The Impact of Atypical Sensory Processing on Social Impairments in Autism Spectrum Disorder

Melissa D. Thye*, Haley M. Bednarz*, Abbey J. Herringshaw*, Emma B. Sartin*, & Rajesh K. Kana*

*Department of Psychology, University of Alabama at Birmingham, Birmingham, AL 35233

Corresponding author
Rajesh K. Kana
Department of Psychology
UAB Civitan International Research Center, CIRC 235G
1719 6th Avenue South, Birmingham, AL 35233
Phone: (205) 934-3171
E-mail: rkana@uab.edu

*All authors contributed equally to this paper

ABSTRACT

Altered sensory processing has been an important feature of the clinical descriptions of autism spectrum disorder (ASD). There is evidence that sensory dysregulation arises early in the progression of ASD and impacts social functioning. This paper reviews behavioral and neurobiological evidence that describes how sensory deficits across multiple modalities (vision, hearing, touch, olfaction, gustation, and multisensory integration) could impact social functions in ASD. Theoretical models of ASD and their implications for the relationship between sensory and social functioning are discussed. Furthermore, neural differences in anatomy, function, and connectivity of different regions underlying sensory and social processing are also discussed. We conclude that there are multiple mechanisms through which early sensory dysregulation in ASD could cascade into social deficits across development. Future research is needed to clarify
these mechanisms, and specific focus should be given to distinguish between deficits in primary sensory processing and altered top-down attentional and cognitive processes.

Keywords: autism spectrum disorder; sensory; social cognition; sensory sensitivity

Number of words: 10,078

1. Introduction

Autism Spectrum Disorder (ASD) is a complex neurodevelopmental disorder characterized by deficits in social communication and the presence of restricted, repetitive behaviors (RRB) (American Psychiatric Association, 2013); current estimates state that it affects 1 in 68 children (Christensen, 2016). Despite the first scientific report of ASD mentioning altered sensory perception as a characteristic feature (Kanner, 1943), ASD research has historically been heavily focused on social impairments (see Leekam, 2016 for a review), with many popular theories construing it as a social disorder (including social motivation hypothesis, Dawson et al., 2005; and the mindblindness account, Baron-Cohen et al., 1985; Baron-Cohen, 1990). In recent years, however, research focusing on the sensory domain has found that sensory processing abnormalities in ASD (see Baum et al., 2015, or Marco et al., 2011, for reviews) are reported across all ages and levels of symptom severity (Leekam et al., 2007) and adversely affect both daily functioning (Suarez, 2012) and academic performance (Howe & Stagg, 2016). Such abnormalities have been documented across all sensory modalities (e.g., Kientz & Dunn, 1997), and up to 95% of parents of children with ASD report some atypical sensory behavior in their child (e.g., seeming indifference to pain, avoidance of certain sounds or textures, unusual smelling of objects, seeking out visual experiences of lights or movement; Rogers & Ozonoff,
Acknowledging this, the most recent edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-5; American Psychiatric Association, 2013) lists “hyper-or–hypo-reactivity to sensory input or unusual interests in sensory aspects of the environment” as a type of restricted and repetitive behavior. Thus, there is behavioral, neurophysiological and anecdotal evidence of sensory impairment as a prevalent characteristic feature of ASD.

While prior research has often focused on the sensory and social features of ASD independently of one another, new theoretical and empirical evidence suggests a stronger relationship between the two than previously thought (Ronconi et al., 2016). Sensory and social behaviors may arise from a common underlying mechanism and/or may exert reciprocal influence on each other in the course of a child’s development (Gliga et al., 2014). This relationship is also evident from findings of early abnormal sensory sensitivity to stimuli predicting later joint attention and language development (Baranek, 2013), development of social play (Miller Kuhaneck & Britner, 2013), increased withdrawal and negative temperament (Brock et al., 2012b), and higher levels of social impairment in adults with ASD (Hilton et al., 2010). Thus, the relationship between social and sensory features in ASD may be bidirectional and inter-dependent. For example, a child that is overly sensitive to loud noises may withdraw from socio-communicative environments that are over-stimulating, leading to less practice with social scenarios and ultimately resulting in a breakdown of successful social interaction.

This review will examine the behavioral and neurobiological studies on social and sensory processing in ASD to explore the relationship between sensory and social impairments in ASD. Specifically, we will 1) discuss the possible mechanisms by which atypical sensory processing across the five basic senses could manifest in the social deficits characteristic of individuals with ASD; 2) review the existing hypotheses that have attempted to integrate these
features; and 3) review evidence from neuroimaging studies to highlight differences in sensory and social representations often observed in ASD. We will also discuss how early abnormalities in sensory processing can be compounded over time, creating a maladaptive developmental trajectory of cascading delays and deficits.

The relationships between sensory and social processing may occur at many hierarchical levels. At the very basic level, sensory receptors are stimulated by environmental stimuli. This sensory information is then relayed to the brain to create a subjective neural representation, a process known as perception (Perrone, 2007). Sensation and perception are inter-related constructs. A breakdown of sensation results in a lack of perception, and similarly, without perception the activation of a sensory receptor is meaningless (Goldstein and Brockmole, 2017). Often in research, perception is the behavioral output of interest, which presumes sensation. A related confound in sensory research is attention. Specifically, an individual may sense and perceive a stimulus, but can fail to attend to it in an expected way (Heald, 2014; Naatanen, 1990). It can, thus, become problematic to disentangle these constructs and know definitively if a sensory, perceptual, or attentional deficit is underlying a given response. Thus, an atypical behavioral or neural outcome can reflect a breakdown at any point within this adopted hierarchy. In many cases, the research has not progressed enough to allow for a definitive disentangling of these concepts, but evidence of sensory, perceptual, and attentional abnormalities in ASD individuals will be outlined where possible. The study of these processes in each sensory modality and their role in social functioning in individual with ASD will be the primary focus of this paper.
2. Vision

Individuals on the autism spectrum often seek out or avoid intense visual stimulation (Leekam et al., 2007). Atypical visual processing has been widely documented in individuals with ASD (see Simmons et al., 2009 for a review), with alterations in basic perceptual functions, including contrast sensitivity (Behrmann et al., 2006; Bertone et al., 2003), boundary detection (Vandenbroucke et al., 2008), field of view size (Song et al., 2015) and color perception (Franklin et al., 2008). Deficits in visual form processing (Spencer & O’Brien, 2006) and motion perception (see Kaiser & Shiffrar, 2009 for a review), reduced susceptibility to illusion (Happe, 1996; Bölte et al., 2007), superior visual search (Joliffe & Baron-Cohen, 1997), a local processing bias (Dakin & Frith, 2005), spatial attention impairments (Haist et al., 2005), and altered oculomotor function (Goldberg et al., 2002) are also reported. Behaviorally, some differences manifest as enhanced perceptual abilities in ASD, particularly in basic low level visual search tasks; conversely, these may be disruptive to efficient processing in fast-paced, complex visual environments (Happe & Frith, 2006; Mottron et al., 2006; Pellicano & Burr, 2012). Differences in vision have also emerged as one of the earliest stable markers of ASD, with saccade duration in 7-month olds reliably distinguishing children later diagnosed with ASD (Wass et al., 2015). These differences may play a role in social impairments in ASD, as perception of social cues drives visual attention patterns, and thus is crucial in social development and interpersonal interactions. Infants’ preferential attention to eyes and faces (Maurer & Salapatek, 1976) reflects how early social understanding is built on observation. The frequency of lateral glances and visual hypo-responsivity predict poorer social skills and greater overall ASD symptomology (Hellendoorn et al., 2014; Kern et al., 2007). Further, children with visual impairments often have social deficits due to difficulties in social learning through visual
cues, modeling, or feedback (Kekelis, 1992; McGaha & Farran, 2001). In the subsections below, we discuss the relevance of vision in important social functions widely studied in autism (eye gaze, face processing, and biological motion) and the developmental impact of early visual processing abnormalities.

2.1 Gaze Processing

Previous research has questioned whether atypical visual processing underlies poor eye contact and joint attention, impairments of both are reported in ASD (Sigman et al., 1986; Charman et al., 1997; Stone et al., 1994; Leekam et al., 1997). Joint attention (JA) involves two participants coordinating mutual engagement with their mutual focus on a third entity (Tomasello 1995). Developmentally, eye contact serves an important early social function for infants (Stern, 1985), regulating face-to-face interactions (Lee et al., 1998; Leekam et al., 1997) and fostering emerging social skills. JA is also critical to social and cognitive development, predicting language abilities (e.g., Gillespie-Lynch et al., 2015), understanding intention (Mundy &Newell, 2007), and pretend play (Rutherford et al., 2007b). Eye contact and JA are dependent upon an intact ability to detect gaze and understand gaze cues. Many studies suggest that individuals with ASD are able to determine the direction of others’ gaze, but fail to effectively use this information socially (Leekam et al., 1997; Pelphrey & Carter, 2008). However, others have found ASD individuals to be less accurate in judging the intent behind both direct and averted gaze, particularly in more ambiguous situations (Senju et al., 2003; Ashwin et al., 2009; Forgeot d’Arc et al., 2016). At the neurobiological level, a failure to shift from the magnocellular to parvocellular pathway in ASD early in life (Mundy et al., 2009; McCleery et al., 2007) could underlie delayed gaze detection abilities, since these pathways coordinate distinct patterns of visual preference. Additionally, poor gaze detection during JA has been associated with
decreased occipital pole activation in ASD participants (Tanabe et al., 2012). Engagement in JA also involves extending gaze detection to gaze following, requiring the regulation of visual attention. Evidence for difficulties in oculomotor control and visual attention regulation are more robust in ASD. An inability to visually disengage from a central to a peripheral stimulus at 14-months was predictive of later ASD diagnosis in high-risk infants (Elsabbagh et al., 2013a), and poor visual disengagement is seen in ASD across various tasks and ages (see Sacrey et al., 2014). Additional elements of oculomotor control, such as smooth pursuit eye movements are also disrupted in ASD (Takarae et al., 2004), possibly related to reduced functional connectivity between V1 and inferior frontal areas (Villalobos et al., 2005). Thus, difficulties perceiving gaze cues may contribute to joint attention difficulties in individuals with ASD.

2.2 Face Processing

Intact visual processing is a prerequisite for attending to and recognizing faces, making face processing a social as well as perceptual skill. Face processing abnormalities in individuals with ASD, including less focus on eyes and increased looking to the mouth (Klin et al., 2002), have been studied extensively (e.g., Schultz et al., 2000; Teunisse & De Gelder, 1994; Klin et al., 1999; Pierce et al., 2001; Nomi & Uddin, 2015; Weigelt et al., 2012). In addition, poorer facial identity recognition (e.g., Kirchner et al., 2011), facial memory (e.g., Wilson et al., 2010), face discrimination (e.g., Rutherford et al., 2007a), and deficits in facial emotion recognition (e.g., Hobson, 1986; Baron-Cohen, 1991; Harms et al., 2010) have also been reported in ASD. At the neural level, individuals with ASD show hypo-activation in the fusiform face area (FFA), superior temporal sulcus (STS), and the occipital face area (Schultz et al., 2000; Humphreys et al., 2008). Atypical face processing in ASD could arise from sociocognitive factors, or reflect visual processing deficits more broadly, such as distinguishing between both social and non-
social stimuli that are visually complex or highly similar, including upright faces, inverted faces, and cars (Ewing et al., 2013); and poor ability to discriminate between novel, and perceptually similar objects (Greebles) and faces (Scherf et al., 2008). Difficulties in rapidly processing visual information are also seen in ASD, leading to reduced attention to faces (Charrier et al., 2016). These studies suggest that impairments perceiving certain visual characteristics (i.e., complexity, higher frequency, higher distortion, fast-moving) contribute to face processing and emotion recognition difficulties in ASD. These basic impairments may be exacerbated by the rapid, complex visual information conveyed by human faces in social interactions, and further compounded by social-cognitive impairments characteristic of ASD.

2.3. Biological Motion Processing

According to Johansson (1973), biological motion (motion of humans and animals) is characterized by distinct, highly complex spatiotemporal movement patterns. Preferential attending to biological motion has been reported in typically developing children by 2 days of age (Simion et al., 2008). This plays an important role in developing joint attention, imitation, emotion recognition, and social cognition in general (Pavlova, 2012). However, studies have reported disruptions in attending to and in recognizing biological motion in individuals with ASD (Kaiser & Pelphrey, 2012). Studies using point-light displays, which allow motion perception without the confound of form, reveal that children with ASD fail to preferentially attend to biological over non-social motion (Klin et al., 2009; Blake et al., 2003; Annaz et al., 2012). Moreover, individuals with ASD have difficulty using information from biological motion to infer emotions (Nackaerts et al., 2012), recognize faces (O'Brien et al., 2014) and follow pointing (Swettenham et al., 2013). Some evidence suggests that motion processing impairments in ASD are specific to biological motion perception (e.g., Koldewyn et al., 2011),
possibly stemming from a failure to modulate posterior STS activity specifically for biological motion (Pelphrey et al., 2007; Pelphrey & Carter, 2010). However, others have reported similar impairments in ASD in coherent motion processing more broadly (e.g., Manning et al., 2013; Freitag et al., 2008). Individuals with ASD also show reduced activity in V1 and other early visual areas during both coherent and biological motion processing (Robertson et al., 2014; Kröger et al., 2014). Further, poorer recognition of basic motion patterns in ASD has been found to be correlated with the ability to recognize emotions from biological motion (Atkinson, 2009). There is additional evidence that global motion processing abilities might depend on task speed (e.g., Manning et al., 2013) or duration (Hadad et al., 2015), raising the possibility that motion perception in ASD is technically intact, but too inefficient to process complex, fast-paced interactions in social scenarios. Thus, evidence suggests some deficits in low-level visual motion perception in ASD, stemming from early visual processing areas, which may contribute to biological motion processing impairments, which in turn is central to the social impairments seen in ASD.

2.4 Developmental Consequences of Atypical Vision

Prospective studies of infants at high risk for ASD suggest atypical visual processing is present within the first year of life. Infants later diagnosed with ASD make faster saccades and have difficulty in visual disengagement at 7 months of age (Wass et al., 2015; Elsabbagh et al., 2013a). Superior visual-search abilities at 9 months were also predictive of later ASD symptoms (Gliga et al., 2015). Interestingly, such alterations in visual processing may precede quantifiable differences in social functioning. For example, gaze following is intact at 7 and 13 months in children later diagnosed with ASD (Bedford et al., 2012); these infants also attend to faces as frequently or even more frequently than typically developing children in the first year of life.
(Elsabbagh et al., 2013b; Jones & Klin, 2013; Yirmiya et al., 2006), decreasing this social attention thereafter and falling behind typical development in the second year (Jones & Klin, 2013; Ozonoff et al., 2010). It is possible that pre-existing visual processing deficits may disrupt developing social skills by preventing the perception of visual cues that signal social rewards, making the cause and effect of social interactions unpredictable. Over time, these infants might begin to lose interest in these “unpredictable” social interactions, and instead seek out repetitive and predictable non-social stimulation (Gliga et al., 2014). This view aligns with the findings that visual attention to social stimuli in ASD is initially increased, as increased looking time in infants is interpreted as a marker of an unexpected event (e.g., Csibra et al., 2016). Moreover, altered eye contacts and visual social attention in children with autism in early life can result in a practice effect and lead to a secondary neurological assault, ultimately resulting in a brain-behavior cycle with adverse effects on social life (Mundy & Crowson, 1997; Klin et al., 2015). Thus, atypical visual processing in early development in ASD could have cascading deleterious effects on subsequent social and cognitive development through the ongoing process of experience-dependent learning.

3. Auditory Processing

Hearing, like vision, is an important aspect of successful participation in social-communicative interactions. The earliest exposure to auditory stimuli occurs in the intrauterine environment; and postnatal studies indicate infants’ recognition and preference for mother’s voice (Purhonen et al., 2004). Infants engage in preferential orientation to, and discrimination of speech versus non-speech sounds (see Moore & Linthicum, 2007 for review), which is predictive of both receptive language development (Paul et al., 2007) and expressive vocabulary (Vouloumanos and Curtin, 2014). Early auditory inputs facilitate the extraction of socially salient
information from the environment. Thus, altered sensation, perception, and attention to different auditory stimuli may have direct implications for social functioning.

Atypical auditory processing is well-documented in ASD (see O’Connor, 2012 for review) with a profile of enhanced pitch perception (Bonnel et al., 2003, 2010; O’Riordan & Passetti, 2006), increased sensitivity to loud noises (Khalfa et al., 2004), lack of auditory orientation (Paul et al., 2007), impaired perception of prosody (Järvinen-Pasley et al., 2008), and diminished auditory stream segregation (Teder-Sälejärvi et al., 2005). Sensory level deficits within the central auditory nervous system and relevant auditory pathways in ASD have been reported using auditory brainstem response (ABR) paradigms (Kwon et al., 2007); and this delayed response distinguishes ASD from other neurodevelopmental disorders (Källstrand et al., 2010). Delayed ABR has also been seen in response to phonemes, which are the basic units that comprise language, but not to non-speech sounds such as clicking which elicited a typical brainstem response (Russo et al., 2009). These findings collectively indicate that change in pitch, accompanied by increased complexity of auditory stimuli, is an area of significant deficit in ASD. The central hub of auditory processing is the primary auditory cortex located within Heschl’s gyrus in the superior temporal cortex (Belin et al., 2004). Structural imaging studies of adults with ASD reveal increased cortical thickness in Heschl’s gyrus although these findings were accompanied by global neuroanatomical differences in ASD (Hyde et al., 2010). With competing sources of auditory information, individuals with ASD display limited ability to isolate certain features of concurrent auditory information (Lepistö et al., 2009) and are less able to focus auditory attention on the more salient information in the environment compared to controls, even after controlling for IQ and hearing ability (Teder-Sälejärvi et al., 2005). Thus, even in the absence of a basic auditory sensory impairment, some individuals with ASD have
difficulty filtering auditory information which may underscore a general deficit in integrating information. This deficit in auditory stream segregation interferes with the ability to perceive or attend to social information in the presence of competing auditory input. Thus, abnormal auditory processing is consistently reported in ASD and stems from atypical sensation, altered perception, and lack of preferential attention to auditory stimuli which directly impacts successful social engagement.

