CHAPTER 25

Joint Attention and Neurodevelopmental Models of Autism

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Autism is a neurodevelopmental disorder characterized by the early onset of a robust disturbance of social and communicative development (Bailey, Philips, & Rutter, 1996; Kanner, 1943/1973; Volkmar, Lord, Bailey, Schultz, & Klin, 2004). Because the nature of this disorder is very complex, it will likely require significant broadening of the current boundaries of behavioral neuroscience before sufficient knowledge is available to ameliorate the impairments of individuals with autism. This expansion is well underway and is exciting to witness. From animal models to intervention studies, from metabolic genetics and neuroimaging to the identification of early behavioral manifestations, the syndrome of autism is being examined from multiple perspectives to piece together a veridical picture of the true nature of this disorder.

One important piece of the picture has been revealed over the past 20 years by studies on the nature of early social-communication impairments in children with autism. In this chapter, we discuss a fundamental facet of this work that has revolved around research on joint attention impairment in children with autism. Many aspects of this research have been reviewed elsewhere (Charman, 1998; Leekam & Moore, 2001; Mundy & Crowson, 1997), including several chapters in this *Handbook* (e.g., Chawarska, Chapter 8; Prizant & Wetherby, Chapter 36). Nevertheless, relatively little attention has focused on the emergent theoretical and empirical interface between research on joint attention disturbance and neurodevelopment in autism. The aim of this chapter is to provide a discussion of this vital topic.

Most broadly, *joint attention* refers to the capacity of young children to coordinate their visual attention with a social partner. This capacity unfolds between 6 and 18 months in typical development and is exemplified by the ability to follow the line of visual regard of a social partner or to initiate episodes of shared attention with eye contact and gestures such as showing (see Figure 25.1). Children with autism display a robust disturbance in these and related social-orienting skills. This disturbance is problematic because joint attention skills provide a fulcrum around which much of social learning and self-organization revolves in the first years of life (Baldwin, 1995). It may be especially important to recognize that one of the more pernicious aspects of joint attention impairment is the early onset of a dramatic reduction in the tendency of children with autism to *initiate episodes of social sharing* with other people (Mundy, 1995). A reduction in the tendency of young children with autism to initiate critical social behaviors may be singularly important because developmen-

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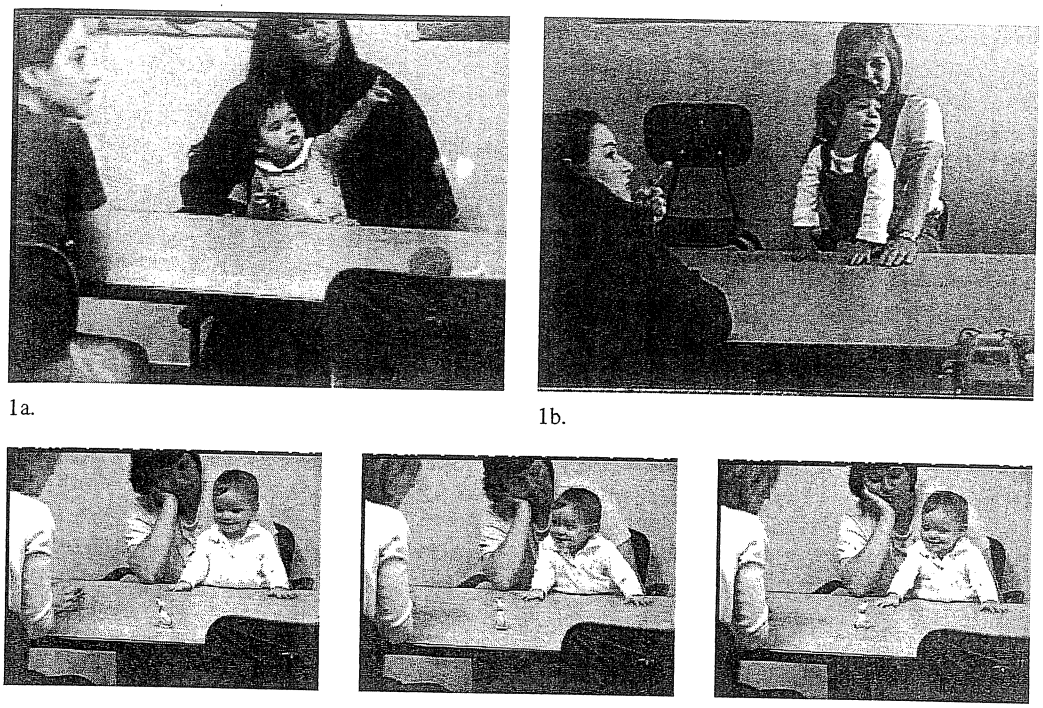

1a. 1b.

Figure 25.1 Examples of (a) responding to joint attention bids, (b) initiating joint attention with a point, and (c) initiating joint attention with alternating gaze. *Source:* "A Preliminary Manual for the Abridged Early Social Communication Scales (ESCS)", by P. Mundy, A. Hogan, and P. Doehring, 1996, available from http://yin.psy.miami.edu:80/Child/Pmundy/manual.html; and "Assessing Interactional Competencies: The Early Social Communication Scales," by J. M. Seibert, A. E. Hogan, and P. C. Mundy, 1982, *Infant Mental Health Journal, 3,* pp. 244–245.

tal theory suggests that a large part of early ontology hinges on experience, including the experiences children create for themselves through their own actions (Cicchetti & Tucker, 1994; Gottlieb & Halpern, 2002; Piaget, 1952). More recently, theory also has begun to suggest that not only do infants play a role in creating critical experiences for themselves, but also a failure to create these self-generated social experiences may contribute to suboptimal neurodevelopmental outcomes (cf. Greenough, Black, & Wallace, 1987). We have attempted to incorporate some of these important ideas into our own efforts to understand the significance of joint attention disturbance in autism. The result is a coactive model of development (Gottlieb & Halpern, 2002) that suggests there may be a complex interplay between early behavior disturbance (i.e., symptoms of autism) and subsequent neurodevelopmental pathology in autism. In particular, joint attention disturbance may be viewed as associated with a robust disturbance in the early tendency of young children with autism to initiate social-orienting and sharing with others (Dawson, Meltzoff, Osterling, Rinaldi, & Brown, 1998; Mundy, 1995). This behavioral disturbance reduces the flow of social information to the child to such an extent that it contributes to subsequent disorganization in the neural, as well as behavioral, development of these children (Dawson, Webb, et al., 2002; Klin, Warren, Schultz, & Volkmar, 2003; Mundy & Crowson, 1997; Mundy & Neal, 2001). We review elements of this coactive model of the neurodevelopmental disturbance of autism later in this chapter.

The observation that autism is characterized by a deficit in the *initiation of joint attention* with others may also be especially important as we attempt to understand the brain systems that play a role in this syndrome. Currently, much of the brain-behavior research

and theory on the social impairments of autism emphasizes the study of the perception of social behavior rather than systems involved in the initiation of social behavior (Baron-Cohen et al., 2000; Carver & Dawson, in press; Critchley et al., 2000). This emphasis is not necessarily misplaced because individuals with autism display deficits in social perception (e.g., Baron-Cohen et al., 1999; Hobson, 1993; Langdell, 1978; Sigman, Kasari, Kwon, & Yirmiya, 1992). Moreover, the interpretation of research on the neurodevelopment of social perception in autism is supported by a rich corpus of data on the brain systems that are involved in the perception of social behaviors in primates and humans (Adolphs, 2001; Brothers, 1990; Elgar & Cambell, 2001; LeDoux, 1989). However, as noted earlier, autism is marked not only by social-perceptual or social-information processing difficulties but also by impairments in the spontaneous generation and expression of social behaviors and cognition (U. Frith, 1989; Klin et al., 2003; Leslie, 1987; Minshew et al., 2002; Mundy, 1995). Therefore, in addition to research on the neural systems involved in social perception, neurodevelopmental studies of the systems involved in the self-initiation of social behavior may be of great importance for research on autism.

It may be instructive to recognize that the brain systems involved in *initiating* social behavior may not be identical to those involved in the *perception* of social behavior. For example, several papers have emphasized the importance of ventral "social brain" brain systems in perception of social behaviors and the social pathology of autism. These brain systems include the orbitofrontal cortex, temporal cortical areas including the superior temporal sulcus (STS) and superior temporal gyrus (STG), and subcortical areas such as the amygdala (Adolphs, 2001; Bachvalier, 1994; Baron-Cohen et al., 2000; Brothers, 1990). In contrast, when the tendency to initiate social behaviors, such as joint attention bids or social-cognitive problem solving is studied, research suggests that a more dorsal, medial-frontal cortical (DMFC) system may be involved in autism (U. Frith & Frith, 1999, 2001; Mundy, 2003). Thus, understanding the functional neurodevelopment of dorsal systems for the self-initiation of social behaviors and cognition and how these dorsal systems relate to ventral social-perceptual systems constitutes a goal of the highest order in the current field of research on autism (cf. Frith & Frith, 1999, 2001). Indeed, it is important to recognize that we do not yet clearly understand the degree to which the initiation of social behaviors serves to organize social perception (or vice versa). Detailed knowledge of this topic may be critical to understanding the atypical neurodevelopment of autism.

In this chapter, we take a small step in this direction by reviewing research that links joint attention development and its disturbance in autism to the DMFC system. We also provide a discussion of the potential links between research on the DMFC and brain systems involved in social perception. Finally, we attempt to link the coactive model of the neurodevelopmental disturbance of autism and research on the DMFC. To provide a foundation for these discussions, we begin with a brief overview of joint attention disturbance in autism.

JOINT ATTENTION AND SOCIAL IMPAIRMENT IN AUTISM

As is well known, Kanner (1943/1973) first noted that the pathognomonic feature of autism was the "children's inability to relate themselves in the ordinary way to people and situations" because "these children have come into the world with an innate inability to form the usual biologically provided affective contact with people, just as other children come into the world with innate physical or intellectual handicaps" (Kanner, 1943/1973, pp. 42–43). It is less well known that in the three decades following Kanner's and Asperger's (1944) identification of the syndrome, very little empirical or theoretical work was devoted to defining the nature of the fundamental social impairments that afflict these children (Howlin, 1978). One result of this paucity of information was a relatively impoverished diagnostic system. The statement that children with autism display "a pervasive lack of responsiveness to others" (e.g., American Psychiatric Association, 1980) was the only descriptor of the social deficits associated

with autism until the late 1980s (e.g., American Psychiatric Association, 1987). This descriptor painted a broad but inaccurate picture of the social behavior of these children. It described only the most aloof subgroup of children with autism and contributed substantially to an underestimation of the prevalence of autism (see Wing & Potter, 2002, for a related discussion). Indeed, it was only with the publication of the most recent nosology (e.g., American Psychiatric Association, 1994) that there are sufficiently well-articulated diagnostic criteria to *begin* to provide a clear and comprehensive description of the social impairments of autism.

