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COMMENTARY

Shedding light on infant brain function: the use of near-infrared spectroscopy (NIRS) in the study of face perception

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The human face provides a wealth of socially relevant information. Adults readily detect faces and decode all kinds of information from the face such as age, gender, familiarity, race, gaze direction, emotion, etc. Given the multitude of information that can be gleaned from the face, it is not surprising that face perception is mediated by a complex and highly specialized distributed neural system in human adults. The functional organization of this system can be broadly characterized by a distinction between (a) the representation of invariant structural aspects of faces, which constitutes the basis of recognizing individuals, and (b) the interpretation of dynamic changes of faces such as eye gaze and emotional expression that are used in face-to-face communication with others (1,2). Although neuropsychological and neuroimaging work have helped identify a distributed network of specialized brain areas involved in adults' face processing, the more basic question remains, how do these adult abilities develop and what are their precursors? It is thus crucial to look at the earliest stage of face processing: infancy.

So far, infant face perception has been predominantly investigated using electroencephalography (EEG) and event-related potentials (ERPs) (see (3)), which offer good temporal but relatively poor spatial resolution. However, in recent years, researchers have begun to use near-infrared spectroscopy (NIRS) to study infant brain function, permitting more precise localization of brain activation by measuring haemodynamic responses (for a review see (4)). In their article, Carlsson et al. (5) present an innovative study that uses this optical imaging technique to examine the brain processes that underlie 6- to 9-month-olds' recognition of their mother's face. NIRS measurements were obtained from two locations over the right hemisphere, one over posterior (occipital) cortex and another over anterior (fronto-temporal) cortex. The interesting finding was that the anterior region differentiated between mother's and stranger's face such that concentration changes of oxygenated haemoglobin were significantly greater in response to the mother's face than to the stranger's face, whereas the posterior region did not discriminate between the two faces. These findings are an important extension of previous work that has used ERPs to assess the timing of the brain processes implicated in maternal face recognition (6). This is because it provides first insights into the brain structures that might be involved in infants' recognition of a familiar face.

Invited commentary on Carlsson et al. Activation of the right fronto-temporal cortex during maternal facial recognition in young infants.

There are at least two critical questions regarding the *specificity* and the *lateralization* of brain responses that should be examined in future studies in order to understand the specialization of the face recognition system: First, how face specific is the response measured by Carlsson et al.? In other words, would other highly familiar objects that are not faces result in a similar response when compared to unfamiliar objects? Moreover, would other familiar faces engage the same brain process or are there brain regions that are specifically tuned to the mother's face? Second, is this infant brain response lateralized to the right hemisphere like in adults? Carlsson et al. only measured from the right hemisphere, which does not allow an assessment of the lateralization of the response. Nonetheless, there is evidence to suggest that such a lateralization might emerge early in development. Otsuka and colleagues (7) presented 5- to 8-month-old infants with upright and inverted faces using NIRS bilaterally over temporal cortex and found that infants activated right temporal regions more in response to upright faces.

Furthermore, when compared to adult neuroimaging findings, the right anterior region that Carlsson and colleagues find is involved in the recognition of the infant's mother's face has been shown to be one of the regions that adults employ in face-identity matching tasks testing face memory (8). This seems to suggest an early specialization of the brain processes involved in face recognition. However, contrary to this notion, there is a body of evidence based on recent functional magnetic resonance (fMRI) studies with children suggesting that the face recognition system is very slow to specialize (not adult-like until adolescence; see (9)). These fMRI studies have focused on face-specific responses when compared to other object categories in the mid-fusiform gyrus. This region, also called fusiform face area (FFA), is located at the ventral surface of the brain and can therefore almost certainly not be measured by NIRS that obtains most of the signal from superficial cortical structures (see (10) and (11) for more information on optimal source–detector distance and depth resolution of NIRS with infants). The fact that NIRS might not be sensitive to deeper or ventrally located brain structures is a general limitation that applies to all NIRS studies but poses a specific constraint on the study of face perception since it precludes not only the investigation of the FFA but also the amygdala and the orbito-frontal cortex which have been shown to play a critical role in the adult system. Taken together, for all the reasons discussed here, at this stage, any conclusions about the early specialization of brain processes for face recognition seem premature.

As mentioned above, besides the face recognition system, in adults, there is another system that deals with the interpretation of dynamic changes of faces such as eye gaze and emotional expression that are used in social communication with others. These processes have generally been associated with the superior temporal sulcus (STS) (12). In current and ongoing work in our laboratory we are using NIRS to illuminate the early development of the brain system that is concerned with this aspect of social perception. In this work we have shown that posterior superior temporal regions are specifically engaged when observing human biological motion when compared to (non-biological) mechanical motion (13). More important for the current context, we have also investigated whether cortical regions implicated in adults' perception of facial communication signals are functionally active in early infancy (14). Four-month-old infants watched two kinds of dynamic scenarios in which a face either established eye contact or averted its gaze, both of which were followed by an eyebrow raise with accompanying smile. Haemodynamic responses were measured with NIRS from temporal cortex and anterior prefrontal cortex of both hemispheres. The results revealed that perceiving facial communication signals specifically activates areas in the infant right posterior superior temporal cortex and right anterior prefrontal cortex that correspond to the brain regions implicated in these processes in adults (15,16). This suggests an early (adult-like) specialization of the cortical network involved in the perception of dynamic facial communication cues, which is essential for infants' interactions with others. In addition, adopting a novel multi-method approach, we measured neural activity with EEG in another group of 4-month-olds in response to the same facial communication scenarios to provide temporal information about the underlying cortical processes. The EEG analysis revealed that (a) at posterior temporal channels, an increase in neural activity in response to eye contact emerged earlier than at anterior prefrontal channels, and (b) that eye contact itself and the eyebrow raise with an accompanying smile in the context of eye contact produce similar cortical activations. Taking such a multi-method neuroimaging approach can provide information about the structural and temporal characteristics of the brain processes that underlie infant face perception, opening a whole new vista for future experiments on brain function in early human development.

In conclusion, if we strive to understand the functional organization and early development of human face perception, we will have to systematically investigate and compare the developmental trajectories of cortical specialization of the face recognition and the facial communication systems. By using modern optical imaging techniques that are particularly well suited to study the awake, behaving infant, important progress has been made, and Carlsson et al.'s findings add an important piece to the emerging picture. Clearly, the field is just in its infancy, and as it approaches toddlerhood, major theoretical and methodological challenges lie ahead.

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