3.1 Speech Recognition

Possibly the most socially salient auditory stimuli in early development is the mother’s voice. In contrast to typically developing peers, infants with autism do not preferentially attend to mother’s speech or child-directed speech (Dawson et al., 1998; Klin, 1991; Paul et al., 2007). Infants at high-risk for ASD diagnosis respond to speech versus non-speech sounds less than low-risk infants. This trend is associated with ASD symptomatology in the high-risk group and with language development in the low-risk group (Curtin and Vouloumanos, 2013). Children with ASD who do not preferentially orient to child-directed speech have poor sound discrimination, highlighting the role of basic sensory impairment in social behavior (Kuhl et al., 2005). Children with ASD display oversensitivity to local changes in auditory information such as pitch at the expense of global auditory information such as speech (Foster et al., 2016). There are conflicting reports, however, finding both disrupted (Foxton et al., 2003) and intact (Heaton, Williams, Cummins, & Happé, 2007; Mottron et al., 2000) global auditory processing. Research utilizing a mismatch negativity (MMN) EEG paradigm found reduced preference for social and affective auditory information in children with ASD as well as decreased sensory discrimination between expected and unexpected speech (Fan & Cheng, 2014) suggesting that social information is filtered out and ignored at a basic sensory or perceptual level. Researchers have
also reported delayed latencies of event-related potentials (ERPs) in ASD in response to auditory stimuli using EEG and MEG (Roberts et al., 2010; Whitehouse and Bishop, 2008), and this pattern of auditory processing is associated with language functioning (Oram Cardy et al., 2008). However, there is debate over whether speech-related auditory impairment in ASD is a sensory deficit or an orienting deficit (Ceponiene et al., 2003). Evidence supporting the role of attention deficit in auditory processing in ASD comes from fMRI studies of adults with ASD who show decreased activation in STG in response to speech stimuli, a pattern not seen in response to non-social sound stimuli (Gervais et al., 2004; Lai et al., 2011). Furthermore, adults with ASD show greater recruitment of right STG, compared to left, which was seen in typically developing participants passively listening to speech. The reduced activation in left hemispheric language processing areas might underlie a core deficit in processing speech which may inhibit the perception and production of language (Boddaert et al., 2004). Altered recruitment of STG in ASD may indicate a sensory level deficit or a breakdown of higher order functions such as attention or language processing due to the dual roles of the STG in both language and auditory processing (see Redcay, 2008 for review). There is additional evidence supporting the role of attention in auditory discrimination tasks (Dunn et al., 2008). However, it should be noted that high functioning individuals with ASD score in the atypical range on sensory processing behavioral measures and these scores predict the severity of social functioning (Hilton et al., 2010). Thus, failure to preferentially respond to speech early in development may be indicative of a lower level sensory or perceptual deficit or a higher order impairment in attention or language processing which can cascade into impairments in speech recognition.

Enhanced pitch discrimination, well-documented in autism (Bonnel et al., 2003, 2010; Bouvet et al., 2014; O’Riordan & Passetti, 2006), extends to both music (Mottron et al., 2000)
and speech (Järvinen-Pasley & Heaton, 2007) and represents a relative area of strength in auditory processing in autism (see O’Connor, 2012 for review). It should be noted that language delays are reported among adults with ASD who display enhanced pitch perception (Bonnel et al., 2010; Eigsti & Fein, 2013; Jones et al., 2009). In addition, there is neural evidence of enhanced pitch processing of non-speech sounds, but not speech sounds in ASD (Yu et al., 2015) possibly suggesting that superior pitch processing in childhood may lead to attentional exclusion of language-related pitch and subsequent delays in language acquisition. For instance, a child with superior pitch perception might be more attuned to all changes in pitch in the environment without selectively attending to speech-related changes in pitch. Enhanced auditory processing of pitch and oversensitivity to loudness (Khalfa et al., 2004) can result in heightened awareness of simple perceptual features of auditory information at the exclusion of complex auditory input such as speech (Lin et al., 2016) and the inability to discriminate the salient social information in the auditory environment, an ability known as auditory stream segregation. Currently, the relationship between pitch perception and language ability or age is not explicitly clear. Nevertheless, these factors are indicative of an early maladaptive auditory processing profile in children with autism.

3.2 Prosody and Evaluation of Affect

Prosody is an expressive mechanism of speech that allows for nuanced exchange of emotion and intention in communication (Frühholz et al., 2012). Inappropriate use of prosody (Kanner, 1943; Järvinen-Pasley et al., 2008; Wang et al., 2006) as well as difficulty extracting socially salient features from speech such as vocal affect (Järvinen-Pasley et al., 2008) is associated with worse social and communication skills (Paul et al., 2005) and is consistently reported in ASD. ABR research suggests that changes in pitch that are inherent to affective
prosody do not evoke a rapid brainstem response in ASD participants which has ramifications for decoding pitch in affective language (Russo et al., 2008). Although not a basic sensory mechanism, the perception of and attention to emotionally-laden speech has implications for social functioning. Prosodic differences in ASD may suggest a breakdown of higher-order perceptual or attentional processes. Additionally, altered sensory response to auditory stimuli coupled with impaired integration of perceptual information may have cascading effects on the use and understanding of language. Individuals with ASD may have a deficit specific to affective prosody. This is supported by findings of unimpaired perception of pragmatic prosody, but disrupted perception of affective prosody despite intact pitch discrimination and direction recognition in ASD (Globerson et al., 2015). Neuroimaging studies of affective prosody reveal that, in addition to IFG and STG activation seen in the control group, participants with ASD recruit the right caudate nucleus and rate the stimuli as less emotionally intense (Gebauer et al., 2014). Furthermore, more widespread activation of IFG and pSTS is also noted in the ASD group compared to controls in response to angry prosody perhaps indicating a lack of habitual processing or expertise in perception of affective prosody (Eigsti et al., 2012). MEG studies have found longer response latencies and reduced recruitment of the left hemisphere in individuals with ASD in response to rapidly presented auditory stimuli. Additionally, this pattern of response was associated with vocal affect recognition indicating that impairments in affect recognition impact rapid processing of socially salient auditory information (Demopoulos et al., 2015). Further evidence of altered neural responses to prosody comes from studies of irony (Wang et al., 2006), prosody perception (Hesling et al., 2010), and word-level affective prosody (Korpilahti et al., 2007). Therefore, problems in evaluating affect from auditory stimuli in individuals with ASD can directly impact social reciprocity by limiting their ability to extract
socially relevant information from voices and respond appropriately. Although it is evident that many individuals with ASD experience basic sensory impairments, there are also important perceptual and attentional mechanisms that lead to problems in social behavior. It is therefore likely that atypical sensation, altered perception, and inattention occur at varying levels across different auditory paradigms and social settings.

3.3 Developmental Considerations

Current evidence suggests that atypical auditory processing in ASD occurs early in development. Certain auditory profiles (enhanced pitch perception and discrimination) are seen predominantly in children with ASD and to a lesser degree in adults with ASD. Enhanced pitch perception is only reported in a subset of adults with ASD who predominantly have language delays (Bonnel et al., 2010; Eigsti & Fein, 2013; Jones et al., 2009). Conversely, the ability to process rapidly presented speech decreases with age in both typical development and in ASD; however, the decline in processing begins earlier in ASD (Mayer & Heaton, 2014). This has direct implications for social functioning as the interpersonal socio-communicative world is fast and dynamic. Collectively, these areas of atypical auditory processing in ASD suggest an auditory profile of oversensitivity to basic auditory features at the expense of the ability to filter out background noise and selectively attend to speech or other relevant social cues. Additionally, abnormal perception of affective prosody has direct implications for decoding intentions and reciprocating social exchanges. Thus, atypical auditory processing in ASD is noted early in development and has cascading effects on speech processing, social engagement, and language acquisition.
4. Tactile Processing

Touch is considered one of the most basic ways in which individuals interact with the world around them (Barnett, 1972). Touch plays a significant role in communication (Hertenstein, 2002; Hertenstein et al., 2006; Langland & Panicucci, 1982), developing social bonds (Dunbar, 2010; Langland & Panicucci, 1982), and overall physical development (Field, 1998; Polan & Ward, 1994). Recent findings suggest that touch also promotes the development and connectivity of brain areas (Brauer et al., 2016; Björnsdotter et al., 2014) associated with social cognition and the “social brain” (Adolphs, 2009; Brothers, 2002; Frith, 2007). Stimulation of C-tactile (CT) afferents, nerve fibers that process affective and limbic touch (Wessberg & Norrsell, 1993), have been shown to correlate with activation of regions of the social brain (Kaiser et al., 2016; Gordon, et al., 2013; Björnsdotter & Olausson, 2011; Björnsdotter et al., 2009; Olausson, et al., 2002; Olausson et al., 2010), supporting the hypothesis that skin is a “social organ” (Olausson, et al., 2002; Kaiser, et al., 2016; McGlone et al., 2014; Löken & Olausson, 2010). Recent evidence supports both hypo-and-hyper-reactivity to tactile stimuli in ASD, with these responses varying according to stimuli and context (Lane et al., 2011; Crane et al., 2009; Ben-Sasson et al., 2007; Tomchek & Dunn, 2007; Allely, 2013; Brown & Dunn, 2010; Cascio et al., 2008). Individuals with ASD display abnormal detection of tactile stimuli (Blakemore et al., 2006) as well as a lack of habituation to tactile stimuli (Tannan et al., 2008). Mechanistically, some have suggested that alterations in GABAergic feedforward loops might play a role in atypical tactile responsivity in ASD (e.g., Tannan et al., 2008; Puts et al., 2014; Tavassoli et al., 2016). Studies also suggest an abnormal functioning (hypo: Kaiser et al., 2016; hyper: Riquelme et al., 2016) and abnormal numbers (less: Silva & Schalock, 2016) of CT
afferents in ASD populations. Thus, although individuals with ASD most likely have an altered experience of touch and pain, it is not likely that they always exhibit hypo or hyper reactivity.

4.1 Tactile Processing and its Role in Social Functioning in ASD

There is evidence to suggest that irregularities in touch and tactile perception may be associated with broad levels of social dysfunction in ASD. For example, touch-seeking behaviors have been found to predict levels of social impairment, and tactile hyposensitivity was associated with both poorer social functioning and nonverbal communication skills (Foss-Feig et al., 2012). Differences in tactile processing and tactile preference behaviors in ASD are observed in early infancy (Mammen et al., 2015). Further, several studies suggest that maternal touch in early infancy critically influences a secure attachment later (Weiss et al., 2000). Social touch has been found to increase self-esteem, well-being, health status, life satisfaction and self-actualization, faith or belief, and self-responsibility (Butts, 2001), while a lack of social touch can lead to higher levels of anxiety, stress, and depression (Gupta et al., 1998; Hertenstein, 2002, Weiss, 2001), which are commonly seen in ASD population (Wallace et al., 2016; Uljarevic et al., 2016; Kerns & Kendall, 2012; Ghaziuddin et al., 2002). Atypical touch during infancy can develop into critical deficits later in life, specifically in regards to attachment. While individuals with ASD are capable of forming a secure attachment to their caregivers (Shapiro et al., 1987; Teague et al., 2017), they tend to be less securely attached than their typically developing peers (for a meta-analysis, see Rutgers et al., 2004). Further, individuals with ASD who have secure attachments tend to have less socially severe symptoms than individuals with ASD who are not securely attached, suggesting symptom severity and overall level of functioning could impact the strength of attachment (Capps et al., 1994). Touch is important in developing attachment during infancy through both maternal stimulation and orienting. Infants who are later diagnosed with
ASD have been observed to have less maternal touch stimulation (Baranek, 1999), and failure to orient has been associated with poor attachment (Reece et al., 2016; Weiss et al., 2000). Therefore, a lack of social touch early in development can have important social and interpersonal implications.

Touch is also important in developing social bonding. Positive tactile stimuli (touch, warmth, odors) can release oxytocin (Uvnäs-Moberg, 1998), the neuropeptide primarily involved in social bonding. Interestingly, oxytocin has been found to increase the perceived pleasantness of the touch of opposite gender, along with activity in parts of the social brain (Scheele et al., 2014). However, the behavioral and neural effects of oxytocin were negatively correlated with autistic-like traits, suggesting these effects to be blunted in individuals with autistic-traits. This may lead to a limited seeking of touch in the interpersonal interactions of individuals with ASD. Further evidence of attenuation of oxytocin in ASD comes from abnormalities in oxytocin peptide and plasma levels (Green et al., 2001; Modahl et al., 1998), and alterations in: the gene that encodes the oxytocin receptor, OXTR, (Ebstein et al. 2009; Hammock & Levitt, 2006), in oxytocin receptors (Campbell et al., 2011; Liu et al., 2010; Skuse et al., 2014, Wermter et al., 2010, Wu et al., 2005), and in epigenetic mechanisms (Gregory et al., 2009; Kumsta et al., 2015). It should be noted that the use of oxytocin in ASD individuals in clinical settings is becoming increasingly popular (for a review see, Anagnostou et al., 2014).

In addition to the basic sensory and perceptual level tactile deficits noted in ASD, failure to socially orient may also be dependent on touch. Atypical tactile perception around the face and mouth could disrupt tactile stimulation of the orienting reflex, reducing face-to-face orienting and the positive social attention associated with it (Sokolov, 1963). A recent study (Silva et al., 2015) explored this concept using the Autism Touch and Self-Regulation Checklist.
In addition to finding a relationship between overall severity of sensory abnormalities and the severity of ASD symptoms, this study found that five questions related to touch/pain responses on the face and mouth correctly identified 83% of the ASD population from typically developing controls. Further, when the researchers included all questions regarding failure to orient, 91% of the ASD population was correctly identified. Future research should look further into the importance of tactile perception in orienting and self-regulation in infancy, as well as its impact on other social domains not previously explored.

5. Olfaction and Gustation

While there is relatively less research on olfaction and gustation in ASD, there is evidence of atypical response, disrupted taste detection (Tavassoli & Baron-Cohen, 2012), in these domains. The literature available on olfaction is varied on whether ASD individuals are hypo- or hyper-sensitive, with several studies reporting intact odor detection, some finding problems with odor identification (OI; Suzuki et al., 2003; Bennetto et al., 2007), and others reporting problems with odor detection but intact OI (Dudova, et al., 2011). Overall, difficulties in eating behavior and sensitivity to smell are common concerns for individuals with ASD. Youth with ASD have been found to be more selective regarding food groups, textures, tastes, and temperatures, and are more likely to exhibit higher levels of food refusal (Bennetto et al., 2012; Wiggins et al., 2009;). Individuals with ASD are also more likely to have a body mass index (BMI) within the obesity or overweight range for their ages (Bennetto et al., 2012), and their selective food preferences have been related to patterns of restricted and repetitive behaviors and olfactory functioning (Bennetto et al., 2012; Wiggins et al., 2009). Moreover, in ASD, there is a relationship between OI and ratings of initiation, maintenance, and social
interchange during conversation (Bennetto et al., 2007). Brang & Ramachandran (2010) suggest that olfactory bulb dysgenesis, resulting in reduced vasopressin and oxytocin receptor binding (related to social bonding) could be one of the neural foundations of autism. Recently, Zou et al. (2016) reported a positive relationship between olfactory sensitivity and the extent of TD individuals’ social network. Interestingly, this study found that functional connectivity of the amygdala with the orbitofrontal cortex, a connection that has been suggested to impact the repetitive, stereotypical behaviors of ASD in socio-emotional cognition and behavioral self-regulation (Bachevalier & Loveland, 2006), appeared to be related to both of these factors (olfactory sensitivity and the extent of the social network). The impact of olfaction on emotion is further evident from findings of impairments in olfaction and social cognition in patients with bipolar disorder (BD; Lahera et al., 2016). In the BD population, there are relationships between OI and affect recognition and theory of mind, all of which are consistently found to be deficits in autism (Baron-Cohen, 1997; Baron-Cohen et al., 1985; Gallagher et al., 2000; Harms, Martin, & Wallace, 2010; Bölte & Poustka, 2003). These findings suggest that future studies should further examine the relationship between olfaction and the social symptoms of ASD.

6. Multisensory Integration

The integration of multisensory stimuli is essential for the perception of complex social information. For example, social interactions require the integration of another person’s voice, face, lip movements, and gestures, failure of which may lead to misinterpretation and abnormal social response. Even if the perception of each individual sense is intact, the integration of these senses into a perceptual whole may fail (Iarocci & McDonald, 2006), and the integration affords more information than the sum of its components (Stein & Stanford, 2008). The automatic integration of multimodal stimuli creates a predictable social environment out of “noise” and
inevitably influences how an individual interacts socially within that environment. Multisensory integration begins early in the stream of processing (Foxe & Schroeder, 2005) and is influenced by feed-forward operations before reaching higher-level processing centers of the brain (Stein & Stanford, 2008). Alterations in basic sensory integration have been reported in ASD (Waterhouse et al., 1996), with evidence of abnormal integration of auditory and visual stimuli during the flash-beep illusion, either perceiving the illusion over a longer temporal window (Foss-Feig et al., 2010), or being less susceptible to the illusion (Stevenson et al., 2014b). There is evidence of a relationship between ASD symptoms and a bias to perceive auditory stimuli that occur before visual stimuli as concurrent (Donohue et al., 2012). Individuals with ASD benefit less from the addition of auditory information to a visual search task (Collignon et al., 2013), show decreased multisensory facilitation to audiovisual inputs (Brandwein et al., 2013), and exhibit altered cortical recruitment during simultaneous audio-visual stimuli presentation (Russo, 2010). In addition, ASD individuals are less susceptible to visual-tactile illusions (Cascio et al., 2012; Greenfield et al., 2015) and struggle to integrate visual stimuli into motor planning and execution (Dowd et al., 2012). Multisensory integration has also been related to social functioning in ASD. For example, a recent study found the ERP response associated with multisensory integration to be reduced as a function of ASD symptom severity (Brandwein et al., 2015). In addition, social communication in ASD has been associated with abnormal upregulation of visual regions during auditory processing (Jao Keehn et al., 2016), indicating altered neural recruitment among the senses. Moreover, impairments in perceptual-motor integration also have been associated with communication and social deficits in ASD (Linkenauger et al., 2012). In summary, individuals with ASD show altered integration of senses across multiple domains, which may impact their social functioning.
6.1 Language Development

The atypical language development in ASD (Tager-Flusberg et al., 2005) is an important contributor to social functioning and may be impacted by deficits in multisensory integration. In TD individuals, information about a speaker’s facial movements and gestures facilitates speech comprehension (Rosenblum, 2008; Macleod & Summerfield, 1987; Butcher et al., 2000). Individuals with ASD often struggle to appropriately integrate additional visual information to auditory speech (Iarocci et al., 2010; Mongillo et al., 2008; Smith & Bennetto, 2007), which may impair comprehension. For example, infants at high-risk for ASD do not show differential looking during congruent and incongruent speech and lip-movement; this indicates difficulty matching auditory and visual information (Guiraud et al., 2012). Less susceptibility to the McGurk effect in children with ASD (Williams et al., 2004; Bebko et al., 2014; de Gelder et al., 1991; Stevenson et al., 2014a) (although this appears to normalize at older age ranges (Taylor et al., 2010)) may demonstrate limited influence of visual stimuli on the perceived speech phoneme (McGurk & Macdonald, 1976). There is also evidence of impaired lip-reading ability in ASD (Foxe et al., 2015), which depends on proper detection and integration of congruent audio-visual speech information (Dodd, 1979). While listening to auditory speech, individuals with ASD struggle to integrate previous exposure to speaker-specific facial information to optimize auditory speech recognition (Schelinski et al., 2014). Lastly, individuals with ASD do not benefit from the addition of gestures to auditory speech (Silverman et al., 2010) and do not properly synchronize gestures with their own speech to aid comprehension (de Marchena & Eigsti, 2010). Recruitment of regions such as the STG and STS during concurrent speech and beat gestures is found to be absent in children with ASD, with increased activity in visual areas; this was associated with increased social deficits (Hubbard et al., 2012). Altogether, there is evidence that
individuals with ASD fail to integrate visual cues to speech, which may negatively impact speech comprehension, a function critical to social behavior.