The observation that early social-communication disturbance in autism is exemplified by a robust failure to adequately develop joint attention skills (Curcio, 1978; Loveland & Landry, 1986; Mundy, Sigman, Ungerer, & Sherman, 1986; Wetherby & Prutting, 1984) has contributed to the improved description of the social deficits of autism (Mundy & Crowson, 1997; Ozonoff & South, 2001). As noted previously, the term *joint attention skills* refers to the capacity of individuals to coordinate or share attention with a social partner regarding an object or event. This capacity in infancy may involve only the social coordination of overt aspects of visual attention, as when a toddler shows a toy to a parent (Carpenter, Nagell, & Tomasello, 1998; Rheingold, Hay, & West, 1976). However, with development, joint attention skills in older children and adults also play a role in the social coordination of covert aspects of attention, as when social partners coordinate attention vis-à-vis psychological phenomena, such as ideas, intentions, or emotions (Bretherton, McNew, & Beeghly-Smith, 1981; Tomasello, 1999). Thus, the regulation and sharing of overt visual attention in early development is thought to contribute (in a manner we do not yet fully understand) to the subsequent development of the capacity to socially share aspects of cognition later in development.

Joint attention skill deficits in children with autism involve a robust and early-onset disturbance in the tendency to share or coordinate overt visual attention with a social partner. It is manifest in an attenuation of the functional use of eye contact, affect, and gestures for the sharing experiences with others (Kasari, Sigman, Mundy, & Yirmiya, 1990; Mundy et al., 1986). In previous work, we argued that joint attention disturbance in autism was central to what Kanner described as the "children's inability to relate themselves in the ordinary way to people and situations" (Mundy & Sigman, 1989).

The capacity for joint attention begins to emerge by 6 months of age (Scaife & Bruner, 1975) and takes several different forms, each of which may be reliably measured in infants and young children. One behavior involves infants' ability to follow the direction of gaze, head turn, and/or pointing gesture of another person (Scaife & Bruner, 1975). This behavior is called *responding to joint attention skill* (RJA; Mundy et al., 2003; Seibert, Hogan, & Mundy, 1982). Another type of skill involves infants' use of eye contact and/or deictic gestures (e.g., pointing or showing) to spontaneously initiate coordinated attention with a social partner. This type of protodeclarative act (Bates, 1976) is referred to as *initiating joint attention* (IJA; Mundy et al., 2003; Seibert et al., 1982). These behaviors, especially IJA, appear to serve social functions as the goal, and reinforcement for these behaviors seems to relate simply to the value of sharing experience with others (Bates, 1976; Mundy, 1995). Social attention coordination may also be used for imperative purposes (Bates, 1976). Infants and young children may use eye contact and gestures to initiate attention coordination with another person to elicit aid in obtaining an object or event. This may be referred to as a proto-imperative act (Bates, 1976) or *initiating behavior requests* (IBR; Mundy et al., 2003). This type of attention coordination serves a less social function, insofar as it is employed as part of an instrumental goal of obtaining a desired object or event (Bates, 1976; Mundy, 1995).

Joint attention skill acquisition is a major milestone of early development (Bakeman & Adamson, 1984), in part, because these skills assist infants in organizing social information to facilitate their own learning and development. In language learning, for example, parents do not sit with their infants in structured situations to teach vocabulary word by word. Rather, much of early language acquisition

takes place in unstructured or incidental social-learning situations where: (1) the parent provides a learning opportunity by referring to a new object or event in the environment, but (2) the infant may need to discriminate among a number of stimuli in the environment in order to focus on the correct object/event and acquire the new word-object-event association. Thus, the infant is confronted with the possibility of committing a referential mapping error or focusing on the wrong stimuli during incidental word learning opportunities (Baldwin, 1995). To resolve this problem, the infant may attend to and process the direction of gaze of the parent (i.e., use RJA skill) to limit the number of potential stimuli they need to attend to, thereby increasing the likelihood of a correct word learning experience (Baldwin, 1995). Similarly, when the infant initiates a bid for joint attention, the responsive caregiver may follow the child's line of regard and take advantage of the child's focus of attention to provide a new word in a context that maximizes the learning opportunity (cf. Tomasello, 1995). Joint attention skills assist infants in organizing social information input and avoiding referential mapping errors in these situations (Baldwin, 1995). Hence, joint attention may be regarded as an early developing *self-organizing facility* that is critical to much of subsequent social and cognitive development (e.g., Baldwin, 1995; Bruner, 1975; Mundy & Neal, 2001).

Children with autism, unfortunately, display robust levels of impairments in the tendency to initiate and respond to joint attention bids. This impairment contributes to a significant deficit in the capacity for early social learning. Observations suggest that joint attention disturbance may be manifest in children with autism as early as between 12 and 18 months of age (Osterling & Dawson, 1994; Swettenham et al., 1998). Theoretically, from early in development, children with autism display deficits in types of social behaviors that ordinarily serve to organize and facilitate subsequent social and communicative development. It is interesting, though, that this deficit in early social-communication skill is not pervasive as children with autism display only modest evidence of IBR impairments on measures of social attention coordination for instrumental purposes (see Charman, 1998; Leekam & Moore, 2001; Mundy & Crowson, 1997, for reviews).

The self-organizing function of joint attention in autism may be illustrated with findings from a recent important study by Bono and Sigman (in press). In this study, 29 children with autism were followed longitudinally between approximately 4 and 5 years of age. Data on the amount of time per week children were in structured interventions were collected, as were data on joint attention abilities using the Early Social-Communication Scales (ESCS; Mundy et al., 2003) and data from standardized language assessments. The results revealed that across this 1-year period, both IJA and RJA were significantly related to language gains. Alternatively, amount of intervention was only weakly related to language gains across the 1-year interval. However, significant conditional intervention effects were observed such that more time in structured intervention was associated with significant language gains for children with better-developed RJA skills. Thus, measures of joint attention may be a marker of individual differences in intervention responsivity among children with autism. One possible interpretation of this finding is that differences in RJA skills reflected differences in the ability of children with autism to self-organize information in social learning situations and that this skill contributes to their capacity to benefit from early intervention.

In addition to reflecting a self-organizing disturbance, joint attention deficits in autism may reflect impairments in the social-cognitive capacity to represent another person's perspectives (Leslie & Happé, 1989), as well as a disturbance in the social motivation to approach or orient to social partners (Mundy, 1995). Joint attention deficits in children with autism, however, should not be confused with processes associated with attachment because children with autism display atypical, but clear, signs of attachment (Sigman & Mundy, 1989; see also Pierce, Frank, Farshad, & Courchesne, 2001). Moreover, attachment does not appear to be strongly related to joint attention skills in children with autism or typical development (Capps, Sigman, & Mundy, 1994; Crowson, Mundy, Neal, & Meyer, 2003).

Although young children with autism display deficits in both IJA and RJA skills, the impairment in RJA appears to remit to a significant degree with development (Leekam & Moore, 2001; Mundy, Sigman, & Kasari, 1994). The impairment in IJA, however, remains in older children (Baron-Cohen, 1995). Research also suggests that symptom intensity (Mundy et al., 1994) and symptom course, such as the tendency to initiate interaction with peers in later childhood and adolescence (Lord, Floody, Anderson, & Pickles, 2003; Sigman & Ruskin, 1999), are related to individual differences in IJA, but not RJA impairment among young children with autism. A dissociated pattern of IJA and RJA development is also observed in typical development and may occur because IJA and RJA reflect different integrations of neurodevelopmental, social-cognitive, and social-emotional processes (Mundy, Card, & Fox, 2000; Mundy & Willoughby, 1998).

IJA reflects the tendency to spontaneously initiate social attention coordination behavior, whereas RJA is a measure of the tendency to respond to another person's signal to shift attention. Hence, IJA may be more affected by executive and social-motivation processes involved in the generation and self-initiation of behavioral goals than RJA (Mundy, 1995; Mundy & Willoughby, 1998; Mundy et al., 2000). In particular, IJA appears to involve the tendency to spontaneously initiate episodes of sharing the affective experience of an object or event with a social partner (Mundy, Kasari, & Sigman, 1992). Indeed, a significant component of IJA disturbance in autism may be explained in terms of an attenuation of the tendency to initiate episodes of shared positive affect with a social partner (Kasari et al., 1990). However, a recent report has failed to replicate this finding, suggesting the need for more research on this important topic (Plousia, 2002).

This literature has led to the instantiation of joint attention disturbance, and especially IJA disturbance, as a cardinal symptom of autism. For example, a "lack of spontaneous seeking to share enjoyment, interests, or achievements with other people (e.g., by a lack of showing, bringing or pointing out objects of interest)" is now one of four symptoms of the social impairment of autism in a current nosology (American Psychiatric Association, 2000, p. 75). Thus, many of the current autism diagnostic and screening instruments include measures of joint attention (Baron-Cohen et al., 1996; Charman, 1998; Lord et al., 1999; Stone, Coonrod, & Ousley, 2000). The gold standard Autism Diagnostic Observation Schedule (Lord et al., 1999) even reflects the notion of a developmental dissociation in joint attention. Measures used for diagnosis with the youngest children (Module 1) include both IJA and RJA assessments, while Module 2 designed for developmentally more advanced children includes only the IJA measures in the diagnostic scores.

JOINT ATTENTION, SOCIAL ORIENTING, AND AUTISM

Given its central role in the phenotype of autism, it is not surprising that considerable effort over the past 20 years has been directed toward understanding the development of joint attention. Most models of joint attention disturbance, indeed most models of autism, approach the social symptoms of the syndrome from a relatively linear and deterministic perspective. These models view behavioral symptoms of the syndrome, such as joint attention disturbance, as the end point of a unidirectional process. This process starts with some form of genotypic atypicality that leads directly to neurodevelopmental anomalies, which, in turn, are unerringly expressed as abnormal social behavior (Minshew, Johnson, & Luna, 2001). For example, social behavior disturbance in autism has been viewed as an end-point outcome of "core" neurodevelopmental deficits in a social-cognitive module (Baron-Cohen, 1995; Leslie & Happé, 1989), executive functions (McEvoy, Rogers, & Pennington, 1993), or cerebellar contributions to attention control (Courchesne et al., 1994). However, an understanding of atypical, as well as typical development, may benefit from a less linear and deterministic perspective (Cicchetti & Tucker, 1994). "Epigenetic," "relational," or "coactive" models of causality suggest that biological and environmental experience *interact over time and maturation* to yield developmental disturbance (Gottlieb &

Halpern, 2002). Moreover, "experience" as a causal influence on development includes not only external sources of stimulation but also forms of stimulation that the individual actively generates through self-initiated interactions with the world (Piaget, 1952; Scarr, 1992). Thus, rather than end points in pathological process, it may be especially important to understand how the early onset of impairments in major milestones of social development potentially contributes to the subsequent unfolding of the full syndrome of autism across the first years of life. It may be especially instructive to consider the potential developmental impact of an early disturbance of the self-organizing functions of joint attention.

