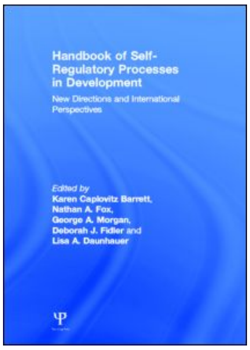

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Karen Caplovitz Barrett, Nathan A. Fox, George A. Morgan, Deborah J. Fidler, Lisa A. Daunhauer

The Integration of Self and Other in the Development of Self-Regulation

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Heather A. Henderson, Peter C. Mundy
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Typical and Atypical Processes

Heather A. Henderson and Peter C. Mundy

INTRODUCTION

Self-regulation is thought to arise from the gradual transfer of primary control of thoughts, behaviors, and emotions from external to internal sources (Kopp, 1982; Luria, 1961; Rothbart & Derryberry, 1981; Vygotsky; 1962). This transfer of control emerges through a series of transactions between an infant and his/her environment—most importantly, interactions with others. In this chapter, we discuss the central role of early dyadic and triadic interactions for the development of self-regulation. We argue that these interactions directly support the development of self-regulation through their influence on the quality and quantity of social learning experiences as well as through their influence on the development and coordination of posterior orienting and anterior executive attention systems. We further argue that early interactions indirectly influence self-regulation through their effects on social cognition; specifically, the development and integration of information processing about the self versus others.

In this chapter, we present a developmental model in which we describe bidirectional relations between social perception, social initiations, attention regulation, and self-regulation as well as the neural systems underlying these processes. We discuss this model in the context of individual differences in self-regulation in typically developing children. In addition, we note that this model has applications for children with developmental disabilities, who are often characterized by deficits in self-regulation. To illustrate this point, we focus on autism to exemplify how impaired social attention coordination in infancy may set the stage for atypical neural and social cognitive development, which in turn contribute to poor behavioral and emotional self-regulation.

SELF-REGULATION

Self-regulation, defined as the ability to regulate behavior, emotion, and cognition in response to internal and external stimulation, is vital for autonomous and adaptive psychological and social functioning (Calkins, 2007). In young children, self-regulation encompasses a wide range of mental processes that support behaviors including the ability to comply with requests, change behaviors in response to situational demands, inhibit prepotent responses based on contextual or social demands, self-monitor behaviors and emotions, and generate socially approved behaviors in the absence of external monitoring (e.g., Block & Block, 1979; Kopp, 1982; Rothbart, Posner, & Kieras, 2006). These emerging capacities support the development and maintenance of a positive sense of efficacy, agency, and self-worth, which in turn support positive adaptation across the lifespan (Blair, Calkins, & Kopp, 2010; Hrabok & Kerns, 2010; Moffitt et al., 2011).

In her highly influential model of the development of self-regulation, Kopp (1982) described a gradual transfer from external to internal sources of regulation over the course of infancy and early childhood. Kopp described a progression from reflexive, neurophysiological, and caregiver-mediated forms of control early in infancy to more intentional and self-initiated forms of control over the course of early childhood. The transfer from external to internal sources of control and regulation has been hypothesized to depend in large part on the development and coordination of core attention systems (Rueda, Posner, & Rothbart, 2011; Ruff & Rothbart, 1996). In early infancy, posterior alerting and orienting systems are predominant such that attention is primarily controlled by exogenous factors including visual and auditory sensory events. Initially, attention orienting is rigid and marked by an inability to flexibly shift attention. By the middle of the first year, however, the ability to disengage attention begins to develop and marks one of the earliest *self*-regulatory abilities (Johnson, Posner, & Rothbart, 1991). From this point forward, attention comes under increasing endogenous control allowing attention to be flexibly allocated in order to resolve conflict among thoughts, feelings, and behavior in the service of behavioral and emotional regulation. This gradual transition is critically supported by a later developing executive attention system that coordinates, monitors, and resolves conflicts between other brain networks (Rothbart, Sheese, Rueda, & Posner, 2011). The executive attention system includes the anterior cingulate and lateral prefrontal cortex and shows a more prolonged development, with decreases in gray matter density and increases in myelination and long-distance connectivity continuing well into early adulthood (Fair et al., 2009; Giedd, 2008). This protracted time course of the frontal circuitry underlying executive control may make this system particularly open to the effects of social learning experiences (Greenberg, 2006).

This emphasis on internal control of attention contrasts with earlier theories of self-regulation rooted in relational frameworks in which self-regulation was thought to develop primarily as a function of the affective-motivational features of parent–infant relationships (e.g., Stayton, Hogan & Ainsworth, 1971). Nevertheless, Kopp's model clearly emphasizes *within-child* maturational and biological factors as well. Specifically, Kopp hypothesized that this transfer from reflexive to intentional and externally to internally mediated control is facilitated by *both* maturational and experiential processes that support the development of social cognitive skills including self-awareness, self-monitoring, and the internalization of caregivers' expectations for self-control. Despite differences in points of emphasis and level of analysis, almost all current models of the development of self-regulation acknowledge the importance of the interplay of within-child, biological and neural factors with contextual factors including interpersonal relationships and environmental contexts (e.g., Derryberry & Rothbart, 1997; Eisenberg et al., 2005; Grolnick & Farkas, 2002; Lewis & Todd, 2007). This dynamic biological–environmental conceptualization represents the understanding that neurophysiological factors not only shape responsiveness to social experiences, but that social experiences promote functional neural development (Gottlieb, 2002).

Kopp and others have proposed that the key experiential factor in the development of self-regulation is participation in dynamic social interactions. Importantly, Kopp emphasized that socialization experiences facilitate, rather than cause, the emergence of self-regulation both directly and indirectly. For example, periods of attention and affective synchrony directly support the development of self-regulation by maximizing periods of shared positive affect while minimizing the experience of negative emotion. Indirectly, the coordination of attention and the shared experience of positive affect support the development of self-regulation by reinforcing the tendency to coordinate attention with others, the foundation of much social learning (Parlade et al., 2009). Indirectly, parent–infant interactions support self-regulation through their influence on neural functions supporting basic attention systems including the orienting and executive attention systems. For example, caregivers support infants' use of attention engagement and disengagement as a means of distracting and calming (e.g., Harman, Rothbart, & Posner, 1997; Kopp, 1982). Thus effective socialization experiences engage and help develop and coordinate crucial neural systems that allow infants and young children to integrate social, cognitive, and affective processes that support the emergence of *self*-regulation (Henderson & Wachs, 2007).

