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BRIEF REPORT

Brief Report: Joint Attention and Information Processing in Children with Higher Functioning Autism Spectrum Disorders

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Abstract Theory suggests that information processing during joint attention may be atypical in children with Autism Spectrum Disorder (ASD). This hypothesis was tested in a study of school-aged children with higher functioning ASD and groups of children with symptoms of ADHD or typical development. The results indicated that the control groups displayed significantly better recognition memory for pictures studied in an initiating joint attention (IJA) rather than responding to joint attention (RJA) condition. This effect was not evident in the ASD group. The ASD group also recognized fewer pictures from the IJA condition than controls, but not the RJA condition. Atypical information processing may be a marker of the continued effects of joint attention disturbance in school aged children with ASD.

Keywords Joint attention · Information processing · Social cognition · Autism Spectrum Disorder

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Introduction

Research on joint attention has played a significant role in defining critical features of the social-cognitive development of children with Autism Spectrum Disorders (e.g. Mundy et al. 2009). The term 'social-cognition' is often used to refer to behavioral measures indicative of mental processes involved in inferring the intentions, beliefs, or emotions of another person. However, this is only one facet of social-cognition. Another vital component of the social-cognition that is especially pertinent to joint attention research refers to changes in stimulus coding effects that occur as the result of social-attention coordination (e.g. Edwards et al. 2015; Mundy 2016; Kim and Mundy 2012). Recognition of this aspect of social-cognition has emerged, in part, from mounting evidence that the experience of joint attention influences and in some case enhances encoding of visual stimuli and words in infancy (e.g. Hirotani et al. 2009; Kopp and Lindenberger 2011; Striano et al. 2006) and adults (e.g. Bayliss et al. 2013; Böckler et al. 2011; Boothby et al. 2014; Frischen and Tipper 2004; Linderman et al. 2011; Kim and Mundy 2012).

The effect of joint attention on stimulus encoding was illustrated in a recent study of Kim and Mundy (2012) who observed that stimulus encoding and subsequent recognition memory for pictures was enhanced in one of two types of virtual joint attention conditions in adults. Specifically, picture encoding was more positively affected when an *avatar followed the participants gaze shifts* to stimuli, rather than when *participants followed the gaze shifts of an avatar to pictures* on study trials. The former condition was an analogue of the experience of initiating joint attention bids (IJA), while the latter condition was analogous to responding to joint attention bids (RJA). Kim and Mundy (2012) concluded that the experience of being the object of

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attention of the avatar during virtual IJA had a different and more powerful effect on recognition memory than RJA did in adults. This pattern of results and conclusion is consistent with other observations that adults are sensitive to being the object of the attention of others, and that this type of "gaze-leading" has an important impact on cognition (Bayliss et al. 2013; Boothby et al. 2014; Edwards et al. 2015).

The study by Edwards et al. (2015) also reported observations that are relevant for the study of Autism Spectrum Disorders (ASD). In that study, individual differences in the impact of initiating joint attention, or gaze leading, on information processing was lower for people who self-reported more symptoms of the Broad Autism Phenotype (BAP) in a sample of typical adults. It is also the case that ASD individual differences in the development of initiating joint attention are related to problems in learning from and with other people (e.g. Kasari et al. 2008), and theory has suggested that differences in the influence of joint attention on information processing contributes to the link between joint attention and learning problems in affected children (Mundy 2016; Mundy et al. 2009).

Given these observations, this study was designed to examine the possible effects of joint attention on information processing in higher function children with ASD in order to better understand the role of joint attention in the learning problems of affected children. A virtual joint attention information processing paradigm was used to examine three predictions related to hypothesis that joint attention affects information processing differently in children with ASD. The first was that typical children and adolescents would display evidence of enhanced information processing in IJA relative to RJA conditions as previously observed in typical adults (Kim and Mundy 2012). The second hypothesis was that many children with ASD would not display the level of enhanced information processing in the IJA condition exhibited by typical children. The third hypothesis was that the lack of enhanced information processing in the context of IJA would be specific to ASD rather than a phenomenon associated with the general attention problems exhibited by a clinical control sample of children with elevated ADHD symptoms.