To understand this developmental impact, consider the notion that joint attention disturbance may be part of a broader social-orienting impairment in autism. The term *social-orienting impairment* has been introduced to the field by the seminal work of Dawson et al. (1998), who observed that children with autism may display a more robust orienting deficit to social rather than nonsocial sounds. However, the notion that children with autism display a deficit in orienting to social stimuli has a long history in research on autism. For example, it can be discerned in various forms in models of autism that emphasize impairments in the first year of life in cerebellar processes (Courchesne et al., 1994) or in the biological reward mechanisms that serve to promote social behavior (Mundy, 1995; Panksepp, 1979). The latter impairments may be related to a disturbance in the early onset of orbital and/or more dorsal medial-frontal contributions to orienting and learning (Dawson, Munson, et al., 2002; Mundy, 2003; Mundy et al., 2000), as well as problems in the perception or processing of affect and behavioral contingencies (Dawson & Lewy, 1989; Hobson, 1993). All these models embrace the supposition that a social-orienting impairment may reflect an initial or core aspect of pathology that has ramifications for the subsequent development of social, cognitive, and even neurological disturbance in autism.

Our own version of social-orienting impairment in autism is based in part on the assumption that in the first year of life, there are predispositions that guide attention deployment to relevant aspects of the environment (Bahrick & Lickliter, 1999; Karmiloff-Smith, 1995). These predispositions provide a "preparedness with which human infants come to the task of learning" (Tomasello, 1999, p. 305) and a starting point around which subsequent brain and behavior development organizes. In particular, infants may display a predisposition toward social information processing (Blass, 1999; Cummins & Cummins, 1999). A disturbance of such a bias in autism may result from imbalances in general aspects of early perception and information processing (Mottron & Burack, 2001) or aspects of perception that are specific to social information processing (e.g., Adolphs, 2001). In any event, a critical assumption of our social-orienting model has been that joint attention skill deficits in children with autism reflect a disturbance in the predilection to spontaneously orient to and process social information that is normally manifest in the first years of life (Mundy, 1995; Mundy & Sigman, 1989).

Results of several studies suggest social-orienting and joint attention skills are related and that impairments in these domains may be manifest very early in children with autism. For example, 20-month-old infants who were subsequently diagnosed with autism at 42 months have been observed to display far less social orienting, or spontaneous gaze shifts between objects and people, than did control infants (Swettenham et al., 1998). Measuring spontaneously alternating gaze between an object and a person is also a core component of the assessment of IJA skill. In fact, it was the type of behavior that best discriminated children with autism from comparison children in our original joint attention study (Mundy et al., 1986).

Other research also speaks to the commonality and very early onset of social-orienting and joint attention disturbance in autism. The literature on normal development indicates that forms of social-orienting and joint attention skill development emerge between 6 and 12 months of age (Morales, Mundy, & Rojas, 1998; see Moore & Dunham, 1995, for review). In research on autism, studies of family videotape records suggest that by 12 months of age, children with autism may display evidence of a disturbance in joint attention and social ori-

enting (Osterling & Dawson, 1994). Measures of joint attention skills have also contributed to the very early identification of autism at 18 months of age in a sample of 16,000 children (Baron-Cohen et al., 1996). Even earlier social-orienting measures such as parent reports of eye contact, showing interest in others, reacting when spoken to, and laughing to others may serve to facilitate early identification as early as 14 months (Willensen-Swinkel et al., 2002).

Several other studies provide further evidence for a basic social-orienting disturbance in autism. Klin (1991) has reported that the typical preference for speech and speech-like sounds, usually displayed by infants in the first months of life, was not present in any of the children with autism observed by him. It was, however, present in all of the developmentally delayed matched controls observed in this study. As noted earlier, Dawson et al. (1998) examined the degree to which children with autism, Down syndrome, or normal development oriented (displayed a head turn) toward social stimuli (clapping hands or calling the child's name) and to nonsocial stimuli (playing a musical jack-in-the-box or shaking a rattle). The results indicated that the children with autism displayed deficits in orienting to both types of stimuli. Their failure to orient to social stimuli, however, was significantly more impaired than their orienting to nonsocial stimuli. Furthermore, individual differences in difficulty with social orienting, but not object-orienting, were significantly related to a measure of joint attention among the children with autism. Additional efforts from this group have also shown that joint attention is directly related to language acquisition, and social-orienting measures are indirectly related to language through their association with joint attention development in 3- to 4-year-old children with autism (Dawson et al., 2004). Research also suggests that a social-orienting factor may reflect a symptom cluster assessed with the Childhood Autism Rating Scale (CARS; Stella, Mundy, & Tuchman, 1999). Processes involved in individual differences in joint attention measures of social orienting have displayed long-term continuity with processes involved in adaptive outcomes. Individual differences in early joint attention predict the social and cognitive outcomes of adolescent children with autism (Sigman & Ruskin, 1999), as well as how well children with autism process nonverbal social-affective information (Dissanayake, Sigman, & Kasari, 1996).

NEURAL PLASTICITY, SOCIAL ORIENTING, AND JOINT ATTENTION

How do joint attention and related early social-orienting impairments play a role in the etiology of autistic developmental pathology? The microgenetic theory of pathology suggests that understanding the developmental nature and timing of symptoms may be of critical importance if the complete basis of pathology is to be understood (Brown, 1994). This may be the case with respect to the developmental nature and timing of joint attention and social-orienting disturbance in autism. Thus, another critical feature of our model is based on theory that suggests early experience drives a substantial portion of postnatal brain development.

Several researchers have suggested that since the normal environment reliably provides species members with certain invariable types of stimulation and experience, many mammalian species have evolved neural mechanisms that take advantage of the consistency of experience to shape and organize neural development (e.g., Brown, 1994; Changeux & Danchin, 1976; Goldman-Rakic, 1987; Gottlieb & Halpern, 2002; Greenough et al., 1987). One research group has described this process as *experience-expectant* neural development (Greenough et al., 1987). Experience-expectant process in neural development involves a "readiness of the brain" to receive specific types of information from the environment (Black, Jones, Nelson, & Greenough, 1998). This assumption parallels the notion in developmental research and theory that there are predispositions that guide attention and learning early in infancy (Bahrick & Lickliter, 1999; Karmiloff-Smith, 1995; Tomasello, 1999). One aspect of this readiness is an initial overproduction of potential neural connections in the brain. Research on cortical development suggests that the number of synaptic connections between neurons increases dramatically for several years postnatally, especially in the first 12 to 24 months of life. Subsequently,

average brain volume, as measured in terms of synaptic density, gradually decreases (see Huttenlocher, 1994, for review). This decrease in brain volume involves the process of culling the early proliferation of synaptic neural connections through the effects of experience into a more efficient and functional system of connections (Brown, 1994; Changeux & Danchin, 1976; Gottlieb & Halpern, 2002; Greenough et al., 1987; Huttenlocher, 1994). Distinctive aspects of environmental stimulation encountered by each member of a species (e.g., patterned visual stimulation, speech sounds, social-affective exchanges) may promote species-specific functional neurodevelopment during early sensitive periods of development (Black et al., 1998). Many of these sensitive periods are thought to occur in the first few years of life (Greenough et al., 1987). Typically, activated or functional synapses are retained, while those that are not activated by stimulation degenerate. Consequently, variation in the environment and stimulus input during an early sensitive period of neural plasticity may lead to fundamental effects on physiological, morphological, and functional aspects of central nervous system development that lay a foundation for future typical or atypical neurobehavioral development (Black et al., 1998; Greenough et al., 1987).

If there is a robust failure of early information input into developing neural subsystems, then a decrease in synapse elimination may occur, leaving a persistent and abnormal organization of neural structure (Greenough et al., 1987). For example, Huttenlocher (1994, pp. 139–141) reviewed studies that suggested that the early blockade of neuromuscular activity in animals, through curare administration or forelimb restraint, leads to significantly more (albeit less usefully organized) synaptic connections in the motor cortex. Thus, early in development, a significant impairment in the input to and/or output from brain systems may result in a stable, diffuse, and overabundant pattern of connections that renders the system functionally atypical. Consequently, the development of behaviors based on this diffuse and overabundant system may be substantially less than optimal.

Greenough et al. (1987) also noted that, while evidence of experience-expectant processes in neurological development currently stems almost exclusively from research on sensory development, it is likely that other aspects of human neurobehavioral development are also affected by experience-expectant processes. In this aspect of their discussion, Greenough et al. make two comments that are potentially relevant to understanding the impact of a joint attention/social-orienting impairment in autism. They suggested that some early experience-expectant effects may involve self-organizing processes whereby "some types of 'expected' experience may rely largely on the infant to produce them" (p. 545). They also suggested that infant preverbal social communication interactions may provide an example of the "active participation of the infant in acquiring and organizing experience" that provides necessary and critical experience-expectant information in early stages of human development (Greenough et al., 1987, p. 553; see Gottlieb & Halpern, 2002; McWhinney, 1998, for related discussions). Infants' tendency for early social orienting and to ultimately engage in numerous episodes of social attention coordination, or joint attention, may make a contribution that is critical to experience-expectant processes that serve to organize social neurodevelopment (Mundy & Neal, 2001). Moreover, in children with autism, a disruption of social orienting and joint attention may lead to an impoverishment of critical forms of social information input that exacerbates atypical social neurodevelopment through an attenuation of the typical experience-expectant process (Mundy & Crowson, 1997; Mundy & Neal, 2001; see Figure 25.2).

In our initial discussion of this possibility (Mundy & Sigman, 1989), we noted that a failure of joint attention development may serve to isolate the infant with autism from the typical pattern of social exchange, contributing to something akin to a primate isolation effect (Kraemer, 1985). Primate isolation syndrome is a behavioral response to attenuated early social interactive opportunities that leads to some symptoms that have been observed in children with autism, such as stereotypies. We subsequently revised this notion to suggest that autism may be characterized by an initial neuropathological process (INP), which leads to

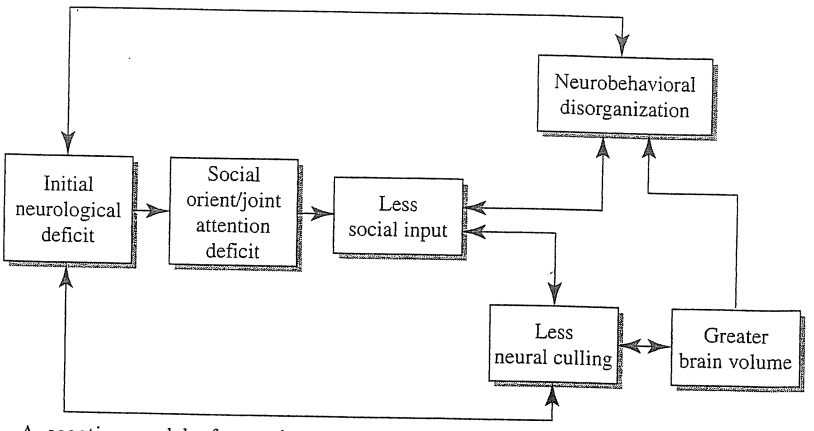

Figure 25.2 A coactive model of organism-environment interaction in the neurobehavioral development of autism in the first 6 years of life. Adapted from "Joint Attention and Early Communication: Implications for Intervention with Autism," by P. Mundy and M. Crowson, 1997, *Journal of Autism and Developmental Disorders, 27,* 653–675; and "Neural Plasticity, Joint Attention and a Transactional Social-Orienting Model of Autism," by P. Mundy and R. Neal, 2001, *International Review of Mental Retardation, 23,* pp. 139–168.

less than optimal social-orienting behavior in the first months of life (Mundy & Crowson, 1997). The INP may involve a deficit in neural systems that contribute to social reward sensitivity (Mundy, 1995; Panksepp, 1979) or other processes that may affect social orienting (e.g., Courchesne et al., 1994; Dawson & Lewy, 1989). *Indeed, the model is not about the cause of the INP. Rather, it raises the hypotheses that the social behavior symptoms caused by the INP may themselves contribute to the etiology of the subsequent neurodevelopmental pathology of autism.* Specifically, this model illustrated the possibility that a robust attenuation of social orienting in the first months of life could, in turn, contribute to secondary neurological disturbance (SND) in autism (Mundy & Crowson, 1997).

