

## Letter

### The neurodevelopmental origins of seeing social interactions

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In a recent letter [1], Grossmann argues that, in young children and non-human primates, third-party social interaction recognition is supported by top-down processing in the medial prefrontal cortex (mPFC). He suggests that top-down signals in the developing brain may be used to train neural systems in the superior temporal sulcus (STS), which, in adults, appears to process social interactions in a visual manner [2]. The hypothesis that the visual computations supporting social interactions are trained using top-down signals from the mentalization network is interesting. However, activation of mPFC when viewing social interactions does not preclude visual processing. As we discuss in our original article [2], when seeing social interactions, viewers can make rich inferences about the goals and mental states of the interacting agents. Young children and non-human primates may spontaneously engage higher-level cognitive processes when viewing social interactions, but we argue these processes are separate from the recognition of the interaction itself. Later, we review evidence suggesting that social interactions are processed visually in both young children and non-human primates and that STS selectivity emerges early in life.

Before reviewing the neural evidence, we first note that cortical selectivity is not required for visual processing and behavioral studies can provide strong evidence to help distinguish vision from cognition. As outlined in our original article [2], human infants and non-human primates show

behavioral signatures of visual processing of social interactions. For example, both human infants and Japanese macaques are sensitive to the visual features of chasing displays [3,4], and macaques' sensitivity to visual features is the same as adult humans [3]. While more work is needed to evaluate whether infants and non-human primates exhibit other behavioral signatures of visual processing (e.g., attentional capture and visual adaptation), preliminary evidence supports a visual basis for social interaction recognition in non-human primates and early in human development.

A small number of studies have investigated the neural development of social interaction selectivity in infants and children using functional magnetic resonance imaging (fMRI) and functional near infrared spectroscopy (fNIRS). As Grossmann points out, one fMRI study suggests that STS responses to social interactions are not fully adult-like until age 9–11 years [5]. However, this result was based on an exploratory subgroup analysis. The main analysis from that study finds social interaction selectivity in the STS in children as young as 6 years old [5]. Notably, they do not find social interaction selectivity in children outside of the STS, including in mPFC. There may be developmental changes in these regions, but STS selectivity is seen even in young children.

One prior study investigated responses to observed social interactions in infancy (6- to 13-month-olds) using fNIRS [6]. The authors concluded that there is selectivity in mPFC but not in the STS. However, we disagree with the latter part of this claim for a couple of reasons. First, while they found that only mPFC responded more to dyadic social interactions than both independent actions and inverted interactions during their selected time window, the superior temporal cortex (STC) responded more to dyadic interactions than independent

actions (the typical contrast used in studies of social interaction selectivity [7,8]). Further, their time course analysis showed a strong early response in the STC channel for dyadic interactions, over both independent actions and inverted interactions, providing some evidence for STS selectivity even in infancy.

The neural basis of social interaction recognition has also been investigated in Old World (Rhesus macaques) and New World (common marmosets) non-human primates [9,10]. These neural investigations in non-human primates are important not only as a lens into the evolutionary basis of human social cognition but also because of the invasive electrophysiological methods available in these species. However, to our knowledge, no study has yet investigated the functional homologies between social interaction regions in humans and non-human primates, so, currently, it is difficult to draw decisive conclusions from region-wise comparisons across species. Nonetheless, these studies have revealed an extensive network of regions that responds more to social interactions than other actions, predominantly prefrontal regions but also in visually responsive parietal regions of both species [9,10]. Though more research is needed on the neural basis of social interaction processing in non-human primates, current studies suggest some involvement of visual brain regions during social interaction processing.

Understanding the ontogenetic and phylogenetic origins of social interaction recognition in humans and non-human primates can provide important insights into the neural computations taking place in the adult human brain. While this is an important area for future mechanistic studies [2], there is promising preliminary evidence to suggest social interactions are extracted via bottom-up visual processing in both young children and non-human primates.

### Acknowledgments

We would like to thank Lindsey Powell and Manasi Malik for helpful feedback on an earlier draft of this letter. This work is supported in part by NIMH R01MH132826 awarded to L.I.

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<https://doi.org/10.1016/j.tics.2023.12.007>

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