Methods

This research was conducted in compliance with the appropriate university Institutional Review Board, and written consent and assent was obtained from parents and participants before gathering any data.

Thirty-two 9- to 13-year-olds with HFASD, 27 children with high ADHD symptoms, and 23 children with typical development (TD Group) participated in this study. The HFASD, ADHD and TD groups did not differ in mean age: 11.4 years (2.1), 12.2 years (2.3) and 11.8 years, respectively. However, the groups did differ on IQ, F (2, 83) = 4.67, $p < .025$, eta^2 = .09 with the HFASD and ADHD groups lower than the TD group: 103.6 (15.2), 101.1, (15.1) and 112.6, (14.1) respectively. Intellectual level was estimated with the Wechsler Abbreviated Scales of Intelligence (Wechsler 2011) and group differences in IQ were covaried in all group comparisons.

Children with ASD and children with elevated symptoms of ADHD were recruited from the MIND Institute research participant tracking system, as well as from local schools. ASD symptom presentation was confirmed with parent report on the Social Communication Questionnaire (SCQ, Berument et al. 1999), means = 21, 4.9, 2.3 for the ASD, ADHD, and TD groups, as well as the Autism Spectrum Symptom Questionnaire (ASSQ, Ehlers et al. 1999), means = 18, 7.5, 1.8 respectively. The ASSQ has been validated on a large sample for the identification of ASD in higher functioning children (Posserud et al. 2006). An ADHD clinical control sample was recruited to control for the possibility that ADHD symptom comorbidity in the ASD group could account for group differences on an information processing measure. ADHD symptoms were confirmed with parent report on the Conner-3 (Conners 2010). The two clinical groups displayed comparable scores on Total Conner's ADHD symptoms, but significantly differed from the TD group, F (2, 82) = 31.2, $p < .001$. The mean T-scores were, ASD = 71.4 (13.9), ADHD = 74.9 (12.4), and TD = 49.1 (9.1). To examine the effects that individual differences in memory on task performance the participants were also assessed on the Wide Range Assessment of Memory and Learning (WRAML2, Sheslow and Adams 2003). The TD group displayed significantly better performance on the Total memory score, 111 (13.1), than did the ASD group, 99.3 (15.6), and the ADHD group 100 (13.4), F (2, 82) = 5.18, $p < .01$.

Procedures

The participants were presented with a virtual reality paradigm (Fig. 1) that is more fully described in Study 2 of Kim and Mundy (2012). Two blocks of 12 RJA picture study trials (24 studied pictures) and two blocks of 12 IJA trials (24 pictures) were presented in one of two counterbalanced orders starting either with a block of RJA trials or a block of IJA trials (e.g. RJA Block 1, IJA Block 1, RJA Block 2, IJA Block 2). In the RJA condition, children were directed to make eye contact with an avatar, then follow the gaze direction of an avatar to the left or right to view a picture that they studied for 1 s. At the beginning of each trial the avatar "waited and responded" to mutual gaze