One assumption of this model is that social-orienting and joint attention behaviors create a vital and unique source of social information that is necessary for typical experience-expectant social neurodevelopment. In particular, episodes of joint attention, especially those initiated by the child, are thought to provide unique information for infants. This involves the integration of proprioceptive information on the actions and intentions of the self with exteroceptive information from observations of the actions and intentions of others, in reference to some third object or event (Mundy, Sigman, & Kasari, 1993). For example, during showing, infants have the opportunity to monitor their own experience of an object (e.g., enjoyment), while also observing the response of a social partner (e.g., their direction of gaze and affect) to both the object and their own behavior. Thus, self-initiated bids for joint attention provide a rich opportunity for infants to compare information about a social partner's awareness and responses to the displayed object with their own (Bates, 1976). This kind of self-other comparison of experience with respect to a third object or referent provides information that makes a vital contribution to the development of the capacity of infants to simulate the mental states of others. Simulation theory suggests that individuals use their awareness of their own current or past mental processes to analyze and estimate the intentions of others (Gallese & Goldman, 1998; Stich & Nichols, 1992). That is, developmentally, people learn to use self-knowledge, derived from context-specific self-monitoring, to extrapolate and make inferences about the covert psychological processes that contribute to the behaviors of other people in related contexts. In infancy, joint attention, as well as other behaviors such as imitation, provides fundamental opportunities to practice and develop the ability to simulate the mental states of others (Meltzoff & Gopnik, 1993; Mundy et al., 1993). Thus, an attenuation of joint attention deprives children

with autism of the practice of self and other social information processing that may be critical to the stimulation of neural systems involved in social-cognitive development (Mundy, 1995, 2003; Mundy & Neal, 2001; Mundy et al., 1993).

Another assumption inherent to this model is that the contribution of the SND to the developmental processes involved in autism will be reduced to the degree early intervention increases the tendency of the young child with autism to process social information (see Mundy & Crowson, 1997, for discussion). Indeed, a model of autism that incorporates a disturbance of experience-expectant processes may assist in understanding intervention process and may assist us in understanding the common observation that earlier intervention may work better than later intervention and that more intervention may work better than less (Black et al., 1998).

The coactive component of the social-orienting model is not so much an alternative to other models of autism as it is a complement or extension of extant models. For example, it is possible that a social-orienting disturbance, and subsequent disruption of experience-expectant neural development, is an important part of the disturbance of the development of social-cognitive modules envisioned in the theory of mind (ToM) model of autism (Mundy, 1995). A basic notion of the latter is that there has been an evolution toward increasing specialization of central nervous systems to support complex social-cognitive and social-communication functions (Baron-Cohen, 1995; Brothers, 1990; Cosmides, 1989; Humphrey, 1976; Whiten & Byrne, 1988). If this notion is accurate, it is also plausible that there has been an evolution of experience-expectant neurodevelopmental processes that provide a foundation for modular social-cognitive development. Indeed, research with sensory-impaired children suggests that sufficient social input is required for typical ToM development, measured by false belief tasks (Peterson & Siegal, 1995). Thus, in the modular terms of the ToM model, a failure of early experience in social interactions may yield a disturbance of early information processing. This failure contributes to a disturbance in the neurological development of dedicated systems necessary for the typical development and function of social-cognitive modules (Mundy, 1995). This presents a complementary but different view than typical ToM models, which emphasize critical errors within the specific functional parameters of one or another module but do not consider possible errors in the developmental processes that may give rise to the modules themselves.

THE SOCIAL-ORIENTING MODEL AND BRAIN VOLUME IN AUTISM

We have briefly reviewed theory and evidence on early neural plasticity that suggests that proliferation of *potential* synaptic connections between neurons leads to an increase in brain volume in the first 12 to 24 months followed by a gradual decrease in brain volume in part due to experience-expectant processes of culling understimulated or underutilized connections (Greenough et al., 1987; Huttenlocher, 1994). We have also suggested that an attenuation of social information processing and experience-expectant processes early in the life of children with autism may contribute to a disruption of this typical pattern of neural plasticity and development (Mundy & Neal, 2001).

One of the more interesting and consistent findings in neuroanatomical research is that many individuals with autism display larger than average brain volumes (Hardan, Minshew, Mallikarjuhn, & Keshavan, 2001; Piven et al., 1995), at least across the first 6 years of development (Aylward, Minshew, Field, Sparks, & Singh, 2002). Moreover, recent evidence suggests that level of impairment may be positively associated with brain volume in autism (Akshoomoff et al., 2004). However, the current neuroanatomical findings in research on autism are often inconsistent. Null findings and even decreased regional brain volumes among individuals with autism have also been noted in the literature (Aylward et al., 1999; Haznedar et al., 1997). Variations among studies complicate this type of research but may be expected because: (1) The power of these studies is often low due to small sample sizes, (2) consensus has yet to be reached on uniform imaging and data analysis methods to be used across studies, and (3) there is a need to con-

trol for comparison group differences in somatic, developmental, or cognitive status.

Nevertheless, in a seminal magnetic resonance imaging (MRI) study that controlled for individual differences in height and nonverbal IQ, Piven et al. (1995) reported male autistic individuals displayed significantly greater total brain volume than controls. This difference was not just due to greater ventricle volume but also reflected greater brain tissue volume. In a second report, Piven, Arndt, Bailey, and Andreasen (1996) examined MRI data from 35 autistic and 36 comparison research participants, also controlling for height and nonverbal IQ. They again observed larger brain volumes in male but not female participants with autism. Furthermore, significant enlargement was observed for the temporal, parietal, occipital, but not frontal lobes of these individuals. In a third report, these authors focused on an examination of cerebellar anomalies in the sample of 35 people with autism and 35 controls (Piven, Saliba, Bailey, & Arndt, 1997). They observed no decrease in the posterior lobules of the cerebellum, but did observe a significantly higher total cerebellar volume than in the comparison group. More recently, others have also observed higher total cerebellar, cortical, and basal ganglia volumes (Courchesne et al., 2001; Hardan, Minshew, Harenski, & Keshavan, 2001; Hardan, Minshew, Mallikarjuhn, et al., 2001; Sears et al., 1999).

These findings are consistent with observations of higher autopsy brain weight, as well as above average head circumference in autism (Bailey et al., 1996). It is important to note that brain enlargement may not be a general feature of mental retardation or developmental disorders. Children with mental retardation, but not autism, have been observed to display lower total brain volumes than comparison individuals (e.g., Hamano, Iwasaki, Kawashima, & Takita, 1990). Thus, in the aggregate, these studies are consistent with the notion that autism, unlike other developmental disorders, may be characterized by macroencephaly.

The nature of the processes that lead to increased brain volume in autism is not clear. Many researchers currently conceptualize this phenomenon singularly in terms of genetic, neurotransmitter, neural migration, and apoptosis processes gone awry (Akshoomoff, Pierce, & Courchesne, 2002). However, human development does not necessarily occur as an unerring response to unfolding biological process. Rather, it may be the outcome of complex organism-environment interactions. Therefore, understanding developmental disorders may require an epigenetic and coactive perspective that emphasizes organism-environment interactions in understanding this aspect of autistic pathology (Gottlieb & Halpern, 2002; Greenough et al., 1987). Moreover, it may also be important to understand that some critical components of the environment ensue from the child's own behavior, especially in social development, where the learning environment primarily involves children's active participation in interactions with social partners. Thus, a robust disturbance of early social proclivities may dramatically change the social environment of the child and lead to a chronic disruption of fundamental organism-environment interactions during a sensitive period of development. We think it is important to consider the hypothesis that early arising behavioral deficits in social orienting and joint attention lead to a critical impoverishment in the first years of social information input, which contributes to the course of atypical neurodevelopment in autism (see Figure 46.2). To the degree that an attenuation of social environmental input makes a major contribution to the excess brain volume phenomena in autism, it may be difficult to identify biological markers of atypical processes related to synaptogenesis and/or apoptosis. This coactive hypothesis of atypical neurodevelopment also serves to emphasize why studies of early identification and behavioral intervention may be so important. According to this model, very early behavioral intervention may serve to not only ameliorate existing levels of disturbance but also prevent or attenuate the subsequent neurodevelopmental disturbance that potentially arises from early impoverished social interactions in the first years of life (see Mundy & Crowson, 1997; Mundy & Neal, 2001).

Although individuals with autism typically display a deficit in joint attention and social orienting, they also display significant individual differences in joint attention development

that are related to their developmental outcomes (Mundy, Sigman, Kasari, 1990; Sigman & Ruskin, 1999). If, as we suspect, individual differences in joint attention reflect the differences in the degree to which impoverished social orienting plays a role in the atypical development of children, individual differences in early social orienting and joint attention measures may be correlated with or predict the course of volumetric brain growth in samples of children with autism. With advances in early identification (Willensen-Swinkel et al., 2002), testing of this important hypothesis may become possible within the next few years. Furthermore, an even stronger test of this model may be provided in intervention studies. That is, according to this model, ameliorating the social-orienting disturbance early in the lives of children with autism may be expected to directly impact neurodevelopmental organization and volumetric indices of brain growth in children with autism (Mundy & Neal, 2001).