In this chapter, we review literatures detailing how early socialization experiences support social cognitive development and, specifically, children's abilities to integrate their own thoughts, behaviors, and emotions with those of important others (Feldman, Greenbaum, & Yirmiya, 1999; Kopp, 1982; Vaughan Van Hecke et al., 2007). We argue that these social cognitive developments influence (and are influenced by) neural systems underlying social responsiveness, social initiation, and their integration, which in turn support effective behavioral and emotional self-regulation. We discuss the neural systems supporting different forms of regulation and learning and their integration in the service of self-regulation. In the final section, we use autism as an example of a developmental disorder in which atypical early social learning experiences may alter the development of social cognitive skills deemed essential for self-regulation, and how these alterations affect (and are affected by) neural systems underlying self-regulation.

THE DEVELOPMENTAL SHIFT FROM EXTERNAL TO INTERNAL REGULATION: THE ROLE OF SHARED SOCIAL ATTENTION

Reflexive and Externally Mediated Sources of Shared Social Attention as a Foundation for the Development of Self-Regulation

Newborns enter the world biologically and behaviorally prepared, or expectant, to engage in interpersonal interactions. This experience-expectant state reflects a highly evolutionarily conserved mechanism that supports adaptive social development. Newborns' perceptual systems are poised to preferentially process social information as evidenced by the fact that within moments of birth, infants are drawn toward social stimuli. Visually, infants' preferentially attend to face and face-like stimuli (Goren, Sarty, & Wu, 1975) and their limited visual acuity allows attention to be focused on the close inspection of caregivers' faces while blocking out the processing of ancillary and distracting detailed visual stimuli in the larger environment. Within weeks of birth, infants show a clear preference for viewing social stimuli over other stimuli matched in complexity, color, or contour dimensions (Mondloch et al., 1999). Infants' scanning patterns reveal a rapid developmental shift from a preference for eyes and facial contours to scanning between the eyes and mouth, which represents an increasing sensitivity to the natural flow of dynamic social interactions (Hunnius & Geuze, 2004).

Developments within other sensory and perceptual systems also support the rapid development and narrowing of information processing abilities that support early social learning. For example, neonates prefer their own mothers' speech over other sound patterns (Spence & DeCasper, 1987) and quickly learn to recognize their caregivers based on olfactory cues (Porter & Levy, 1995). Typically developing infants also quickly develop the ability to visually discriminate biological motion from general motion, which also supports the processing of socially relevant information in their environments (Fox & McDaniel, 1982). By 5 months of age, infants preferentially attend to people who were previously observed using infant-directed (over adult-directed) speech, suggesting that infants select social partners who optimize social learning experiences (Schachner & Hannon, 2011). These very early abilities and preferences are adaptive in the most traditional evolutionary sense of ensuring infants bond with and maintain proximity to their caregivers that afford basic protection, but they are also adaptive in the sense that they set the stage for essential social cognitive learning (Yoon & Johnson, 2009). Specifically, these early preferences are believed to facilitate the development of core social cognitive processes including the ability to understand and predict the thoughts, intentions, and feelings of others (Dittrich, Troscianko, Lea, & Morgan, 1996). In turn, these social cognitive skills allow children to internalize socialization experiences allowing for the transfer of regulatory control from external sources to internal sources.

The functional significance of these early social preferences for the development of self-regulation is demonstrated in part by infants' tendencies to use information they perceive from their social environments to guide and change their attention, behavior, and emotion. For example, classic studies demonstrate that some newborns mimic others' emotional expressions (e.g., Meltzoff & Moore, 1983), vocal patterns, and body postures (Meltzoff & Moore, 1989), and synchronize their actions with aspects of others' behavior including speech (Condon & Sander, 1974). This early imitation is thought to reflect an infant's ability to recognize the equivalences between the facial and body movements of others and themselves. These very early forms of imitation are considered non-volitional or reflexive and are believed to facilitate essential social learning by not only establishing and maintaining interpersonal rapport but by directly linking perceptions of actions and emotions in others to one's own experience of actions and emotions at perceptual, cognitive, and neural levels. Meltzoff and Moore (1989) speculated that this early mapping of self- and other-actions reflects the functioning of a common "internal code."

Recently, there has been speculation that the prefrontal mirror neuron system (MNS) might be a physiological representation of this common internal code (Rizzolatti, Fogassi, & Gallese, 2009; Sinigaglia & Rizzolatti, 2011). Although the MNS may be necessary for the development of imitation and social cognition, it is likely not sufficient as these abilities require broader neurocognitive networks (Meltzoff & Decety, 2003). Common in these models, however, is the idea that the ability to perceive and act on self–other correspondences is a central skill for early social learning. We believe that these experiences further provide practice in the ability to flexibly shift, and integrate, attention between self- and other-, which is critical for the emergence of self-regulation. Importantly, deficits in early mimicry and imitative abilities have been hypothesized to underlie several developmental disorders, most notably autism (e.g., Rizzolatti & Fabbri-Destro, 2010; Rogers, 1999).

While many species engage in mimicry and imitation, humans are unique in that these experiences are believed to support the emergence of higher level social cognition and mental processes not seen in other species. Human infants are able to learn through the transaction between observing and doing and therefore construct prototypes for later more intentional cognitive operations. Humans appear particularly attuned to the connection between observing and doing in socially motivated and emotional contexts, which may make the construction of self–other correspondences particularly important for the development of self-regulation.

Throughout the lifespan, mimicry and imitation are intimately connected to the experience and regulation of emotion. For example, contagious, or mimicked, responses are particularly likely when the observed behavior signifies the inner states of others (e.g., laughing, yawning) and are enhanced by feelings of affiliation (Yabar, Johnston, Miles, & Peace, 2006). In turn, mimicry increases feelings of closeness and connection, creating a feedback loop in which social connections are maintained and strengthened (Lakin & Chartrand, 2003). While these initial mappings tend to be formed in the context of parent–infant interactions, over early childhood they generalize to other social partners including siblings and peers. These synchronous acts support the development of language (e.g., "proto-conversations"; Bruner, 1983), joint attention, and emotion regulation. For example, during social interactions, partners' emotions tend to (subconsciously) converge over a period of time. This emotional convergence is thought to be facilitated in part through imitation processes through which social partners reflexively imitate one another's facial expressions, bodily postures, and speech patterns (Niedenthal, Barsalou, Ric, & Krauth-Gruber, 2005), physical changes that provide afferent feedback and produce emotional changes. In summary, the co-experience of behaviors and emotions is central to social-emotional development through the support provided for the development of the understanding of others' perspectives, the differentiation of self and other, and the development of empathy, all of which are essential for effective self-regulation (Rogers & Williams, 2006).