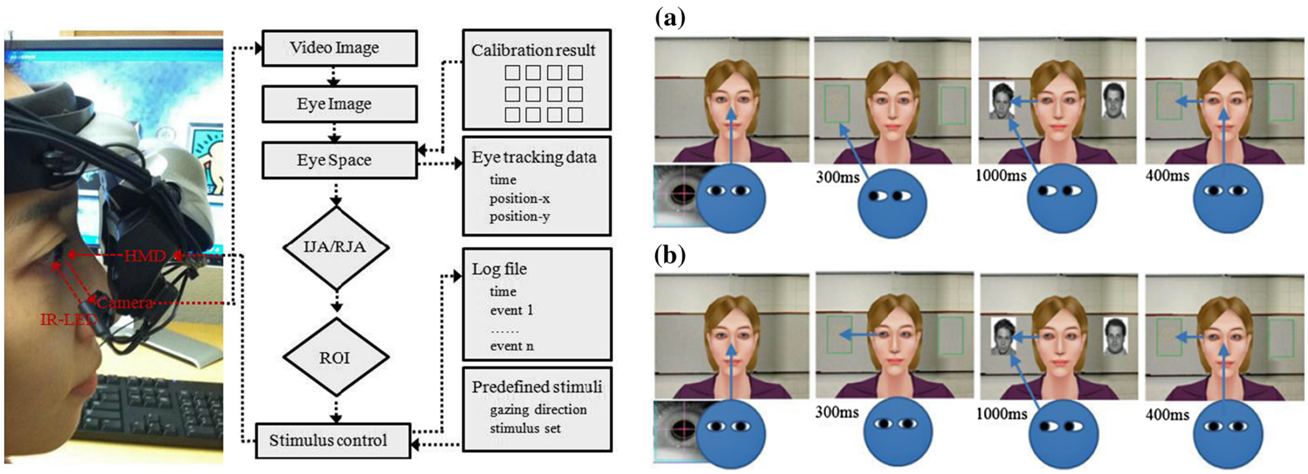

Fig. 1 Illustration of the head mounted display used to gather data in the virtual joint attention conditions (*left panel*) and illustration of the avatar's and participants eye movements in the IJA condition (*right panel* **a**) and in the RJA condition (*right panel* **b**). (Figure reprinted with permission from Frontiers.org, *Frontiers in Human Neuroscience*, Kim and Mundy 2012, Vol. 6, in accord with the open access guidelines of the journal)

from participant (a fixation of 300 ms) and shifted "her" gaze left or right. The participants' gaze shift in the correct direction triggered a 1 s appearance of a picture to the left and right location (houses, faces, or abstract patterns). Different pictures from the same category appeared in correct and incorrect left/right locations on each trial. The IJA condition was similar except the child was told to choose which side of the avatar to look. After the participants' shift of gaze the pictures would appear and the *avatar would follow the child's* line of regard. After the participant returned to midline on all IJA and RJA trials the avatar shifted gaze to midline following a 400 ms delay. This allowed the participant to see the avatar return "her" gaze to the midline in order to emphasize the participants' experience of "gaze leading" or "gaze following" on trials.

Thirty-six test trials were presented immediately after the last study trial. The test trials paired equal numbers of "familiar" pictures studied in the IJA and RJA conditions (18 pictures per condition) paired with novel pictures. Correct hits and false alarms (errors of commission) were scored for each test trial and summed for test trials associated with each condition. The dependent measures were the percentage of pictures correctly recognized in conjunction with each condition as well as the percentage of false positive (FP) errors of commission recognition for each condition.

Results

Preliminary analyses indicted there were no diagnostic group differences in attention (fixations or duration of study time) to pictures in either condition, or in following gaze in the RJA condition, or in attention to the face of the Avatar in either condition. The preliminary analyses also revealed no effects of study stimulus presentation order. There were also no significant correlations (r) between total WRAML memory scores and IJA or RJA correct recognition (hit) scores for the ASD group (.30, .24), the ADHD group (.01, .05), or the TD group (.28, .07), and no differences in WRAML correlation with IJA or RJA hit scores within groups. These analyses revealed no evidence that individual differences in working memory contributed to the pattern of group differences observed in this study (see below).

