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COMMENTARY

Autism 101 Commentaries

Research on social attention in autism and the challenges of the research domain criteria (RDoC) framework

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Abstract

The fuzzy nature of categories of psychopathology, such as autism, leads to significant research challenges. Alternatively, focusing research on the study of a common set of important and well-defined psychological constructs across psychiatric conditions may make the fundamental etiological processes of psychopathology easier to discern and treat (Cuthbert, 2022). The development of the research domain criteria (RDoC) framework is designed to guide this new research approach (Insel et al., 2010). However, progress in research may be expected to continually refine and reorganize the understanding of the specifics of these mental processes (Cuthbert & Insel, 2013). Moreover, knowledge gleaned from the study of both normative and atypical development can be mutually informative in the evolution of our understanding of these fundamental processes. A case in point is the study of social attention. This Autism 101 commentary provides an educational summary of research over the last few decades indicates that social attention is major construct in the study of human social-cognitive development, autism and other forms of psychopathology. The commentary also describes how this research can inform the Social Process dimension of the RDoC framework.

Lay Summary

Autistic people, like all people, display a lot of individual differences. This makes the category of "autism" difficult to define. Instead of trying to define autism as a distinct category it may be better to try to define a common set of important mental processes that contribute to all human differences including the difference we refer to as autism. However, defining that important set of mental processes can also be difficult. Ironically, sometimes the study of category, like autism, can reveal an important dimension of human mental development. This commentary describes how this is the case for research on the nature and development of social attention in autistic people. Once conclusion is that research with autistic people also has much to say about understanding human nature more broadly.

KEYWORDS

autism, eye contact effect, face processing, joint attention, psychopathology, research domain criteria, social orienting

INTRODUCTION

There are significant neurobehavioral and genetic commonalities between autism and other psychiatric conditions (Antshel & Russo, 2019; Baribeau et al., 2019; Hyman, 2019; Stergiakouli et al., 2017). There is also significant heterogeneity in the expression of autism across individuals and development (Georgiades et al., 2013; Lord & Jones, 2012; Warrier et al., 2022). These observations, among others, challenge the validity of a categorical definition of autism. Alternatively, adopting a dimensional approach where psychiatric conditions may be best described in terms of varied patterns of disturbance across a common set of neurocognitive, motivation, sensory and psychophysiological constructs may be a more useful approach to the study of autism, and psychopathology more generally (Hollander et al., 1998; Hyman, 2021; Kim et al., 2019; Sanislow et al., 2010).

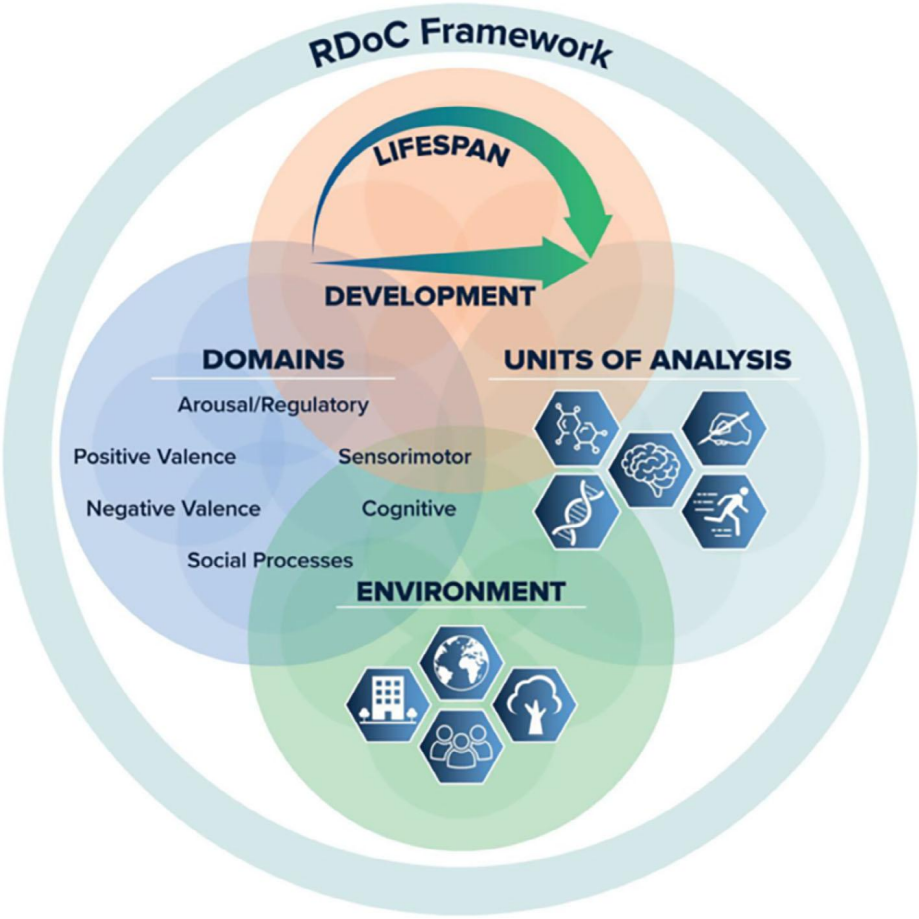

FIGURE 1 An illustration from Sanislow et al. (2022, p. 656) of the main features of the RDoC framework including element that recognizes inclusion of the importance of development functions in interaction with domain construct, units of analysis and environment from. This figure was published in the public domain by the American Psychological Association in the *Journal of Psychopathology and Clinical Science*.