JOINT ATTENTION AND BRAIN BEHAVIOR RESEARCH

Given the foregoing literature, it is reasonable to assume that understanding the brain systems involved in joint attention development may provide clues to critical aspects of the neurobehavioral pathology of autism (Mundy & Neal, 2001; Mundy et al., 2000). Current brain behavior research and theory on autism emphasize the importance of investigating the role of areas related to the ventromedial prefrontal cortex, medial temporal cortex, and STS involved in the perception of social action and the valence of social stimuli (e.g., Dawson, Munson, Estes, Osterling, McPartland, et al., 2002; Kawashima et al., 1999). Recall, though, that social orienting and joint attention disturbance in autism may involve systems involved in self-monitoring and the self-initiation or generation of behavior as well as those involved in the perception of the behaviors of a social partner (Mundy et al., 1993). It may be important to broaden inquiry to include the study of brain systems involved in the social initiations as well as social perceptions. Indeed, when the brain-behavior correlates of initiating versus responding to joint attention measures have been directly examined with imaging and electrophysiological methods, both dorsal-cortical and ventromedial brain activation correlates have been observed.

Perhaps the first study of brain behavior relations and joint attention development was conducted at UCLA by Caplan et al. (1993), who studied the behavioral outcome of 13 infants who underwent hemispherectomies in an attempt to treat their intractable seizure disorders. The ESCS (Mundy et al., 2003) were used to assess the postsurgical development of joint attention and related behaviors among these children. Positron emission tomography (PET) data were gathered prior to surgical intervention. These data indicated that metabolic activity in the frontal hemispheres, especially the left frontal hemisphere, predicted the development of IJA skill in this sample. However, neither RJA skill nor IBR skill was observed to relate to any of the PET indices of cortical activity. Moreover, metabolic activity recorded from other brain regions was not significantly associated with joint attention or other social-communication skills in this study. These regions included orbital, parietal, superior temporal, middle temporal, inferior temporal, mesial temporal, lateral occipital, and mesial occipital. Thus, frontal activity appeared to be specifically related to the development of the tendency to spontaneously initiate social attention coordination with others to share experience.

A post-hoc explanation of the frontal connection to IJA was offered in a later paper (Mundy, 1995). A frontal and left lateralized system emerges in infancy by 10 months of age that plays a role in the executive and emotional processes associated with approach tendencies. These approach tendencies are involved in positive social affiliative behaviors (Fox, 1991). Mundy suggested that the IJA impairment in autism may reflect a disturbance in the emergence of this left frontal "social-approach" system. Based on earlier work (Panksepp, 1979), an impairment in IJA was hypothesized to reflect a developmental disturbance in frontally mediated processes involved in assigning positive reward value to social stimuli. Impairment in these frontally mediated processes leads to a relative insensitivity to the social reward value of social inter-

actions and an attenuation of the motivation to emphasize social information processing early in life. Consequently, social-cognitive and social-behavioral development in children with autism is marginalized (Mundy, 1995).

To begin to test aspects of this model, Mundy et al. (2000) examined the hypothesis that EEG activity in a left lateralized, frontal-cortical system would be a significant correlate of IJA development in typical infants. EEG and joint attention data using the ESCS were collected on 32 infants at 14, 16, and 18 months of age. The EEG data were collected while infants were involved in attending to a nonsocial stimulus (i.e., balls moving about in a cage). The results indicated that individual differences in 18-month IJA were predicted by a complex pattern of 14-month EEG activity in the 4–6Hz band that included indices of left medial-frontal EEG and left occipital activation, as well as indices of right central and right occipital deactivation. Although the location of the generators of the EEG data could not be definitively determined in this study, the frontal correlates of IJA reflected activity derived from electrodes positioned at F3 of the 10/20 placement system (Jasper, 1958). In terms of cortical coordinates, these electrodes were positioned on infants above a point of confluence of Brodmann's areas 8 and 9 of the DMFC of the left hemisphere (Martin, 1996). This area includes aspects of the frontal eye fields and supplementary motor cortex involved in visual attention control. Theory on attention development (e.g., Posner & Petersen, 1990) suggested that, in addition to DMFC activity, data from these electrodes likely reflected activity in the anterior cingulate (AC), a subcortical structure ventral to cortical areas 8/9 (Martin, 1996).

Alternatively, neither RJA nor IBR measures were associated with the pattern of EEG activity that was associated with IJA (Mundy et al., 2000). However, RJA assessed at 18 months was predicted by EEG indices of left parietal activation and right parietal deactivation at 14 months of age. This observation was consistent with research that suggests parietal areas specialized for spatial orienting and attention, perhaps along with temporal systems specialized for processing gaze, contribute to the human capacity to shift attention in response to the gaze direction of a social partner (Kawashima, Sugiura, Kato, Nakamura, Hatano, et al., 1999; Kingstone, Friesen, & Gazzaniga, 2000; see Vaughan & Mundy, in press, for review). However, eye contact and, especially, gaze aversion have also been observed to activate components of the DMFC (Calder et al., 2002). Thus, a frontal contribution to RJA should not be ruled out on the basis of this one study. Perhaps the use of alternative RJA-related paradigms (Hood, Willen, & Driver, 1998), as well as different age groups from those previously studied (Mundy et al., 2000), will shed light on this issue in future research.

The observations of Mundy et al. (2000) suggest that a dual process or multiple system model of neurodevelopmental disturbance in joint attention in autism may be useful to consider. A dual parietal and frontal model of joint attention would be consistent with theory on typical attention development (Posner & Petersen, 1990), as well as evidence of both parietal and frontal contributions to orienting impairments in autism (Townsend et al., 2001). Moreover, a dual process model of joint attention is consistent with observations of a dissociation between IJA and RJA impairments in the development of children with autism (Leekam & Moore, 2001; Mundy et al., 1994). The dual process model may also have implications for current neuropsychological research on joint attention in autism.

Two studies have suggested that both IJA and RJA involve common inhibitory processes that, in comparative studies, tend to be associated with dorsolateral cortical activity (Griffith, Pennington, Wehner, & Rogers, 1999; McEvoy et al., 1993). Alternatively, a seminal study conducted by Dawson, Munson, et al. (2002) led to the observation that joint attention ability in children with autism appears to be significantly correlated with a delayed nonmatch to sample (DNMS) measure associated with activity of a temporal-ventromedial frontal circuit, rather than a dorsolateral frontal system. Dawson et al. suggested that the DNMS task provided a measure of the children's sensitivity to shifts in reward contingencies. However, the latent variable reflecting joint attention used in structural equations modeling by the Dawson, Munson, et al. study was composed of two measures of

RJA to one measure of IJA and may have been referenced to one of the RJA measures. Thus, it was not clear whether these results were applicable to RJA, IJA, or both types of skills. Subsequently, a study by Nichols, Fox, and Mundy (in press) attempted to replicate and extend Dawson, Munson, et al.'s observation in a study of typically developing infants. This study used separate measures of IJA and RJA and observed that infant DNMS performance was related to IJA but not RJA development. Moreover, this study also included a measure of self-recognition to examine the hypothesis that self-monitoring functions associated with the DMFC would also be associated with IJA (Mundy, 2003). The results of the study supported this hypothesis and suggested that multiple functions (e.g., sensitivity to reward contingencies and self-monitoring), supported by ventromedial and dorsomedial cortical systems, may contribute to IJA but not necessarily RJA development. Thus, it may be important to consider a dual or multiple process model of neurodevelopmental disturbance in joint attention skills as we attempt to better understand the basis of autistic impairment in this domain of development.

The dual process model of IJA and RJA, and especially the putative relations between a medial-frontal system and IJA, requires additional substantiation. A critical study was provided by Henderson, Yoder, Yale, and McDuffie (2002), who also used the ESCS to examine the EEG correlates of joint attention in twenty-seven 14- to 18-month-old typically developing infants. However, to improve the spatial resolution of their data, this research group used a high-density array of 64 electrodes. In addition they reasoned that, since the total ESCS scores for measures of IJA and related behaviors that had been used in the Mundy et al. (2000) study were composites of several items, the exact nature of the behaviors involved in associations with EEG activity were unclear. To address this issue, Henderson et al. compared the EEG correlates of only two behaviors: infants' self-initiated pointing to share attention regarding their observation of an active mechanical toy (IJA pointing), versus self-initiated pointing to elicit aid in obtaining an out of reach object (IBR pointing).

Several significant observations emerged from this study. First, no significant correlations were observed between any of the 14-month EEG data and 18-month IBR pointing. Alternatively, in the 3–6 Hz band, there were four significant correlations of 14-month EEG power and 18-month IJA pointing ($r = -.55$ to $-.62$, $ps < .01$). These correlations indicated that bilateral activity recorded above DMFC sites at 14 months was associated with more IJA pointing at 18 months. These correlations involved electrodes that were placed above cortical regions corresponding to Brodmann's areas 8, 9, and 6. Henderson et al. also analyzed data from the 6–9 Hz band, which revealed 15 significant correlations with IJA pointing ($r = -.60$ to $-.78$, $ps < .01$). Again, bilateral activity corresponding to the previously identified dorsal medial-frontal sites were the strongest predictors of IJA pointing at 18 months. It is interesting that in the 6–9 Hz bandwidth, data from sites corresponding to temporal, orbitofrontal, as well as dorsolateral activity at 14 months also predicted IJA pointing at 18 months.

These observations are extremely important for a number of reasons. First, the bilateral nature of the Henderson et al. (2002) findings suggest that Mundy's (1995) model emphasizing processes associated with left frontal functions and IJA may, at best, be incomplete. Nevertheless, these results do provide support for the hypothesis that DMFC processes play an important role in IJA development (Mundy et al., 2000). As previously noted, the specific DMFC areas of involvement observed in the studies by Mundy et al. and Henderson et al. correspond to aspects of both the frontal eye fields and supplementary motor cortex associated with the control of saccadic eye movement and motor movement planning (e.g., Brodmann's area 8/9; Martin, 1996). It may be tempting to suggest that these associations simply reflect the motor control of eye movements and/or gestural behaviors that are intrinsic to IJA behavior. However, the simple elegance of the Henderson et al. study controls for this possible interpretation. The motor movements involved in IJA pointing and IBR pointing are virtually identical. Therefore, a neuromotor explana-

tion of the different cortical correlates of IJA and IBR appears unlikely. Instead, since IJA pointing and IBR pointing serve different social-communicative functions, it is reasonable to assume that the difference in EEG correlates of these infant behaviors also reflects differences in the neurodevelopmental substrates of these functions.

Another important aspect of the results of the Henderson et al. (2002) study is that they suggest baseline activity in *other* cortical areas such as dorsolateral, orbitofrontal, and temporal cortex may be involved in IJA. The latter observations are especially intriguing as they are consistent with the hypothesis that IJA development reflects an integration of dorsal-cortical functions with ventral "social brain" facilities noted in other research (Dawson, Munson et al., 2002). We return to the possible nature of this integrated activity later in this chapter.