Initially, parents tend to take the lead in directing periods of synchronous interaction. As a result, young infants are primarily reliant on their caregivers and external supports to help maintain or enhance periods of positive affect and minimize periods of negative affect. Hofer (1994) described parents as early external regulators of infants' states of arousal across multiple sensory levels and emphasized that transfer to internal control emerges gradually through the natural course of daily activities and communicative exchanges—activities that permit the development of shared understandings of others and the world, or intersubjectivity. Consistent with this view, early parent–infant interactions are focused primarily on state regulation and these interactions capitalize on infants' sensitivity to the facial and vocal cues of others, and generally focus on using these cues to change and direct an infant's focus of attention.

As early as 3 to 5 months of age, attention coordination expands beyond the social dyad to include episodes of joint attention that describe triadic interactions between self, other, and an external object, event, or symbol. Joint attention (JA) has long been considered a pivotal skill that supports the development of a wide range of cognitive and social skills including receptive and expressive language, social competence, and self-regulation (Bakeman & Adamson, 1984; Baldwin, 1993; Mundy & Sigman, 2006; Vaughan van Hecke et al., 2007). The parallel processing of information about one's own and another's attention allows an infant to build up and internalize these representations and is considered essential for human learning (Mundy, Sullivan, & Mastergeorge, 2009). Between 3 and 9 months of age, the proportion of time infants spend in episodes of shared dyadic attention decreases substantially while the proportion of time spent in shared attention to objects increases rapidly (Landry, 1995). Corresponding to the patterns of development observed in parent–infant dyadic interaction, joint attention episodes become increasingly mutually supported and synchronous over time. Parents and caregivers initially drive these interactions by directing infants' attention to objects in the environment. Infants quickly learn to coordinate their gaze with others' and by the middle of the first year will orient their attention towards an external stimulus based on social cues including gestures and direction of gaze. This responsiveness to others' cues for attention allows caregivers an avenue for soothing and state regulation. For example, 3- to 6-month-old infants' distress can be temporarily reduced through distraction towards a toy (Harman et al., 1997). As evidence of young infants' high degree of reliance on external cues for achieving regulation, and the reflexive nature of early attention orienting, there is initially a very tight coupling of distress and distraction, with almost immediate resurgences in distress appearing upon removal of the distracting stimulus.

The ability to respond to joint attention (RJA) is considered reflexive and a cross-species indicator of sensitivity to socially mediated cues (Jaime, Lopez, & Lickliter, 2009; Mundy & Jarrold, 2010; Mundy & Newell, 2007). The triangulation of attention between the self, a social partner, and an environmental event lays the foundation for learning about key aspects of the environment (e.g., object labeling) as well as for understanding the intentions and perspectives of others. As is the case in the developmental progression of attention regulation from exogenous to endogenous control, overt joint attention gradually becomes internalized into covert, representational operations that guide a child's behaviors and emotions. Infants' abilities to reorient their attention based on the facial, vocal, and visual cues of those around them provide the basis for the earliest forms of state regulation.

Joint attention appears to facilitate and self-organize learning in part by directing and enhancing infants' attention to salient stimuli. The facilitative effects of joint attention on attention and learning (over object processing in the absence of shared attention) have been indexed both behaviorally (Reid & Striano, 2005) and physiologically. For example, Striano, Reid, and Hoehl (2006) reported enhanced amplitude negative component (Nc) responses when infants viewed objects in joint attention contexts relative to when viewing the same objects in non-joint attention contexts. The Nc is a mid-latency negative event-related potential (ERP) component that is prominent at fronto-central sites and thought to reflect attention orienting (Nelson, 1994), and is enhanced during periods of sustained attention (Richards, 2003). Enhanced Nc amplitudes during joint attention interaction suggest that joint attention functions to scaffold, prioritize, or amplify infants' engagement with salient aspects of the environment, which, in turn, supports learning.

At a neural level, early reflexive forms of social interaction including mimicry and RJA are supported by a posterior attention orienting system that includes the parietal/precuneous and superior temporal cortices (Rothbart et al., 2006). The relatively early structural and functional development of this network supports many of the innate social preferences just described by prioritizing the processing of social cues including biological motion and the perception of eyes and head orientations in others. This network is also important in facilitating self- and other-mappings as evidenced by the fact that it is selectively activated during viewing of classically contagious stimuli (e.g., yawning) and is therefore thought to underlie non-conscious or automatic aspects of self-referenced processing (Platek, Mohamed, & Gallup, 2005; Schurmann et al., 2004) that are deemed essential for self-regulation.

In this section, we reviewed literatures documenting infants' early sensitivity to social signals. States of shared attention and the recognition of similarities between the self and others through dyadic and triadic interactions optimize early social learning and support the development of attention regulation. We hypothesize, as described in the next section, that this effortful attention regulation is a core mental process that underlies the gradual developmental shift over early childhood to primarily internal sources of control that are necessary for behavioral and emotional *self*-regulation.

Intentional Attention Sharing and the Development of Self-Regulation

Although the earliest forms of interaction and regulation are primarily reflexive, consistent with Kopp's developmental model, infants quickly begin to use intentional strategies to maintain interpersonal interactions and foster state regulation. This shift towards greater intentionality is demonstrated in studies of the temporal dynamics of early face-to-face interactions between infants and their caregivers. At 3 months of age, synchronous interactions are maintained primarily by caregivers who, on a moment-by-moment basis, respond to the changing attention, behavioral, and emotional state of their infant. However, by 9 months of age, the most common pattern of synchronous interaction is mutual synchrony in which both the infant and caregiver actively adjust their behaviors in response to the other (Feldman, 2007). While many early models of parent–infant interaction emphasized caregivers' active contributions and adaptations to the signals of their infants (e.g., Brazelton, Koslowski, & Main, 1974), it has become clear that from a young age, infants actively contribute to, and learn from, these dynamic interactions. Through repeated interactions with social partners, infants quickly come to expect and seek out synchrony between their own and others' levels of affect, vocal quality, and attention orientation.

Classic studies of infants' reactions during the face-to-face-still-face (FFSF) paradigm demonstrate that infants' expressions of positive affect and visual engagement with an interaction partner are maximized during periods of synchronous interaction (Tronick et al., 1978). In the still-face paradigm, following a period of synchronous exchange, parents are instructed to disengage from the interaction and hold a constant neutral expression. Infants tend to find this lack of synchrony aversive and stressful, as evidenced by initial attempts to reengage the caregiver's attention quickly followed by a decrease in the frequency and intensity of positive affect expressions and a coinciding increase in the frequency and intensity of expressions of distress. The tight coupling of infants' own affect and state with those around them is demonstrated by the almost immediate return (although not complete) to a state of positive affect and engagement when the parent reinstates a normal interaction pattern. This almost universal pattern of responding demonstrates that, early on, infants form clear expectations regarding the ebb and flow of social interactions and violations of these expectations are experienced as distressing. This pattern also demonstrates the early and tight coupling of young children's affective states with those of their social partners (Chow, Haltigan, & Messinger, 2010) and the fact that, by the middle to end of the first year of life, infants work actively to maintain interactive episodes.