This type of dimensional approach is exemplified by the experimental research domain criteria (RDoC) framework of the National Institute of Mental Health in the USA (Cuthbert, 2022; Insel et al., 2010). The RDoC encourages research that would identify the fundamental set of biobehavioral mental process that contribute to symptoms across diagnostics groupings, with the goal of making the essential etiological processes of psychopathology easier to discern and treat (Cuthbert, 2022). To this end, the RDoC framers identified six primary biobehavioral dimensions for study, (1) cognitive systems, (2) behavioral approach systems, (3) behavioral avoidance systems, (4) arousal modulation systems, (5) sensory motor systems and (6) social process systems.[1] A set of hypothetical mental processes, or "constructs," are also delineated within each biobehavioral dimension of the RDoC along with their operationally defining observable behavioral measures.

The measurable constructs of the RDoC have two essential attributes. First, they need to be characterized by compelling evidence of their measurement and construct validity as defined in psychological research (Cronbach & Meehl, 1955; MacCorquodale & Meehl, 1948). Second, there needs to be strong evidence that the behavioral measures of a construct are theoretically and empirically associated with mechanisms of a biological system, such as a specifiable brain circuit (see pages 4–6, Cuthbert & Insel, 2013).

The creation of the current RDoC was a challenging task that was based largely on the knowledge acquired up through the first decade of the millennium (Insel et al., 2010). It has been successful in many ways, but also has several limitations (Cuthbert, 2022). One limiting factor, for example, is that the constructs of the RDoC "tended to represent … adult dimensions rather than developmental functions" (p. 655) and there was "an insufficient degree of specification regarding constructs, paradigms and measures regarding developmental research" pertinent to psychiatric conditions (p. 654, Sanislow et al., 2022). This creates a significant problem for the application of the RDoC framework to the types of developmental psychopathology studies necessary to understanding the early onset of autism and other forms of childhood conditions. In recognition of this issue, the Sanislow et al. (2022) describe the need to move toward a new, more developmentally informed model of the RDoC framework, as is illustrated in Figure 1. Cuthbert and Insel (2013) also recognize that the nature of the dimensions and constructs of the RDoC "are always

[1]See https://www.nimh.nih.gov/research/research-funded-by-nimh/rdoc/constructs/rdoc-matrix

dependent upon the march of research to continually refine and evolve" (p. 4). However, another challenge to the ongoing validity of framework is that a process for updating the RDoC framework to allow it to evolve in response to advances in research has not been explicitly described (Cuthbert, 2022).

Revision of the social process systems dimensions of the RDoC may be expressly needed and significant for autism research for several reasons. The centrality of social symptoms to the diagnosis of autism makes research on the development of human social processes systems especially germane (Klin et al., 2002). Moreover, the study of social-emotional and social cognitive neuroscience processes has been rapidly evolving since 2010 (Carver & Johnson, 2018; Kliemann & Adolphs, 2018; Pan et al., 2022; Redcay & Schilbach, 2019). It seems likely that observations from this recent epoch of research could improve the conceptualization of the RDoC social process systems dimension. Second, many of the constructs of the social process systems, such as attachment and affiliation, social communication, and perception and understating of mental states, are associated with mental processes that begin in the first 2 years of life, which are thought to have significant cascading effects on subsequent phases of development (e.g., Csibra, 2003; Feldman, 2017; Fonagy et al., 2007). The study of some these mental processes has been crucial to research on the nature of the early onset of important individual differences social development that typify autism (e.g., Baron-Cohen, 1989; Chevallier et al., 2012; Mundy & Sigman, 1989; Sigman & Mundy, 1989; Vivanti & Messinger, 2021). Over the last 20 years these "clinical" studies in combination with related advances in basic research have catalyzed advances in the identification of pivotal aspects of the development of human social process systems over the last 20 years that are not well captured in the current RDoC framework. Thus, there has been a vita dynamic interplay between basic cognitive science and research focused on autism in defining the mental dimensions of human social process systems (Mundy, 2021) that has the potential to inform the next generation of the RDOC framework. A case in point is provided by evidence of the pivotal nature of research on measures of social attention in the study of autism (Mundy & Bullen, 2022) and psychopathology more generally (Tso et al., 2020) and the implications of this research for the refinement of the RDoC social processes systems dimension.

THE HYPOTHETICAL CONSTRUCT OF SOCIAL ATTENTION IN AUTISM RESEARCH

Studies have long observed that differences in social attention were prominent in the development of autism and seemed to play an essential role in the social phenotype (Dawson et al., 2004; Klin, 1991; Loveland & Landry, 1986; Mundy et al., 1986; Wetherby & Prutting, 1984). Subsequently, research and theory began to explicitly suggest that these types of social attention measures reflect constructs, or unobservable mental processes, that play an important role in the development of social cognition from infancy to adulthood (Baron-Cohen, 1994; Birmingham & Kingstone, 2009; Emery, 2000; Frischen, Bayliss, et al., 2007; Frischen, Smilek, et al., 2007; Klein et al., 2009; Mundy & Newell, 2007; Nummenmaa & Calder, 2009).

In current autism research social attention now most often refers to mental processes and underlying biobehavioral mechanisms involved in: (1) social orienting behaviors, or the motivation and mental processes involved in the prioritization of attention to social stimuli such as faces, eyes, biological motion, social sounds and speech, (2) gaze processing and joint attention, which involve motivation and cognitive processes attendant to coordinating attention with another person and, (3) the impact of social presence on behavior, such as the eye contact and audience effects, in which the perception and awareness of being the object of attention of another person impacts cognitive and emotional processes. The basic research and theory that has given rise to this tripartite definition has been detailed in numerous reviews (e.g., Birmingham & Kingstone, 2009; Braithwaite et al., 2020; Dawson et al., 2012; Freeth & Morgan, 2022; Itier & Batty, 2009; Klin et al., 2015; Mundy & Bullen, 2022; Mundy & Newell, 2007; Nummenmaa & Calder, 2009; Salley & Colombo, 2016; Senju & Johnson, 2009a, 2009b; Tomasello et al., 2005).

