

## Fine-grained Analysis of Spatiotemporal Contingency in Infant-Caregiver Interaction

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Interaction between infants and caregivers is dynamic. They both send various signals to each other, which mutually shape the interaction. We aim at understanding such dynamic and microscopic structure of interaction by measuring information transfer between infants and caregivers. Their body movement and gaze direction are measured by a motion capture system (Figure 1) and the spatiotemporal contingency between them is calculated using transfer entropy (Schreiber, 2000). Transfer entropy is an information theoretic measure, which defines the degree of influence of time series data on other data. For example, if an infant follows the gaze direction of his/her caregiver, it is detected as higher transfer entropy from the caregiver's gaze to the infant's gaze. Improvement of their hand coordination can also be measured as an increase in transfer entropy between the two hands.

Adopting this measure, we assessed infants' development as well as caregivers' adaptation with respect to social contingency and body coordination. Participants were divided into two age groups: a younger age group for 6- to 8-month-old infants (M = 186.4 days, SD = 22.64, N = 16) and an older age group for 11- to 13-month-old infants (M = 359.5 days, SD = 16.72, N = 10). The caregivers were instructed to demonstrate a cup-nesting task to their infants while infants were watching the demonstration.

The first analysis focusing on the spatial aspect of interaction revealed higher transfer entropy for the older-age group than for the younger-age group. Older infants were more sensitive to social signal from caregivers (e.g., caregivers' gaze) whereas younger infants looked mainly at visually salient signals (e.g., the movement of caregivers' hand) (Figure 2, top). Older infants were also good at coordinating their hands than younger infants. Asymmetric transfer entropy between their hands (i.e., higher from the right to left hands than from the left to the right hands) indicates the development of their dominant hand. Of particular interest is co-development of caregivers. Caregivers increased the complexity of social contingency and body coordination as infants developed. Transfer entropy from infants to caregivers and within caregivers was significantly higher for the older-age group.

The second analysis focusing on the temporal aspect of interaction demonstrated the development of infants' turn taking. Comparing transfer entropy with different history length revealed a significant peak at a certain history length only for older infants but not for younger infants (Figure 2, bottom). Older infants responded to caregivers with a certain delay (about 1 sec) whereas younger infants had various length of delay. In contrast, no significant change was found in the temporal coordination of caregivers. Caregivers interacting with younger infants as well as those with older infants had a significant peak in transfer entropy with the same history length. Their timing of turn taking had already been established and thus did not change regardless of infants' age. Taken together, these results show a strong potential of our approach to understanding dynamic and microscopic structure of infant-caregiver interaction.

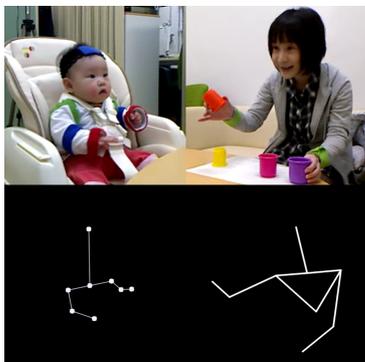


Figure 1: Body movement of an infant and a caregiver detected by a motion capture system

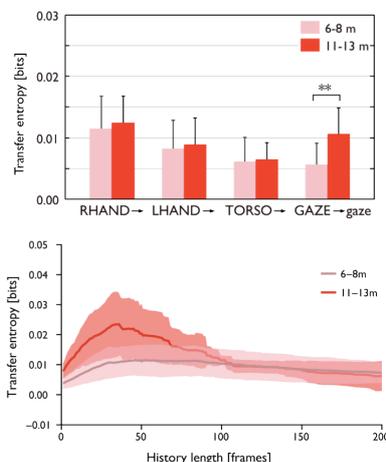


Figure 2: Transfer entropy from caregivers to infants. top: from caregivers' body parts (upper-case letters) to infants' gaze (lower-case letters). bottom: with different history length