Infants' own efforts to restore and maintain synchronous interactions in laboratory paradigms such as the still-face are likely reflective of their behaviors in day-to-day interactions. It has been hypothesized that during daily interactions with sensitive caregivers, infants' attempts at repairing asynchronies are usually successful, and that experiences of successful repair are fundamental to an emerging sense of self-efficacy. Further, practice with the self-correcting function of these repairs provides the foundation for emerging self-regulatory skills (Fogel, 1993; Gianino & Tronick, 1988; Tronick & Gianino, 1986).

These more volitional shifts in attention and attempts to coordinate attention with others allow infants to build up a representation of contingencies between their own emotional states and those of others (Feldman, 2007). With these contingencies in place, infants actively seek out important others to help guide their behavioral and emotional reactions in novel or uncertain contexts. For example, by the end of the first year, infants intentionally reference caregivers (or other adults) as a means of gathering information in ambiguous or novel situations (Walden & Ogan, 1988). Importantly, this is clearly an intentional action (as opposed to reflexive response) as infants selectively look to people perceived to have greater expertise in a situation to gather information. For example, infants will preferentially look to an experimenter over a familiar caregiver when novel objects are presented in novel laboratory situations where presumably the experimenter has greater awareness of the situation (e.g., Stenberg, 2009). In turn, the messages conveyed during referencing are used by the infant to regulate his/her own emotions and interactions with novel objects and people or in novel environments (Stenberg & Hagekull, 1997). Social referencing processes have been hypothesized to be especially important in the cross-generational transmission of affective and motivational biases, and, in particular, social withdrawal. Murray and colleagues reported that infants expressed more social wariness with a stranger after observing their mother interact with the same stranger in a socially anxious style under both semi-naturalistic (Murray et al., 2008) and experimental conditions (de Rosnay, Cooper, Tsigaras, & Murray, 2006). These effects were particularly strong for infants high in temperamental fear, suggesting that highly reactive infants are particularly attuned and responsive to the emotional reactions of their caregivers.

In addition to social referencing in which infants intentionally gather information from others about the positive or negative valence of events or objects, infants also begin to engage in intentional, goal-directed attempts to direct the attention of others to a point of interest for the infants. This increasing capacity to *initiate* joint attention bids (IJA) with social partners allows for the shared processing and experience of objects and events in the environment. This more gradually developing ability builds on the more reflexive attention sharing skills characteristic of earlier infancy and reflects more intentional and flexible attention engagement/disengagement processes as well as social cognitive developments including representations of others' perspectives. As such, IJA depends on the functioning of diverse neural structures subsuming attention regulation and executive function that includes medial and dorsal frontal systems involved in integrating social cognition, executive functioning, and social approach tendencies (Grossman & Johnson, 2009; Henderson, Yoder, Yale, & McDuffie, 2002; Mundy, 2003; Nichols, Fox, & Mundy, 2005). The association between IJA and frontal executive attention systems has been demonstrated in several studies. For example, reduced alpha power in the frontal region (which indexes frontal activation) at 14 months of age was significantly associated with increased use of pointing for joint attention (a core feature of IJA) in a sample of healthy infants (Henderson et al., 2002). Thus, IJA is distinct from RJA in terms of neural underpinnings, developmental time course, patterns of individual differences, and patterns of predictions to later cognitive and social outcomes (Mundy et al., 2009).

The frontally mediated executive control network is considered the core of self-regulation (Calkins & Degnan, 2006; Henderson & Wachs, 2007; Posner & Rothbart, 2007). The executive control network includes the lateral and medial frontal cortices including the anterior cingulate cortex (ACC). The prefrontal cortex supports effortful cognitive and behavioral functions that allow for self-regulation including the ability to plan, detect errors, and inhibit dominant responses in favor of subdominant responses. The ACC monitors and resolves conflict between other brain networks (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Holroyd & Coles, 2002) and is therefore central in coordinating behaviors and emotions in the service of self-regulation.

Behavioral and neural imaging studies demonstrate rapid developments in the executive control network over the toddler and preschool years. Over this time period, executive attention is thought to take over the primary regulatory role from the more reflexive attention systems described earlier

(Rothbart et al., 2011), facilitating the transfer of regulation from external to internal sources, and from exogenous to endogenous control. The ability to flexibly and intentionally shift attention based on internal motivational states and cues (as opposed to the directives of caregivers) remains a core component of self-regulation across the lifespan (Metcalfe & Mischel, 1999; Urry & Gross, 2010). Importantly, these developmental changes in effortful control and the neural correlates are attributed to the dynamic interplay of neural maturational processes and socialization experiences with caregivers (Landry & Smith, 2010).

Linking Early Experiences of Shared Attention to Later Self-Regulation

Self-regulation is considered one of the most important early socialization goals and several longitudinal studies clearly demonstrate that the quantity and quality of dyadic and triadic social interactions are important predictors of self-regulatory skills (e.g., Feldman et al., 1999; Kochanska, 1994; Kopp, 1982; Lecuyer & Houck, 2006; Maccoby, 1992; Schore, 1996). For example, Martin (1981) found that maternal responsiveness in the first year of life predicted child compliance at 12 and 24 months. Feldman and colleagues reported that maternal synchrony at 3 months and mutual synchrony at 9 months were *independently* predictive of self-control (compliance and delay) at 2 years of age (Feldman et al., 1999). This suggests that children's engagement in both reflexive (maternal synchrony) and intentional (mutual synchrony) forms of attention regulation are important for later self-regulation, but in different ways.

Interestingly, the associations between mutual synchrony and later self-control were particularly strong for infants classified as having a difficult temperament, suggesting that the experience of synchrony may be particularly salient, and provide a protective effect, for children at risk of regulatory problems. Mother–infant synchrony in the first year of life was positively correlated with children's compliance to maternal directives at 2, 4, and 6 years of age (Feldman et al., 1999). These effects are likely mediated through effects of early synchrony on the quantity and quality of later, more complex social learning experiences.