6.2 Emotion recognition

The ability to accurately perceive and recognize emotions is essential to appropriate social functioning and involves the integration of facial expressions, vocal tone, posture, and gestures. In TD, there is evidence that visual and auditory stimuli (Massaro & Egan, 1996; Piwek et al., 2015; Stienen et al., 2011; de Gelder & Vroomen, 2000) as well as visual and olfactory stimuli (Novak et al., 2015) are integrated in emotion detection. Several studies have indicated that individuals with ASD do not appropriately integrate multisensory information in the context of emotion recognition. For example, adults with ASD struggle to discriminate whether faces and voices have congruent or incongruent emotion (O’Connor, 2007) and receive less benefit from bimodal (audio-visual) information when differentiating fear and disgust (Charbonneau et al., 2013) or identifying other emotions (Xavier et al., 2015). There is evidence of an altered temporal phase response to paired fearful faces and voices (Magnée et al., 2008), along with evidence that such altered neural responses may be modulated by attention (Magnée et al., 2011). Individuals with ASD recruit alternate brain regions in the parietofrontal network during the audio-visual integration of emotion cues, compared to controls, which recruit regions in frontal and temporal association cortices (Doyle-Thomas et al., 2013a). While not all studies have found TD-ASD differences in multimodal processing of emotion (Vannetzel et al., 2011; Magnee et al., 2007), overall, there is great evidence that deficits in multisensory integration may hinder emotion recognition in ASD.

6.3 Imitation
Motor imitation requires the integration of a stimulus with one’s own proprioceptive movements. The act of imitation has been proposed to provide a substrate for the development of theory of mind, empathy (Meltzoff & Decety, 2003), and peer relationships (Rubin et al., 2011). Many studies have observed imitation deficits in ASD (Williams et al., 2004; Edwards, 2014), and ASD symptom severity has been negatively associated with imitation abilities (Edwards, 2014). These deficits in imitation could potentially be influenced by weaknesses in integrating external inputs with one’s own proprioceptive behavior. The rubber hand illusion has been used as a paradigm to investigate visual-tactile integration (essential for imitation) in ASD. Among non-clinical adults, increased ASD traits have been associated with decreased susceptibility to the rubber-hand illusion (Palmer et al., 2013). Individuals with ASD also take longer to show the effects of the illusion (Cascio et al., 2012), are less sensitive to aspects of the illusion (Paton et al., 2012), and may rely more on proprioceptive inputs than visual cues (Paton et al., 2012; Izawa et al., 2012). Among individuals with ASD, decreased sensitivity to the illusion has been associated with low levels of empathy (Cascio et al., 2012). At the neural level, there is evidence for asynchrony between intrinsic motor and visual brain networks in ASD; such neural differences were related to social functioning and have been postulated to underlie the imitation deficits in this population (Nebel et al., 2016). Alterations in the ability to integrate proprioceptive cues with visual inputs could greatly impact imitation, which is crucial for the development of many social functions.

6.4 Developmental considerations of impairments in multisensory integration

The real impact of a deficit in multisensory integration likely lies in its cascading effects on the ability to detect and focus on salient social information throughout development. There is converging evidence that infants can detect amodal information – such as space, time, and
intensity - at very young ages (Lewkowicz, 2000; Lewkowicz, 2010; Bahrick & Pickens, 1994) and find stimuli particularly salient when amodal information is synchronously available to multiple senses [known as inter-sensory redundancy] (Bahrick & Lickliter, 2000; Bahrick et al., 2004). It has been proposed (Bahrick, 2010; Bahrick & Todd, 2012) that social stimuli – such as speech, faces, voices - inherently provide large amounts of inter-sensory redundancy, resulting in preferences for social over nonsocial stimuli in infants (Farah, et al., 1998); there is evidence that these preferences are altered in ASD (Swettenham et al., 1998). Thus, the ability to detect amodal information is a prerequisite for sensory integration; alterations in early integration abilities could limit the salience of social stimuli and cascade into social deficits across development.

Interoception, which involves processing of self in terms of bodily functions and their sensory integration, might produce a more basic, lower-order processing of self in terms of bodily functions, visceral sensations (such as temperature, stretch and pain from the gut, light nondiscriminatory touch, itch tickle, and hunger; Quattrocki & Friston, 2014) and their sensory integration in constituting self-relatedness and identity (Zaytseva et al., 2014). Poor recruitment of these regions in individuals with ASD may underlie their failure to adopt the bodily-anchored psychological and communicative stance of another person (Hobson & Meyer, 2005). Thus, this physical self might be a precursor for developing a more abstract sense of self, and a lack of ability to integrate in ASD populations might be an obstacle in forming the sense of self needed for mastering theory-of-mind (ToM) skills.

7. Theoretical Models Integrating Sensory and Social Features of ASD

7.1 Temporal Binding Hypothesis
The temporal binding hypothesis (Brock et al., 2002) has previously been used to explain altered sensory functioning in ASD. It is based on the premise that sensory stimuli that occur in close temporal proximity are more likely to be integrated and perceived as emanating from the same source; thus, timing information is crucial to binding and integrating associated stimuli (Shams et al., 2000; McGurk & MacDonald, 1976; Stevenson et al., 2012). There is converging evidence that the “temporal binding window” is extended in individuals with ASD, which may give rise to alterations in sensory processing (see Wallace & Stevenson, 2014 for a review; Foss-Feig et al., 2010; Kwakye et al., 2011; Stevenson et al., 2014b). A longer temporal binding window could create a “fuzzier”, unpredictable sensory environment (Wallace & Stevenson, 2014), as unrelated stimuli become bound together. Throughout development, important social cues may fail to become integrated or salient. For example, the concurrent lip movement and voice of a parent calling a child’s name may not become salient over the other co-occurring stimuli in the environment. This would affect social responses and potentially lead to a preference for restrictive, repetitive behaviors as a refuge from the unpredictable social environment (Johnson et al., 2015). An altered temporal binding window could also impact social learning, such as those involving rewards. Reward learning requires critically timed and predictable co-occurrence of stimuli, and an abnormal ability to bind neutral cues with rewards and punishments would be detrimental to social development. There is evidence of altered stimulus-reward associations in ASD (Dawson et al., 2001; Dawson et al., 2002; Zalla et al., 2009; Kohls et al., 2011). Thus, an extended temporal binding window could negatively impact social behavior in ASD through altered binding of social cues.

7.2 Intense World Theory
The Intense World Theory offers another mechanism for how the sensory and social features of ASD may be related (Markram et al., 2007; Markram & Markram, 2010). This neurobiologically-informed theory proposes that there is excessive functioning of neural circuits, such that the neural circuits are hyper-reactive, hyper-plastic, and generally up-regulated. This creates an intense world, a fragmented world (with focus on individual components of the environment), and an aversive world. Low-level sensory perception is enhanced (intense world), coupled with deficits in sensory integration (fragmented world). Such perceptual up-regulation results in an avoidance of highly emotional and unpredictable cues, such as eyes, faces, and social interactions. This results in eye gaze aversion, social withdrawal, limited communication, and a focus on stable, predictable cues instead (Markram & Markram, 2010). Throughout development, this could lead to an over-specialization for perceiving primary sensory cues at the expense of the ability to navigate in a socially complex world (Markram & Markram, 2010). In this way, the Intense World Theory explains both the unique sensory and social features of ASD and offers a mechanism for how an up-regulation in primary sensory perception results in social avoidance and withdrawal.

### 7.3 Atypical Hierarchical Information Processing

Atypical hierarchical information processing may hinder sensory and social functioning in individuals with ASD. To efficiently perceive and operate in a dynamic world, humans use both incoming sensory information (bottom-up processes) and inference from prior experience and context (top-down processes) (e.g., Knill & Pouget, 2004). Research has suggested that under-utilization of top-down processes such as context or experience (e.g., Pellicano & Burr, 2012) or an over-reliance on bottom-up sensory perception (e.g., Brock, 2012a; Mottron & Burack, 2001; Mottron et al., 2006) characterizes perception in ASD. Predictive coding, hypo-
priors, Weak Central Coherence, and Enhanced Perceptual Functioning accounts characterize perception in ASD as under-utilizing top-down processes (context, prior knowledge, or global coherence) or over-functioning of bottom-up sensory processes (Pellicano & Burr, 2012; van Boxtel & Lu, 2013; Van de Cruys et al., 2013; Lawson et al., 2014; Frith, 1989; Happe & Frith, 2006; Mottron & Burack, 2001; Mottron et al., 2006). These models all predict the superior perception seen at times in ASD, such as reduced susceptibility to illusions, and superior visual search and pitch perception (Happe, 1996; Bonnel et al., 2003; Jolliffe & Baron-Cohen, 1997; Pellicano et al., 2006; Muth et al., 2014), but inefficient perception of ambiguous or complex sensory information. At the neural level, this profile may reflect hyper-activation of primary sensory cortices, decreased prefrontal activity, and reduced neural habituation during sensory processing (Ring et al., 1999; Lee et al., 2007; Kana et al., 2013; Guiraud et al., 2011; Green et al., 2015). This information processing profile may hamper social functioning, as the interpersonal world demands strong central coherence, integration of context, and utilization of prior knowledge. This is supported by evidence that local processing biases and enhanced perceptual abilities negatively predict social skills (Meaux et al., 2011; Russell-Smith et al., 2012). Predictive coding may also underlie mentalizing (Palmer et al., 2015), as individuals with ASD are impaired in using social information to predict others’ actions (von der Lühé et al., 2016). Thus, over-functioning of bottom-up sensory processing coupled with under-utilizing top-down perception in ASD could explain both enhanced sensory processing and inefficient social functioning in this population.

8. Neurobiology of the Sensory-Social Axis in ASD

The neurobiological underpinnings of sensory abnormalities in the context of social cognition in autism have been less addressed in the literature. However, many of the atypical
functional and anatomical circuits that underlie sensory processing are also implicated in social processing impairments in autism. While several primary sensory and association cortex areas may be involved in sensory processing and integration of that information, we will focus on a few important areas and address their role in sensory and social processing in individuals with ASD. These regions are the: 1) Thalamus, Insula, and Cingulate Cortex; 2) Superior Temporal Sulcus; and 3) Cerebellum.

8.1 Thalamus, Insula, and Cingulate Cortex

The thalamus and basal ganglia form circuits throughout the brain that are connected to cognitive, motor, and emotional functioning (Schuetze et al., 2016). The thalamus is a relay center in subserving both sensory and motor mechanisms, and awareness (Smythies, 1997), attention (Büchel et al., 1998) and other neurocognitive processes such as memory and language (Engelborghs et al., 1998; Johnson & Ojemann, 2000). All sensory input with the exception of olfaction passes through the thalamus before reaching their associated primary cortical areas. The thalamus is also believed to have a complex feed-forward and feedback connectivity with cortical and subcortical areas (Sherman, 2007). Neuroimaging studies of the thalamus have found atypical functional and anatomical connectivity (Horwitz et al., 1988; Nair et al., 2013), decreased thalamic volume (Tsatsanis et al., 2003; Tamura et al., 2010), lower levels of N-acetylaspartate, phosphocreatine, creatin, and choline-containing metabolites (Hardan et al., 2008; Haznedar et al., 2006), and reduced neuronal integrity (Friedman et al., 2003) in ASD. It should be noted that some of these findings, such as lower levels of metabolites, were also associated with higher levels of sensory abnormalities (Hardan et al., 2008). Abnormal connections from thalamus or lesions to this area have been associated with major depressive disorder, irritability, and sadness (Hamilton et al., 2014; Gentilini, De Renzi, & Crisi, 1987). Thus, the thalamus may
be an important structure in the pathobiology of autism, specifically in sensory and social differences.

The anterior cingulate cortex (ACC) and insula receive input from the thalamus, and are thought to be major nodes of the limbic system which contributes to emotion processing (Hadland et al., 2003), learning (Bush et al., 2000; Devinsky et al., 1995), and memory (Frankland et al., 2004; Sutherland et al., 1988). These areas are also involved in interoceptive awareness (Craig, 2003). Neuroanatomical alterations (Ebisch et al., 2011; Uddin & Menon, 2009; Doyle-Thomas et al., 2013b; Haznedar, et al., 1997; Henderson, et al., 2006) of these areas in ASD may result in poor ability to integrate the physical self into a self-identity, possibly creating the stereotypical deficit in ToM in autism. This metabolic activity could also play a part in the regulation of affective reactions and forming associations between sensory stimuli and their emotional values (Strata, Scelfo, & Sacchetti, 2011). Relationships between the ACC and insula activation and social interaction in ASD have also been reported (Schmitz, et al., 2008; Doyle-Thomas et al., 2013b). These findings suggest the role of ACC and insula in both the sensory and social impairments observed in ASD.

8.2 Superior Temporal Cortex

The superior temporal cortex (STC), including the superior temporal sulcus and gyrus, is considered a hub of the “social brain” network (Pelphrey & Carter, 2008), with important roles in emotion recognition (Narumoto et al., 2001), understanding intention (Pelphrey et al., 2004a; Castelli et al., 2002; Kana et al., 2009; 2015), biological motion perception (Allison et al., 2000) and gaze detection (Pelphrey et al., 2004b; Mosconi et al., 2005; Saitovitch et al., 2016), amongst other social-cognitive skills. The STC may be abnormally developed in ASD, with reductions in overall volume, decreased activity during social tasks, and decreased connectivity with other
regions (Boddaert et al., 2004; Patriquin et al., 2016; Venkataraman et al., 2015; Shih et al., 2011). Further, the functional connectivity difference in STC has been found to predict emotion recognition and other social difficulties in ASD (Chien et al., 2015; Alaerts et al., 2014). STC dysfunction during social interactions is seen across sensory modalities and in many of the sensory-linked social impairments discussed above; for example, STC hypo-activation has been documented in ASD during biological motion detection (Pelphrey et al., 2007), speech perception (Redcay, 2008), processing affective touch (Kaiser et al., 2016), and integrating auditory and visual speech information (Stevenson et al., 2011; Loveland et al., 2008).

The STC also underlies many non-social sensory and perceptual functions, including conscious perception of visual motion, listening to both meaningful and non-meaningful sounds, and multisensory integration (Becker et al., 2013; Lewis et al., 2004; Lapenta et al., 2012). Reduced STC activity or connectivity has also been documented in non-social sensory processing in ASD, including listening to tones and perceptual integration (Samson et al., 2011; Edgar et al., 2014; Peiker et al., 2015). In addition to the role of STC in sensory and social processes, it has been hypothesized that the many connections of the STC with primary sensory cortices, multimodal associative systems, and the limbic system, may explain its role in a diverse range of functions (Boddaert & Zilbovicius, 2002). It has also been proposed that the STC may play a common role across its many associated functions such that it processes and integrates various modes of incoming sensory information in order to assign meaning to one’s world (Redcay, 2008; Jou et al., 2010). Thus, the critical role of the STC in perceptual and social functioning in ASD makes it an important candidate for understanding the complex symptomatology of autism.

8.3 Cerebellum
The cerebellum, consistently implicated in ASD neuropathology (Fatemi et al., 2012), perhaps explains the co-occurrence of sensory and social deficits in ASD. An overarching description is that the cerebellum is a “co-processor”, modulating diverse regions and functions of the brain through feedback loops (Wolpert et al., 1998; D’Angelo & Casali, 2012); in this way, it can impact both sensory and social functions. The cerebellum has been proposed to enhance and depress sensory stimuli and could contribute to abnormal sensory perception in ASD (Kern, 2002). The cerebellum is functionally connected with different cortical nodes, allowing it to modulate diverse functions - ranging from sensory to social - through feedback loops (Wolpert et al., 1998; D’Angelo & Casali, 2012). Specifically, the interaction of the cerebellum with higher-order intrinsic connectivity networks (Habas et al., 2009; Krienen & Buckner, 2009) could similarly modulate executive function, mentalizing, and salience detection – functions critical for social cognition and social interaction (Menon, 2011). In fact, the cerebellum is involved in language, emotion, and social cognition specifically (Stoodley & Schmahmann, 2009; Van Overwalle et al., 2014). The cerebellum also forms feedback loops with multisensory regions such as the superior colliculus (SC). Abnormal cerebellar-SC connectivity could lead to altered eye contact and orientation to stimuli, functions controlled by the SC (Kern, 2002; Quaia et al., 2012). Thus, extensive connections of the cerebellum with brain regions and networks primarily associated with sensory and social processing could allow it to simultaneously modulate behaviors within each domain.

The cerebellum also has an important role in timing, prediction, and learning (Ivry & Keele, 1989; Baumann et al., 2015). Alterations in timing could impair integration of temporally synchronous stimuli (Wallace & Stevenson, 2014), which would have profound effects on sensory perception and ultimately social responses (D’Angelo & Casali, 2012). Such
abnormalities in timing are apparent in the extended temporal binding window in ASD (Foss-Feig et al., 2010). The role of the cerebellum in prediction and learning also critically impacts sensory and social processes. The cerebellum operates in a feed-forward manner (Wolpert et al., 1998; Miall et al., 1993), making predictions about the environment and learning from error signals (Marr, 1969) to optimize behavior. In this way, the cerebellum utilizes internal models to dynamically coordinate behavior during social interactions in a way similar to motor control (Wolpert et al., 2003; Ito, 2008; Wolpert et al., 2003; D’Angelo & Casali, 2012). Inability of the cerebellum to either integrate social cues, or to form internal models based on these cues, would have ultimate effects on social behavior.

9. Conclusion

Sensory abnormalities are one of the earliest emerging markers of infants later diagnosed with ASD, with differences noted as early as 6-months of age (Clifford et al., 2013). The sensory characteristics seen across ASD are heterogeneous, with many features ranging from intact, enhanced, or impaired from one sample to the next. Despite these inconsistencies, dysregulated sensory processing can be considered universal in ASD. This paper consolidated the evidence emerging from behavior, neuroscience, and other modalities of research on sensory to social processing in ASD in order to establish their inter-relationship and impact on ASD symptomatology. Abnormal sensory sensitivity in ASD has significant clinical and social implications. Clinically, atypical sensory processing in ASD can interfere with obtaining an accurate assessment of skills, progression of therapy, and treatment outcomes. Oversensitivity to perceptual level sensory features can come at the expense of inability to filter out extraneous information and selectively attend to instruction in the therapeutic environment. Conversely, hyposensitivity to sensory stimuli in the environment can result in delayed visual and auditory
processing, lack of appropriate response, and poor multisensory integration. Socially, this profile of sensory sensitivity can impact selective attention to social stimuli, decoding intentions, social reciprocity, and adherence to social norms of behavior. In general, sensory issues, which may differ across individuals on the autism spectrum, take an important role in social and communicative difficulties in ASD, and hence future research needs to consider it seriously while designing treatment plans for children with ASD.