Some of the roots of social attention research can be found in the study of the prelinguistic precursors of infants' understanding of interpersonal communicative reference that provides a cognitive foundation for subsequent language development (Baldwin, 1995; Bates et al., 1975; Bruner, 1995; Csibra, 2003). The literature on social attention was also informed by observations of the human tendency to prioritize attending to faces (Purcell & Stewart, 1988), and the study of the reflexive nature of spatial orienting in response to gaze direction cues (Friesen & Kingstone, 1998; Ristic et al., 2007), as well as how processing spatial directional cuing from gaze differs from processing of non-social directional cues (Frischen, Bayliss, et al., 2007; Frischen, Smilek, et al., 2007; Ristic et al., 2007). Social attention has also been studied in social psychology, especially under the rubric of audience effects or how being observed by other people effects behavior (Chevallier et al., 2014; Freeth & Morgan, 2022; Hamilton & Lind, 2016), as well a related developmental research on the eye contact effect or how eye contact impacts cognitive, stimulus valence, and a sense of affiliation (Becchio et al., 2008; Hietanen, 2018; Senju & Johnson, 2009a).

More recently, developmental studies of the infant siblings of children with autism have consistently

indicated that the atypical development of social orienting and joint attention are symptoms of the emergence of autism that can begin to be observed in infants between 6- and 12-months of age (e.g. Chawarska et al., 2013; Franchini et al., 2019; Jones & Klin, 2013; Stallworthy et al., 2022). In children 3 years of age or older observations of differences in social attention are associated with large group effects between children with autism, and children with developmental delays or children with neurotypical development (Dawson et al., 2004; Mundy et al., 1986). Consequently, they exhibit evidence of substantial diagnostic sensitivity and specificity, ranging from 0.82 and 0.81 (Dawson et al., 2004) to 0.92 and 0.92 respectively (Mundy et al., 1986).

Large diagnostic group effect sizes, and indices of diagnostic sensitivity and specificity, can be one important characteristic to consider in identifying behavioral measures of mental constructs that are important to particular psychopathological phenotypes (e.g., Gold et al., 2012). In research on autism evidence of their preschool sensitivity and specificity contributed to the inclusion of social attention items in many evidence-based diagnostic and screening instruments for autism (Gotham et al., 2007; Mosconi, Reznick, et al., 2009; Robins et al., 2014; Stone et al., 2004). For example, the Social Affect scale of Modules 1 and 2 of the revised version of the Autism Diagnostic Observation Schedule (ADOS-2, Lord et al., 2012) includes several social attention items, such as measures of initiating and responding to joint attention, pointing, showing and gestures, in the Social Affect (SA) scale of Modules 1 and 2 of the ADOS-2. Modules 1 and 2 are used in the diagnosis of preschool children. Gotham et al. (2007, 2008) observed evidence that these items converge on a single factor or construct in the SA scale of these modules. The manual for the ADOS-2 also provide substantial evidence for the inter-rater reliabilities of the social attention behavior items in the ADOS (Lord et al., 2012, pp. 256–257).

Mundy and Bullen (2022) have reviewed additional evidence of this kind measurement construct validity with respect to social attention, such as observations that, (1) experimental measures of social-orienting and joint attention behaviors are correlated (e.g., Franchini et al., 2009) even across auditory and visual social attention paradigms (Dawson et al., 2004), (2) observations of social orienting and joint attention in an experimental paradigm are correlated with independent clinical observations on the SA scale of the ADOS-2 (e.g., Mosconi, Reznick, et al., 2009), and (3) multivariate measures of the latent construct of social attention increase the power of research (Dawson et al., 2004) and are applicable across cultures (Frazier et al., 2021).

Several other studies indicate that social attention items of the ADOS-2, exhibit current and predictive criterion validity. The in that they are associated with cognitive, language, and social adaptive outcomes in autistic children and adolescents in a manner consistent with social attention theory (Bal et al., 2020; Harrison et al., 2016; Maljaars et al., 2012; Sano et al., 2021; Thurm et al., 2007; Zachor & Ben-Itzchak, 2020). Moreover, several longitudinal studies provide evidence for a significant association between neurotypical infant social-attention development and childhood social-cognitive task performance (Abreu et al., 2014; Brooks & Meltzoff, 2015; Kuhn-Popp et al., 2015; Sodian & Kristen-Antonow, 2015). This is the type of concurrent and predictive criterion validity also provides an important type of evidence of construct validity in psychological science (Cronbach & Meehl, 1955; Strauss & Smith, 2009).

Thus, current research has begun to demonstrate evidence of the construct validity of social attention measures for the study mental processes involved on neurodevelopmental disorders and psychopathology (Frazier et al., 2021; Mundy & Bullen, 2022; Tso, Angstadt, et al., 2021). However, consensus has not yet been reached on the validity the social attention construct (Salley & Columbo, 2016; Falck-Ytter et al., 2022). Nevertheless, additional research that informs the evaluation of its construct validity is rapidly becoming available (Doherty et al., 2019; Ji et al., 2020; McKay et al., 2022; Ristic & Capozzi, 2022; Vallorani et al., 2022).