Both parents and infants appear to benefit from high levels of early synchrony. For example, early gaze and affect synchrony is associated with the effective scaffolding behaviors in parents at later ages—that is, parenting behaviors that elaborate and extend children's ongoing play and language. Sensitive parenting behaviors (e.g., following and engaging child's own interests) in challenging contexts that require child compliance are predictive of better developed self-concepts, more social competence, and a better ability to independently comply with requests to delay gratification in later childhood (Lecuyer & Houck, 2006). A variety of studies support this notion that the experience of early synchrony and sensitive parenting supports a host of social cognitive skills including self-concept, emotional awareness, theory of mind, and empathy, across childhood and into adolescence (Feldman et al., 1999; Feldman & Eidelman, 2004; Hane, Feldstein, & Dernetz, 2003; Harrist, Pettit, Dodge, & Bates, 1994; Kirsh, Crnic, & Greenberg, 1995; Murray, Hipwell, Hooper, Stein, & Cooper, 1996).

One mechanism through which early dyadic interactions supports later self-regulation is through the effects on infants' joint attention. Specifically, parents who display more scaffolding during play at 9 months having infants who engage in higher levels of IJA with an experimenter at 12 months (Adamson & Bakeman, 1985; Vaughan et al., 2003). In contrast, levels of joint attention tend to be lower in children exposed to less parental sensitivity as a function of parental affective disturbance (Goldsmith & Rogoff, 1997), disorganized attachment security (Claussen, Mundy, Willoughby, & Scott, 2002), and the general level of social stimulation in the home (Wachs & Chen, 1986).

Several studies have directly related joint attention, both IJA and RJA, to later self-regulatory skills. As is the case for maternal and mutual synchrony, IJA and RJA are both important for later self-regulation, but in different ways. In several independent samples of children, higher levels of IJA (but not RJA) are predictive of better general social functioning. In children with autism, Sigman and Ruskin (1999) reported that rates of IJA predicted later rates of social initiations with peers. Similarly, in a sample of young children prenatally exposed to cocaine, early IJA predicted higher levels of teacher-reported prosocial behavior (Sheinkopf, Mundy, Claussen, & Willoughby, 2004).

Early joint attention skills may reflect the development of, and individual differences in, the ability to flexibly disengage and re-engage attention, which is central to the emergence of self-regulation (Posner & Rothbart, 2007). Consistent with this view, the ability to shift attention in response to caregiver cues at 6 months is predictive of the use of attention shifting as a strategy for resisting temptation at 2 years of age (Morales, Mundy, Crowson, Neal, & Delgado, 2005). Similarly, typically developing children who engaged in more joint attention with their mothers during free play used more distraction strategies to regulate their behaviors and emotions during a delay of gratification task (Raver, 1996). In contrast, in both typically developing (Vaughan Van Hecke et al., 2007) and at-risk (Sheinkopf et al., 2004) children, IJA and RJA uniquely predict variability in externalizing behavior problems, suggesting that RJA relates more to basic attention regulation and behavioral control compared to IJA, which reflects a more social regulatory skill.

SELF- AND OTHER-PROCESSING AS A SOCIAL COGNITIVE MECHANISM LINKING EARLY DYADIC AND TRIADIC INTERACTIONS TO LATER SELF-REGULATION

As reviewed earlier, there is extensive evidence that early experiences of dyadic and triadic shared attention are associated with better self-regulation. There are likely several direct and indirect mechanisms that link early experiences to later outcomes. First, these experiences directly affect the development of self-regulation because they increase the quantity and quality of socialization experiences surrounding issues of compliance and regulation (Aksan, Kochanska, & Ortmann, 2006). Second, these experiences influence self-regulatory skills by providing practice with engaging and coordinating core attention skills, including orienting, shifting, and executive control, which, in turn, facilitate self-regulation. Third, these experiences affect self-regulation through their influence on the social cognitive and neural representations of similarities and differences between the self and other, and these representations motivate and support the development of effective self-regulation. Later, we review literature in support of this third potential mechanism.

Over time, experiences of coordinated dyadic and triadic attention are internalized allowing children to use representations of these experiences to effectively regulate behaviors and emotions. While specific information is internalized through shared attention (e.g., the meaning of others' emotional expressions, word labels), global information about the mapping of one's own behaviors, emotions, and thoughts onto those of others is internalized as well. Mundy and colleagues have hypothesized that early processing of information from one's own body relative to the environment scaffolds the attribution of meaning to perceptions of others' behavior (Mundy & Vaughan Van Hecke, 2008). While this is initially effortful, with practice, this type of parallel processing of self- and other-information becomes automatic for typically developing children. Children begin to effortlessly recognize and integrate information about both similarities and differences between their own and others' thoughts, behaviors, and emotions. These perceptions of self–other overlaps are crucial for the development of self-regulation in several different ways. While the ability to *differentiate* self from other is deemed essential for the effective regulation of affect in response to another's expressions and the experience of empathy, the ability to detect *similarities* between self and other allow for the enhancement of specific social learning experiences related to self-regulation (e.g., Kang, Hirsh, & Chasteen, 2010). Therefore, self-regulation likely depends on the ability to rapidly and flexibly encode information about self–other overlap in a context-dependent way.

The understanding of similarities and differences between self and other is considered a top-down regulatory process that allows for effective behavioral and emotional self-regulation. The ability to regulate personal distress in response to others' distress is contingent on the development of a clear understanding of the differentiation between self and others (Geangu, Benga, Stahl, &

Striano, 2011). For example, infants and children with better regulatory skills are better able to dampen, or self-regulate, their arousal in response to the distress of a peer (Fabes et al., 1994) and this reduced distress supports prosocial responding (e.g., Kochanska, Murray, & Coy, 1997). Thus, understanding the source of distress as coming from others as opposed to the self supports the ability to move beyond reflexive aspects of emotion contagion and affect sharing to support emotion regulation. A similar process of differentiating one's own feelings from those of others is deemed necessary for the expression of empathy (Decety, 2010). Empathic responses require the ability to share the feelings of others while simultaneously differentiating self from other so that feeling is accurately recognized as originating from the other person and not the self. This ability to quickly and effortlessly process and interpret both the similarities and differences between self and other is considered essential for empathy and a strong motivator for self-regulation at all developmental stages (Tucker, Luu, & Derryberry, 2005).

While the understanding of self as distinct from others facilitates some forms of self-regulation, the perception of similarities between the self and important others or the inclusion of others in the conception of self has long been emphasized in the study of close relationships (Aron, Aron, Tudor & Nelson, 1991). Specifically, close relationships are defined as those in which an individual acts as though some or all aspects of the partner are partially the individual's own. This sense of self–other overlap facilitates social processing and motivates social behavior, including more empathic responding and improved perspective taking. Interestingly, the experience of empathy activates the same neural regions, including the insular and anterior cingulate cortices, involved in the mapping of one's own internal bodily and subjective feeling states (Bird, Silani, Brindley, White, Frith, & Singer, 2010). Therefore, the development of shared neural representations of the thoughts and feelings of the self and others may play a crucial role in self-regulation, and difficulties recognizing and representing one's own emotions would result in a deficit in representing others' (e.g., Singer et al., 2004).