There are several cognitive and neurobiological mechanisms through which sensory processing abnormalities might either cause or exacerbate many of the social impairments seen in autism. Functional and anatomical differences seen in the thalamus of individuals with ASD may be central to this considering the role of thalamus as a relay station for most senses. Furthermore, abnormalities found in regions such as the ACC, insula and STC in ASD also point to a network of regions at the intersection of sensory processing and social cognition. The cerebellum also plays a complex role in sensory feedback and integration of social cues within the environment. We find that altered sensory processing and sensory integration in autism affect language, communication, emotion, response to reward, and interpersonal functioning in individuals with ASD. Early intervention is instrumental in altering the developmental progression of ASD (see Reichow, 2012), suggesting the need for early identification of sensory as well as other predictors of the disorder. It is also important to continue building models of ASD that incorporate both the social and non-social features of the disorder, and also to design individualized interventions which address both social/communicative and sensory processing. In this way, the two core symptom domains of autism are interrelated and require intervention that targets both domains in conjunction.
Funding Source

This project was funded by the UAB Department of Psychology Faculty Funds and the McNulty-Civitan Scientist Award.
References
Adolphs, R. (2009). The social brain: Neural basis of social knowledge. *Annual review of psychology, 60*, 693.

Alaerts, K., Woolley, D. G., Steyaert, J., Di Martino, A., Swinnen, S. P., & Wenderoth, N. (2014). Underconnectivity of the superior temporal sulcus predicts emotion recognition deficits in autism. *Soc Cogn Affect Neurosci, 9*(10), 1589-1600. doi: 10.1093/scan/nst156

Allely, C. S. (2013). Pain sensitivity and observer perception of pain in individuals with autistic spectrum disorder. *The Scientific World Journal.*

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: Role of the STS region. *Trends Cogn Sci, 4*(7), 267-278.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, D.C.: American Psychiatric Association.

Anagnostou, E., Soorya, L., Brian, J., Dupuis, A., Mankad, D., Smile, S., & Jacob, S. (2014). Intranasal oxytocin in the treatment of autism spectrum disorders: A review of literature and early safety and efficacy data in youth. *Brain research, 1580*, 188-198.

Annaz, D., Campbell, R., Coleman, M., Milne, E., & Swettenham, J. (2012). Young children with autism spectrum disorder do not preferentially attend to biological motion. *J Autism Dev Disord, 42*(3), 401-408. doi: 10.1007/s10803-011-1256-3

Ashwin, C., Ricciardelli, P., & Baron-Cohen, S. (2009). Positive and negative gaze perception in autism spectrum conditions. *Soc Neurosci, 4*(2), 153-164. doi: 10.1080/17470910802337902

Atkinson, A. P. (2009). Impaired recognition of emotions from body movements is associated with elevated motion coherence thresholds in autism spectrum disorders. *Neuropsychologia, 47*(13), 3023-3029. doi: 10.1016/j.neuropsychologia.2009.05.019
Bachevalier, J., & Loveland, K. A. (2006). The orbitofrontal–amygdala circuit and self-regulation of social–emotional behavior in autism. *Neuroscience & Biobehavioral Reviews, 30*(1), 97-117.

Bahrick, L. E. (2010). Intermodal Perception and Selective Attention to Intersensory Redundancy: Implications for Typical Social Development and Autism. Wiley-Blackwell Handbook of Infant Development, Second Edition (Vol. 1). http://doi.org/10.1002/9781444327564.ch4

Bahrick, L. E., & Lickliter, R. (2000). Intersensory redundancy guides attentional selectivity and perceptual learning in infancy. *Developmental Psychology, 36*(2), 190–201. http://doi.org/10.1037//0012-1649.36.2.190

Bahrick, L. E., & Pickens, J. N. (1994). Amodal relations: The basis for intermodal perception and learning. In *The development of intersensory perception: Comparative perspectives* (pp. 204–233). New Jersey: Lawrence Erlbaum Associates.

Bahrick, L. E., Lickliter, R., & Flom, R. (2004). Intersensory redundancy guides the development of selective attention, perception, and cognition in infancy. *Current Directions in Psychological Science, 13*, 99-102. http://doi.org/10.1111/j.0963-7214.2004.00283.x

Bahrick, L., & Todd, J. (2012). Multisensory processing in autism spectrum disorders: Intersensory processing disturbance as a basis for atypical development. *The New Handbook of Multisensory Processes*, 657–674.

Baranek, G. (1999). Autism during infancy: A retrospective video analysis of sensory-motor and social behaviors at 9-12 months of age. *Journal of autism and developmental disorders* 29(3), 213-224.
Baranek, G. T., Watson, L. R., Boyd, B. A., Poe, M. D., David, F. J., & McGuire, L. (2013). Hyporesponsiveness to social and nonsocial sensory stimuli in children with autism, children with developmental delays, and typically developing children. *Dev Psychopathology, 25*(2), 307-320. doi: 10.1017/s0954579412001071

Barnett, K. (1972). A theoretical construct of the concepts of touch as they relate to nursing. *Nursing research, 21*(2), 102-109.

Baron-Cohen, S. (1990). Autism: A Specific Cognitive Disorder of “Mind-Blindness.” *Int. Rev. Psychiatry, 2*, 81–90. doi:10.3109/09540269009028274

Baron-Cohen, S. (1991). Do people with autism understand what causes emotion? *Child development, 62*(2), 385-395.

Baron-Cohen, S. (1997). Mindblindness: An essay on autism and theory of mind. *MIT press.*

Baron-Cohen, S., Leslie, A. M., & Frith, U. (1985). Does the autistic child have a “theory of mind”? *Cognition, 21*(1), 37-46.

Baum, S. H., Stevenson, R. A., & Wallace, M. T. (2015). Behavioral, perceptual, and neural alterations in sensory and multisensory function in autism spectrum disorder. *Prog Neurobiol, 134*, 140-160. doi: 10.1016/j.pneurobio.2015.09.007

Baumann, O., Borra, R. J., Bower, J. M., Cullen, K. E., Habas, C., Ivry, R. B., … Sokolov, A. A. (2015). Consensus Paper: The Role of the Cerebellum in Perceptual Processes. *Cerebellum, 14*(2), 197–220. http://doi.org/10.1007/s12311-014-0627-7

Bebko, J. M., Schroeder, J. H., & Weiss, J. A. (2014). The McGurk effect in children with autism and Asperger syndrome. *Autism Research, 7*(1), 50–59. http://doi.org/10.1002/aur.1343
Becker, H. G., Haarmeier, T., Tatagiba, M., & Gharabaghi, A. (2013). Electrical stimulation of the human homolog of the medial superior temporal area induces visual motion blindness. *J Neurosci, 33*(46), 18288-18297. doi: 10.1523/jneurosci.0556-13.2013

Bedford, R., Elsabbagh, M., Gliga, T., Pickles, A., Senju, A., Charman, T., & Johnson, M. H. (2012). Precursors to social and communication difficulties in infants at-risk for autism: Gaze following and attentional engagement. *J Autism Dev Disorder, 42*(10), 2208-2218. doi: 10.1007/s10803-012-1450-y

Behrmann, M., Thomas, C., & Humphreys, K. (2006). Seeing it differently: Visual processing in autism. *Trends in cognitive sciences, 10*(6), 258-264.

Belin, P., Fecteau, S., & Bedard, C. (2004). Thinking the voice: Neural correlates of voice perception. *Trends in Cognitive Sciences, 8*(3), 129–135. http://doi.org/10.1016/j.tics.2004.01.008

Bennetto, L., Kuschner, E., & Hyman, S. (2007). Olfaction and taste processing in autism. *Biological psychiatry, 62*(9), 1015-1021.

Bennetto, L., Zampella, C., Kuschner, E., Bender, R., & Hyman, S. (2012). Food preferences in autism spectrum disorders and their relationship to sensory and behavioral symptoms. *International Meeting for Autism Research, Toronto.*

Ben-Sasson, A., Cermak, S. A., Orsmond, G. I., & Tager-Flusberg, H. (2007). Extreme sensory modulation behaviors in toddlers with autism spectrum disorders. *The American Journal of Occupational Therapy, 61*(5), 584.

Bertone, A., Mottron, L., Jelenic, P., & Faubert, J. (2003). Motion Perception in Autism: A “Complex” Issue. *J Cogn Neurosci, 15*(2), 218-225. doi: 10.1162/089892903321208150
Björnsdotter, M., & Olausson, H. (2011). Vicarious responses to social touch in posterior insular cortex are tuned to pleasant caressing speeds. *The Journal of Neuroscience, 31*(26), 9554-9562.

Björnsdotter, M., Gordon, I., Pelphrey, K., Olausson, H., & Kaiser, M. (2014). Development of brain mechanisms for processing affective touch. *Frontiers in behavioral neuroscience, 8*, 24.

Björnsdotter, M., Löken, L., Olausson, H., Vallbo, Â., & Wessberg, J. (2009). Somatotopic organization of gentle touch processing in the posterior insular cortex. *The Journal of Neuroscience, 29*(29), 9314-9320.

Blake, R., Turner, L. M., Smoski, M. J., Pozdol, S. L., & Stone, W. L. (2003). Visual recognition of biological motion is impaired in children with autism. *Psychological science, 14*(2), 151-157.

Blakemore, S. J., Tavassoli, T., Calò, S., Thomas, R. M., Catmur, C., Frith, U., & Haggard, P. (2006). Tactile sensitivity in Asperger syndrome. *Brain and cognition, 61*(1), 5-13.

Boddaert, N., Chabane, N., Belin, P., Bourgeois, M., Royer, V., Barthelemy, C., … Zilbovicius, M. (2004). Perception of complex sounds in autism: Abnormal auditory cortical processing in children. *American Journal of Psychiatry, 161*(11), 2117–2120. http://doi.org/10.1176/appi.ajp.161.11.2117

Boddaert, N., & Zilbovicius, M. (2002). Functional neuroimaging and childhood autism. *Pediatr Radiol, 32*(1), 1-7. doi: 10.1007/s00247-001-0570-x

Bölte, S., & Poustka, F. (2003). The recognition of facial affect in autistic and schizophrenic subjects and their first-degree relatives. *Psychological medicine, 33*(05), 907-915.

Bolte, S., Holtmann, M., Poustka, F., Scheurich, A., & Schmidt, L. (2007). Gestalt perception
and local-global processing in high-functioning autism. *J Autism Dev Disord*, 37(8), 1493-1504. doi: 10.1007/s10803-006-0231-x

Bonnel, A., McAdams, S., Smith, B., Berthiaume, C., Bertone, A., Ciocca, V., … Mottron, L. (2010). Enhanced pure-tone pitch discrimination among persons with autism but not Asperger syndrome. *Neuropsychologia*, 48(9), 2465–75. http://doi.org/10.1016/j.neuropsychologia.2010.04.020

Bonnel, A., Mottron, L., Peretz, I., Trudel, M., Gallun, E., & Bonnel, A.-M. (2003). Enhanced pitch sensitivity in individuals with autism: A signal detection analysis. *Journal of Cognitive Neuroscience*, 15(2), 226–235. http://doi.org/10.1162/089892903321208169

Bouvet, L., Donnadieu, S., Valdois, S., Caron, C., Dawson, M., & Mottron, L. (2014). Veridical mapping in savant abilities, absolute pitch, and synesthesia: An autism case study. *Frontiers in Psychology*, 5, 106. http://doi.org/10.3389/fpsyg.2014.00106

Brandwein, A. B., Foxe, J. J., Butler, J. S., Frey, H. P., Bates, J. C., Shulman, L. H., & Molholm, S. (2015). Neurophysiological Indices of Atypical Auditory Processing and Multisensory Integration are Associated with Symptom Severity in Autism. *Journal of Autism and Developmental Disorders*, 45(1), 230–244. http://doi.org/10.1007/s10803-014-2212-9

Brandwein, A. B., Foxe, J. J., Butler, J. S., Russo, N. N., Altschuler, T. S., Gomes, H., & Molholm, S. (2013). The development of multisensory integration in high-functioning autism: High-density electrical mapping and psychophysical measures reveal impairments in the processing of audiovisual inputs. *Cerebral Cortex*, 23(6), 1329–1341. http://doi.org/10.1093/cercor/bhs109
Brang, D., & Ramachandran, V. (2010). Olfactory bulb dysgenesis, mirror neuron system dysfunction, and autonomic dysregulation as the neural basis for autism. *Medical hypotheses, 74*(5), 919-921.

Brauer, J., Xiao, Y., Poulain, T., Friederici, A., & Schirmer, A. (2016). Frequency of Maternal Touch Predicts Resting Activity and Connectivity of the Developing Social Brain. *Cerebral Cortex, 26*(8), 3544-3552. doi: 10.1093/cercor/bhw137

Brock, J. (2012a). Alternative Bayesian accounts of autistic perception: comment on Pellicano and Burr. *Trends Cogn Sci, 16*(12), 573-574; author reply 574-575. doi: 10.1016/j.tics.2012.10.005

Brock, J., Brown, C. C., Boucher, J., & Rippon, G. (2002). The temporal binding deficit hypothesis of autism. *Development and Psychopathology, 14*(2), 209–224. http://doi.org/10.1017/S0954579402002018

Brock, M. E., Freuler, A., Baranek, G. T., Watson, L. R., Poe, M. D., & Sabatino, A. (2012b). Temperament and sensory features of children with autism. *J Autism Dev Disord, 42*(11), 2271-2284. doi: 10.1007/s10803-012-1472-5

Brothers, L. (2002). The social brain: A project for integrating primate behavior and neurophysiology in a new domain. *Foundations in social neuroscience, 367*-385.

Brown, N. B., & Dunn, W. (2010). Relationship between context and sensory processing in children with autism. *American Journal of Occupational Therapy, 64*(3), 474-483.

Büchel, C., Josephs, O., Rees, G., Turner, R., Frith, C. D., & Friston, K. J. (1998). The functional anatomy of attention to visual motion. A functional MRI study. *Brain, 121*(7), 1281-1294.
Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in cognitive sciences*, 4(6), 215-222.

Butcher, C., Goldin-Meadow, S., & McNeill, D. (2000). Gesture and the transition from one- to two-word speech: when hand and mouth come together. *Language and Gesture*. http://doi.org/10.1017/CBO9780511620850

Butts, J. (2001). Outcomes of comfort touch in institutionalized elderly female residents. *Geriatric Nursing*, 22(4), 180-184.

Campbell, D. B., Datta, D., Jones, S. T., Lee, E. B., Sutcliffe, J. S., Hammock, E. A., & Levitt, P. (2011). Association of oxytocin receptor (OXTR) gene variants with multiple phenotype domains of autism spectrum disorder. *Journal of neurodevelopmental disorders*, 3(2), 101.

Capps, L., Sigman, M., & Mundy, P. (1994). Attachment security in children with autism. *Development and psychopathology*, 6(02), 249-261.

Cascio, C. J., Foss-Feig, J. H., Burnette, C. P., Heacock, J. L., & Cosby, A. A. (2012). The rubber hand illusion in children with autism spectrum disorders: Delayed influence of combined tactile and visual input on proprioception. *Autism*, 16, 406–419. http://doi.org/10.1177/1362361311430404

Cascio, C., McGlone, F., Folger, S., Tannan, V., Baranek, G., Pelphrey, K. A., & Essick, G. (2008). Tactile perception in adults with autism: A multidimensional psychophysical study. *Journal of autism and developmental disorders*, 38(1), 127-137.

Castelli, F., Frith, C., Happe, F., & Frith, U. (2002). Autism, Asperger syndrome and brain mechanisms for the attribution of mental states to animated shapes. *Brain*, 125(8), 1839-1849.
Ceponiene, R., Lepistö, T., Shestakova, A., Vanhala, R., Alku, P., Näätänen, R., & Yaguchi, K. (2003). Speech-sound-selective auditory impairment in children with autism: They can perceive but do not attend. *Proceedings of the National Academy of Sciences of the United States of America, 100*(9), 5567–72. http://doi.org/10.1073/pnas.0835631100

Charbonneau, G., Bertone, A., Lepore, F., Nassim, M., Lassonde, M., Mottron, L., & Collignon, O. (2013). Multilevel alterations in the processing of audio-visual emotion expressions in autism spectrum disorders. *Neuropsychologia, 51*(5), 1002–1010. http://doi.org/10.1016/j.neuropsychologia.2013.02.009

Charman, T., Swettenham, J., Baron-Cohen, S., Cox, A., Baird, G., & Drew, A. (1997). Infants with autism: an investigation of empathy, pretend play, joint attention, and imitation. *Dev Psychol, 33*(5), 781-789.

Charrier, A., Tardif, C., & Gepner, B. (2016). Slowing down the flow of facial information enhances facial scanning in children with autism spectrum disorders: A pilot eye tracking study. *L'Encephale*. doi: 10.1016/j.encep.2016.02.005

Chien, H. Y., Lin, H. Y., Lai, M. C., Gau, S. S., & Tseng, W. Y. (2015). Hyperconnectivity of the Right Posterior Temporo-parietal Junction Predicts Social Difficulties in Boys with Autism Spectrum Disorder. *Autism Res, 8*(4), 427-441. doi: 10.1002/aur.1457

Christensen, D. L., Baio, J., Braun, K. V. N., Bilder, D., Charles, J., Constantino, J. N., ... Yeargin-Allsopp, M. (2016). Prevalence and Characteristics of Autism Spectrum Disorder Among Children Aged 8 Years-Autism and Developmental Disabilities Monitoring Network, 11 Sites, United States, 2012. *MMWR. Surveillance Summaries, 65*(3), 1–23. http://doi.org/10.15585/mmwr.ss6503a1
Clifford, S.M., Hudry, K., Elsabbagh, M., Charman, T., Johnson, M.H., BASIS Team, 2013. Temperament in the first 2 years of life in infants at high-risk for autism spectrum disorders. J. Autism Dev. Disord. 43, 673–86. doi:10.1007/s10803-012-1612-y

Collignon, O., Charbonneau, G., Peters, F., Nassim, M., Lassonde, M., Lepore, F., … Bertone, A. (2013). Reduced multisensory facilitation in persons with autism. Cortex, 49(6), 1704–1710. http://doi.org/10.1016/j.cortex.2012.06.001

Craig, A. D. (2003). Interoception: the sense of the physiological condition of the body. Current opinion in neurobiology, 13(4), 500-505.

