasts are part of the phonological repertoire of their native language (Werker & Lalonde, 1988). But, between 6 and 12 months of age, this ability undergoes marked reorganization, whereby infants shift to displaying categorical discrimination only for consonant contrasts occurring within their native language. Kuhl and colleagues investigated whether exposing 9-month-old infants to non-native language input might alter the course of this typical developmental pattern in phonological acquisition. They conducted two experiments in this regard. First, they exposed English-learning American infants to either native Mandarin Chinese speakers or English speakers across twelve 25 minute sessions. Subsequently, a head-turn conditioning procedure was utilized to test infants' Mandarin speech discrimination. Relative to the infants in the English-exposed control group, infants exposed to Mandarin speakers showed less of a decline in categorical discrimination of Mandarin contrasts. In fact, these American infants exposed to Mandarin Chinese performed at comparable levels to infants in Taiwan. In the second experiment, the social context was manipulated. A new group of infants was exposed to either audiovisual or audio-only recordings of the same interactions with Mandarin speakers that infants in the prior experiment had experienced. Strikingly, however, infants receiving Mandarin input in this manner – stripped of the directly social – displayed the predictable decline in categorical discrimination for the Mandarin contrasts tested. Thus, infants' phonetic learning was affected only when they were engaged by a live speaker, supporting the notion that social interaction enhances infants' linguistic processing.

Although the Kuhl et al. (2003) research documents social gating in the context of phonological acquisition, the precise manner in which it operated is not yet clear. Social interaction might have benefitted infants' language learning for a variety of reasons. Kuhl (2007) points to two likely possibilities — attention/arousal and information. Indeed, infants attended significantly more to the live speaker than to a televised version of the same speaker in their experiment, and observations of the infants during the sessions also suggested an increase in arousal during social interactions — these infants showed excitement to the speaker, watched the door for her arrival, and the like. Perhaps increased attention and arousal lead infants to be more likely to encode linguistic information, or to encode it in higher-fidelity fashion.

Other research provides evidence that helps to illuminate how social gating may operate in the language domain. Kuhl (2007) describes two characteristics of a social agent that might make them unique, and thus highly salient — interactivity and contingency. As it turns out, contingent behavior is known to affect infants' tendency to vocalize (e.g., Bloom & Esposito, 1975). Bloom, Russell, and Wassenberg (1987) engaged infants in either a conversational turn-taking interaction with an adult or to an adult who was randomly responsive. They then counted infant vocalizations, including syllabic, speech-like sounds and nonspeech-like, vocalic sounds. Contingent, interactive, responsive turn-taking led infants to produce a higher ratio of syllabic versus vocalic sounds. This research of course does not clarify what infants may or may not have learned via their contingency-induced increase in syllabic vocalizations, and thus the findings do not directly illuminate social gating effects on language learning. They clearly suggest, however, that the interactive, contingent quality characteristic of social interaction is likely an influential aspect of the social gating phenomenon.

A finding reminiscent of social gating has also emerged in another language learning arena — the domain of word learning. For many years, word learning was typically regarded as a largely associative enterprise: it was thought that the learner simply needs to associate a given word with an appropriate referent for learning to be achieved (e.g., Whitehurst, Kedesdy, & White, 1982). This simple associative account is subject to serious problems, however (e.g., Markman, 1989; Quine, 1960). One such problem is that infants hear any given word in the presence of a multitude of things, and they also hear many different words in the presence of any particular thing. For principles of association to carry the day in language learning, massive amounts of input would be needed to sort out the relevant word-to-world covariates. Interestingly, in contrast to this prediction, by 18 months of age word learning is typically very rapid — one-trial learning is not uncommon, for example (e.g., Nelson & Bonvillian, 1973). A sizable body of research demonstrates that infants' skill at capitalizing on social cues is part of the explanation for how they solve the associative complexities with such ease and rapidity (e.g., Akhtar & Tomasello, 2000; Baldwin, 2000). Infants actively monitor cues to reference that speaker's display – such as gaze direction, body posture, gestures, and the like – and rely on these cues to guide their inferences about what words mean. In several studies (Baldwin, 1991, 1993), for example, infants as young as 16–17 months have shown the ability to resist linking a novel label with an object they were actually attending to at the time they heard the label (contrary to what an associative account would predict), because they subsequently discovered that the speaker's focus of attention (as evidenced by gaze direction, voice direction, and body posture) was directed toward a different object. Thus this is another case in which infants' sensitivity to social input enhances their language learning. A related body of research confirms this link in a different manner: infants who are especially responsive to social cues such as gaze direction and pointing gestures acquire vocabulary at a faster pace (e.g., Brooks & Meltzoff, 2008; Mundy et al., 2007).

One set of studies in the word learning domain seems to document an effect especially akin to social gating (Baldwin et al., 1996). In these studies, infants were disinclined to establish a new word-object link if social cues were lacking. In two experimental conditions, they heard a novel label while gazing at a novel object. Where the conditions differed was in whether social cues were available to clarify the speaker's referential intent. In one condition, such cues were available — the speaker sat next to infants and gazed in infants' direction while producing the novel label. In the other condition, the speaker was hidden behind a rice paper (and hence sound conducting) screen, and thus social cues were unavailable to clarify whether she intended to refer to the object infants' were gazing at. What made the condition contrast interesting in this research was that, in purely associative terms, the learning potential of both conditions was identical: infants heard a novel label the same number of times and at equivalent volume while gazing at a novel object. It was thus striking that, in a subsequent comprehension test, they displayed