Neural Systems Supporting Self-Regulation through the Integration of Self and Other

While behavioral and learning mechanisms might account for the robust findings linking early interaction patterns to later complex social and emotional behaviors, including self-regulation, questions remain about the neural systems that might mediate these relations. Given the extensive human and non-human animal literatures on the psychobiology of stress and emotion regulation, it seems likely that early socialization experiences translate into physiological changes that support effective regulation (Feldman, 2004; Hofer, 1996). Feldman, Magori-Cohen, Galili, Singer & Louzoun (2011) have hypothesized that parent–infant behavioral and affective synchrony is mirrored by the development of physiological synchrony. For example, Feldman and colleagues reported that mother–infant dyads displaying a high degree of behavioral and affective synchrony in the interactive episode of the FFSF also displayed physiological synchrony as indexed by changes in maternal heart rate that were contingent on changes in infant heart rate. Mothers who engage in highly synchronous interactions with their infants also displayed heightened activation of "social brain" regions, including the superior temporal gyrus, anterior cingulate, thalamus, and midbrain implicated in social behavior, parenting, and emotion regulation (Feldman, 2007).

While it is currently unknown what the experience of synchrony looks like neurally from the infant's perspective, it has been hypothesized that experience of the give and take, coordination, miscoordination, and repair of social exchange through dyadic interactions provides critical inputs for the maturation of a variety of neural systems implicated in self-regulation (e.g., Feldman, 2007). For example, Schore (1994, 1996) proposed that the experience of visual-affective coordination, miscoordination, and recoordination provides critical input for the development of the prefrontal cortex and associated socioaffective functions. Based on the results of an event-related potential (ERP) study with typically developing 4-month-old infants, Johnson et al. (2005) concluded that social brain structures, including the superior temporal sulcus, the fusiform gyrus, and the orbitofrontal region, are selectively activated during mutual gaze processing (i.e., viewing a direct gaze), but not while viewing the same faces gazing elsewhere. Given that parents are highly responsive to periods of mutual gaze, infants' social brain systems may be primed and exercised through the natural course of synchronous interactions (Feldman, 2007).

As described earlier, experiences of shared dyadic and triadic attention also provide crucial inputs to both posterior/orienting and anterior/executive attention networks. While studies of behavioral and neural development support the idea of a gradual transition from reflexive to more intentional sources of self-regulation over childhood, both systems maintain important regulatory functions over the lifespan (Rothbart et al., 2011). Thus, monitoring, coordinating, and integrating these systems is essential to promote optimal self-regulation, and there is clear evidence in adults that the orienting and executive networks routinely operate in parallel (Dosenbach et al., 2007). Early social interactions rely on infants' abilities to respond and react to cues around them (e.g., RJA) and these continued interactions allow infants to develop the ability to initiate attention and behavioral changes that support social interactions. The gradual emergence of self-regulation depends, in large part, on the internalization of shared attention processes and the ability to effortlessly coordinate self and other perspectives. At a neural level, this internalization likely depends on the maturation and coordination of these two systems in order to flexibly respond to changing internal and environmental demands (Decety & Sommerville, 2003; Mundy, Gwaltney, & Henderson, 2010). Keysers and Perrett (2004) hypothesized that instances of shared attention and coordination support the development of integrated self- and other-neural systems through Hebbian principles in which repeated experiences of co-activation create an inextricable link between regions such that activity in one network triggers activity in the other. As such, Mundy et al. (2009) proposed that through repeated practice and engagement in states of dyadic and triadic shared attention, self- and other-processing systems are co-activated and provide the foundation for the "social executive functions" underlying self-regulation.

Recent research on a variety of *social brain systems* provides empirical support for the key role of integrated self- and other-processing for the development of effective, well-regulated social and emotional responding. The default mode network (DMN) is a medial cortical network that includes the medial prefrontal cortex (MPFC) and adjacent rostral anterior cingulate cortex (rACC), posterior cingulate cortex (PCC), and precuneus (PrC). The DMN is activated during self-reflective thought, self-monitoring, and higher order social and emotional processing. In contrast, DMN activity is suppressed during the performance of non-social, externally directed, attention-demanding, and goal-oriented tasks. This pattern of deactivation is thought to support task performance by interrupting ongoing internally directed thought processes.

Interestingly, this system is also highly active at rest, suggesting that the human default state involves reflections on the self (see Kennedy, Redcay, & Courchesne, 2006; Raichle et al., 2001). This system seems particularly tuned to not only self-processing, but, specifically, to the processing of self in relation to others in the environment as indexed by activations during tasks tapping the perception of social interactions, theory of mind, the experience of joint attention, and self- and other-person judgments (e.g., Frith & Frith, 1999). For example, van Buuren, Gladwin, Zandbelt, Kahn, & Vink (2010) found that midline areas of the DMN showed the greatest activation when participants made judgments about themselves, but there was also significant activation when making judgments about others. They hypothesized that people engage in some degree of self-referential processing in order to make judgments about others, or that well-developed self-processing skills scaffold the understanding of others. Thus, it seems reasonable that this system plays a crucial role in the integration of self- and other-related information that is critical for the development of self-regulation, and that this system would be impaired in children with atypical early social development including autism (e.g., Mundy, 2003; Pelphrey, Shultz, Hudac, & Vander Wyk, 2011).

In adults, the DMN is highly connected to other networks involved in social orienting and self-regulation, including the posterior attention orienting and executive control networks just described. Therefore, insult or atypical development in either of these early developing networks would have widespread consequences on brain connectivity and subsequent functionality related to self-regulation.

In cross-sectional studies of the DMN, there are striking developmental changes in both structural and functional connectivity of the DMN (Fair et al., 2009; Supekar et al., 2010). In adults, activity in the ventral mPFC is strongly correlated with activity in other DMN regions including the posterior cingulate and lateral parietal cortex, whereas in 7- to 9-year old children there is minimal connectivity between the same regions. Supekar et al. (2010) found that connectivity between the PPC and mPFC was the most immature in 7- to 9-year-old children. Fair et al. (2009) hypothesize that the functional integration of the DMN is dependent on maturation and experiences that trigger synchronized neuronal activity that support functional connections. This protracted developmental course of the DMN and between the DMN and other regions may make the region particularly open to the effects of social learning experiences (Supekar et al., 2010). This progressive integration of the DMN over childhood and the strengthening of inverse relations with regions supporting task states likely supports the development of higher order control systems that are essential for self-regulation, including inhibition and set shifting (Crone, Ridderinkhof, Worm, Somsen, & van der Molen, 2004; Rueda et al., 2004).