It is clearly the case, though, that measures of social attention are a significant part of the reliable operational diagnostic definition of the preschool phenotype of autism (Mundy & Bullen, 2022). Moreover, beyond the preschool period, social attention can also be reliably and validly measured in children, adolescents and adults with typical development and autism (e.g., Bayliss et al., 2013; Freeth et al., 2020; Freeth & Bugembe, 2019; Gregory & Kessler, 2022; Grynszpan et al., 2019; Mundy et al., 2016; Nowell et al., 2020; Oberwelland et al., 2016), as well as among individuals who exhibit the broad autism phenotype (Elsabbagh et al., 2009; Morgan et al., 2023; Nayar et al., 2022; Swanson et al., 2013; Swanson & Siller, 2014; Zhao et al., 2017). Recent research also suggests that social attention measures may be sensitive to sex differences in autism (Charwarska et al., 2016; Harrop et al., 2020).

Social attention can be assessed in various ways, such as multivariate measures (Nayar et al., 2022), parent report measures (Birkeneder et al., n.d., in submission), measures of temporal dynamics (Del Bianco et al., 2021) and response to eye contact measures (Akechi et al., 2014; Grynszpan et al., 2017; Mundy et al., 2016). Visual social attention can also be assessed directly in social interactions (Freeth & Bugembe, 2019), or with auditory measures in brain imaging studies in children with autism (Hernandez et al., 2020), and in terms of its impact on memory functions (Doherty et al., 2019).

Latency measures can be used to assess the effort associated with social attention/joint attention (Gredebäck et al., 2010; Oberwelland et al., 2016; Vaughn Van Hecke et al., 2012). This is notable because

research suggests that social-attention may remain less efficient or more effortful in older autistic individuals and those who exhibit the broad autism phenotype (Birmingham et al., 2017; Freeth et al., 2020), as well as in social interactions involving higher perceptual or cognitive load (Haskins et al., 2022; Hernandez et al., 2020). Thus, with development children and adults with autism may be better able to engage in social attention, but this may require greater effort which taxes the adaptive and effective use of social attention in social communication or didactic learning interactions (Mundy & Bullen, 2022).

Recall that the RDoC framework also calls for strong evidence that the behavioral measure (s) of a construct maps onto a specific biological system, such as specific functional brain circuits. In this regard, several reviews have summarized the numerous EEG, fMRI, diffusion tensor imaging and optical imaging studies of infants, children and adults that have begun to elucidate the neural circuits that activate during social attention (e.g., Mundy, 2018; Nummenmaa & Calder, 2009; Stephenson et al., 2021; Tso et al., 2020). The studies reviewed suggest that important nodes of the social attention network substantially overlap with social cognitive networks including nodes in the posterior superior temporal sulcus, medial frontal cortex, cingulate cortex, insula and striatum (see Figure 2 for an illustrative model). There is also a nascent research literature on neurotransmitters and metabolic regulators that may be involved in social attention (see Mundy & Bullen, 2022). Translational research also has begun to outline the utility of social attention measures as biomarkers of response in intervention studies with autistic children (Billeci et al., 2017; Bradshaw et al., 2019; Jones et al., 2017).

Of course, an important issue for autism research is whether social attention reflects distinct, domain specific biobehavioral mechanisms, or is better conceptualized in terms of domain general attention mechanisms. It is likely that the development of social and non-social attention reflects overlapping mechanisms, especially early in life (Braithwaite et al., 2020; Falck-Ytter et al., 2022; Nichols et al., 2005). However, theory stipulates that social attention and non-social attention mechanisms differentiate with development as the unique task demands of social attention and non-social attention lead to neural network functional adaptations and the neurodevelopment of distinct neural circuits (Mundy, 2018; Mundy & Bullen, 2022). Indeed, research suggests that social attention measures tap distinct motivation, social cognitive, and referential communication mechanisms not associated with domain general attention (e.g., Birmingham & Kingstone, 2009; Joseph et al., 2015; Mundy & Bullen, 2022; Nummenmaa & Calder, 2009) and that social and non-social attention measures provide unique and complimentary information about the development in autistic children (Bedford et al., 2014) and human social processes (Ramsey & Ward, 2020). A complete consideration of this issue is beyond the scope of this paper but for additional discussions see Braithwaite et al. (2020), Mundy and Bullen (2022), Ramsey and Ward (2020) and Salley and Colombo (2016).

SOCIAL ATTENTION AND THE CURRENT RDOC MATRIX

The importance of measures of social attention was recognized in the conceptualization of the RDoC social process dimension, which includes behavioral measures of joint attention, reciprocal eye contact, and eye gaze detection, as well as face scanning and animacy perception measures of social-orienting. However, the conceptualization of a social attention construct was in an early stage during the development of the RDoC. So, it is not surprising that these measures were not conceptualized as reflecting social attention pe se. Rather they were included as measures of other sub-constructs such as the Reception of Facial Communication, Production of Facial Communication, Reception of Non-Facial Communication. However, this designation is debatable for several reasons.

First, social attention is not limited to the visual modality. Social attention can be measured in the auditory modality and, therefore, does not always occur in conjunction with looking at faces (Adamson et al., 2021; Bigelow, 2003; Hernandez et al., 2020). Indeed, the first observations of social orienting symptoms in autism came from research on orienting to social sounds, not faces (Dawson et al., 1998; Klin, 1991). It is also the case that studies indicate that the combined complexity of visual and auditory stimuli creates a level of stimulus complexity that may impact selective social attention in autistic children. Shic et al. (2014, 2020) have observed that infants with autistic siblings, as well as toddlers with autism, display face related social attention disturbance more clearly in the presence of a speaking social partner rather than a silent social partner.