Crane, L., Goddard, L., & Pring, L. (2009). Sensory processing in adults with autism spectrum disorders. Autism, 13(3), 215-228.

Csibra, G., Hernik, M., Mascaro, O., Tatone, D., & Lengyel, M. (2016). Statistical treatment of looking-time data. Dev Psychol, 52(4), 521-536. doi: 10.1037/dev0000083

Curtin, S., & Vouloumanos, A. (2013). Speech preference is associated with autistic-like behavior in 18-months-olds at risk for Autism Spectrum Disorder. Journal of Autism and Developmental Disorders, 43(9), 2114–20. http://doi.org/10.1007/s10803-013-1759-1

D’Angelo, E., & Casali, S. (2012). Seeking a unified framework for cerebellar function and dysfunction: From circuit operations to cognition. Frontiers in Neural Circuits, 6, 116. http://doi.org/10.3389/fncir.2012.00116

Dakin, S., & Frith, U. (2005). Vagaries of visual perception in autism. Neuron, 48(3), 497-507. doi: 10.1016/j.neuron.2005.10.018

Dawson, G., Meltzoff, A. N., Osterling, J., Rinaldi, J., & Brown, E. (1998). Children with autism fail to orient to naturally occurring social stimuli. Journal of Autism and Developmental Disorders, 28(6), 479–485.
Dawson, G., Munson, J., Estes, A., Osterling, J., McPartland, J., Toth, K., … Abbott, R. (2002). Neurocognitive function and joint attention ability in young children with autism spectrum disorder versus developmental delay. *Child Development, 73*(2), 345–358. http://doi.org/10.1111/1467-8624.00411

Dawson, G., Osterling, J., Rinaldi, J., Carver, L., & McPartland, J. (2001). Brief Report: Recognition Memory and Stimulus-Reward Associations: Indirect Support for the Role of Ventromedial Prefrontal Dysfunction in Autism. *Journal of Autism and Developmental Disorders, 31*(3), 337–341. http://doi.org/10.1023/A:1010751404865

Dawson, G., Webb, S.J., & McPartland, J. (2005). Understanding the nature of face processing impairment in autism: Insights from behavioral and electrophysiological studies. *Dev. Neuropsychol.* 27, 403–424. doi:10.1207/s15326942dn2703_6

de Gelder, B., & Vroomen, J. (2000). The perception of emotions by ear and by eye. *Cognition & Emotion, 14*(3), 289–311. http://doi.org/10.1080/026999300378824

de Gelder, B., Vroomen, J., & van der Heide, L. (1991). Face recognition and lip-reading in autism. *European Journal of Cognitive Psychology, 3*(1), 69–86. http://doi.org/10.1080/09541449108406220

de Marchena, A., & Eigsti, I.-M. (2010). Conversational gestures in autism spectrum disorders: Asynchrony but not decreased frequency. *Autism Research, 3*(6), 311–322. http://doi.org/10.1002/aur.159

Demopoulos, C., Hopkins, J., Kopald, B. E., Paulson, K., Doyle, L., Andrews, E., … Lewine, J. D. (2015). Neuropsychology Deficits in Auditory Processing Contribute to Impairments in Vocal Affect Recognition in Autism Spectrum Disorders: A MEG Study Deficits in Auditory Processing Contribute to Impairments in Vocal Affect Recognition in Autism
Spectrum Disor, 29(6), 895–908. http://doi.org/10.1037/neu0000209

Devinsky, O., Morrell, M. J., & Vogt, B. A. (1995). Contributions of anterior cingulate cortex to behaviour. *Brain, 118*(1), 279-306.

Dodd, B. (1979). Lip reading in infants: Attention to speech presented in- and out-of-synchrony. *Cognitive Psychology, 11*(4), 478–484. http://doi.org/10.1016/0010-0285(79)90021-5

Donohue, S. E., Darling, E. F., & Mitroff, S. R. (2012). Links between multisensory processing and autism. *Experimental Brain Research, 222*(4), 377–387. http://doi.org/10.1007/s00221-012-3223-4

Dowd, A. M., McGinley, J. L., Taffe, J. R., & Rinehart, N. J. (2012). Do planning and visual integration difficulties underpin motor dysfunction in autism? A kinematic study of young children with autism. *Journal of Autism and Developmental Disorders, 42*(8), 1539–1548. http://doi.org/10.1007/s10803-011-1385-8

Doyle-Thomas, K. R., Goldberg, J., Szatmari, P., & Hall, G. B. C. (2013a). Neurofunctional underpinnings of audiovisual emotion processing in teens with autism spectrum disorders. *Frontiers in Psychiatry, 4*, 48. http://doi.org/10.3389/fpsyt.2013.00048

Doyle-Thomas, K. A., Kushki, A., Duerden, E. G., Taylor, M. J., Lerch, J. P., Soorya, L. V., Wang, A.T., Fan, J., & Anagnostou, E. (2013b). The effect of diagnosis, age, and symptom severity on cortical surface area in the cingulate cortex and insula in autism spectrum disorders. *Journal of child neurology, 28*(6), 729-736.

Dudova, I., Vodicka, J., Havlovcova, M., Sedlacek, Z., Urbanek, T., & Hrdlicka, M. (2011). Odor detection threshold, but not odor identification, is impaired in children with autism. *European child & adolescent psychiatry, 20*(7), 333-340.
Dunbar, R. (2010). The social role of touch in humans and primates: Behavioural function and neurobiological mechanisms. *Biobehavioral Reviews, 34*(2), 260-268.

Dunn, M.A., Gomes, H., Gravel, J., 2008. Mismatch Negativity in Children with Autism and Typical Development. *J. Autism Dev. Disord.* 38, 52–71. doi:10.1007/s10803-007-0359-3

Ebisch, S. J., Gallese, V., Willems, R. M., Mantini, D., Groen, W. B., Romani, G. L., Buitelaar, J.K., & Bekkering, H. (2011). Altered intrinsic functional connectivity of anterior and posterior insula regions in high-functioning participants with autism spectrum disorder. *Human brain mapping, 32*(7), 1013-1028.

Ebstein, R. P., Israel, S., Lerer, E., Uzefovsky, F., Shalev, I., Gritsenko, I., ... & Yirmiya, N. (2009). Arginine vasopressin and oxytocin modulate human social behavior. *Annals of the New York Academy of Sciences, 1167*(1), 87-102.

Edgar, J. C., Lanza, M. R., Daina, A. B., Monroe, J. F., Khan, S. Y., Blaskey, L., . . . Roberts, T. P. (2014). Missing and delayed auditory responses in young and older children with autism spectrum disorders. *Front Hum Neurosci*, 8, 417. doi: 10.3389/fnhum.2014.00417

Edwards, L. A. (2014). A meta-analysis of imitation abilities in individuals with autism spectrum disorders. *Autism Research, 7*(3), 363–380. http://doi.org/10.1002/aur.1379

Eigsti, I.-M., & Fein, D. A. (2013). More is less: Pitch discrimination and language delays in children with optimal outcomes from autism. *Autism Research : Official Journal of the International Society for Autism Research, 6*(6), 605–13. http://doi.org/10.1002/aur.1324

Eigsti, I.-M., Schuh, J., Mencl, E., Schultz, R. T., & Paul, R. (2012). The neural underpinnings of prosody in autism, *Child Neuropsychology, 18*(6), 600–617. http://doi.org/10.1080/09297049.2011.639757.
Elsabbagh, M., Fernandes, J., Jane Webb, S., Dawson, G., Charman, T., & Johnson, M. H. (2013a). Disengagement of visual attention in infancy is associated with emerging autism in toddlerhood. *Biol Psychiatry*, 74(3), 189-194. doi: 10.1016/j.biopsych.2012.11.030

Elsabbagh, M., Gliga, T., Pickles, A., Hudry, K., Charman, T., & Johnson, M. H. (2013b). The development of face orienting mechanisms in infants at-risk for autism. *Behav Brain Res*, 251, 147-154. doi: 10.1016/j.bbr.2012.07.030

Engelborghs, S., Marien, P., Martin, J. J., & De Deyn, P. P. (1998). Functional anatomy, vascularisation and pathology of the human thalamus. *Acta Neurologica Belgica*.

Ewing, L., Pellicano, E., & Rhodes, G. (2013). Reevaluating the selectivity of face-processing difficulties in children and adolescents with autism. *J Exp Child Psychol*, 115(2), 342-355. doi: 10.1016/j.jecp.2013.01.009

Fan, Y. T., & Cheng, Y. (2014). Atypical mismatch negativity in response to emotional voices in people with autism spectrum conditions. *PLoS ONE*, 9(7), 1–10. http://doi.org/10.1371/journal.pone.0102471

Farah, M. J., Wilson, K. D., Drain, M., & Tanaka, J. N. (1998). What is “special” about face perception? *Psychological Review*, 105(3), 482–498. http://doi.org/10.1037/0033-295X.105.3.482

Fatemi, S. H., Aldinger, K. A., Ashwood, P., Bauman, M. L., Blaha, C. D., Blatt, G. J., … Welsh, J. P. (2012). Consensus paper: Pathological role of the cerebellum in Autism. *Cerebellum*, 11(3), 777–807. http://doi.org/10.1007/s12311-012-0355-9

Field, T. M. (1998). Touch Therapy Effects on Development. *International Journal of Behavioral Development*, 22(4), 779–797. http://doi.org/10.1080/016502598384162

Forgeot d'Arc, B., Delorme, R., Zalla, T., Lefebvre, A., Amsellem, F., Moukawane, S., …
Ramus, F. (2016). Gaze direction detection in autism spectrum disorder. *Autism*. doi: 10.1177/1362361316630880

Foss-Feig, J. H., Heacock, J. L., & Cascio, C. J. (2012). Tactile responsiveness patterns and their association with core features in autism spectrum disorders. *Research in autism spectrum disorders, 6*(1), 337-344.

Foss-Feig, J. H., Kwakye, L. D., Cascio, C. J., Burnette, C. P., Kadivar, H., Stone, W. L., & Wallace, M. T. (2010). An extended multisensory temporal binding window in autism spectrum disorders. *Experimental Brain Research, 203*(2), 381–389. http://doi.org/10.1007/s00221-010-2240-4

Foster, N.E. V, Ouimet, T., Tryfon, A., Doyle-Thomas, K., Anagnostou, E., Hyde, K.L., 2016. Effects of Age and Attention on Auditory Global–Local Processing in Children with Autism Spectrum Disorder. *J. Autism Dev. Disord.* 46, 1415–1428. doi:10.1007/s10803-015-2684-2

Foxe, J. J., & Schroeder, C. E. (2005). The case for feedforward multisensory convergence during early cortical processing. *Neuroreport, 16*, 419–423. http://doi.org/10.1097/00001756-200504040-00001

Foxe, J. J., Molholm, S., Del Bene, V. A., Frey, H. P., Russo, N. N., Blanco, D., … Ross, L. A. (2015). Severe multisensory speech integration deficits in high-functioning school-aged children with autism spectrum disorder (ASD) and their resolution during early adolescence. *Cerebral Cortex, 25*(2), 298–312. http://doi.org/10.1093/cercor/bht213

Foxton, J.M., Stewart, M.E., Barnard, L., Rodgers, J., Young, A.H., O’Brien, G., Griffiths, T.D., 2003. Absence of auditory “global interference” in autism. *Brain* 126, 2703–9. doi:10.1093/brain/awg274
Frankland, P. W., Bontempi, B., Talton, L. E., Kaczmarek, L., & Silva, A. J. (2004). The involvement of the anterior cingulate cortex in remote contextual fear memory. *Science, 304*(5672), 881-883.

Franklin, A., Sowden, P., Burley, R., Notman, L., & Alder, E. (2008). Color perception in children with autism. *J Autism Dev Disord, 38*(10), 1837-1847. doi: 10.1007/s10803-008-0574-6

Freitag, C. M., Konrad, C., Haberlen, M., Kleser, C., von Gontard, A., Reith, W., . . . Krick, C. (2008). Perception of biological motion in autism spectrum disorders. *Neuropsychologia, 46*(5), 1480-1494. doi: 10.1016/j.neuropsychologia.2007.12.025

Friedman, S. D., Shaw, D. W., Artru, A. A., Richards, T. L., Gardner, J., Dawson, G., Posse, S., & Dager, S. R. (2003). Regional brain chemical alterations in young children with autism spectrum disorder. *Neurology, 60*(1), 100-107.

Frith, C. D. (2007). The social brain? *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 362*(1480), 671-678.

Frith, U. (1989). Autism: Explaining the enigma. *British Journal of Developmental Psychology, 21*(3), 465-468. doi: 10.1348/026151003322277801

Frühholz, S., Ceravolo, L., & Grandjean, D. (2012). Specific brain networks during explicit and implicit decoding of emotional prosody. *Cerebral Cortex (New York, N.Y. : 1991), 22*(5), 1107–17. http://doi.org/10.1093/cercor/bhr184

Gallagher, H. L., Happé, F., Brunswick, N., Fletcher, P. C., Frith, U., & Frith, C. D. (2000). Reading the mind in cartoons and stories: An fMRI study of ‘theory of mind’ in verbal and nonverbal tasks. *Neuropsychologia, 38*(1), 11-21.

Gebauer, L., Skewes, J., Horlyck, L., & Vuust, P. (2014). Atypical perception of affective
prosody in Autism Spectrum Disorder. *NeuroImage: Clinical*, 6, 370–378. http://doi.org/10.1016/j.nicl.2014.08.025

Gentilini, M., De Renzi, E. N. N. I. O., & Crisi, G. (1987). Bilateral paramedian thalamic artery infarcts: Report of eight cases. *Journal of Neurology, Neurosurgery & Psychiatry*, 50(7), 900-909.

Gervais, H., Belin, P., Boddaert, N., Leboyer, M., Coez, A., Sfaello, I., … Zilbovicius, M. (2004). Abnormal cortical voice processing in autism. *Nature Neuroscience*, 7(8), 801–2. http://doi.org/10.1038/nn1291

Ghaziuddin, M., Ghaziuddin, N., & Greden, J. (2002). Depression in persons with autism: Implications for research and clinical care. *Journal of autism and developmental disorders*, 32(4), 299-306.

Gillespie-Lynch, K., Khalulyan, A., del Rosario, M., McCarthy, B., Gomez, L., Sigman, M., & Hutman, T. (2015). Is early joint attention associated with school-age pragmatic language? *Autism*, 19(2), 168-177. doi: 10.1177/1362361313515094

Gliga, T., Bedford, R., Charman, T., & Johnson, M. H. (2015). Enhanced Visual Search in Infancy Predicts Emerging Autism Symptoms. *Current Biology*, 25(13), 1727-1730. doi: 10.1016/j.cub.2015.05.011

Gliga, T., Jones, E. J., Bedford, R., Charman, T., & Johnson, M. H. (2014). From early markers to neuro-developmental mechanisms of autism. *Dev Rev*, 34(3), 189-207. doi: 10.1016/j.dr.2014.05.003

Globerson, E., Amir, N., Kishon-Rabin, L., & Golan, O. (2015). Prosody recognition in adults with high-functioning autism spectrum disorders: from psychoacoustics to cognition. *Autism Research: Official Journal of the International Society for Autism Research*, 8(2),
Goldberg, M. C., Lasker, A. G., Zee, D. S., Garth, E., Tien, A., & Landa, R. J. (2002). Deficits in the initiation of eye movements in the absence of a visual target in adolescents with high functioning autism. Neuropsychologia, 40(12), 2039-2049.

Goldstein, E.B., Brockmole, J.R., 2017. Sensation and Perception, 10th ed. Cengage Learning, Boston, MA.

Gordon, I., Voos, A., Bennett, R., Bolling, D., Pelphrey, K., & Kaiser, M. (2013). Brain mechanisms for processing affective touch. Human Brain Mapping, 914-922.

Green, L., Fein, D., Modahl, C., Feinstein, C., Waterhouse, L., & Morris, M. (2001). Oxytocin and autistic disorder: alterations in peptide forms. Biological psychiatry, 50(8), 609-613.

Green, S. A., Hernandez, L., Tottenham, N., Krasileva, K., Bookheimer, S. Y., & Dapretto, M. (2015). Neurobiology of Sensory Overresponsivity in Youth with Autism Spectrum Disorders. JAMA Psychiatry, 72(8), 778-786. doi: 10.1001/jamapsychiatry.2015.0737

Greenfield, K., Ropar, D., Smith, A. D., Carey, M., & Newport, R. (2015). Visuo-tactile integration in autism: Atypical temporal binding may underlie greater reliance on proprioceptive information. Molecular Autism, 6(1), 51. http://doi.org/10.1186/s13229-015-0045-9

Gregory, S. G., Connelly, J. J., Towers, A. J., Johnson, J., Biscocho, D., Markunas, C. A., ... & Langford, C. F. (2009). Genomic and epigenetic evidence for oxytocin receptor deficiency in autism. BMC medicine, 7(1).

Guiraud, J. A., Kushnerenko, E., Tomalski, P., Davies, K., Ribeiro, H., Johnson, M. H., & BASIS Team. (2011). Differential habituation to repeated sounds in infants at high risk for autism. Neuroreport, 22(16), 845–9. http://doi.org/10.1097/WNR.0b013e32834c0bec
Guiraud, J. A., Tomalski, P., Kushnirenko, E., Ribeiro, H., Davies, K., Charman, T., … BASIS Team. (2012). Atypical audiovisual speech integration in infants at risk for autism. *PloS One*, 7(5), 3–8. http://doi.org/10.1371/journal.pone.0036428

Gupta, M., Gupta, A., & Watteel, G. (1998). Perceived deprivation of social touch in psoriasis is associated with greater psychological morbidity: An index of the stigma experience in dermatologic disorders. *Cutis*, 61(6), 339-342.

Habas, C., Kamdar, N., Nguyen, D., Prater, K., Beckmann, C. F., Menon, V., & Greicius, M. D. (2009). Distinct Cerebellar Contributions to Intrinsic Connectivity Networks, 29(26), 8586–8594. http://doi.org/10.1523/JNEUROSCI.1868-09.2009

Hadad, B., Schwartz, S., Maurer, D., & Lewis, T. L. (2015). Motion perception: A review of developmental changes and the role of early visual experience. *Front Integr Neurosci*, 9. doi: 10.3389/fnint.2015.00049

Hadland, K. A., Rushworth, M. F., Gaffan, D., & Passingham, R. E. (2003). The effect of cingulate lesions on social behaviour and emotion. *Neuropsychologia*, 41(8), 919-931.

