Gaze-based minimal virtual reality paradigm for tracking developing sensitivity to dyadic interactions

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Part 1: Establishing the interactive learning advantage

In the first part of our project, we established that infants learn better from interactive than non-interactive agents, and that interactivity is an especially important cue for young learners. Using gaze-contingent eye-tracking, we designed a virtual agent that reacted (or did not react) to infants' gaze, and who taught them new words (Figure 1).

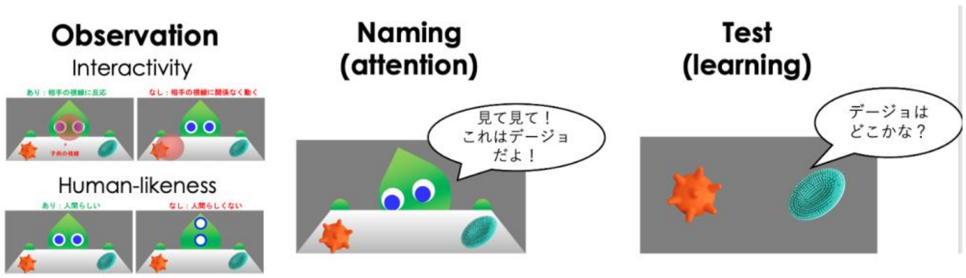

Figure 1. Virtual agent experimental design

Our findings show that young learners are able to learn these new words from the reactive agent, but no the non-reactive agent. We also established that this effect is especially pronounced around the age of 1 year and becomes less relevant with increasing age. Moreover, the interactivity of an agent was more important than another important cue to agency, the human-likeness of its face.

Part 2: Exploring the mechanisms underlying the interactive learning advantage

After establishing the importance of interactivity for language learning, the second part of our project sought to assess the mechanisms behind this interactive learning advantage. To this end, we developed a two-way gaze-contingent eye-tracking paradigm, in which infant and experimenter mutually track each other's eye movements in an abstract, screen-mediated setting.

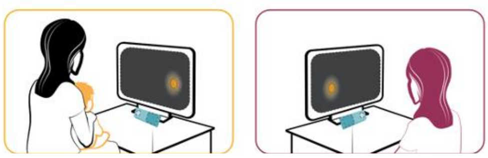

Figure 2. Two-way eyetracking experimental setup

This setup allows to measure the complex dynamics of interaction in real time, but in a tightly controlled experimental settings. We have established that infants can distinguish between interactive and non-interactive events based on the on-screen dynamics alone, and without any other cue to agency. Interactive events lead to more frequent and longer encounters, which is a potential mechanism underlying the social learning advantage. Future study will link these findings to language learning outcomes and provide important insights on the design of interactive AI agents for maximizing learning success.

Part 3: Improving remote online assessment of infant gaze

Our project fell into the pandemic, which prevented in-person testing for over a year. In this period, we worked on improving the methods surrounding automatic, web-cam based assessment of infant gaze. Different from lab studies, remote, at-home assessment of infant gaze is noisy, since environmental settings are less controlled, no expert experimenter is present, and gaze needs to be extracted from webcam data instead of a high-quality eye-tracking device. We therefore identified a wide range of sources of noise from infant webcam data, replicated these sources in an adult lab study, and identified which of these sources impacted the performance of automatic coding algorithms the most. Based on these insights, we are now developing ways to mitigate noise in infant online studies.

Future outlook

We are planning to expand this project on a multi-modal scale, by not only tracking gaze, but also gestures and vocal signals during child-adult interaction. This will provide theoretical insights into the mechanisms sustaining communication as well as a basis for designing infant-focused conversational AI agents.

Peer-reviewed journal publications

Issard, C., Tsuji, S., & Cristia, A. (2022). Infants' preference for speech is stable across the first year of life: Meta-analytic evidence. Accepted for publication in *Infancy*.

Phillipsen, A., Tsuji, S., & Nagai, Y. (2022). Quantifying developmental and individual differences in spontaneous drawing completion among children. *Frontiers in Psychology, 13,* 783446. doi: 10.3389/fpsyg.2022.783446

Philippsen, A. K., Tsuji, S., & Nagai, Y. (2022). Simulating developmental and individual differences of drawing behavior in children using a predictive-coding model. *Frontiers in Neurorobotics, 16*, 856184.

Havron, N., Lovcevic, I., Kee, M. Z. L., Chen, H., Chong, Y. S., Daniel, M., Broekman, B. F. P., & Tsuji, S. (2022). The effect of older sibling, postnatal maternal stress, and household factors on language development in two- to four-year-old children. *Developmental Psychology.* Developmental Psychology, 58(11), 2096–2113.

Zaadnoordijk, L., Buckler, H., Cusack, R., Tsuji, S., & Bergmann, C. (2021). A global perspective on testing infants online: introducing ManyBabies-AtHome. Frontiers in Psychology, 3811.

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