Two MANCOVAS, controlling for IQ, were conducted separately for picture recognition sores associated with the IJA and RJA study conditions. In the first of these a 3 (DX Groups) by 2 types of scores (IJA Correct Hits and IJA False Positive % picture recognition scores) analysis revealed a significant DX Group by Type of IJA score interaction, Wilks' Lambda = .84, $F\ (2, 83) = 7.74$, $p < .001$, $\text{eta}^2 = .16$ (see Fig. 2a1). Planned follow-up analyses indicated that the DX Groups differed on IJA-Correct scores, $F\ (2, 83) = 8.26$, $p < .001$, but not on IJA-FP scores, $F\ (2, 83) = 1.53$, $p > .20$. Pairwise comparisons (Tukey) revealed that the HFASD group had lower IJA-Correct recognition scores than did the ADHD sample ($p < .05$) or the TD sample ($p < .05$), however the latter two groups did not significantly differ. Additional planned repeated measure analyses within each group indicated that the TD and ADHD samples displayed significantly higher IJA-Correct scores than RJA-Correct scores, $F\ (1, 22) = 37.83$, $p < .001$, $\text{eta}^2 = .63$, $F\ (1,27) = 9.91$, $p < .004$, $\text{eta}^2 = .27$. However, there was no evidence of this difference in the IJA-Correct and RJA-Correct scores in the HFASD sample, $F\ (1, 34) = .08$. This pattern of

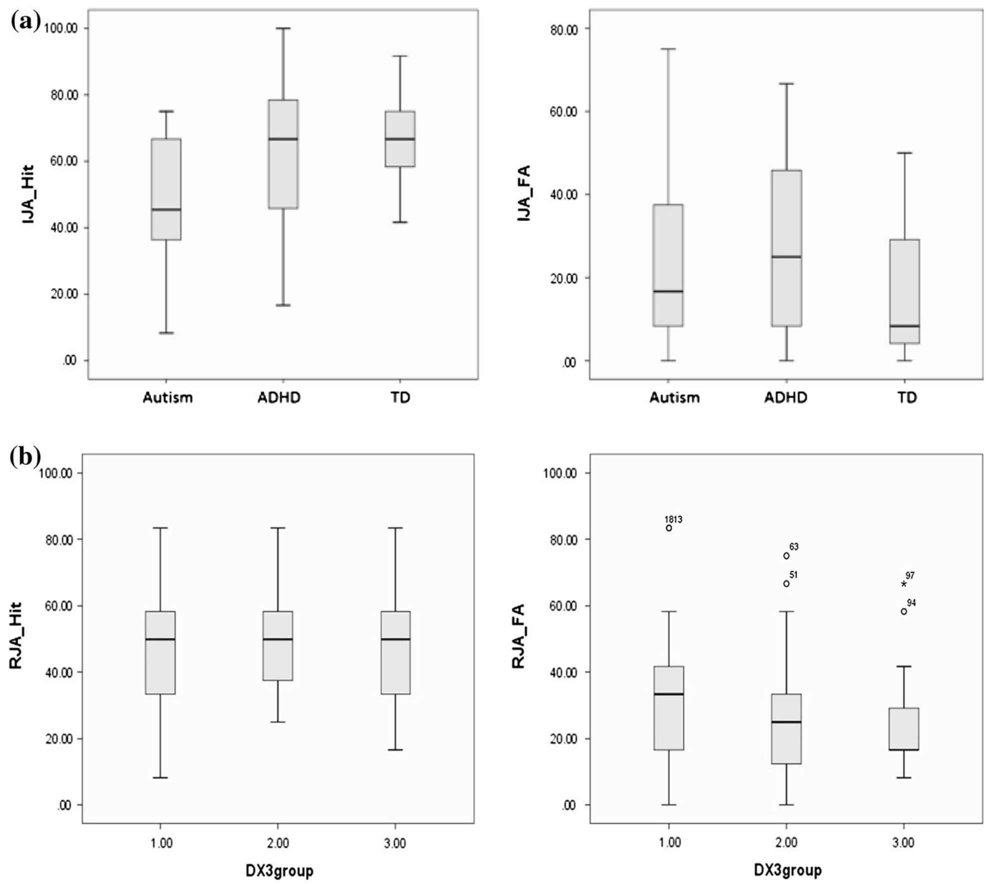

Fig. 2 **a** The Diagnostic Group differences in percentage of correct picture recognition in the IJA condition (IJA-Hit, *left panel* **a**) and the percent of errors of commission for IJA (IJA-FP, *right panel* **a**). **b** The Diagnostic Group differences in percentage of correct picture recognition in the RJA condition (RJA-Hit, *left panel* **b**) and the percent of errors of commission for RJA (RJA-FP, *right panel* **b**)

results was consistent with the hypothesis that the HFASD sample was less likely to exhibit effects of IJA on information processing compared to a typical or clinical control sample. The specifics of this pattern of results were observed in analyses that included full scale IQ as a covariate.