Haist, F., Adamo, M., Westerfield, M., Courchesne, E., & Townsend, J. (2005). The functional neuroanatomy of spatial attention in autism spectrum disorder. *Dev Neuropsychol*, 27(3), 425-458. doi: 10.1207/s15326942dn2703_7

Hamilton, J. P., Chen, M. C., Waugh, C. E., Joormann, J., & Gotlib, I. H. (2014). Distinctive and common neural underpinnings of major depression, social anxiety, and their comorbidity. *Social cognitive and affective neuroscience*, 10(4), 552-560. doi: 10.1093/scan/nsu084

Hammock, E. A., & Levitt, P. (2006). The discipline of neurobehavioral development: The emerging interface of processes that build circuits and skills. *Human Development*, 49(5), 294-309.
Happe, F. G. (1996). Studying weak central coherence at low levels: children with autism do not succumb to visual illusions. A research note. *J Child Psychol Psychiatry, 37*(7), 873-877.

Happe, F., & Frith, U. (2006). The weak coherence account: detail-focused cognitive style in autism spectrum disorders. *J Autism Dev Disord, 36*(1), 5-25. doi: 10.1007/s10803-005-0039-0

Hardan, A. Y., Minshew, N. J., Melhem, N. M., Srihari, S., Jo, B., Bansal, R., Keshavan, M.S., & Stanley, J. A. (2008). An MRI and proton spectroscopy study of the thalamus in children with autism. *Psychiatry Research: Neuroimaging, 163*(2), 97-105.

Harms, M. B., Martin, A., & Wallace, G. L. (2010). Facial emotion recognition in autism spectrum disorders: A review of behavioral and neuroimaging studies. *Neuropsychol Rev, 20*(3), 290-322. doi: 10.1007/s11065-010-9138-6

Haznedar, M. M., Buchsbaum, M. S., Hazlett, E. A., LiCalzi, E. M., Cartwright, C., & Hollander, E. (2006). Volumetric analysis and three-dimensional glucose metabolic mapping of the striatum and thalamus in patients with autism spectrum disorders. *American Journal of Psychiatry, 163*(7), 1252-1263.

Haznedar, M. M., Buchsbaum, M. S., Metzger, M., Solimando, A., Spiegel-Cohen, J., & Hollander, E. (1997). Anterior cingulate gyrus volume and glucose metabolism in autistic disorder. *American Journal of Psychiatry, 154*(8), 1047-1050.

Heald, S.L.M., Nusbaum, H.C., 2014. Speech perception as an active cognitive process. Front. Syst. Neurosci. 8, 35. doi:10.3389/fnsys.2014.00035

Heaton, P., Williams, K., Cummins, O., Happé, F.G.E., 2007. Beyond perception: musical representation and on-line processing in autism. *J. Autism Dev. Disord. 37*, 1355–60. doi:10.1007/s10803-006-0283-y
Hellendoorn, A., Langstraat, I., Wijnroks, L., Buitelaar, J. K., van Daalen, E., & Leseman, P. P. (2014). The relationship between atypical visual processing and social skills in young children with autism. *Res Dev Disabil, 35*(2), 423-428. doi: 10.1016/j.ridd.2013.11.012

Henderson, H., Schwartz, C., Mundy, P., Burnette, C., Sutton, S., Zahka, N., & Pradella, A. (2006). Response monitoring, the error-related negativity, and differences in social behavior in autism. *Brain and cognition, 61*(1), 96-109.

Hertenstein, M. (2002). Touch: Its communicative functions in infancy. *Human Development, 45*(2), 70-94.

Hertenstein, M., Keltner, D., App, B., Bulleit, B., & Jaskolla, A. (2006). Touch communicates distinct emotions. *Emotion, 6*(3), 528.

Hesling, I., Dilharreguy, B., Peppé, S., Amirault, M., Bouvard, M., & Allard, M. (2010). The integration of prosodic speech in high functioning autism: A preliminary fMRI study. *PloS One, 5*(7), e11571. http://doi.org/10.1371/journal.pone.0011571

Hilton, C. L., Harper, J. D., Kueker, R. H., Lang, A. R., Abbacchi, A. M., Todorov, A., & Lavesser, P. D. (2010). Sensory responsiveness as a predictor of social severity in children with high functioning autism spectrum disorders. *Journal of Autism and Developmental Disorders, 40*(8), 937–945. http://doi.org/10.1007/s10803-010-0944-8

Hobson, R. P. (1986). The autistic child's appraisal of expressions of emotion. *Journal of Child Psychology and Psychiatry, 27*(3), 321-342.

Hobson, R. P., & Meyer, J. A. (2005). Foundations for self and other: A study in autism. *Developmental Science, 8*(6), 481-491.

Horwitz, B., Rumsey, J. M., Grady, C. L., & Rapoport, S. I. (1988). The cerebral metabolic landscape in autism: Intercorrelations of regional glucose utilization. *Archives of*
Howe, F. E., & Stagg, S. D. (2016). How Sensory Experiences Affect Adolescents with an Autistic Spectrum Condition within the Classroom. *J Autism Dev Disord, 46*(5), 1656-1668. doi: 10.1007/s10803-015-2693-1

Hubbard, A. L., Mcnealy, K., Scott-Van Zeeland, A. A., Callan, D. E., Bookheimer, S. Y., & Dapretto, M. (2012). Altered integration of speech and gesture in children with autism spectrum disorders. *Brain and Behavior, 2*(5), 606–619. http://doi.org/10.1002/brb3.81

Humphreys, K., Hasson, U., Avidan, G., Minshew, N., & Behrmann, M. (2008). Cortical patterns of category-selective activation for faces, places and objects in adults with autism. *Autism Res, 1*(1), 52-63. doi: 10.1002/aur.1

Hyde, K. L., Samson, F., Evans, A. C., & Mottron, L. (2010). Neuroanatomical differences in brain areas implicated in perceptual and other core features of autism revealed by cortical thickness analysis and voxel-based morphometry. *Human Brain Mapping, 31*(4), 556–66. http://doi.org/10.1002/hbm.20887

Iarocci, G., & McDonald, J. (2006). Sensory integration and the perceptual experience of persons with autism. *Journal of Autism and Developmental Disorders, 36*(1), 77–90. http://doi.org/10.1007/s10803-005-0044-3

Iarocci, G., Rombough, A., Yager, J., Weeks, D. J., & Chua, R. (2010). Visual influences on speech perception in children with autism. *Autism: The International Journal of Research and Practice, 14*(4), 305–320. http://doi.org/10.1177/1362361309353615

Ito, M. (2008). Control of mental activities by internal models in the cerebellum. *Nature Reviews Neuroscience, 9*(4), 304–313. http://doi.org/10.1038/nrn2332
Ivry, R. B., & Keele, S. W. (1989). Timing Functions of the Cerebellum. *Journal of Cognitive Neuroscience*, 1(2), 136–152. http://doi.org/10.1162/jocn.1989.1.2.136

Izawa, J., Pekny, S. E., Marko, M. K., Haswell, C. C., Shadmehr, R., & Mostofsky, S. H. (2012). Motor learning relies on integrated sensory inputs in ADHD, but over-selectively on proprioception in autism spectrum conditions. *Autism Research*, 5(2), 124–136. http://doi.org/10.1002/aur.1222

Jao Keehn, R. J., Sanchez, S. S., Stewart, C. R., Zhao, W., Grenesko-Stevens, E. L., Keehn, B., & Müller, R.-A. (2016). Impaired downregulation of visual cortex during auditory processing is associated with autism symptomatology in children and adolescents with autism spectrum disorder. *Autism Research*. http://doi.org/10.1002/aur.1636

Järvinen-Pasley, A., & Heaton, P. (2007). Evidence for reduced domain-specificity in auditory processing in autism. *Developmental Science*, 10(6), 786–793. http://doi.org/10.1111/j.1467-7687.2007.00637.x

Järvinen-Pasley, A., Peppé, S., King-Smith, G., & Heaton, P. (2008). The relationship between form and function level receptive prosodic abilities in autism. *Journal of Autism and Developmental Disorders*, 38(7), 1328–40. http://doi.org/10.1007/s10803-007-0520-z

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception & psychophysics*, 14(2), 201-211.

Johnson, M. D., & Ojemann, G. A. (2000). The role of the human thalamus in language and memory: evidence from electrophysiological studies. *Brain and cognition*, 42(2), 218-230.
Johnson, M. H., Jones, E. J. H., & Gliga, T. (2015). Brain adaptation and alternative developmental trajectories. *Development and Psychopathology, 27*, 425–442. http://doi.org/10.1017/S0954579415000073

Jolliffe, T., & Baron-Cohen, S. (1997). Are people with autism and Asperger syndrome faster than normal on the Embedded Figures Test? *J Child Psychol Psychiatry, 38*(5), 527-534.

Jones, C. R. G., Happé, F., Baird, G., Simonoff, E., Marsden, A. J. S., Tregay, J., ... Charman, T. (2009). Auditory discrimination and auditory sensory behaviours in autism spectrum disorders. *Neuropsychologia, 47*(13), 2850–8. http://doi.org/10.1016/j.neuropsychologia.2009.06.015

Jones, W., & Klin, A. (2013). Attention to eyes is present but in decline in 2-6-month-old infants later diagnosed with autism. *Nature, 504*(7480), 427-431. doi: 10.1038/nature12715

Jou, R. J., Minshew, N. J., Keshavan, M. S., Vitale, M. P., & Hardan, A. Y. (2010). Enlarged right superior temporal gyrus in children and adolescents with autism. *Brain Res, 1360*, 205-212. doi: 10.1016/j.brainres.2010.09.005

Kaiser, M. D., & Pelphrey, K. A. (2012). Disrupted action perception in autism: behavioral evidence, neuroendophenotypes, and diagnostic utility. *Dev Cogn Neurosci, 2*(1), 25-35. doi: 10.1016/j.dcn.2011.05.005

Kaiser, M. D., & Shiffrar, M. (2009). The visual perception of motion by observers with autism spectrum disorders: a review and synthesis. *Psychon Bull Rev, 16*(5), 761-777. doi: 10.3758/pbr.16.5.761

Kaiser, M. D., Yang, D. Y., Voos, A. C., Bennett, R. H., Gordon, I., Pretzsch, C., ... Pelphrey, K. A. (2016). Brain Mechanisms for Processing Affective (and Nonaffective) Touch Are Atypical in Autism. *Cereb Cortex, 26*(6), 2705-2714. doi: 10.1093/cercor/bhv125
Källstrand, J., Olsson, O., Nehlstedt, S.F., Sköld, M.L., Nielzén, S., 2010. Abnormal auditory forward masking pattern in the brainstem response of individuals with Asperger syndrome. Neuropsychiatr. Dis. Treat. 6, 289–96.

Kana, R. K., Keller, T. A., Cherkassky, V. L., Minshew, N. J., & Just, M. A. (2009). Atypical frontal-posterior synchronization of Theory of Mind regions in autism during mental state attribution. Soc Neurosci, 4(2), 135-152. doi: 10.1080/17470910802198510

Kana, R. K., Liu, Y., Williams, D. L., Keller, T. A., Schipul, S. E., Minshew, N. J., & Just, M. A. (2013). The local, global, and neural aspects of visuospatial processing in autism spectrum disorders. Neuropsychologia, 51(14), 2995-3003. doi: 10.1016/j.neuropsychologia.2013.10.013

Kana, R. K., Maximo, J. O., Williams, D. L., Keller, T. A., Schipul, S. E., Cherkassky, V. L., . . . Just, M. A. (2015). Aberrant functioning of the theory-of-mind network in children and adolescents with autism. Mol Autism, 6, 59. doi: 10.1186/s13229-015-0052-x

Kanner, L., 1943. Autistic disturbances of affective contact. Nerv. Child 2, 217–250.

Kekelis, L. S. (1992). Peer interactions in childhood: The impact of visual impairment. The development of social skills by blind and visually impaired students, 2, 13-35.

Kern, J. K. (2002). The possible role of the cerebellum in autism/PDD: Disruption of a multisensory feedback loop. Medical Hypotheses, 59(3), 255–260. http://doi.org/10.1016/S0306-9877(02)00212-8

Kern, J. K., Trivedi, M. H., Grannemann, B. D., Garver, C. R., Johnson, D. G., Andrews, A. A., . . . Schroeder, J. L. (2007). Sensory correlations in autism. Autism, 11(2), 123-134. doi: 10.1177/1362361307075702
Kerns, C. M., & Kendall, P. C. (2012). The presentation and classification of anxiety in autism spectrum disorder. *Clinical Psychology: Science and Practice, 19*(4), 323-347.

Khalfa, S., Bruneau, N., Rogé, B., Georgieff, N., Veuillet, E., Adrien, J.-L., … Collet, L. (2004). Increased perception of loudness in autism. *Hearing Research, 198*(1-2), 87–92.

Kientz, M. A., & Dunn, W. (1997). A comparison of the performance of children with and without autism on the Sensory Profile. *Am J Occup Ther, 51*(7), 530-537.

Kirchner, J. C., Hatri, A., Heekeren, H. R., & Dziobek, I. (2011). Autistic symptomatology, face processing abilities, and eye fixation patterns. *Journal of autism and developmental disorders, 41*(2), 158-167.

Klin, A. (1991). Young autistic children’s listening preferences in regard to speech: A possible characterization of the symptom of social withdrawal. *Journal of Autism and Developmental Disorders, 21*(1), 29–42.

Klin, A., Jones, W., Schultz, R., Volkmar, F., & Cohen, D. (2002). Visual fixation patterns during viewing of naturalistic social situations as predictors of social competence in individuals with autism. *Archives of general psychiatry, 59*(9), 809-816.

Klin, A., Lin, D. J., Gorrindo, P., Ramsay, G., & Jones, W. (2009). Two-year-olds with autism orient to non-social contingencies rather than biological motion. *Nature, 459*(7244), 257-261. doi: http://www.nature.com/nature/journal/v459/n7244/suppinfo/nature07868_S1.html

Klin, A., Shultz, S., & Jones, W. (2015). Social visual engagement in infants and toddlers with autism: early developmental transitions and a model of pathogenesis. *Neurosci Biobehav Rev, 50*, 189-203. doi: 10.1016/j.neubiorev.2014.10.006

Klin, A., Sparrow, S. S., De Bildt, A., Cicchetti, D. V., Cohen, D. J., & Volkmar, F. R. (1999). A
normed study of face recognition in autism and related disorders. *Journal of autism and developmental disorders*, 29(6), 499-508.

Knill, D. C., & Pouget, A. (2004). The Bayesian brain: the role of uncertainty in neural coding and computation. *Trends Neurosci*, 27(12), 712-719. doi: 10.1016/j.tins.2004.10.007

Kohls, G., Peltzer, J., Schulte-Rüther, M., Kamp-Becker, I., Remschmidt, H., Herpertz-Dahlmann, B., & Konrad, K. (2011). Atypical brain responses to reward cues in autism as revealed by event-related potentials. *Journal of Autism and Developmental Disorders*, 41(11), 1523–1533. http://doi.org/10.1007/s10803-011-1177-1

Koldewyn, K., Whitney, D., & Rivera, S. M. (2011). Neural correlates of coherent and biological motion perception in autism. *Dev Sci*, 14(5), 1075-1088. doi: 10.1111/j.1467-7687.2011.01058.x

Korpilahti, P., Jansson-Verkasalo, E., Mattila, M.-L., Kuusikko, S., Suominen, K., Rytky, S., … Moilanen, I. (2007). Processing of affective speech prosody is impaired in Asperger syndrome. *Journal of Autism and Developmental Disorders*, 37(8), 1539–49. http://doi.org/10.1007/s10803-006-0271-2

Krienen, F. M., & Buckner, R. L. (2009). Segregated fronto-cerebellar circuits revealed by intrinsic functional connectivity. *Cerebral Cortex*, 19(10), 2485–2497. http://doi.org/10.1093/cercor/bhp135

Kröger, A., Bletsch, A., Krick, C., Siniatchkin, M., Jarczok, T. A., Freitag, C. M., & Bender, S. (2014). Visual event-related potentials to biological motion stimuli in autism spectrum disorders. *Soc Cogn Affect Neurosci*, 9(8), 1214-1222. doi: 10.1093/scan/nst103

Kuhl, P. K., Coffey-Corina, S., Padden, D., & Dawson, G. (2005). Links between social and linguistic processing of speech in preschool children with autism: Behavioral and
electrophysiological measures. *Developmental Science*, 8(1), F1–F12.
http://doi.org/10.1111/j.1467-7687.2004.00384.x

Kumsta, R., Hummel, E., Chen, F. S., & Heinrichs, M. (2015). Epigenetic regulation of the oxytocin receptor gene: implications for behavioral neuroscience. *Social Hormones and Human Behavior: What Do We Know and Where Do We Go from Here*, 19.

Kwakye, L. D., Foss-Feig, J. H., Cascio, C. J., Stone, W. L., & Wallace, M. T. (2011). Altered auditory and multisensory temporal processing in autism spectrum disorders. *Frontiers in Integrative Neuroscience*, 4, 129. http://doi.org/10.3389/fnint.2010.00129

Kwon, S., Kim, J., Choe, B.H., Ko, C., Park, S., 2007. Electrophysiologic assessment of central auditory processing by auditory brainstem responses in children with autism spectrum disorders. J. Korean Med. Sci. 22, 656–9. doi:10.3346/jkms.2007.22.4.656

Lahera, G., Ruiz-Murugarren, S., Fernández-Liria, A., Saiz-Ruiz, J., Buck, B. E., & Penn, D. L. (2016). Relationship between olfactory function and social cognition in euthymic bipolar patients. *CNS spectrums*, 21(01), 53-59.

Lai, G., Schneider, H. D., Schwarzenberger, J. C., & Hirsch, J. (2011). Speech stimulation during functional MR imaging as a potential indicator of autism. *Radiology*, 260(2), 521–30. http://doi.org/10.1148/radiol.11101576

Lane, A. E., Dennis, S. J., & Geraghty, M. E. (2011). Brief report: Further evidence of sensory subtypes in autism. *Journal of autism and developmental disorders*, 41(6), 826-831.

Langland, R., & Panicucci, C. (1982). Effects of touch on communication with elderly confused clients. *Nursing*, 8(3), 152-155.

Lapenta, O. M., Fregni, F., Oberman, L. M., & Boggio, P. S. (2012). Bilateral temporal cortex
transcranial direct current stimulation worsens male performance in a multisensory integration task. *Neurosci Lett, 527*(2), 105-109. doi: 10.1016/j.neulet.2012.08.076

Lawson, R. P., Rees, G., & Friston, K. J. (2014). An aberrant precision account of autism. *Front Hum Neurosci, 8*, 302. doi: 10.3389/fnhum.2014.00302

Lee, K., Eskritt, M., Symons, L. A., & Muir, D. (1998). Children's use of triadic eye gaze information for “mind reading”. *Developmental psychology, 34*(3), 525.