Second, social attention also may involve the "eye contact effect" (Becchio et al., 2008; Niedźwiecka, 2020; Senju & Johnson, 2009a). Again, this refers to observations that gaze directed to one's self has an impact on cognitive arousal, attention engagement, stimulus salience, motivation and affiliative behavior in infants, children and adults (Bayliss et al., 2013; Conty et al., 2016; Hietanen, 2018; Jarick & Bencic, 2019; Rayson et al., 2019; Rogers et al., 2014). Hypothetically, the eye contact effect is a function of a "fast track" neural network that is engaged approximately 150–170 msec after perception of eye-gaze directed either toward or away from an individual (Conty et al., 2010). Eye gaze direction is first processed via the superior colliculus, pulvinar, and amygdala (see Senju & Johnson, 2009a for review) and relayed for cortical processing. Both the time scale and cortical systems involved in this effect are distinct from those deemed specific to face processing

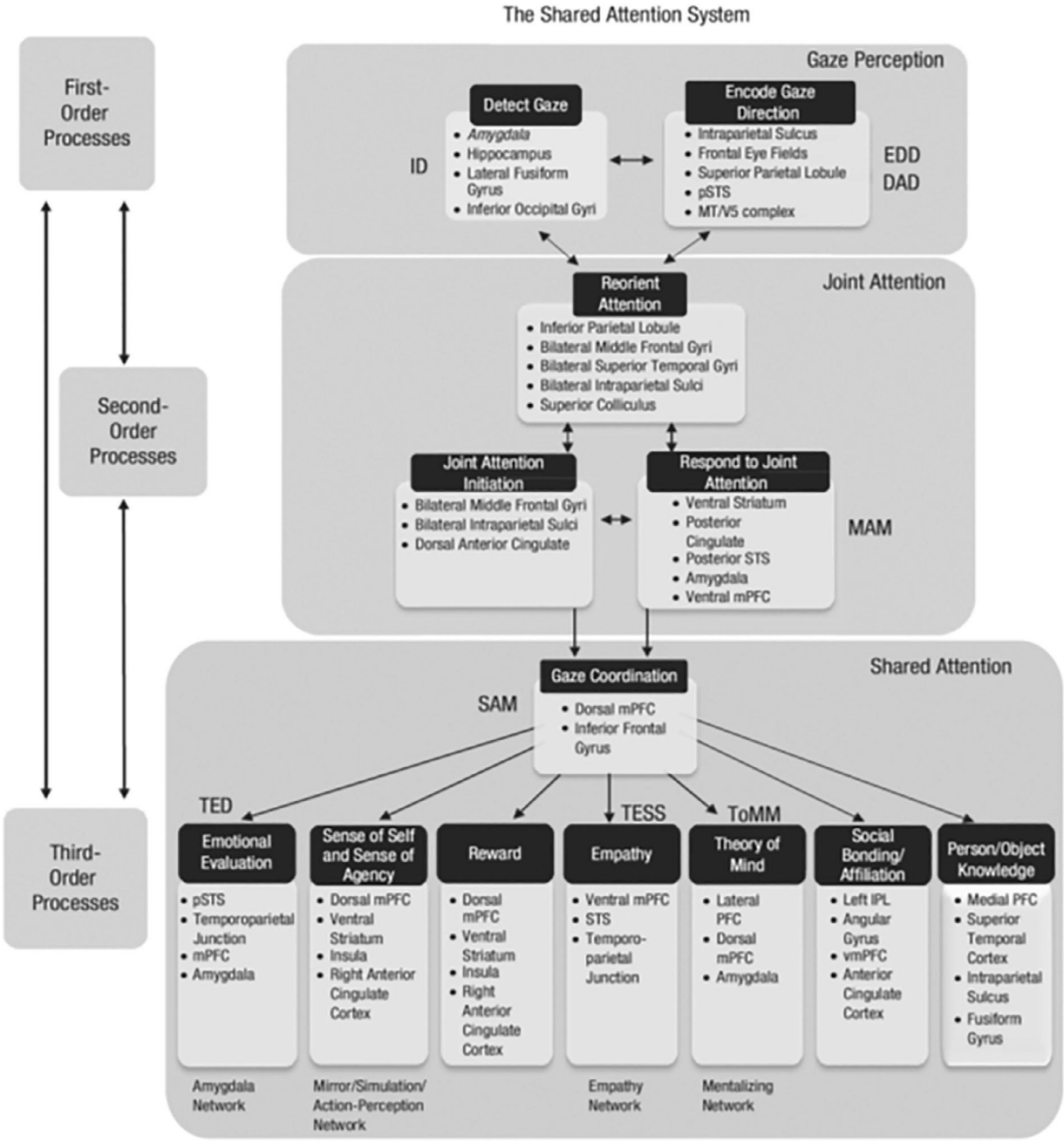

FIGURE 2 An illustration of one model of social processes associated with shared attention that depicts neurocognitive developmental relations between gaze processing, joint attention and social cognition from Stephenson et al. (2021, p. 563). This model illustrates how socially shared attention develops and contributes to important social cognitive outcomes including sense of self and agency, theory of mind, social bonding/affiliation and person knowledge. This model is based, in part, on Baron-Cohen's (1994, 2005) conceptualizations of the development of neurocognitive mechanisms for intentionality detection (ID), an eye-direction detection (EDD), as well as a shared attention mechanism (SAM), the emotion detector (TED), the emphasizing system (TESS) and the theory of mind mechanism (ToMM). It also incorporates the direction of attention detection (DAD) mechanism, and mutual-attention mechanism (MAM) described by Perrett and Emery (1994), as well as "social brain" networks as delineated by Stanley and Adolphs (2013), specifically the amygdala network, empathy, mentalizing and mirror/simulation/action perception networks. This figured first appeared in *Perspectives on Psychological Science* and was reprinted with permission from Sage Publications (license 5434360763908).