A three Diagnostic Groups by 2 types of scores (RJA Correct Hits and RJA False Positive % picture recognition scores) did not reveal evidence of a main effect of Diagnostic Groups, F (2, 83) = .42, $p < .70$, or a DX Group by type of RJA score interaction, Wilks' Lambda = .96, F (1, 83) = 1.56, $p > .22$.

Discussion

The results of this study provide observations about the nature of joint attention and its roles in autism spectrum development. Like the effects previously observed with adults (Kim and Mundy 2012), children and adolescents with typical development as well as children with elevated symptoms of ADHD displayed evidence of enhanced stimulus information processing and recognition memory during the experience of virtual IJA relative to RJA study trials. This observation is consistent with the hypothesis that joint attention affects stimulus encoding (e.g. Bayliss et al. 2013; Becchio et al. 2008; Boothby et al. 2014; Edwards et al. 2015; Frischen and Tipper 2004; Kopp and Lindenberger 2011). This joint attention effect may be part of human social-cognition across the lifespan (Mundy 2016; Mundy et al. 2009), however, too little is currently know currently to be certain about the mechanism underlying this phenomenon. Moreover, the validity of virtual reality paradigms for eliciting *social* cognitive processes is not yet clear. Nevertheless, the data are consistent with one hypothesis posits that being the object of attention of others triggers a subcortical arousal network that leads to enhanced cortical information processing (Senju and Johnson 2009). Another possibility is that initiation of joint attention activates self-referenced processing to a greater degree than RJA, and this results in activation of a neural network that enhances information processing (Mundy and Jarrold 2010). These and other hypotheses may guide future research future research to determine the mechanisms by which joint attention enhances human information processing.

A second major observation was that atypical information processing during joint attention may be a clinically specific feature of the childhood development of ASD, at least among higher functioning children. That is to say the atypical pattern of information processing response to joint attention was observed in the ASD sample, but not in an IQ-matched sample of children with ADHD. Moreover, the atypical pattern of information processing was observed even though there were no diagnostic group differences in following the gaze direction of the avatar, fixating the face of the avatar, or attending to the study pictures. Thus, the atypical pattern of information processing was evident even though the HFASD children appeared to engage in the joint attention behaviors in much the same way as the control samples. Attention of any kind is inextricably linked to information processing (e.g. Sperling and Weichselgartner 1995), this includes joint attention (Mundy 2016). When this facet of joint attention is recognized and measured, the lifespan effects of joint attention on people affected by ASD may become more apparent.

This study is not the first to suggest that joint attention does not elicit typical levels of information processing in children with ASD. Falck-Ytter et al. (2015) examined RJA in 3-year-old children with ASD and comparison groups of children with other developmental disabilities or typical development. The children with ASD did not differ from the control groups in following the gaze of a social partner to objects. However, the duration of fixation times during social-attention coordination to the objects were significantly shorter for the group with ASD than for the controls. Falck-Ytter et al. (2015) concluded that these results suggested that the group with ASD was more weakly engaged in processing information about the objects in response to RJA bids than were other groups of children. They went on to speculate that an attenuated processing bias in RJA may negatively affect learning opportunities in children with ASD.

In addition, Zhao et al. (2015) have observed an effect of gaze following, or RJA, on information processing that is associated with the Broad Autism Phenotype or BAP. Adults with more symptoms of ASD did not display the gaze-cuing attention-directing effects when a stimulus appeared longer after gaze cues (800 ms), but adults with lower BAP symptoms did respond to gaze cues to longer delayed stimuli. However, both high and low BAP adults responded comparably to gaze cues with short stimulus onset intervals of 200 ms. This important finding suggests that the direction of cuing information and/or valence of shifts of eye-gaze is weaker, or degrades more quickly, among people who display more evidence of the BAP. However, the basic mechanism of gaze-cuing is intact, regardless of the relative presence of the BAP.