Lee, P. S., Foss-Feig, J., Henderson, J. G., Kenworthy, L. E., Gilotty, L., Gaillard, W. D., & Vaidya, C. J. (2007). Atypical neural substrates of Embedded Figures Task performance in children with Autism Spectrum Disorder. *Neuroimage, 38*(1), 184-193. doi: 10.1016/j.neuroimage.2007.07.013

Leekam, S. (2016). Social cognitive impairment and autism: what are we trying to explain? *Philosophical Transactions of the Royal Society of London. Series B: Biological Sciences, 371*(1686), 20150082. doi: 10.1098/rstb.2015.0082

Leekam, S. R., Nieto, C., Libby, S. J., Wing, L., & Gould, J. (2007). Describing the sensory abnormalities of children and adults with autism. *J Autism Dev Disord, 37*(5), 894-910. doi: 10.1007/s10803-006-0218-7

Leekam, S., Baron-Cohen, S., Perrett, D., Milders, M., & Brown, S. (1997). Eye-direction detection: A dissociation between geometric and joint attention skills in autism. *British journal of developmental psychology, 15*(1), 77-95.

Lepistö, T., Kuitunen, A., Sussman, E., Saalasti, S., Jansson-Verkasalo, E., Nieminen-von Wendt, T., & Kujala, T. (2009). Auditory stream segregation in children with Asperger syndrome. *Biological Psychology, 82*(3), 301–307. http://doi.org/10.1016/j.biopsycho.2009.09.004
Lewis, J. W., Wightman, F. L., Brefczynski, J. A., Phinney, R. E., Binder, J. R., & DeYoe, E. A. (2004). Human brain regions involved in recognizing environmental sounds. *Cereb Cortex, 14*(9), 1008-1021. doi: 10.1093/cercor/bhh061

Lewkowicz, D. J. (2000). The development of intersensory temporal perception: An epigenetic systems/limitations view. *Psychological Bulletin, 126*(2), 281–308. http://doi.org/10.1037/0033-2909.126.2.281

Lewkowicz, D. J. (2010). Infant perception of audio-visual speech synchrony. *Developmental Psychology, 46*(1), 66–77. http://doi.org/10.1037/a0015579

Lin, I.-F., Agus, T. R., Suied, C., Pressnitzer, D., Yamada, T., Komine, Y., … Kashino, M. (2016). Fast response to human voices in autism. *Scientific Reports, 6*, 26336. http://doi.org/10.1038/srep26336

Linkenauger, S. A., Lerner, M. D., Ramenzoni, V. C., & Proffitt, D. R. (2012). A Perceptual-Motor Deficit Predicts Social and Communicative Impairments in Individuals With Autism Spectrum Disorders. *Autism Research, 5*(5), 352–362. http://doi.org/10.1002/aur.1248

Liu, X., Kawamura, Y., Shimada, T., Otowa, T., Koishi, S., Sugiyama, T., … & Umekage, T. (2010). Association of the oxytocin receptor (OXTR) gene polymorphisms with autism spectrum disorder (ASD) in the Japanese population. *Journal of human genetics, 55*(3), 137-141.

Löken, L., & Olausson, H. (2010). The skin as a social organ. *Experimental Brain Research, 204*(3), 305-314.

Loveland, K. A., Steinberg, J. L., Pearson, D. A., Mansour, R., & Reddoch, S. (2008). Judgments of auditory-visual affective congruence in adolescents with and without autism: A pilot
study of a new task using fMRI. Percept Mot Skills, 107(2), 557-575. doi: 10.2466/pms.107.2.557-575

MacLeod, a, & Summerfield, Q. (1987). Quantifying the contribution of vision to speech perception in noise. British Journal of Audiology, 21, 131–141. http://doi.org/10.3109/03005368709077786

Magnée, M. J. C. M., De Gelder, B., Van Engeland, H., & Kemner, C. (2007). Facial electromyographic responses to emotional information from faces and voices in individuals with pervasive developmental disorder. Journal of Child Psychology and Psychiatry and Allied Disciplines, 48(11), 1122–1130. http://doi.org/10.1111/j.1469-7610.2007.01779.x

Magnée, M. J. C. M., de Gelder, B., van Engeland, H., & Kemner, C. (2011). Multisensory integration and attention in Autism Spectrum disorder: Evidence from Event-related potentials. PLoS ONE, 6(8), 6–10. http://doi.org/10.1371/journal.pone.0024196

Magnée, M. J., de Gelder, B., van Engeland, H., & Kemner, C. (2008). Atypical processing of fearful face-voice pairs in Pervasive Developmental Disorder: An ERP study. Clinical Neurophysiology, 119(9), 2004–2010. http://doi.org/10.1016/j.clinph.2008.05.005

Mammen, M. A., Moore, G. A., Scaramella, L. V., Reiss, D., Ganiban, J. M., Shaw, D. S., Leve, L.; & Neiderhiser, J. M. (2015). Infant avoidance during a tactile task predicts autism spectrum behaviors in toddlerhood. Infant mental health journal, 36(6), 575-587.

Manning, C., Charman, T., & Pellicano, E. (2013). Processing slow and fast motion in children with autism spectrum conditions. Autism Res, 6(6), 531-541. doi: 10.1002/aur.1309

Marco, E. J., Hinkley, L. B., Hill, S. S., & Nagarajan, S. S. (2011). Sensory processing in autism: a review of neurophysiologic findings. Pediatr Res, 69, 48-54. doi:
Markram, H., Rinaldi, T., & Markram, K. (2007). The intense world syndrome— an alternative hypothesis for autism. *Frontiers in Neuroscience, 1*(1), 77–96. http://doi.org/10.3389/neuro.01.1.006.2007

Markram, K., & Markram, H. (2010). The intense world theory - a unifying theory of the neurobiology of autism. *Frontiers in Human Neuroscience, 4*(December), 224. http://doi.org/10.3389/fnhum.2010.00224

Marr, D. (1969). A theory of cerebellar cortex. *The Journal of Physiology, 202*(2), 437–470. http://doi.org/10.2307/1776957

Massaro, D. W., & Egan, P. B. (1996). Perceiving affect from the voice and the face. *Psychonomic Bulletin & Review, 3*(2), 215–221. http://doi.org/10.3758/BF03212421

Maurer, D., & Salapatek, P. (1976). Developmental changes in the scanning of faces by young infants. *Child development, 523*-527.

Mayer, J. L., & Heaton, P. F. (2014). Age and sensory processing abnormalities predict declines in encoding and recall of temporally manipulated speech in high-functioning adults with ASD. *Autism Research: Official Journal of the International Society for Autism Research, 7*(1), 40–9. http://doi.org/10.1002/aur.1333

McCleery, J. P., Allman, E., Carver, L. J., & Dobkins, K. R. (2007). Abnormal magnocellular pathway visual processing in infants at risk for autism. *Biol Psychiatry, 62*(9), 1007-1014. doi: 10.1016/j.biopsych.2007.02.009

McGaha, C. G., & Farran, D. C. (2001). Interactions in an inclusive classroom: The effects of visual status and setting. *Journal of visual Impairment and Blindness, 95*(2), 80-94.
McGlone, F., Wessberg, J., & Olausson, H. (2014). Discriminative and affective touch: Sensing and feeling. *Neuron*, 737-755.

McGurk, H., & Macdonald, J. (1976). Hearing lips and seeing voices. *Nature*, 264, 691–811. http://doi.org/10.1038/264746a0

Meaux, E., Gillet, P., Bonnet-Brilhault, F., Barthelemy, C., & Batty, M. (2011). Atypical perception processing and facial emotion disorder in autism. *Encephale*, 37(5), 371-378. doi: 10.1016/j.encep.2010.10.005

Meltzoff, A. N., & Decety, J. (2003). What imitation tells us about social cognition: a rapprochement between developmental psychology and cognitive neuroscience. *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 358(1431), 491–500. http://doi.org/10.1098/rstb.2002.1261

Menon, V. (2011). Large-scale brain networks and psychopathology: A unifying triple network model. *Trends in Cognitive Sciences*, 15(10), 483–506. http://doi.org/10.1016/j.tics.2011.08.003

Miall, R. C., Weir, D. J., Wolpert, D. M., & Stein, J. F. (1993). Is the cerebellum a smith predictor? *Journal of Motor Behavior*, 25(3), 203–216. http://doi.org/10.1080/00222895.1993.9942050

Miller Kuhaneck, H., & Britner, P. A. (2013). A preliminary investigation of the relationship between sensory processing and social play in autism spectrum disorder. *OTJR (Thorofare NJ)*, 33(3), 159-167. doi: 10.3928/15394492-20130614-04

Modahl, C., Green, L. A., Fein, D., Morris, M., Waterhouse, L., Feinstein, C., & Levin, H. (1998). Plasma oxytocin levels in autistic children. *Biological Psychiatry*, 43(4), 270-277.
Mgillo, E. A., Irwin, J. R., Whalen, D. H., Klaiman, C., Carter, A. S., & Schultz, R. T. (2008). Audiovisual processing in children with and without autism spectrum disorders. *Journal of Autism and Developmental Disorders, 38*(7), 1349–1358. http://doi.org/10.1007/s10803-007-0521-y

Moore, J. K., & Linthicum, F. H. (2007). The human auditory system: A timeline of development. *International Journal of Audiology, 46*(9), 460–478. http://doi.org/10.1080/14992020701383019

Mosconi, M. W., Mack, P. B., McCarthy, G., & Pelphrey, K. A. (2005). Taking an "intentional stance" on eye-gaze shifts: A functional neuroimaging study of social perception in children. *Neuroimage, 27*(1), 247-252. doi: 10.1016/j.neuroimage.2005.03.027

Mottron, L., & Burack, J. A. (2001). Enhanced perceptual functioning in the development of autism. In: Burack, Charman, Yirmiya, & Zelazo (Eds.), *The development of autism: Perspectives from theory and research.* (pp. 131–148). Mahwah, NJ: Erlbaum.

Mottron, L., Dawson, M., Soulieres, I., Hubert, B., & Burack, J. (2006). Enhanced perceptual functioning in autism: An update, and eight principles of autistic perception. *J Autism Dev Disord, 36*(1), 27-43. doi: 10.1007/s10803-005-0040-7

Mottron, L., Peretz, I., & Ménard, E. (2000). Local and global processing of music in high-functioning persons with autism: Beyond central coherence? *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 41*(8), 1057–65.

Mundy, P., & Crowson, M. (1997). Joint attention and early social communication: Implications for research on intervention with autism. *Journal of Autism and Developmental disorders, 27*(6), 653-676.

Mundy, P., & Newell, L. (2007). Attention, Joint Attention, and Social Cognition. *Curr Dir
Mundy, P., Sullivan, L., & Mastergeorge, A. M. (2009). A parallel and distributed-processing model of joint attention, social cognition and autism. *Autism Res, 2*(1), 2-21. doi: 10.1002/aur.61

Muth, A., Honekopp, J., & Falter, C. M. (2014). Visuo-spatial performance in autism: a meta-analysis. *J Autism Dev Disord, 44*(12), 3245-3263. doi: 10.1007/s10803-014-2188-5

Näätänen, R., Broadbent, D.E., James, W., 1990. The role of attention in auditory information processing as revealed by event-related potentials and other brain measures of cognitive function. *Behav. Brain Sci. 13*, 201–233. doi:10.1017/S0140525X00078407

Nackaerts, E., Wagemans, J., Helsen, W., Swinnen, S. P., Wenderoth, N., & Alaerts, K. (2012). Recognizing biological motion and emotions from point-light displays in autism spectrum disorders. *PLoS ONE, 7*(9), e44473. doi: 10.1371/journal.pone.0044473

Nair, A., Treiber, J. M., Shukla, D. K., Shih, P., & Müller, R. A. (2013). Impaired thalamocortical connectivity in autism spectrum disorder: A study of functional and anatomical connectivity. *Brain, 136*(6), 1942-1955.

Narumoto, J., Okada, T., Sadato, N., Fukui, K., & Yonekura, Y. (2001). Attention to emotion modulates fMRI activity in human right superior temporal sulcus. *Brain Res Cogn Brain Res, 12*(2), 225-231.

Nebel, M. B., Eloyan, A., Nettles, C. A., Sweeney, K. L., Ament, K., Ward, R. E., … Mostofsky, S. H. (2016). Intrinsic Visual-Motor Synchrony Correlates with Social Deficits in Autism. *Biological Psychiatry, 79*(8), 633–41. http://doi.org/10.1016/j.biopsych.2015.08.029

Nomi, J. S., & Uddin, L. Q. (2015). Face processing in autism spectrum disorders: From brain
regions to brain networks. *Neuropsychologia, 71*, 201-216. doi: 10.1016/j.neuropsychologia.2015.03.029

Novak, L. R., Gitelman, D. R., Schuyler, B., & Li, W. (2015). Olfactory-visual integration facilitates perception of subthreshold negative emotion. *Neuropsychologia, 77*, 288–297. http://doi.org/10.1016/j.neuropsychologia.2015.09.005

O’Connor, K. (2007). Brief report: Impaired identification of discrepancies between expressive faces and voices in adults with Asperger’s syndrome. *Journal of Autism and Developmental Disorders, 37*(10), 2008–2013. http://doi.org/10.1007/s10803-006-0345-1

O’Connor, K. (2012). Auditory processing in autism spectrum disorder: A review. *Neuroscience and Biobehavioral Reviews, 36*(2), 836–854. http://doi.org/10.1016/j.neubiorev.2011.11.008

O’Riordan, M., & Passetti, F. (2006). Discrimination in autism within different sensory modalities. *Journal of Autism and Developmental Disorders, 36*(5), 665–675. http://doi.org/10.1007/s10803-006-0106-1

O’Brien, J., Spencer, J., Girges, C., Johnston, A., & Hill, H. (2014). Impaired perception of facial motion in autism spectrum disorder. *PLoS ONE, 9*(7), e102173. doi: 10.1371/journal.pone.0102173

Olausson, H. L., Ekholm, S., Strigo, I., Worsley, K., Vallbo, Å., & Bushnell, M. C. (2002). Unmyelinated tactile afferents signal touch and project to insular cortex. *Nature neuroscience, 5*(9), 900-904.

Olausson, H., Wessberg, J., McGlone, F., & Vallbo, Å. (2010). The neurophysiology of unmyelinated tactile afferents. *Neuroscience & Biobehavioral Reviews, 34*(2), 185-191.

Oram Cardy, J.E., Flagg, E.J., Roberts, W., Roberts, T.P.L., 2008. Auditory evoked fields predict language ability and impairment in children. *Int. J. Psychophysiolog. 68*, 170–175.
Ozonoff, S., Iosif, A. M., Baguio, F., Cook, I. C., Hill, M. M., Hutman, T., ... & Steinfeld, M. B. (2010). A prospective study of the emergence of early behavioral signs of autism. *Journal of the American Academy of Child & Adolescent Psychiatry, 49*(3), 256-266.

Palmer, C. J., Paton, B., Hohwy, J., & Enticott, P. G. (2013). Movement under uncertainty: The effects of the rubber-hand illusion vary along the nonclinical autism spectrum. *Neuropsychologia, 51*(10), 1942–1951. http://doi.org/10.1016/j.neuropsychologia.2013.06.020

Palmer, C. J., Seth, A. K., & Hohwy, J. (2015). The felt presence of other minds: Predictive processing, counterfactual predictions, and mentalising in autism. *Conscious Cogn, 36*, 376-389. doi: 10.1016/j.concog.2015.04.007

Paton, B., Hohwy, J., & Enticott, P. G. (2012). The rubber hand illusion reveals proprioceptive and sensorimotor differences in autism spectrum disorders. *Journal of Autism and Developmental Disorders, 42*(9), 1870–1883. http://doi.org/10.1007/s10803-011-1430-7

Patriquin, M. A., DeRamus, T., Libero, L. E., Laird, A., & Kana, R. K. (2016). Neuroanatomical and neurofunctional markers of social cognition in autism spectrum disorder. *Hum Brain Mapp*. doi: 10.1002/hbm.23288

Paul, R., Augustyn, A., Klin, A., & Volkmar, F. R. (2005). Perception and production of prosody by speakers with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 35*(2), 205–20.

Paul, R., Chawarska, K., Fowler, C., Cicchetti, D., & Volkmar, F. (2007). “Listen My Children and You Shall Hear”: Auditory Preferences in Toddlers With Autism Spectrum Disorders.
SENSORY AND SOCIAL IMPAIRMENTS IN ASD

Journal of Speech Language and Hearing Research, 50(5), 1350.
http://doi.org/10.1044/1092-4388(2007/094)

Pavlova, M. A. (2012). Biological motion processing as a hallmark of social cognition. Cereb Cortex, 22(5), 981-995. doi: 10.1093/cercor/bhr156

Peiker, I., David, N., & Schneider, T. R. (2015). Perceptual Integration Deficits in Autism Spectrum Disorders Are Associated with Reduced Interhemispheric Gamma-Band Coherence. 35(50), 16352-16361. doi: 10.1523/jneurosci.1442-15.2015

Pellicano, E., & Burr, D. (2012). When the world becomes ‘too real': a Bayesian explanation of autistic perception. Trends Cogn Sci, 16(10), 504-510. doi: 10.1016/j.tics.2012.08.009

Pellicano, E., Maybery, M., Durkin, K., & Maley, A. (2006). Multiple cognitive capabilities/deficits in children with an autism spectrum disorder:” Weak” central coherence and its relationship to theory of mind and executive control. Development and psychopathology, 18(1), 77.

Pelphrey, K. A., & Carter, E. J. (2008). Brain mechanisms for social perception: lessons from autism and typical development. Ann N Y Acad Sci, 1145, 283-299. doi: 10.1196/annals.1416.007

Pelphrey, K. A., & Carter, E. J. (2010). Brain mechanisms underlying social perception deficits in autism. Human Behavior, Learning, and the Developing Brain: Atypical Development, 56.

Pelphrey, K. A., Morris, J. P., & McCarthy, G. (2004a). Grasping the intentions of others: the perceived intentionality of an action influences activity in the superior temporal sulcus during social perception. J Cogn Neurosci, 16(10), 1706-1716. doi: 10.1162/0898929042947900
Pelphrey, K. A., Morris, J. P., McCarthy, G., & Labar, K. S. (2007). Perception of dynamic changes in facial affect and identity in autism. *Soc Cogn Affect Neurosci, 2*(2), 140-149. doi: 10.1093/scan/nsm010

Pelphrey, K. A., Viola, R. J., & McCarthy, G. (2004b). When strangers pass: processing of mutual and averted social gaze in the superior temporal sulcus. *Psychol Sci, 15*(9), 598-603. doi: 10.1111/j.0956-7976.2004.00726.x

Perrone, J.A., 2007. Sensation and perception, in: Psychology in Aotearoa/New Zealand. Pearson Education New Zealand, Auckland, New Zealand, pp. 20–25.

Pierce, K., Müller, R. A., Ambrose, J., Allen, G., & Courchesne, E. (2001). Face processing occurs outside the fusiform face area in autism: Evidence from functional MRI. *Brain, 124*(10), 2059-2073.

