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Brief Report: Developmental Neurobiological Aspects of Autism

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Impairment in social functioning is generally accepted as one of the central features of autism. From a neurological perspective, social behaviors consist of signals, generated by the motor system, processed by perceptual systems, and regulated by an elaborate cognitive system. These processes are subserved by a hard-wired, widely distributed network that has evolved in parallel with the complex social-cultural milieu of *Homo sapiens.* There is evidence that this system is impaired, in some unknown way, in autistic individuals. This paper explores some of the neural systems underlying social behaviors.

Social-emotional information is transmitted through three major channels. The *auditory-vocal* channel conveys this information through vocalizations (cries, coos, and grunts) as well as prosody (subtle modulations of the tone, rate, and fundamental frequency of language). The emotional significance of these incoming signals is then extracted and computed by specialized brain areas. Normal neonates show a remarkable ability to use these vocal signals to communicate their emotional states, and these vocal signals are entwined with other social behaviors virtually from the beginning. The rate of vocalization increases during periods in which eye contact is maintained. By 5 months, infants can distinguish affective vocalizations independent of visual information.

The *visual-facial-gestural* channel conveys social-emotional information through facial expressions, gesture, and gaze. These motor programs are in place at birth: newborns smile, and show disgust and pain to their caregivers (Izard, Huebner, Risser, McGinnes, & Dougherty, 1980). By 7

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to 9 months of age, infants have a large and varied repertoire of facial expressions identical to those of the adult. On the perceptual side, infants manifest interest in the human face (both the identity and affect aspects) virtually from the beginning. Haviland and Lelwica (1987) showed that 10-week-old infants were able to discriminate their mothers' happy, sad, and angry faces (without accompanying vocalizations) and respond in a non-random fashion to them.

Gaze System. Social gaze ("eye contact") plays an extremely important role in regulating reciprocal social interactions, and consists of a motor component (eye position) and a perceptual component that is sensitive to minute deviations of the gaze of others (Campbell, Heywood, Cowey, Regard, & Landis, 1990). *Joint visual attention* refers to the ability of an infant to perceive and follow changes in the direction of an adult's gaze. Scaife and Bruner (1975) reported that 30% of normal 2-to 4-month-olds, and virtually all of those 8 to 10 months old had this ability. Up to about 16 weeks, the interaction is paced by the mother. By 26 weeks, babies start to initiate these interactions, and between 18 to 24 months, the child perfects the use of gaze as a signal in social turn-taking.

Touch and Body Position. Another system involves touch, holding, and grooming. Newborns rapidly perfect motor snuggling behaviors and perceive and respond to touching and holding.

Arousal and Autonomic Response. Arousal involves the preparation of the nervous system to respond to a signal and also refers to response of the autonomic nervous system. The associated visceral responses are dissociable from the perception of events and objects.

Neural Pathways Subserving Social Behaviors

The vocal, facial, gestural, and gaze signals and perception of these signals are subserved in part by the same neural systems that underlie other motor and perceptual behaviors. However, the computation of social-emotional information takes place in specialized areas of the brain. There is a rich body of literature based on experimental work in nonhuman primates and humans with brain lesions which provides information about how these systems may function.

The temporal lobe contains a variety of neurons specialized for the processing of facial identity and affective expressions, gestures and actions, and gaze (Perrett, Hietanen, Oram, & Benson, 1992). These investigators have described neurons in the upper bank of superior temporal sulcus in the macaque which are viewer-centered—that is, the cells responding to views of another individual which are specific to the viewer's vantage point.

Other neurons (object-centered) respond to many or all perceptive views of another individual, regardless of view, image position, size, orientation, and different lighting conditions, and a third set of neurons (goal-centered) respond to body movements which have a specific goal or target. Some neurons respond specifically to direction of gaze and therefore appear to underlie *joint visual attention*.

Memory plays a role in social behaviors, in that facial identity and emotional expressions are stored in the hippocampus (declarative memory system). The amygdala links sensory inputs with emotional response. The declarative memory system is dissociable from the autonomic response system, so that some individuals may be able to learn social-emotional information but lack an autonomic response, whereas others may be able respond autonomically to external events without a specific conscious memory of the event (Bechara et al., 1995).

Although the similarities between humans and nonhuman primates have been emphasized, there are some differences: in humans, the right hemisphere is specialized for the processing social-emotional information, analogous to the specialization of the left hemisphere for language (Ojemann, Ojemann, & Lettich, 1992).

Social Cognition and Autism

Social cognition involves the ability to develop abstract metarepresentations of social relationships and sociocultural rules, and to use this information to interpret and respond appropriately to the behaviors of other individuals. A special case of this—theory of mind—is the awareness that other humans may have beliefs and emotions distinct from one's own. Autistic persons have clear deficits in theory of mind. However, it is hard to align the concept of a *cognitive* deficit of this type, which would by its nature emerge late, with the observation that the vast majority of infants destined to become autistic manifest very early anomalies of social behavior (Volkmar & Klin, 1993).

An alternative hypothesis is that the deficit in autism results from deviant development of some aspect of the widely distributed neural *system* underlying social behaviors. This system undoubtedly subserves infantile social behaviors, and, with maturation becomes more elaborate, conscious, and "cognitive."

There are some important differences between perceptual-motor development in the realm of social behaviors and other forms of perceptual-motor learning. In the latter situation, infants can directly observe their own limb movements or hear their own babbling. For example, van der

Meer, van der Weel, & Lee, 1995) showed that newborns control their limb movements in order to keep the extremity in view. They learn about arm/hand configuration and kinesthetics, preparing them to carry out visually guided arm movements a few months later. In contrast, infants cannot directly observe the effect of facial, prosodic, gestural, or gaze motor-programming efforts, except by observing the responses of other humans. Thus, to experience and learn about social behaviors, the infant must be able perceive and generate social-emotional signals and attach appropriate meaning to them. This system may well involve the object-centered neurons described above which compute information related to the object rather than the viewer (analogous to the type of cognitive computation underlying the more abstract, and later-appearing, theory of mind). The system is sufficiently redundant that a perceptual deficit in a specific modality (e.g., blindness or deafness) will not result in autism.

Finally, this hypothesis is congruent with current views of brain development. Rather than developing in a hierarchical manner—that is, primary motor and sensory areas developing first, followed by associational cortex—all cortical areas, primary as well as associational, are laid down simultaneously and are then pruned and remodeled in the course of development in an environmental context. This would explain why, if there were a developmental anomaly in the neural system subserving social-emotional behaviors, not only would infant social behaviors be affected but social cognition, which emerges out of and is dependent on these early experiences, would also not develop in a normal fashion. Moreover, higher order association cortex or related subcortical areas might well be affected by the same early anomaly of brain development, but the effects would not emerge until later, when that particular cortical area becomes functional.

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