Thus, the observations and conclusions of this paper do not describe an isolated phenomenon. Rather, they constitute one more piece of evidence that atypical information processing during joint attention is a feature of ASD (Falck-Ytter et al. 2015), as well as the BAP (Edwards et al. 2015; Zhao et al. 2015). These observations support assertions and predictions of the information processing model of joint attention in the development of ASD (Mundy 2016; Mundy and Jarrold 2010; Mundy et al. 2009). However, the picture here is far from complete. For example, the results of the current study report no effects of RJA on information processing in school-aged children. Other observations, however, have suggested that RJA information processing effects may be observed in younger children (Falck-Ytter et al. 2015), or in older individuals with different measures of information processing (Zhao et al. 2015).

In the final analysis, the results of this study do not provide a complete answer to any one question. However, they do make an important contribution to the theoretical and empirical impetus for more research on the effects of joint attention on stimulus encoding and learning in typical development, as well as in the development of school-aged children affected by ASD.

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Author Contribution I would like to submit a brief paper titled, "Short Report Joint Attention and Stimulus Processing in Autism Spectrum Disorders", for consideration for publication in *J.A.D.D.* The authors of the paper include: Peter Mundy, School of Education and the MIND Institute, UC Davis, Davis, CA, USA; Kwanguk Kim, School of Education, UC Davis, Davis, CA, USA; Nancy McIntyre, School of Education, UC Davis, Davis, CA, USA; Lindsay Lerro, School of Education, UC Davis, Davis, CA, USA; and William Jarrold, School of Education, UC Davis, Davis, CA, USA. Two of the authors have changed their affiliations since the completion of data collection for this study. Kwanguk Kim is now in the Engineering College, Hanyang University, Seoul, Korea. William Jarrold is now at the Natural Language Understanding Laboratory, Nuance Communications, Sunnyvale, CA, USA.

Compliance with Ethical Standards

Conflict of interest P. Mundy declares that he has no conflict of interest. K. Kim declares that he has no conflict of interest. N. McIntyre declares that she has no conflict of interest. L. Lerro declares that she has no conflict of interest. W. Jarrold declares that he has no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

References

Baron-Cohen, S. (1995). The eye-direction detector (EDD) and shared attention mechanism (SAM): Two cases for evolutionary psychology. In C. Moore & P. Dunham (Eds.), *Joint attention: Its origins and role in development* (pp. 41–60). New York, NY: Erlbaum.

Bayliss, A., Murphy, E., Naughtin, C., Kritikos, A., Schilbach, L., & Becker, S. (2013). Gaze leading: Initiating joint attention influence s eye movements and choice behavior. *Journal of Experimental Psychology: General, 142*, 76–92.

Becchio, C., Bertone, C., & Castiello, U. (2008). How the gaze of other influences objects processing. *Trends in Cognitive Sciences, 12*, 254–258.

Berument, S., Rutter, M., Lord, C., Pickles, A., & Bailey, A. (1999). Autism screening questionnaire: Diagnostic validity. *British Journal of Psychiatry, 175*, 444–451.

Böckler, A., Knoblich, G., & Sebanz, N. (2011). Giving a helping hand: effects of joint attention on mental rotation of body parts. *Experimental brain research, 211*(3–4), 531–545.

Boothby, E., Clark, M., & Bargh, J. (2014). Shared experiences are amplified. *Psychological Science, 25*, 2209–2216.

Conners, K. (2010). *Conners* (3rd ed.). North Tonawanda, NY: Multihealth Systems.

Edwards, S. G., Stephenson, L. J., Dalmaso, M., & Bayliss, A. P. (2015). Social orienting in gaze leading: A mechanism for shared attention. *Proceedings of the Royal Society of London: Series B. Biological Sciences, 282*(1812), 20151141. doi:10.1098/rspb.2015.1141.