A common structure in the DMN and the executive network is the anterior eingulate cortex (ACC). The ACC is described as a crucial relay system that integrates and coordinates anterior and posterior networks as well as subcortical/limbic and cortical regions (Botvinick et al., 2001; Holroyd & Coles, 2002). The ACC is important for executive functions, including conflict detection and performance monitoring, with ACC activity triggering engagement of cognitive control mechanisms associated with the prefrontal cortex. As such, the ACC is considered a central structure in the development of self-regulation. Much recent research has been focused on the error-related negativity (ERN), an ERP component that is elicited immediately after the commission of an error, and the feedback-related negativity (FRN) that is elicited following performance feedback.

Recent data suggest that the ACC is not only responsive to one's own performance or performance feedback, but also when one observes someone else perform or receive performance feedback (Hajcak, Moser, Holroyd, & Simons, 2006; Yu & Zhou, 2006). Importantly, the extent to which one perceives an overlap between the self and the other person being observed modulates the extent of ACC activity that is elicited (Kang et al., 2010). These findings suggest that the ACC plays a central role in regulating attention to support observational learning from those we perceive the greatest degree of similarity to. As noted already, the ACC is also closely connected to the insular cortex and both are activated by experiencing pain oneself as well as when experiencing empathy in response to another's pain (Bird et al., 2010). Pfeifer, Iacoboni, Mazziotta, & Dapretto (2008) reported that activation of the insula, inferior frontal mirror areas and amygdala during observation and imitation of emotional expressions was associated with individual differences in empathy. Interestingly, activity in the same regions during the observation of emotional expressions in individuals with autism is inversely associated with symptom severity (Dapretto et al., 2006). Similarly, the insula, posterior cingulate gyrus and precuneus are activated during the experience of contagious yawning, further implicating these regions in non-conscious aspects of self- and other-processing that are known to influence empathy, perspective taking, and self-regulation (Platek et al., 2005).

The responsiveness of the ACC and associated executive control networks to social influences is also evident behaviorally. For example, Moriguchi, Lee, & Itakura (2007) demonstrated that preschoolers' performance on a cognitive inhibition task, the Dimension-Change Card Sort, was influenced by observing a social partner perform the same task. While many models of social cognition posit that basic executive functions, like inhibitory control, support the development of social cognition, Moriguchi et al. interpreted their findings as supporting the opposite direction of effect. That is, they believe that basic executive functions can be socially transmitted, a model supported by findings demonstrating the training on social cognitive tasks, such as "theory of mind," leads to corollary improvements in executive functioning (e.g., Kloo & Perner, 2003).

Individual Differences in Self-Regulation: The Role of Self- and Other-Processing

Given the pivotal role of social coordination for social, cognitive, and self-regulatory development, both parent and child factors that negatively impact the quality and quantity of early social interactions are viewed as global risk factors in development. For example, premature infants engage in less synchronous face-to-face interactions with their mothers, which may contribute to difficulties with early state regulation (Lester, Hoffman, & Brazelton, 1985). Similarly, the offspring of mothers with psychopathology often have difficulty with behavioral and emotional regulation. While these relations may result from the direct effects of genetic transmission of risk for affect dysregulation, there also appear to be indirect effects through alterations in the nature of early attention and affect coordination. For example, maternal depression is associated with less frequent synchronous interactions and less coordinated triadic attention (Gaffan, Martin, Healy, & Murray, 2010; Goldsmith & Rogoff, 1997) and maternal anxiety is associated with a relative insensitivity in the timing of responses to the infant's behavior (Feldman, 2007).

Autism is a particularly salient example of a developmental disorder in which impairments in early social coordination have cascading effects on cognitive, social, and self-regulatory development. Autism is characterized by deficits in social behavior and communication as well as restricted/repetitive behaviors. Despite a growing body of evidence suggesting that there are a wide range of genetic factors contributing to autism, these core symptom are common regardless of etiological pathways. Thus, these varied genetic factors are thought to have the common effect of canalizing neural growth and development in a way that leads to these common deficits (Jones & Klin, 2009). In the following section, we briefly summarize the literature on deficits in early social attention and coordination associated with autism and describe how these deficits might set the stage for altered social learning experiences that are fundamental to the development of self-regulation. We argue that a failure to effectively integrate social perception of others with understandings of the self contributes to the social cognitive deficits characteristic of autism. We further argue that, at a neural level, this failure to integrate social perception with social action leads to less coherence and communication within and between neural regions supporting self-regulation (Mundy et al., 2010).

Young children with autism show a diminished preference for the eye region when viewing faces, relative to typically developing children, who, from birth, show a preference for human faces over other types of stimulus and who quickly learn to allocate attention to the eye region (Jones, Carr, & Klin, 2008). This early failure to attend to the eye region presumably alters the course of development of more complex gaze-related interactive behaviors and learning experiences, including the ability to spontaneously follow others' gaze, to maintain gaze during face-to-face interactions, and to use gaze cues to respond to and bids with social partners. Similarly, young children with autism do not distinguish or show a preference for biological (i.e., human) over non-biological motion, unlike typically developing children, who demonstrate such a preference within days of birth (Klin, Lin, Gorrindo, Ramsay, & Jones, 2009). Together, these findings suggest that young children with autism fail to preferentially detect and allocate attention towards essential socially relevant information in their environments. Converging neuroimaging evidence demonstrates that when individuals with autism view gaze cues or biological motion, they fail to activate social brain structures including the posterior superior temporal sulcus (see Pelphrey et al., 2011).

These deficits in perceiving and preferentially allocating attention towards important social cues have been hypothesized to have cascading effects on development in many domains, including language and communicative development (Baldwin, 1995), social cognition (e.g., theory of mind), empathy (Charman et al., 1997), and self-regulation (Gulsrud, Jahromi, & Kasari, 2010). One mechanism through which these effects occur is through the impact of diminished social orientation on dyadic and triadic shared attention (Mundy & Newell, 2007), which in turn limit the quantity and quality of children's learning experiences about the mapping of their own behavior and emotions (i.e., attention regulation) as well as others' states of mind, including their ideas, intentions, and emotions (e.g., Mundy, Card, & Fox, 2000; Tomasello, 1995). As a result, children with autism may be less sensitive to, and aware of, the social conventions and socialization experiences underlying the typical development of self-regulation. Several research findings support such a model. For example, Yirmiya et al. (2006) found that the younger siblings of children with autism (Sibs-ASD), who are themselves at increased risk for a later diagnosis of autism, display less synchronous interactions with their mothers during infant-led interactions in a free play context at 4 months of age. Sibs-ASD were also less sensitive to the still-face paradigm, displaying more neutral and less negative affect when their mothers discontinued interactions. Among Sibs-ASD, higher levels of neutral affect during the still-face predicted less frequent joint attention initiations at 14 months. Similarly, in a sample of young children with autism, those who engaged in more synchronous parent–child interactions had significantly better developmental outcomes, including language and joint attention skills, several years later (Siller & Sigman, 2002).

