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Physiological and behavioral correlates of babies' social engagement with robot and virtual human artificial intelligence agents

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Exposure to the patterns of natural language in early life—especially in ways that are rich in socially contingent interaction and conversation—is among the most powerful facilitators of the human language acquisition process (Petitto et al., 2016). Adults' infant-directed language (e.g., simple rhythmic nursery rhymes), communicated in social interactions with joint attention, supports babies' biological predisposition to language development in the first year of life (Brook & Meltzoff, 2015). Yet many babies have minimal language exposure in early life that can have devastating consequences for their language learning and reading success—such as the deaf baby. With the aim to develop a learning tool for babies deprived of natural language input during sensitive periods in human development, we studied whether artificial intelligent agents (social robots and virtual humans) can serve as an augmentative communicative partner in early infancy. Using innovative thermal IR imaging technology, we recorded, imaged, and analyzed infants' emotional arousal and behavioral responses during social interactions with a robot, a virtual human, as compared with a real human. We asked whether babies exhibited physiological and behavioral responses of *joint attention* during these robot and virtual human interactions that were similar to or different from interactions with a real human. We hypothesized that if baby-artificial agent emotional arousal measures were observed to be similar to humans, then artificial

agents may potentially serve as a promising tool in the facilitation of language learning in infants with early-life minimal language exposure.

Methods: 10 hearing (nonsigning) infants (five 6-9mths; five 9-12mths). Following Meltzoff et al. (2010), after a brief familiarization period with the robot, infants participated in 6 episodes of robot head and eye gaze turning (left or right). Two screens were placed on each side of the robot, rendering it "looking at the screen" when it turned its head. Contiguous with the robot's gaze/head, both screens showed a nursery rhyme in ASL, performed alternatively by a virtual human or a real human (held constant: physical features and linguistic content).

Results: Time-locked/integrated infant behavior+thermal responses were analyzed (c.f., Merla, 2004; Manini et al., 2013). (1) Behavioral data showed babies followed robot gaze, yet the Thermal IR data added new insights: Significant increase in nasal-tip temperature was observed, indicative of suppression of the sympathetic activity and increase of parasympathetic/pro-social attentiveness. (2) Thermal responses w/virtual human vs real human revealed a phasic decrease of temperature likely associated with increased vigilance and higher cognitive attention processes (e.g., match-mismatch analysis).

Discussion: Robots and virtual humans may be effective as augmentative communicative partners for young babies. Novel here, we observed an integrated physiological and behavioral response of joint attention and social engagement during babies' interaction with the robot. Moreover, the virtual human elicited a peaked attentional arousal reaction, which may be indicative of linguistic stimuli detection and/or a "readiness to learn." The integration of physiological and behavioral responses provide insights that pave the way for groundbreaking applications in the field of artificial intelligence (Merla, 2014) and augmentative learning tools that promote language acquisition in young children.