(George et al., 2001; Hoffman & Haxby, 2000, Hooker et al., 2003; Senju & Johnson, 2009a), such that gaze and face processing involve interactive but unique subcortical and cortical systems (Hadders-Algra, 2022; Yang & Freiwald, 2021). Hypothetically, the mechanisms specific to the eye contact effect play a distinct role in the early development of social orienting, joint attention and the social symptoms of ASD (Akechi et al., 2014; Chevallier et al., 2012; Mundy, 2018; Mundy & Bullen, 2022; Rayson et al., 2019; Senju & Johnson, 2009b).

Third, the communicative functions of face processing and social attention are distinctly different. The former often involves the conveyance or interpretation of information about the identity of individual (e.g. Krebs et al., 2011) or their emotions provided by the expression and perception of facial affect (Mehu & Scherer, 2015). These are clearly important parts of human social process. For example, the perception of facial affect plays a role in the social regulation of behaviors, such as when negative affect of parent directed toward a novel object inhibits approach behaviors in a preschool child (Sigman et al., 1992), as well as other forms of social-emotional reciprocity in ASD (Zampella et al., 2020). Nevertheless, the communicative functions of social attention do not necessarily involve processing facial identity or affect. For example, joint attention involves declarative interpersonal referential communication (Bates et al., 1975; Bruner, 1995; Csibra, 2003). Joint attention requires the capacity of two or more people to coordinate their attention to a common perceptual referent in space (Baldwin, 1995; Butterworth & Jarrett, 1991) or a common mental referent (Mundy, 2018; O'Madagain & Tomasello, 2021), with or without the mediation of facial or vocal affect, in order to share experience or information.

The capacity for social referential attention is fundamental to both the phylogenetic (Gong & Shuai, 2012; Kwisthout et al., 2008) and ontogenetic development of human language (Baldwin, 1995; Mundy et al., 2007; Rudd et al., 2008; Tomasello et al., 2005), as well as individual differences in the development of language in autism (Bottema-Beutel, 2016; Kasari et al., 2008; Kelty-Stephen et al., 2020; Loveland & Landry, 1986). These observations have motivated research on the role of mutual gaze and joint attention in early intervention for autism (Kasari et al., 2008; Murza et al., 2016; Rollins et al., 2021). There is far less evidence that directly links face processing, or facial communication and language development (but see, Bigelow et al., 2022; Glauser et al., 2021; Pascalis et al., 2014). Of course, facial affect may impact joint attention in typical development and autism (Kasari et al., 1990), but joint attention symptoms in autism can be observed in the context of neutral facial affect (Gangi et al., 2014).

It is also the case that eye contact may elicit evidence of emotional responses and be involved in processing of identity (Nomi & Uddin, 2015). However, data on phenomenon associated with directional cuing of gaze (Tye et al., 2022) may more precisely interpreted in relation to the literature on social attention (Frischen, Bayliss, et al., 2007; Frischen, Smilek, et al., 2007; Itier & Batty, 2009; Nummenmaa & Calder, 2009) rather than under the rubric of face processing.

Fourth, individual differences in joint attention development are significantly correlated with intellectual development in autism (Harrison et al., 2016; Mundy et al., 1990; Sano et al., 2021). Didactic instruction requires that a "learner" coordinate their attention with a "teacher," and visa-versa, in order to share information about a common point of reference (Mundy, 2018; O'Madagain & Tomasello, 2021; Striano et al., 2006). Hence, the development of social attention/joint attention plays a fundamental role in human learning (Baldwin, 1995). Autism, in turn, is associated with a syndrome specific distribution of intellectual development wherein 35% of children are comorbid for intellectual disability and another 23% are affected by intellectual disturbance or borderline intellectual difficulties (IQ = 71–85), but 42% function in the average or above average range (IQ > 85%, Maenner et al., 2021). An early onset and chronic disturbance of social attention/joint attention may contribute to the syndrome specific distribution of IQ through its link to learning and cognitive development (Dawson, 2008; Klin et al., 2015; Mundy & Crowson, 1997; Vivanti et al., 2013). Such a link between face processing and intelligence is far less clear (Karle et al., 2018).

Notably, the RDoC does classify joint attention as a measure of the Perception and Understanding of Others but under the subconstructs of Animacy Perception and Action Perception, rather than the subconstruct of Understanding of Mental States. Arguably, though, theory and developmental research have long made the case for a direct and formative role of social attention in the development of the human capacity to understand the mental states of others (e.g., Baron-Cohen, 1994; Charman et al., 2000; Frischen, Bayliss, et al., 2007; Frischen, Smilek, et al., 2007; Itier & Batty, 2009; Mundy, 2018; Stephenson et al., 2021; Tomasello et al., 2005). Accordingly, the early development of joint attention allows infants to repeatedly adopt and experience shared perceptual perspectives with other people between 6- and 18-months of age. This provides a necessary but not sufficient source of self-other social information processing that stimulates the development of our human ability to mentally represent and adopt the perspective of another person (Mundy & Newell, 2007; Mundy et al., 2009; Tomasello et al., 2005). In other words, understanding mental states involves the cognitive developmental internalization of joint attention or the action of sharing perceptual states with other people. Support for the connection between joint attention and the development of mentalizing is supported by longitudinal studies, as noted earlier, and brain imaging studies (Mundy, 2018; Stephenson et al., 2021). The current classifications of the social attention construct in the RDoC is not currently well aligned with these observations.