While failures to preferentially and contingently respond to social cues may initially set the stage for atypical development, the tendency to actively map the emotions and behaviors of others onto one's own and to use these mappings to shape social interactions appear particularly important in the study of self-regulatory processes in autism. Specifically, even when attention is controlled for, individuals with autism are less likely to display mimicry and emotional contagion than typically developing individuals (Helt, Eigsti, Snyder, & Fein, 2010; McIntosh, Reichmann-Decker, Winkielman, & Wilbarger, 2006). Interestingly, McIntosh et al. (2006) reported that although adolescents and adults with autism did not automatically mimic others' emotional expressions, they could do so when explicitly instructed. These findings were interpreted as demonstrating a failure of individuals with autism to integrate reflexive, social motivational with intentional, executively mediated processes underlying social interaction.

Similarly, in studies of joint attention, IJA, which relies on the integration of motivational and executive processes, appears particularly important for the social and self-regulatory development of children with autism. For example, children with autism display more robust and stable deficits in IJA than RJA (Leekam & Moore, 2001; Mundy, Sigman, & Kasari, 1994; Sigman & Ruskin, 1999) and individual differences in early IJA (but not RJA) predict social competence and self-regulation into adolescence (e.g., Sigman & Ruskin, 1999). As noted earlier, IJA is thought to reflect the functioning of frontal executive attention networks that underlie higher order processes including planning and self-monitoring and over time become integrated with affective and social motivational processes. This integration of executive and social motivational processes allows for the development of social executive functions that are the essence of self-regulation (Bachevalier & Loveland, 2006).

Another limiting factor for the development of self-regulation for individuals with autism is that, over the course of childhood and adolescence, individuals with autism fail to develop a highly elaborated sense of self in the way typically developing individuals do (Henderson et al., 2009; Lind 2010). For example, individuals with autism show diminished conscious awareness of their own emotions (Ben Shalom et al., 2006) and mental states (Williams & Happe, 2010). The failure to develop an elaborate self-concept likely impairs the ability to quickly and effortlessly use the understanding of self to scaffold the understanding of others. In addition, unlike typically developing individuals, children and adults with autism fail to preferentially process self- over other-relevant information (Henderson et al., 2009; Lombardo, Barnes, Wheelwright, & Baron-Cohen, 2007). Importantly, individual differences in the extent to which individuals with autism preferentially process self-relevant information are inversely related to autism symptom severity and comorbid emotional symptoms (Henderson et al., 2009), suggesting a crucial role of an elaborated self-system in the development of social competence and general self-regulatory abilities.

The results of several recent neuroimaging studies provide converging evidence of associations between an under elaborated self-system and social functioning in individuals with autism. For example, Kennedy et al. (2006) reported that adults with autism failed to deactivate DMN regions when performing a cognitively demanding task and that this effect was due to significantly less

DMN activation at rest (i.e., there was limited activity to reduce). Importantly, the degree of deactivation in the mPFC was correlated specifically with social impairments such that greater deactivation was associated with less social impairment. Given associations between functioning of the DMN and self- and other-processing including perceptions of social interactions, theory of mind, and the experience of joint attention, these findings support a model of an underdeveloped system of self- and other-processing. Kennedy et al. (2006) speculated that reduced DMN activity at rest in individuals with autism may mean that resting thoughts are less self- and self-in-relation-to-others focused and more focused on obsessive interests, preoccupations, or sensitivities to the external environment. This alteration in default patterns of thought may, in turn, interrupt the full emergence and elaboration of internally directed thoughts, which may lead to deficits in self-regulation.

Some of the most compelling data supporting the central role of self- and other-attention coordination for the development of later social cognitive and self-regulatory skills come from the results of early intervention studies in which early dyadic and triadic interaction patterns are directly targeted. Interventions targeting pivotal behaviors, including parent–child interactional synchrony and joint attention, consistently demonstrate positive effects on the development of more complex functions, including language and emotion regulation (Gulsrud et al., 2010; Wetherby & Woods, 2006). These effects on later complex behaviors likely reflect the increased sensitivity of children to their socialization and learning environments that result from improved attention coordination (Mahoney, Kim & Lin, 2007).

CONCLUSIONS

Consistent with experience-expectant models of development, human infants enter the world prepared to attend to important signals about their social world. Experiences of shared dyadic and triadic attention and practice coordinating attention across contexts provides essential input to developing neural systems and social cognitive skills. The processing of information about others and the development of mappings between self and others provides the foundation for essential social learning experiences. These experiences are thought to be essential for neural growth, development, and integration within the social brain system. Deficits in perceiving others, understanding the self, or mapping the self onto others may result in a failure to fully develop an integrated social brain system, as appears to be the case in individuals with autism.

One challenge in studying the early social and neural bases of self-regulation is disentangling directions of effects between neural development, social learning experiences, and self-regulatory capacities. While one could argue that early social experiences are essential for neural growth, development, and integration, the opposite may be true as well. That is, early structural and functional differences in the brain might limit the quantity and/or quality of early social learning experiences that support the development of self-regulatory skills. Given that infancy marks a period of maximal neuroplasticity and change, large-scale longitudinal studies are needed to understand the dynamic interactions between genetic predisposition, neural development, and social learning experiences as self-regulatory skills emerge and become refined over the course of infancy and childhood. While studies of atypically developing populations offer insight into core processes underlying self-regulation, it remains challenging to isolate early developmental mechanisms. For example, most children with autism do not receive diagnoses until at least 2 or 3 years of age, at which point many of the social and cognitive foundations of self-regulation have already been established. Promising new approaches include studying the younger siblings of children with autism, who are at heightened risk of diagnosis, and even those who do not go on to develop autism often show characteristic, yet subclinical, social and self-regulatory deficits. By studying this unique group of infants from birth, greater insights into the developmental mechanisms underlying the interplay of social learning and neural developments may be gained (e.g., Garon et al., 2009).

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