Ehlers, S., Gillberg, C., & Wing, L. (1999). A screen questionnaire for Aspergers syndrome and other high-functioning autism spectrum disorder in school age children. *Journal of Autism and Developmental Disorders, 29*(2), 129–141.

Falck-Ytter, T., et al. (2015). Brief Report: Lack of processing bias for object other people attend to in 3-year-olds with Autism. *Journal of Autism and Developmental Disorders, 45*(1), 987–1904.

Frischen, A., & Tipper, S. (2004). Orienting attention via observed gaze shifts evokes longer term inhibitory effects: Implications for social interaction, attention and memory. *Journal of Experimental Psychology: General, 133*, 516–533.

Hirotani, M., Stets, M., Striano, T., & Friederici, A. D. (2009). Joint attention helps infants learn new words: Event-related potential evidence. *NeuroReport, 20*(6), 600–605.

Kasari, C., Paparella, T., Freeman, S., & Jahromi, L. B. (2008). Language outcome in autism: Randomized comparison of joint attention and play interventions. *Journal of Consulting and Clinical Psychology, 76*(1), 125–137.

Kim, K., & Mundy, P. (2012). Joint attention, social cognition and recognition memory in adults. *Frontiers in Human Neuroscience Special Topic: Towards a Neuroscience of Social Interaction, 6*, 172. doi:10.3389/fnhum.2012.00172.

Kopp, F., & Lindenberger, U. (2011). The effects of joint attention on long-terms memory in 9 month-old infants: An event related potential study. *Developmental Science, 14*, 660–672.

Linderman, O., Pines, N., Rueschemeyer, S., & Bekkering, H. (2011). Grasping the others's attention: The role of animacy in action cuing of joint attention. *Vision Research, 51*, 940–944.

Lord, C., & Jones, R. (2012). Re-thinking the classification of autism spectrum disorders. *Journal of Child Psychology and Psychiatry, 53*, 490–509.

Mundy, P. (2016). *Autism and joint attention: Developmental, neuroscience, and clinical fundamentals*. New York City, NY: Guilford Pub. Inc.

Mundy, P., & Jarrold, W. (2010). Infant joint attention, neural networks and social cognition. *Neural Networks, 23*(8), 985–997.

Mundy, P., Sigman, C., & Kasari, C. (1994). Joint attention, developmental level and symptom presentation in autism. *Development and Psychopathology, 6*, 389–402.

Mundy, P., Sullivan, L., & Mastergeorge, A. M. (2009). A parallel and distributed-processing model of joint attention, social cognition and autism. *Autism Research, 2*, 2–21.

Posserud, M., Lundervold, A., & Gillberg, C. (2006). Autistic features in a total population of 7–9 year-old children assessed by the ASSQ (Autism Spectrum Screening Questionnaire). *Journal of Child Psychology and Psychiatry, 47*, 167–175.

Senju, A., & Johnson, M. H. (2009). The eye contact effect: Mechanisms and development. *Trends in Cognitive Sciences, 13*(3), 127–134.

Sheslow, D., & Adams, W. (2003). *Wide-range assessment of memory and learning* (2nd ed.). Lutz, FL: Psychological Assessment Resources.

Sperling, G., & Weichselgartner, E. (1995). Episodic theory of the dynamics of spatial attention. *Psychological Review, 102*, 503–532.

Striano, T., Chen, X., Cleveland, A., & Bradshaw, S. (2006). Joint attention social cues influence infant learning. *European Journal of Developmental Psychology, 3*, 289–299.

Wechsler, D. (2011). *Wechsler abbreviated intelligence scale*. San Antonio, TX: Pearson Publishers.

Zhao, S., Uono, S., Yoshimura, S., & Toichi, M. (2015). I s impaired joint attention present in non-clinical individuals with high autistic traits? *Molecular Autism, 6*, 67. doi:10.1186/s13229-015-0059-3.