The EEG methodology of the Mundy et al. (2000) and Henderson et al. (2002) studies were insufficiently precise to be indicative of the specific cortical systems involved in joint attention. Therefore, it is important to consider additional data on brain behavior correlates in social-cognitive development. Joint attention development has long been theoretically linked to subsequent ToM development in research on typical development (Bretherton et al., 1981), as well as in research on the nature of autism (Baron-Cohen, 1995; Mundy et al., 1993). Charman et al. (2000), for example, have observed that, after controlling for differences in typical 20-month-olds' IQ and language development, an IJA measure of alternating gaze at 20 months was a significant predictor of ToM performance at 44 months. This alternating gaze measure was the same measure that most readily identified autism in 20-month-olds (Swettenham et al., 1998) and was similar to the IJA measure that best discriminated autism and control samples in our initial studies (Mundy et al., 1986). Thus, data indicating that ToM skill development is associated with DMFC functioning would provide important indirect support for the hypothesis that the DMFC may contribute to joint attention development. This type of association between the DMFC and ToM have been reported (C. Frith & Frith, 1999; U. Frith & Frith, 2001).

BRAIN-BEHAVIOR RESEARCH AND THEORY OF MIND

In one of the first studies of its kind, Fletcher et al. (1995) observed that the performance of six typical adult men on the ToM stories was associated with PET indices of increased blood flow in an area of the left medial-frontal gyrus corresponding to Brodmann's area 8 relative to their performance on the "physical stories." Goel, Grafman, Sadato, and Hallett (1995) also observed that only tasks involving inferences about other people's minds elicited PET activation of a distributed set of neural networks characterized by prominent activation of the left medial-frontal lobe and left medial-frontal gyrus. These authors concluded that, when inferential reasoning depends on constructing a mental model about the beliefs and intentions of others, activation of the DMFC is required. Goel, Gold, Kapur, and Houle (1997) also observed that while general inferential reasoning processes also seem to involve frontal activation, this activation may be centered on more dorsolateral areas of the frontal cortex (Brodmann's area 46) rather than the more dorsal-medial areas 8/9 associated with social cognition.

Since studies have often used stories, or verbal stimuli, language-related processes may have affected the functional localization of ToM skills in these studies. To address this possibility, Gallagher et al. (2000) used functional magnetic resonance imaging (fMRI) to examine brain activity in both verbal-ToM stories and nonverbally presented ToM tasks that involved the processing of visually presented cartoons. The results indicated that the bilateral brain activation correlates of both tasks displayed considerable overlap, specifically in the paracingulate area of the DMFC. The paracingulate area (Brodmann's area 32) refers to a subcortical frontal structure that forms the ventral border between the DMFC (Brodmann's area 8/9, superior and middle frontal gyri) and the AC of the limbic system (especially Brodmann's area 24). Schultz, Romanski, and Tsatsanis (2000) have also

reported a study that employed nonverbal ToM task presentation called the Social Attribution Task (SAT; Klin, 2000). In this task, a brief sequence of geometric forms moving across a blank white background was presented to eight typical adult participants. People viewing the SAT tend to anthropomorphize the movement sequence of geometric forms and describe it in terms of intentional, animate behavior. Presumably, this is a fundamental component of ToM skill (Klin, 2000). Schultz et al. reported that processing of this task recruited bilateral activation of the DMFC (Brodmann's area 9) in their typical sample. Related research has demonstrated that people with autism spectrum disorders do not tend to anthropomorphize the movement sequence on the SAT (Klin, 2000).

An important control condition was also included in a study by Sabbagh and Taylor (2000). Using evoked response potentials (ERP) and a dense EEG electrode array (128 sites), they presented university students with a paradigm that compared false-belief ToM task performance with an analogous nonsocial task. The latter involves thinking about the contents held within a camera (i.e., picture) instead of the false belief held within someone's mind, as in a ToM task (see Leslie & Thaiss, 1992). Sabbagh and Taylor observed significantly greater ERP data from the left dorsolateral and dorsomedial cortex in the ToM false belief task (e.g., ERP from electrode sites approximately above BA 9/10/46), rather than in the nonsocial camera task in their sample.

Thus, although some imaging and case studies have observed associations between ToM performance and orbital activity, rather than dorsal medial-frontal activity (Bach, Happé, Fleminger, & Powell, 2000; Baron-Cohen et al., 1999), the link between ToM performance and the DMFC currently is the most consistent finding in the relevant literature (U. Frith & Frith, 2001). Moreover, in addition to basic studies, applied research with clinical samples points to the involvement of the DMFC in ToM performance.

In a PET study of autism spectrum disorders, Happé et al. (1996) reported that five adults with Asperger disorder did not display activity in the medial-frontal gyrus in the context of reading and solving ToM stories but did display activity in an immediately adjacent area. This pattern distinguished the people with Asperger disorder from controls. Somewhat different findings emerged in a related fMRI study by Baron-Cohen et al. (1999), which assessed the ability of groups to infer emotional states from pictures of eyes. This social-cognitive assessment method revealed that activity in part of the "social brain" network, involving orbitofrontal cortex, the STG, and the amygdala, was involved in ToM processing. Moreover, significant differences were found between the Asperger and typical samples in this pattern of task-related brain action. In addition, activation of the left and right DMFC was also observed to be a specific component of ToM task performance in this study. However, unlike the data from Happé et al. (1996), the Asperger sample did not differ from controls in task-related activation of this cortical area. It was apparent that the typical controls in Baron-Cohen et al. (1999) displayed evidence of bilateral medial-frontal activation on ToM tasks. Alternatively, the people with Asperger disorder displayed evidence of unilateral left medial-frontal activation, but no evidence of right medial-frontal activation in association with the ToM tasks (see Tables 3 and 4, Baron-Cohen et al., 1999). Thus, there may have been a medial-frontal group difference in this study that was not detected by the analyses provided.

Russell et al. (2000) have also employed a ToM measure known as the "eyes" task (Baron-Cohen et al., 1999) in an fMRI study that examined the neural metabolic activation patterns associated with ToM in individuals affected by schizophrenia. The schizophrenic participants made more errors on this measure of attributions of mental state than did the controls. Moreover, the controls displayed relatively more activity in the medial-frontal lobe (Brodmann's area 45/9) in association with ToM task performance relative to the individuals with schizophrenia. Again, though, the group differences were not limited to the DMFC, but also included ventral "social brain" components of the left inferior-frontal gyrus (Brodmann's areas 44/45/47) and the left middle- and superior-temporal gyri (Brodmann's areas 21/22).

Complementing these group comparison data are observations that suggest there may be dopaminergic activity in the DMFC of children with autism (Ernst, Zametkin, Matochik, Pascualvacae, & Cohen, 1997). A recent voxel-based morphometric study with 28 high-function children and adults with autism also indicated increased gray matter density in the AC and left superior frontal gyrus, as well as the left inferior parietal lobe and right frontal lobe subgyral regions (Hardan, Yorbik, Minshew, Diwadkar, & Keshavan, 2002). Recall that the first three of these brain regions correspond to the dorsal medial-frontal area (Brodmann's areas 8/9/24) that has been implicated in joint attention and social-cognitive processing.

There are also at least two individual difference studies that emphasize the potentially important role of the DMFC in autistic social symptom presentation. Ohnishi et al. (2000) used PET to examine the associations between regional cerebral blood flow (rCBF) and symptom presentation in children with autism and IQ-matched controls. Symptom presentation was measured using factor-based scale scores for the Impairments in Communication and Social Interaction scale and the Obsessive Desire for Sameness scale from the CARS (Schopler, Reichlet, DeVellis, & Daly, 1980). The results indicated that the children with autism displayed decreased baseline rCBF relative to controls in the superior temporal gyrus (BA 22), left inferior frontal gyrus (BA 45), and left medial prefrontal cortex (BA 9/10). Moreover, less activity in the latter area (DMFC, BA 9/10) was reportedly correlated with CARS factor scores indicative of more disturbance on the Impairments in Communication and Social Interaction factor-based scale. Alternatively, rCBF in the right hippocampus and the amygdala was reportedly correlated with the Obsessive Desire for Sameness factor-scaled score.

In another study, Haznedar et al. (2000) used PET and MRI coregistration to examine the hypothesis that the amygdala and hippocampus would display metabolic rate and morphometric differences in 17 high-functioning individuals with autism relative to typical controls. The results, however, revealed few differences in these areas. Alternatively, a consistent pattern of significant findings was revealed for areas of the AC (Brodmann's area 24 and 24'). Volumetric data indicated that the autism group displayed smaller brain volume in the right AC region, especially Brodmann's area 24' relative to the control sample. The autism sample also displayed hypometabolism in the right AC cortex relative to controls. The Asperger subsample displayed left AC hypometabolism relative to controls. This hypometabolism was not observed in more ventral portions of the AC (Brodmann's area 25). Finally, in the autism sample, metabolism in left Brodmann's area 24 was correlated with the social interaction, verbal communication, and nonverbal communication scores on the Autism Diagnostic Interview (ADI), and metabolism in Brodmann's area 24' was correlated with the ADI social interaction scores in the autism sample. Thus, consistent with the notion that the MFC/AC system may be integral to the development of joint attention and social cognition, these studies provide evidence that activity in this system may be related to social symptom presentation in autism.

In summary, theory suggests that infant joint attention and later social-cognitive measures may reflect common processes (e.g., Bretherton et al., 1981; Wellman, 1993) and sources of disturbance in autism (Baron-Cohen, 1995; Mundy et al., 1986). Recent research indicates that common neuropsychological functions of the DMFC/AC may play a role in IJA, ToM, and related social impairments in individuals with autism. At present, though, the functional resolution of the data is inexact, especially those from the joint attention studies. Thus, the degree to which this apparent commonality across tasks and measures actually involves the same functional units within the DMFC/AC system is not clear. Moreover, current data also raise the possibility that DMFC processes contribute to both joint attention and ToM skill in conjunction with processes associated with ventral "social brain" systems (e.g., Henderson et al., 2002; Russell et al., 2000) that may be involved in the perception and analysis of the social behaviors of others. An argument could also be made that other brain systems, such as cerebellar contributions to the attention regulation functions of the DMFC/AC, may also be

involved (Courchesne et al., 1994). Ultimately, it may be necessary to adopt a complex systems approach (e.g., Bressler, 1995; Miller & Cohen, 2001) in attempts to fully understand the dynamic neural systems involved in these behavior domains. Prior to such an inclusive and dynamic level of analysis, a better understanding of the component processes involved in the system will be necessary. However, there has been little detailed recognition of what the DMFC/AC component may bring to such a system (e.g., Adolphs, 2001; Dawson, Munson, et al., 2002). This may be a gap in our collective research efforts with autism that requires reconsideration.

THE ROLE OF THE DORSAL MEDIAL-FRONTAL CORTEX IN SOCIAL AND NONSOCIAL BEHAVIOR

What processes and functions of the DMFC/AC complex may make it important to social development? How do these functions develop? Are they specific to social behavior? Is an impairment in DMFC/AC social functions integral to the pathogenesis of autism? Is there a primary developmental impairment of the DMFC/AC system in autism, or are functions in the DMFC/AC complex disrupted in autism secondary to neurodevelopmental deficits in "upstream" cerebellar mechanisms or ventral-brain mediated social information perception and processing? Does impairment of the DMFC lead to a critical organism-environment disturbance in autism (e.g., the early infancy tendency to initiate social orienting), and does such a disturbance contribute to subsequent neurobehavioral disturbance in autism?