SOCIAL ATTENTION AND A REVISED RDOC FRAMEWORK

If the construct of social attention is not well classified in the current RDoC framework, what is the alternative? A

compelling argument could be made for the designation of social attention as sub-construct under the construct of Perception and Understanding of Others (e.g., Itier & Batty, 2009; Mundy, 2018; Stephenson et al., 2021; Tomasello et al., 2005). However, a recent research review suggests that the social process sub-constructs of Perception and Understanding of Other, Perception and Understanding of Self, Social Communication and Affiliation may reflect a set of social-cognitive functions that involve activation of a common set of neural circuits (Lobo et al., 2023). Hence, it may not be surprising that certain aspects social attention, such as joint attention, could be considered as a subconstruct under social communication (Charman, 2003; Farrant et al., 2011; Kasari et al., 2008). It is also the case, though, that joint attention and eye eye-contact may play significant roles in perception and development of understanding agency and the self (Metcalfe & Terrace, 2013; Mundy et al., 2010; Reddy, 2003) as well as a sense of intersubjectivity, shared experience, relatedness and affiliation with other people (Mundy et al., 1994; Stephenson et al., 2021; Wolf et al., 2016; Wolf & Tomasello, 2020) but not necessarily attachment (Capps et al., 1994; Claussen et al., 2002; Naber et al., 2007).

Thus, social attention is a construct that may be fundamental to many aspects of the human social process systems. The centrality of social attention in this regard has been discussed in a recent paper by Stephenson et al. (2021) on the development of shared social attention and its role in social cognition and is illustrated in Figure 2. However, to entertain a revision of the RDoC framework that would include social attention as a construct, evidence that this construct has applications to psychopathology beyond autism would likely be required.

In this regard, research on social attention/joint attention has contributed to understanding the common and distinct phenotypic feature of autism, specific language delay, fragile X syndrome, Down syndrome, Williams Syndrome and sex chromosome trisomies (Bouw et al., 2022; Brewe et al., 2018; Franchini et al., 2019; Hahn et al., 2018; Thurman & Dimachkie Nunnally, 2022; Vivanti et al., 2017; Wolff et al., 2012). Perhaps even more relevant, Tso et al. (2020) have argued that disruptions of eye gaze perception mechanisms of social attention is a fundamental component of several other mental health conditions.

Schizophrenia is characterized by a tendency to over interpret ambiguous gaze direction information as indicative of self-referenced gaze, or the perception of being the object of attention of another person (Caruana et al., 2019; Chan et al., 2021; Hooker & Park, 2005; Tso et al., 2014; Tso, Angstadt, et al., 2021). This "self-referential bias" in the perception of gaze plays also appears to play a role in bipolar disorder and social anxiety (Berchio et al., 2017; Gamer et al., 2011; Schmitz et al., 2012; Schulze et al., 2013; Yao et al., 2018), and possibly ADHD (Mauriello et al., 2022). Alternatively, hypo-responsiveness to self-referential gaze or the eye contact effect has been observed in research on ASD (Akechi et al., 2014; Grynszpan et al., 2017, Mundy & Bullen, 2022). Interestingly, different patterns of preconscious processing of eye contact have been reported for autism (Akechi et al., 2014) and schizophrenia (Seymour et al., 2016) and differences in response to the perception of gaze direction may distinguish social attention symptoms in autism from those in social anxiety (Hessels et al., 2018). Evidence also indicates that atypical social attention correlates with differences in social-cognition in schizophrenia (Tso et al., 2014) and bipolar disorder (Tso, Burton, et al., 2021; Yao et al., 2018), just as it does in ASD (Oberwelland et al., 2017; von dem Hagen et al., 2014) and in typical development. This literature recently led Tso et al. (2020) to propose that social attention, or at least the altered eye-gaze perception, represents a common pathway to social dysfunction across psychiatric conditions regardless of diagnosis.

As alluded to earlier, in the study of social-attention it is important to employ methods to distinguish whether what appear to be social attention mechanisms can be more parsimoniously explained in terms of general attention mechanisms (Lasagna et al., 2020). Tso et al. (2014); Tso, Angstadt, et al. (2021) have reported datat that indicate that self-referential or eye contact effects of gaze may be regulated by different neural networks than non-social attention mechanisms and the former contribute to different symptoms and functions in individuals with psychopathology. Similarly, domain-general visual attention disengagement and domain specific social attention have been observed to provide unique and additive predictive information about the development of ASD in infant siblings (Bedford et al., 2014). Thus, as noted previously, rather than one dimension being primary or explanatory, social and non-social attention measures may provide additive and complimentary information about the development of ASD (Bedford et al., 2014; Capozzi & Ristic, 2020; Ramsey & Ward, 2020) and psychopathology more generally (Tso et al., 2020).

One reason to expect a complimentary rather the mediational relations between social attention and general attention is that the former taps into specific neural systems (e.g., Klein et al., 2009; Yang & Freiwald, 2021) and interpersonal mental processes that are not involved in the latter (Mundy & Bullen, 2022). Social attention can be bi-directional as it often involves both seeing and being seen (Marotta et al., 2018; Myllyneva & Heitenen, 2016; Reddy, 2003). Social neuroscience has begun to document numerous significant effects of the perception of being seen or being the object of attention of other people (Heitenen, 2018; Mundy & Bullen, 2022; Rayson et al., 2019; Redcay & Schilbach, 2019; Reddy, 2003; Senju & Johnson, 2009a; Stephenson et al., 2021). These phenomena and their underlying neural mechanisms are not measured, or evan measurable in non-social attention paradigms. Nevertheless, current research raises the

hypothesis that processes associated with self-referenced attention may play important roles in various forms of psychopathology (Mundy & Bullen, 2022; Schmitz et al., 2012; Schulze et al., 2013; Tso et al., 2020).