These and related questions may occupy the efforts of many people over the next few years of research on autism. While definitive answers to these questions are not close at hand, a wealth of information is emerging on the functions of the DMFC and AC, which may guide inquiry in this arena. Moreover, several hypotheses concerning the specific social-cognitive, as well as nonsocial functions of the DMFC, have been generated, and these intersect with current theory on autism.

The DMFC and AC may play a central role in several processes that are related to an *executive system.* In particular, the DMFC/AC complex contributes to the planning and execution of self-initiated, goal-directed behavior. The DMFC/AC system also appears to play a role in the *self-monitoring of goal-directed behaviors.* Goal-directed behaviors refer to a range of activities, from control of overt behavior such as saccades in visual orienting, to the more covert mental activity involved in generating or operating on mental representations (cognition). Self-monitoring, in part, refers to the evaluation of whether goal-directed behavior does or does not lead to reward (e.g., Amador, Schlag-Rey, & Schlag, 2000; Busch, Luu, & Posner, 2000; Ferstl & von Cramon, 2001). Related to these facilities is the role the DMFC/AC complex plays in the maintenance of representations of multiple goals in working memory. The DMFC/AC is also involved in the capacity to flexibly switch between goal representations (e.g., Birrell & Brown, 2000; DiGirolamo et al., 2001; Koechlin, Basso, Peirini, Panzer, & Grafman, 1999), as well as the DMFC/AC role in the appraisal of the valence of stimuli and the generation or modulation of emotional responses to stimuli (e.g., Fox & Davidson, 1987; Lane, Fink, Chua, & Dolan, 1997; Teasdale et al., 1999).

The foregoing, in all likelihood, is a nonexhaustive list of DMFC/AC functions. Nevertheless, it is important to note that even in this constrained view, there are functional characteristics of the DMFC/AC system that may provide a unifying bridge between theories of autism that emphasize impairments in basic cognitive functions and those that emphasize specific social-cognitive or social-emotional impairments. For example, in their recent elegant work, Minshew et al. (2001) have argued that autism involves a selective disorder of complex information processing. This disorder of complex information processing is reportedly manifest, at least in higher functioning individuals, as a fundamental impairment in concept formation. This involves the capacity to spontaneously initiate a strategy for eliminating alternatives, and the strategy needs to be monitored and changed in accordance with experience of success or failure while processing the solution (Minshew et al., 2002). Given the current functional analysis of the DMFC briefly outlined earlier, it seems reasonable to suggest that the DMFC/AC system may play a role in this aspect of cognitive disturbance in

autism. Moreover, it is interesting that Minshew et al. (2001) suggest that, at its most basic level, the disorder of complex information processing may be associated with impairments in neocortical systems involved in overt saccade and occulomotor control. Brodmann's area 8/9 of the DMFC/AC system includes portions of the frontal eye fields and is integral to saccadic and occulomotor control (Martin, 1996).

Another recently developed cognitive/perceptual model of autism revolves around the weak central coherence (WCC) hypothesis (U. Frith & Happé, 1994). Briefly, WCC in autism reflects a bias toward processing stimulus details. Alternatively, holistic stimulus processing, which involves integration of multiple dimensions of information (central coherence), is more difficult for people with autism. Hence, they often have difficulty with the types of gestalt, inferential, contextually bound information processing that is necessary to adaptive social information processing, such as in face processing or the processing of pragmatic aspects of communication. One indication of weak central coherence is the difficulty verbal children with autism have on homograph tasks that demand processing of the entire context of the sentence to interpret the correct meaning of a word, such as, "a *tear* in her eye" versus "a *tear* in her dress" (Burnette et al., in press; Happé, 1997). It is interesting that wholistic or inferential text interpretation has recently been observed to be associated with left medial-frontal activation in an MRI study (Ferstl & von Cramon, 2001). Indeed, Ferstl and von Cramon suggest that the "frontomedian area [of the cortex] has a function for the self-initiation of a cognitive process in the context of tasks that require the active utilization of the individual's background knowledge" (p. 338). This function described by Ferstl and von Cramon appears to have much in common with the nature of central coherence. Ferstl and von Cramon also relate this capacity for the self-initiation of background-dependent cognition directly to the capacity for successful performance on ToM measures. Indeed, in our own research, we have recently observed that poorer performance on a homographs task, indicative of WCC, was related to poor performance on the ToM task or evidenced greater social-cognitive impairment among high-functioning children with autism (Burnette et al., in press). Hence, a better understanding of the relations among weak central coherence, DMFC functions, and social-cognitive disturbance in autism may be a useful and integrative goal for future studies.

The executive functions of the DMFC/AC may also play several *specific* roles in social and social-cognitive impairments in autism. Impairments in the DMFC/AC facility for self-monitoring, as well as maintaining multiple goals and representations (Birrell & Brown, 2000; DiGirolamo et al., 2001; Koechlin et al., 1999), may conceivably be essential to the representation decoupling and tagging mechanism that Leslie (1987) suggested underlies metarepresentational processes that may be impaired in autism. IJA may also involve the capacity to shift attention between social and nonsocial goals and representations (Mundy et al., 1986, 2000). Hence, impairment in this facility of the DMFC/AC may also be involved in joint attention disturbance in autism.

From another perspective, though, it may be useful to consider the proposition that, as part of early social development, some of the general executive facilities of the DMFC/AC become redescribed as specific "social-executive functions." These may arise, in part, from the self-monitoring and self-initiating facilities of the DMFC/AC. The hypothesis that the DMFC/AC plays an integral role in self-monitoring stems from several findings (Craik et al., 1999; C. Frith & Frith, 1999; U. Frith & Frith, 2001). Prominent here is research that has led to the observation that, when people make erroneous saccadic responses in an attention deployment task, there is a negative deflection in the stimulus and response locked ERP called the error-related negativity (ERN; Busch et al., 2000; Luu, Flaisch, & Tucker, 2000). Source location suggests the ERN emanates from an area proximal to the AC (e.g., Luu et al., 2000). Observations of the ERN suggest that there are specific cell groups within the DMFC/AC that are not only active in initiating a behavioral act, such as orienting to a stimulus, but also distinct cell groups involved in processing the positive or negative outcome of the response behavior (i.e., accuracy and reinforcement information; e.g., Busch et al., 2000; Stuphorn, Taylor, & Schall,

2000). Thus, cell groups within the DMFC/AC come to serve as part of a supervisory attention system (SAS; Norman & Shallice, 1986) that functions to guide behavior, especially attention deployment, depending on the motivational context of the task (Amador et al., 2000; Busch et al., 2000; Luu et al., 2000).

Robert Schultz and coworkers at Yale (Schultz et al., 2000) have begun to consider this functional role of the DMFC/AC in social behavior and its impairment in autism. In one scenario, Schultz et al. suggested that impaired information flow from the amygdala to the DMFC may attenuate the tendency for social stimuli to acquire their normal valence causing social processing difficulties. The nature of these social processing difficulties is not yet well defined, though this research team has suggested that they might include face processing disturbance in autism, which, in turn, contributes to impairments in the typical development of social-cognitive facilities (Grelotti, Gauthier, & Schultz, 2002).

Similar hypotheses were raised in attempts to understand the nature of joint attention and social-orienting disturbance in autism (Dawson et al., 1998; Dawson, Munson, et al., 2002; Mundy, 1995; Mundy & Neal, 2001). These researchers have suggested that: (1) frontal and temporal/amygdala circuits that mediate reinforcement and emotional/motivational goal guidance contribute to a bias to attend to social stimuli in infancy, and (2) a disturbance in this bias, from the neonatal period onward, plays a fundamental role in developmental disturbance of social behavior and social cognition in autism. As noted in earlier sections of this chapter, an early onset of this disturbance hypothetically leads to a robust disturbance in social orienting in autism and a robust attenuation of the flow of social information to the developing child. The resulting impoverishment of social information could be sufficiently severe to disrupt experience-expectant neurodevelopmental processes (see Greenough et al., 1987) and contribute to the subsequent disorganization and impairment of brain and behavior systems including those that subserve social-emotional and social-cognitive skill development (Dawson, 1994; Loveland, 2001; Mundy & Crowson, 1997; Mundy & Neal, 2001; Mundy & Sigman, 1989).

Previous theory and research on social reward sensitivity and social-orienting disturbance in autism (Dawson et al., 1998; Dawson, Munson, et al., 2002; Grelotti et al., 2002) have emphasized the possible contributions of the orbitofrontal cortex or subcortical structures such as the amygdala (e.g., de-Haan, Pascalis, & Johnson, 2002; Tremblay & Schultz, 1999; Wantanabe, 1999). The literature reviewed herein, though, suggests that it may be useful to expand this focus to include contributions from the DMFC/AC complex. The logic here is twofold. First, infant measures of IJA provide one operationalization of the tendency to spontaneously social orient to an interactive partner (Mundy & Neal, 2001), and there is now empirical evidence to directly link this tendency with DMFC activity (Henderson et al., 2002; Mundy et al., 2000). Second, and equally important, the areas of the DMFC associated with IJA (Brodmann's area 8/9) overlap aspects of the frontal eye fields and supplementary motor cortex. *These cortical areas may be important to consider in understanding processes that hamper the tendency of children with autism to look appropriately or sufficiently often at people because they are vital to regulating attention deployment through the active integration of the context in which reward occurs with the planning and control of saccades or visual orienting* (Amador et al., 2000; Luu et al., 2000; Stuphorn et al., 2000).

There is also some evidence that dopaminergic projections to the AC play a role in the mediation of reward-related activity (Allman, Hakeem, Erwin, Nimchinsky, & Hof, 2001). Moreover, Allman et al. note two characteristics of the AC that make this brain region of particular interest in understanding joint attention and pathology in autism. First, they present evidence to suggest that spindle cell formations in the AC may be a novel specialization of neural circuitry found only in great apes and humans. Interestingly, joint attention facilities and related social-cognitive ability may also be unique to apes and humans (Tomasello, 1999). Allman et al. also suggest that these spindle cells appear to emerge postnatally, at about 4 months of age, and their development may be affected by environmental factors (Allman et al., 2001, pp. 109–112). The timing of the emergence of spindle cell sys-

tems of the AC suggest they have the potential to be involved in experience-expectant, as well as experience-dependent, coactive neurodevelopmental process. A corollary is that this characteristic of the spindle cell system of the AC may be important to consider in exploring the type of coactive, organism environment interactive model of autistic pathology we have outlined here and elsewhere (Mundy & Neal, 2001).