SUMMARY AND IMPLICATIONS

We are still in the age of initial discovery about the nature and mechanisms of human development (Miller, 2003; Ochsner & Lieberman, 2001) and psychiatric conditions, especially with respect to social process systems (Pan et al., 2022). Thus, there is a need to systematically update dimensional frameworks, such as the RDoC, that are designed to guide the development of more refined taxonomies of mental disorders. Observations of reliably measured constructs that are associated with identified neural circuits, and are associated with large or consistent diagnostic groups differences, may be especially useful in this regard. Such appears to be the case with respect to the construct of social attention. However, by no stretch of the imagination has this construct been fully elucidated, but the same can be said for many of the constructs relied upon for research on mental processes. Assuming that the significance of social attention becomes more widely recognized, and included in a future iteration of the RDoC framework, here are few examples of how that could support new and valuable programs of study.

Autism and Attention Deficit Hyperactivity Disorder may be related childhood neurodevelopmental disorders of attention, rather than distinct conditions (Antshel & Russo, 2019; Baribeau et al., 2019; Grzadzinski et al., 2011; Stergiakouli et al., 2017). However, since social attention is a relatively new construct, few studies have compared these diagnostic groups on measures of social attention (Braithwaite et al., 2020). Nevertheless, Groom et al. (2017) observed that autistic and ADHD children differ in electrophysiological response to gaze cues (Groom et al., 2017) and autistic children differ for children with ADHD symptoms in the cognitive impact of having their own gaze followed in the context of joint attention (Mundy et al., 2016). It is reasonable to expect more comparative research on social attention in preschool and school-aged children would provide new insights into the common as well as unique attention mechanisms involved in autism and ADHD (Braithwaite et al., 2020).

A significant neuroimaging literature has emerged that provides a foundation for understanding the neurodevelopment of social attention development in autism (Greene et al., 2011; Mundy, 2018; Nummenmaa & Calder, 2009; Senju & Johnson, 2009b; Stephenson et al., 2021). However, surprisingly little research has been conducted to examine the cortical correlates of social attention development in autism (Mundy, 2018) or comparatively across psychiatric conditions (Tso et al., 2020). Still, there are examples of intriguing if preliminary sets of findings. As one example, Shen et al. (2022) observed altered growth in the amygdala among 6 to 12-month old infants with faster growth related to higher social symptom scores on the SA scale of the ADOS in infants who went on to receive the diagnosis of autism. Connectivity of amygdala with the ventral-medial prefrontal cortex, via the uncinate fasciculus, at 6 months of age has also been observe to predict joint attention in the 9th month of typical development (Elison et al., 2013). However, Mosconi, Cody-Hazlett, et al. (2009) reported that rate of growth of the amygdala by 2 years of age was positively related to joint attention in autistic four-year-olds. This observation is at variance with the general understanding that enlargement of the amygdala is related poorer social development in autism (e.g. Shen et al., 2022). Together, though, the three studies indicate that methods are available to begin a concerted empirical investigation into important questions and hypotheses about the neurodevelopment social attention early in the development of children with autism.

There is a much smaller literature available on the genetics of social attention, but a foundation for future research has emerged (Mundy & Bullen, 2022). Behavioral genetics studies provide evidence of significant heritability of attention to eyes in 18-month-olds (Constantino et al., 2017), as well as gaze direction perception in adolescents (Wang et al., 2018, 2020). Several studies indicate that the dopamine, oxytocin and vasopressin transported genes are related to individual difference and the development of social attention in primates, typical development and autism (Gangi et al., 2016; Hopkins et al., 2023; Nishizato et al., 2017; Sjaarda et al., 2019; Tops et al., 2011; Wade et al., 2014). Moreover, genome wide DNA methylation is associated with attention to face stimuli with direct gaze in infant siblings of children with ASD (Gui et al., 2020) and methylation of the oxytocin receptor gene correlates with individual differences in social attention in typical adults (Puglia et al., 2018). If the construct of social attention is as central to autism, as is suggested here, then an increase in the recognition of the value of the construct for research on the genetics of social attention could advance autism science and developmental psychopathology more generally.

Finally, there is relatively little data on the development of social attention across childhood and adults in autism or other conditions. Paradigms used for preschool social attention research may not be sensitive to significant differences in social attention in older individuals (Mundy & Bullen, 2022). Instead, measures of the effort or efficiency of social attention may be more useful. Moreover, the need to consider the ecological validity in research on social processes argues that we likely need to employ new methods of second person or interpersonal neuroscience in psychiatric research on social attention

(e.g., Canigueral et al., 2022; Hoehl & Markova, 2018; Pan et al., 2022; Redcay & Schilbach, 2019).

In conclusion, over the past two decades science has begun to reveal the fundamental role of social attention in typical and atypical human social development. However, there is much more to be learned about the unique nature and role of social attention in autism and developmental psychopathology in general, and the encouragement of research in that regard is perhaps the most important point to be made in this commentary.

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ETHICS STATEMENT

The author declares that there were no conflicts of interest or any interest or relationships, financial or otherwise that might be pereceived as influencing the objectivity of the content of this paper.

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