One challenge to the notion that the DMFC/AC complex plays a role in the *early* onset of social-orienting disturbance in autism is that frontal occulomotor control of attention deployment may be relatively late to develop in infancy (Johnson, Posner, & Rothbart, 1991). However, recent research suggests that *by* 3 to 4 months, "the cortical eye fields are actively involved in the prospective control of saccades and visual attention" (Canfield & Kirkham, 2001, p. 207). Further inquiry into the mechanisms and early development of this system in relation to early social attention and information processing may hold a key to a deeper understanding of the pathogenesis of autism, as well as typical social development. Future studies may find the ERN paradigm to be useful in infant studies, as well as studies of the cortical control of attention to social and nonsocial stimuli in children affected by autism spectrum disorders. It may also be important to begin to explore the role that spindle cell formation may play in typical development, as well as in the atypical case of autism.

Another issue is that it is not completely clear if social orienting, in particular, is impaired in autism. Although a social-orienting disturbance may be a robust phenomenon in children with autism (Dawson et al., 1998; Klin, 1991), a more general impairment in orienting to nonsocial stimuli is apparent as well (Dawson et al., 1998; Townsend, Harris, & Courchesne, 1996). Moreover, some research suggests that social orienting and social-emotional processing disturbances in autism may not be as pervasive as theory would suggest (Pierce et al., 2001; Sigman et al., 1992; Warreyn & Roeyers, 2002). Instead, autism may be characterized by a general rather than socially specific orienting disturbance that arises from impairment in a complex cerebellar, parietal, and frontal axis of systems involved in the development and control of attention (Carper & Courchesne, 2000; Townsend et al., 1996, 2001). Thus, a major goal of research on autism is to resolve this issue and examine the possible complex interplay among the DMFC/AC complex, orbitofrontal and amygdala functions, and cerebellar input in the development of attention regulation in people affected by this disorder (see Mundy, 2003; Vaughan & Mundy, in press, for related discussions).

In addition to its role in social attention impairment, the DMFC/AC may play another related and critical role in the social disturbance of autism. C. Frith and Frith (1999; U. Frith & Frith, 2001) have suggested that the supervisory attention system of the DMFC that engages in self-monitoring of attention deployment also develops the capacity to represent the actions, goals, intentions, and emotions of the self (see also Craik et al., 1999). Furthermore, Frith and Frith (1999; U. Frith & Frith, 2001) argue that, as the DMFC comes to participate in the development of representations of the self, it also integrates information from the ventral social brain perception system (e.g., STS) that provides information about the goal-directed behaviors and emotions of others. This integrative activity may be facilitated by the abundance of connections between the DMFC and the STS, as well as the orbitofrontal cortex in primates (Morecraft, Guela, & Mesulam, 1993). Moreover, it may be useful to think of this *facility for the integration of proprioceptive self-action information with exteroceptive information on the actions and behaviors of others* as another emergent social-executive facility of the DMFC/AC. Ultimately, this DMFC/AC social-executive function may serve to compare and integrate the actions of self and the actions of others (Frith & Frith, 2001), perhaps utilizing the DMFC/AC facility for the maintenance of representation of multiple goals in working memory. This integration gives rise to the capacity to infer the intentions of others by matching them with representations of self-initiated actions or intentions (cf. Leslie, 1987). Once this integration begins to occur in the DMFC/AC, a fully functional, adaptive human social-cognitive system emerges with experience (C. Frith & Frith, 1999; U. Frith &

Frith, 2001). Thus, it may be very important to better understand the developmental links between temporal systems involved in the perception of social behavior of others (e.g., Adolphs, 2001) and this more dorsal system for self-monitoring and self-other comparison (U. Frith & Frith, 2001). In terms of joint attention development and autism, it may be especially important to understand how information gleaned about others in RJA (presumably via the temporal/parietal other monitoring system) feeds into and affects the development of the DMFC self-other monitoring system putatively involved in IJA.

In a recent essay, we attempted to begin to address this topic by suggesting that the timely and early onset of RJA, and related behavior development, may be an important stimulant for typical IJA and DMFC social-executive development (Vaughan & Mundy, in press). Furthermore, as we noted earlier in this chapter, episodes of joint attention, especially those initiated by the child, provide a context for infants to integrate proprioceptive information on the actions and intentions of self with exteroceptive information on the actions and intentions of others, in reference to some third object or event (Mundy et al., 1993). Recall the example that, during the act of showing, infants have the opportunity to monitor their own experience (e.g., emotions) and their behavior directed toward an object, while observing the response of a social partner (e.g., their direction of gaze and affect) to both the object and the infant's behavior. This interaction provides an opportunity for the infant to process some information about a social partner's awareness and responses to the displayed object as well as the showing (sharing) behavior of the child (cf. Bates, 1976). Thus, self-initiated bids for joint attention may provide infants an important if not unique opportunity to learn about the internal psychological processes of the self and, perhaps, of others as well.

Theoretically, engagement in this process within joint attention episodes facilitates social-cognitive development, as well as social-emotional attunement in typical development (Mundy, Kasari, & Sigman, 1992, 1993; Mundy & Willoughby, 1998; Stern, 1985). A failure in the development of this fundamental and complex interactive skill, albeit through poorly understood processes, has been suggested as an essential component of the genesis of social-cognitive disturbance in autism (Hobson, 1993; Meltzoff & Gopnik, 1993; Mundy et al., 1993). Some have described this, and related phenomena, as a fundamental disturbance in the capacity for children with autism to engage in shared experience or intersubjectivity (Hobson, 1993; Mundy & Hogan, 1994). These observations, in conjunction with the theoretical analysis by C. Frith and Frith (1999; U. Frith & Frith, 2001), lead to the hypothesis that the activity of the DMFC/AC complex may well be integral to this function. Stated more forthrightly, although not yet well recognized in the relevant literature (e.g., Trevarthen & Aitken, 2001), it may well be that DMFC/AC complex may make an important contribution to the neurofunctional platform from which the essential human capacity for intersubjectivity springs.

C. Frith and Frith's (1999; U. Frith & Frith, 2001) model also has parallels with simulation theory as applied to social cognition (e.g., Stich & Nichols, 1992). As noted earlier, simulation theory suggests that individuals use their awareness (i.e., representations) of their own mental processes to simulate and analyze the intentions of others (Gallese & Goldman, 1998). Gallese and Goldman have also discussed the possible role of mirror neurons in the social-cognitive simulation facility of the DMFC/AC. Mirror neurons are a specific class of motor neurons that are activated both by particular actions performed by an individual and when the individual observes a similar action performed by another person. According to Gallese and Goldman, the motor and premotor cortex adjacent to or overlapping with the DMFC is rich in mirror neurons (see Rizzolatti & Arbib, 1998). Too little is yet known about the nature and distribution of mirror neurons to provide an extended discussion here. Nevertheless, further inquiry into the relations among mirror neurons, social cognition, and the DMFC may be useful (Gallese & Goldman, 1998). In particular, there may be a link between mirror neurons and imitative behavior. Since imitation constitutes a domain of impairment in autism that has been theoretically linked to social and social-cognitive disturbance in autism (Melt-

zoff & Gopnik, 1993; Rogers & Pennington, 1991), it may be judicious to explore the tripartite link among imitation, social cognition, and the functions of the DMFC/AC in research on the nature of autism.

There are many other important implications for research on autism to be drawn from the sagacious and potentially seminal synthesis provided by Uta and Chris Frith. One of these was alluded to at the beginning of this chapter. The basic idea is that a component of information that is necessary for adequate social-cognitive development derives from self-monitoring of *self-initiated actions* in social situations (C. Frith & Frith, 1999). Moreover, an impairment in the early tendency to initiate social behaviors may be especially problematic for the development of children with autism because it disrupts their capacity for social action, which ultimately is the foundation of social self-knowledge requisite to social-cognitive development (Mundy, 1995; Mundy & Neal, 2001). It may be useful to adopt something akin to a Piagetian view of development. Among his many brilliant contributions, Piaget (1952) helped us understand that early cognitive development derived in large part from the actions infants took on objects in their world. Indeed, a major component of cognitive development was explained in terms of the redescription of overt action (sensorimotor schemes) to covert mental representations of action in the sensorimotor period (i.e., in infancy). Unfortunately, Piaget did not speak as directly or as completely to social development as he did to cognition applied to solving object-related problems in the world. Nevertheless, his constructivist model of development may be equally applicable to social development. That is, it is plausible that the infant's capacity to initiate action in social interaction (e.g., in orienting to a social partner or showing a toy to a social partner) and to note social reactions to self-initiated action constitute a major early building block of social-cognitive development (see Braten, 1998). Hence, early difficulty in organizing and initiating social action may play as significant a role in the pathogenesis of autism (Mundy & Neal, 2001). Indeed, it may be useful to consider a common developmental path of impairment in autism that begins with the early onset of difficulty in the self-initiation of action (e.g., in social orienting or IJA) in infancy and eventually is manifest in difficulty in the self-initiation of aspects of social cognition (Frith & Frith, 1999), as well as the self-initiation of aspects of nonsocial cognition (Minshew et al., 2001). Moreover, it may be useful to consider this conjecture in the context of the observation that one common goal of intervention protocols with people with autism seems to be to increase their tendency to self-initiate adaptive goal-directed action in social, as well as nonsocial, situations.

CONCLUSION

The study of autism presents an enormously complex puzzle. Unfortunately, several critical pieces of the puzzle seem to be missing. One of these pieces may involve the role of coactive organism-environment interactive processes wherein deficits in the early social behavior repertoire of children with autism contribute to a disturbance in social experience that is so robust as to compromise subsequent neurological and behavioral development. If so, our efforts may need to be redoubled with respect to the development of early identification and intervention methodologies. Another piece that may be missing in our attempt to attain a veridical view of the etiology of autism may involve the role of the DMFC/AC complex in cognitive and social-cognitive development. This role may be embodied in a fundamental disturbance in the capacity to self-initiate, organize, and monitor behavior and cognition. The DMFC/AC complex may be integral to social-orienting disturbance and the coactive organism-experience model of autism we have attempted to outline in this chapter. Moreover, a DMFC/AC system impairment may be central to difficulties that people with autism appear to display in intersubjectivity and social-cognitive development, as well as the development of other complex cognitive processes. Finally, it may be instructive to note that impairment of the DMFC/AC complex reportedly produces a symptom profile that includes apathy, inattention, dysregulation of autonomic functions, variability in pain sensitivity, akinetic mutism, and emotional instability (see Busch et al., 2000). This profile

has obvious commonalities with characteristics of people affected by autism. The observation of related functional commonalities led to the proposal of an influential neurological model some 25 years ago, which also emphasized the role of the DMFC/AC complex in autism (Damasio & Maurer, 1978). When it was proposed, the model of Damasio and Maurer was not easily open to empirical investigation. Currently, though, the tools are at hand and inquiry into the neurodevelopmental role of the DMFC/AC complex in the pathogenesis of autism has once again become an important goal of future research.

Cross-References

Development of infants and young children with autism is discussed in Chapter 8, social development is addressed in Chapter 11, aspects of attention and perception are reviewed in Chapter 13. A convergent theoretical perspective is provided in Chapter 26.

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