Piwek, L., Pollick, F., & Petrini, K. (2015). Audiovisual integration of emotional signals from others’ social interactions. *Frontiers in Psychology, 6*, 1–10. http://doi.org/10.3389/fpsyg.2015.00611

Polan, H., & Ward, M. (1994). Role of the mother's touch in failure to thrive: A preliminary investigation. *Journal of the American Academy of Child and Adolescent Psychiatry, 33*(8), 1098-1105.

Purhonen, M., Kilpeläinen-Lees, R., Valkonen-Korhonen, M., Karhu, J., & Lehtonen, J. (2004). Cerebral processing of mother’s voice compared to unfamiliar voice in 4-month-old infants. *International Journal of Psychophysiology, 52*(3), 257–266. http://doi.org/10.1016/j.ijpsycho.2003.11.003
Puts, N. A., Wodka, E. L., Tommerdahl, M., Mostofsky, S. H., & Edden, R. A. (2014). Impaired tactile processing in children with autism spectrum disorder. *Journal of Neurophysiology, 111*(9), 1803-1811.

Quaia, C., Lefèvre, P., & Optican, L. M. (2012). Model of the Control of Saccades by Superior Colliculus and Cerebellum. *Journal of the International Neuropsychological Society, 18*(9), 999–1018.

Quattrocki, E., & Friston, K. (2014). Autism, oxytocin and interoception. *Neuroscience & Biobehavioral Reviews, 47*, 410-430.

Redcay, E. (2008). The superior temporal sulcus performs a common function for social and speech perception: Implications for the emergence of autism. *Neurosci Biobehav Rev, 32*(1), 123-142. doi: 10.1016/j.neubiorev.2007.06.004

Reece, C., Ebstein, R., Cheng, X., Ng, T., & Schirmer, A. (2016). Maternal touch predicts social orienting in young children. *Cognitive Development, 39*, 128-140.

Reichow, B. (2012). Overview of Meta-Analyses on Early Intensive Behavioral Intervention for Young Children with Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders, 42*(4), 512–520. http://doi.org/10.1007/s10803-011-1218-9

Ring, H. A., Baron-Cohen, S., Wheelwright, S., Williams, S. C., Brammer, M., Andrew, C., & Bullmore, E. T. (1999). Cerebral correlates of preserved cognitive skills in autism: A functional MRI study of embedded figures task performance. *Brain, 122* (Pt 7), 1305-1315.

Riquelme, I., Hatem, S., & Montoya, P. (2016). Abnormal pressure pain, touch sensitivity, proprioception, and manual dexterity in children with Autism Spectrum Disorders. *Neural Plasticity.*
Roberts, T.P.L., Khan, S.Y., Rey, M., Monroe, J.F., Cannon, K., Blaskey, L., Woldoff, S., Qasmieh, S., Gandal, M., Schmidt, G.L., Zarnow, D.M., Levy, S.E., Edgar, J.C., 2010. MEG detection of delayed auditory evoked responses in autism spectrum disorders: towards an imaging biomarker for autism. Autism Res. 3, 8–18. doi:10.1002/aur.111

Robertson, C. E., Thomas, C., Kravitz, D. J., Wallace, G. L., Baron-Cohen, S., Martin, A., & Baker, C. I. (2014). Global motion perception deficits in autism are reflected as early as primary visual cortex. Brain, 137(Pt 9), 2588-2599. doi: 10.1093/brain/awu189

Rogers, S. J., & Ozonoff, S. (2005). Annotation: what do we know about sensory dysfunction in autism? A critical review of the empirical evidence. J Child Psychol Psychiatry, 46(12), 1255-1268. doi: 10.1111/j.1469-7610.2005.01431.x

Ronconi, L., Molteni, M., & Casartelli, L. (2016). Building Blocks of Others' Understanding: A Perspective Shift in Investigating Social-Communicative Deficit in Autism. Front Hum Neurosci, 10, 144. doi: 10.3389/fnhum.2016.00144

Rosenblum, L. D. (2008). Speech perception as a multimodal phenomenon. Current Directions in Psychological Science, 17(6), 405–409. http://doi.org/10.1111/j.1467-8721.2008.00615.x

Rubin, K. H., Coplan, R., Chen, X., Bowker, J., & McDonald, K. L. (2011). Peer relationships in childhood. Social and Personality Development: An Advanced Textbook. 309–360. http://doi.org/10.1093/oxfordhb/9780199958474.013.0011

Russell-Smith, S. N., Maybery, M. T., Bayliss, D. M., & Sng, A. A. (2012). Support for a link between the local processing bias and social deficits in autism: an investigation of embedded figures test performance in non-clinical individuals. J Autism Dev Disord, 42(11), 2420-2430. doi: 10.1007/s10803-012-1506-z
Russo, N., Foxe, J. J., Brandwein, A. B., Altschuler, T., Gomes, H., & Molholm, S. (2010). Multisensory processing in children with autism: High-density electrical mapping of auditory-somatosensory integration. *Autism Research, 3*(5), 253–267. http://doi.org/10.1002/aur.152

Russo, N. M., Skoe, E., Trommer, B., Nicol, T., Zecker, S., Bradlow, A., … Turnbull, D. H. (2008). Deficient brainstem encoding of pitch in children with Autism Spectrum Disorders. *Clinical Neurophysiology: Official Journal of the International Federation of Clinical Neurophysiology, 119*(8), 1720–31. http://doi.org/10.1016/j.clinph.2008.01.108

Russo, N., Nicol, T., Trommer, B., Zecker, S., Kraus, N., 2009. Brainstem transcription of speech is disrupted in children with autism spectrum disorders. Dev. Sci. 12, 557–67. doi:10.1111/j.1467-7687.2008.00790.x

Rutgers, A. H., Bakermans- Kranenburg, M. J., Ijzendoorn, M. H., & Berckelaer- Onnes, I. A. (2004). Autism and attachment: a meta- analytic review. *Journal of Child psychology and Psychiatry, 45*(6), 1123-1134.

Rutherford, M. D., Clements, K. A., & Sekuler, A. B. (2007a). Differences in discrimination of eye and mouth displacement in autism spectrum disorders. *Vision research, 47*(15), 2099-2110.

Rutherford, M. D., Young, G. S., Hepburn, S., & Rogers, S. J. (2007b). A longitudinal study of pretend play in autism. *J Autism Dev Disord, 37*(6), 1024-1039. doi: 10.1007/s10803-006-0240-9

Sacrey, L. A. R., Armstrong, V. L., Bryson, S. E., & Zwaigenbaum, L. (2014). Impairments to visual disengagement in autism spectrum disorder: A review of experimental studies from infancy to adulthood. *Neuroscience & Biobehavioral Reviews, 47*, 559-577.
Saitovitch, A., Popa, T., Lemaitre, H., Rechtman, E., Lamy, J. C., Grevent, D., . . . Zilbovicius, M. (2016). Tuning Eye-Gaze Perception by Transitory STS Inhibition. *Cereb Cortex*, 26(6), 2823-2831. doi: 10.1093/cercor/bhw045

Samson, F., Hyde, K. L., Bertone, A., Soulieres, I., Mendrek, A., Ahad, P. . . . Zeffiro, T. A. (2011). Atypical processing of auditory temporal complexity in autistics. *Neuropsychologia, 49*(3), 546-555. doi: 10.1016/j.neuropsychologia.2010.12.033

Scheele, D., Kendrick, K., Khouri, C., Kretzer, E., Schläpfer, T., Stoffel-Wagner, B., Güntürkün, O., Maier, W., & Hurlemann, R. (2014). An oxytocin-induced facilitation of neural and emotional responses to social touch correlates inversely with autism traits. *Neuropsychopharmacology, 39*(9), 2078-2085.

Schelinski, S., Riedel, P., & von Kriegstein, K. (2014). Visual abilities are important for auditory-only speech recognition: Evidence from autism spectrum disorder. *Neuropsychologia, 65*, 1–11. http://doi.org/10.1016/j.neuropsychologia.2014.09.031

Scherf, K. S., Behrmann, M., Minshew, N., & Luna, B. (2008). Atypical Development of Face and Greeble Recognition in Autism. *J Child Psychol Psychiatry, 49*(8), 838-847. doi: 10.1111/j.1469-7610.2008.01903.x

Schmitz, N., Rubia, K., Van Amelsvoort, T., Daly, E., Smith, A., & Murphy, D. G. (2008). Neural correlates of reward in autism. *The British Journal of Psychiatry, 192*(1), 19-24.

Schuetze, M., Park, M. T. M., Cho, I. Y., MacMaster, F. P., Chakravarty, M. M., & Bray, S. L. (2016). Morphological Alterations in the Thalamus, Striatum, and Pallidum in Autism Spectrum Disorder. *Neuropsychopharmacology.*

Schultz, R. T., Gauthier, I., Klin, A., Fulbright, R. K., Anderson, A. W., Volkmar, F., ... & Gore, J. C. (2000). Abnormal ventral temporal cortical activity during face discrimination
among individuals with autism and Asperger syndrome. *Archives of general Psychiatry*, 57(4), 331-340.

Senju, A., Yaguchi, K., Tojo, Y., & Hasegawa, T. (2003). Eye contact does not facilitate detection in children with autism. *Cognition*, 89(1), B43-B51.

Shams, L., Kamitani, Y., & Shimojo, S. (2000). Illusions. What you see is what you hear. *Nature*, 408(6814), 788. http://doi.org/10.1038/35048669

Shapiro, T., Sherman, M., Calamari, G., & Koch, D. (1987). Attachment in autism and other developmental disorders. *Journal of the American Academy of Child & Adolescent Psychiatry*, 26(4), 480-484.

Sherman, S. M. (2007). The thalamus is more than just a relay. *Current opinion in neurobiology*, 17(4), 417-422.

Shih, P., Keehn, B., Oram, J. K., Leyden, K. M., Keown, C. L., & Muller, R. A. (2011). Functional differentiation of posterior superior temporal sulcus in autism: A functional connectivity magnetic resonance imaging study. *Biol Psychiatry*, 70(3), 270-277. doi:10.1016/j.biopsych.2011.03.040

Sigman, M., Mundy, P., Sherman, T., & Ungerer, J. (1986). Social interactions of autistic, mentally retarded and normal children and their caregivers. *J Child Psychol Psychiatry*, 27(5), 647-655.

Silva, L. M., Schalock, M., & Gabrielsen, K. R. (2015). About face: Evaluating and managing tactile impairment at the time of Autism diagnosis. *Autism research and treatment*.

Silva, L., & Schalock, M. (2016). First Skin Biopsy Reports in Children with Autism Show Loss of C-Tactile. *Journal of Neurological Disorders*, 4(2), 9-11.
Silverman, L. B., Bennetto, L., Campana, E., & Tanenhaus, M. K. (2010). Speech-and-gesture integration in high functioning autism. *Cognition, 115*(3), 380–393. http://doi.org/10.1016/j.cognition.2010.01.002

Simion, F., Regolin, L., & Bulf, H. (2008). A predisposition for biological motion in the newborn baby. *Proceedings of the National Academy of Sciences, 105*(2), 809-813. doi: 10.1073/pnas.0707021105

Simmons, D. R., Robertson, A. E., McKay, L. S., Toal, E., McAleer, P., & Pollick, F. E. (2009). Vision in autism spectrum disorders. *Vision Res, 49*(22), 2705-2739. doi: 10.1016/j.visres.2009.08.005

Skuse, D. H., Lori, A., Cubells, J. F., Lee, I., Conneely, K. N., Puura, K., Lehtimäki, T., Binder, E., & Young, L. J. (2014). Common polymorphism in the oxytocin receptor gene (OXTR) is associated with human social recognition skills. *Proceedings of the National Academy of Sciences, 111*(5), 1987-1992.

Smith, E. G., & Bennetto, L. (2007). Audiovisual speech integration and lipreading in autism. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 48*(8), 813–21. http://doi.org/10.1111/j.1469-7610.2007.01766.x

Smythies, J. (1997). The functional neuroanatomy of awareness: with a focus on the role of various anatomical systems in the control of intermodal attention. *Consciousness and cognition, 6*(4), 455-481.

Sokolov, E. N. (1963). Higher nervous functions: The orienting reflex. *Annual review of physiology, 25*(1), 545-580.

Song, Y., Hakoda, Y., Sanefuji, W., & Cheng, C. (2015). Can They See It? The Functional Field of View Is Narrower in Individuals with Autism Spectrum Disorder. *PLoS ONE, 10*(7),
Spencer, J. V., & O'Brien, J. M. (2006). Visual form-processing deficits in autism. *Perception, 35*(8), 1047-1055.

Stein, B. E., & Stanford, T. R. (2008). Multisensory integration: Current issues from the perspective of the single neuron. *Nature Reviews. Neuroscience, 9*(4), 255–266. http://doi.org/10.1038/nrn2377

Stern, D. N. (1985). The Interpersonal World of the Infant. *A View from Psychoanalysis and Developmental Psychology*. New York: Basic Books.

Stevenson, R. A., Segers, M., Ferber, S., Barense, M. D., & Wallace, M. T. (2014a). The impact of multisensory integration deficits on speech perception in children with autism spectrum disorders. *Frontiers in Psychology, 5*. http://doi.org/10.3389/fpsyg.2014.00379

Stevenson, R. A., Siemann, J. K., Woynaroski, T. G., Schneider, B. C., Eberly, H. E., Camarata, S. M., & Wallace, M. T. (2014b). Evidence for Diminished Multisensory Integration in Autism Spectrum Disorders. *Journal of Autism and Developmental Disorders, 44*(12), 3161–3167. http://doi.org/10.1007/s10803-014-2179-6

Stevenson, R. A., VanDerKlok, R. M., Pisoni, D. B., & James, T. W. (2011). Discrete neural substrates underlie complementary audiovisual speech integration processes. *Neuroimage, 55*(3), 1339-1345. doi: 10.1016/j.neuroimage.2010.12.063

Stevenson, R. A., Zemtsov, R. K., & Wallace, M. T. (2012). Individual Differences in the Multisensory Temporal Binding Window Predict Susceptibility to Audiovisual Illusions. *Journal of Experimental Psychology: Human Perception and Performance, 38*(6), 1517–1529. http://doi.org/10.1037/a0027339
Stienen, B. M. C., Tanaka, A., & de Gelder, B. (2011). Emotional voice and emotional body postures influence each other independently of visual awareness. *PLoS ONE*, 6(10). http://doi.org/10.1371/journal.pone.0025517

Stone, W. L., Hoffman, E. L., Lewis, S. E., & Ousley, O. Y. (1994). Early recognition of autism. Parental reports vs clinical observation. *Arch Pediatr Adolesc Med, 148*(2), 174-179.

Stoodley, C. J., & Schmahmann, J. D. (2009). Functional topography in the human cerebellum: A meta-analysis of neuroimaging studies. *NeuroImage, 44*(2), 489–501. http://doi.org/10.1016/j.neuroimage.2008.08.039

Strata, P., Scelfo, B., & Sacchetti, B. (2011). Involvement of cerebellum in emotional behavior. *Physiological research, 60*, S39.

Suarez, M. A. (2012). Sensory processing in children with autism spectrum disorders and impact on functioning. *Pediatr Clin North Am, 59*(1), 203-214. doi: 10.1016/j.pcl.2011.10.012

Sutherland, R. J., Whishaw, I. Q., & Kolb, B. (1988). Contributions of cingulate cortex to two forms of spatial learning and memory. *The Journal of neuroscience, 8*(6), 1863-1872.

Suzuki, Y., Critchley, H., Rowe, A., Howlin, P., & Murphy, D. (2003). Impaired olfactory identification in Asperger's syndrome. *The Journal of neuropsychiatry and clinical neurosciences, 15*(1), 105-107.

Swettenham, J., Baron-Cohen, S., Charman, T., Cox, A., Baird, G., Drew, A., … Wheelwright, S. (1998). The frequency and distribution of spontaneous attention shifts between social and nonsocial stimuli in autistic, typically developing, and nonautistic developmentally delayed infants. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 39*(5), 747–753. http://doi.org/10.1017/S0021963098002595

Swettenham, J., Remington, A., Laing, K., Fletcher, R., Coleman, M., & Gomez, J. C. (2013).
Perception of pointing from biological motion point-light displays in typically developing children and children with autism spectrum disorder. *J Autism Dev Disord, 43*(6), 1437-1446. doi: 10.1007/s10803-012-1699-1

Tager-Flusberg, H., Paul, R., & Lord, C. (2005). Language and Communication in Autism. In *Handbook of Autism and Pervasive Developmental Disorders, 1*, 335-364. http://doi.org/10.1002/9780470939345.ch12

Takarae, Y., Minshew, N. J., Luna, B., Krisky, C. M., & Sweeney, J. A. (2004). Pursuit eye movement deficits in autism. *Brain, 127*(12), 2584-2594.

Tamura, R., Kitamura, H., Endo, T., Hasegawa, N., & Someya, T. (2010). Reduced thalamic volume observed across different subgroups of autism spectrum disorders. *Psychiatry Research: Neuroimaging, 184*(3), 186-188.

Tanabe, H. C., Kosaka, H., Saito, D. N., Koike, T., Hayashi, M. J., Izuma, K., . . . Sadato, N. (2012). Hard to "tune in": neural mechanisms of live face-to-face interaction with high-functioning autistic spectrum disorder. *Front Hum Neurosci, 6*, 268. doi: 10.3389/fnhum.2012.00268

Tannan, V., Holden, J. K., Zhang, Z., Baranek, G. T., & Tommerdahl, M. A. (2008). Perceptual metrics of individuals with autism provide evidence for disinhibition. *Autism Research, 1*(4), 223-230.

Tavassoli, T., & Baron-Cohen, S. (2012). Taste identification in adults with autism spectrum conditions. *Journal of autism and developmental disorders, 42*(7), 1419-1424.

Tavassoli, T., Bellesheim, K., Siper, P. M., Wang, A. T., Halpern, D., Gorenstein, M., Grodberg, D.; Kolevzon, A.; & Buxbaum, J. D. (2016). Measuring sensory reactivity in autism
spectrum disorder: Application and simplification of a clinician-administered sensory observation scale. *Journal of autism and developmental disorders, 46*(1), 287-293.

Taylor, N., Isaac, C., & Milne, E. (2010). A comparison of the development of audiovisual integration in children with autism spectrum disorders and typically developing children. *Journal of Autism and Developmental Disorders, 40*(11), 1403–1411. http://doi.org/10.1007/s10803-010-1000-4

Teague, S. J., Gray, K. M., Tonge, B. J., & Newman, L. K. (2017). Attachment in children with autism spectrum disorder: A systematic review. Research in Autism Spectrum Disorders, 35, 35-50.

Teder-Sälejärvi, W. A., Pierce, K. L., Courchesne, E., & Hillyard, S. A. (2005). Auditory spatial localization and attention deficits in autistic adults. *Cognitive Brain Research, 23*(2-3), 221–34. http://doi.org/10.1016/j.cogbrainres.2004.10.021

Teunisse, J. P., & Gelder, B. D. (1994). Do autistics have a generalized face processing deficit? *International Journal of Neuroscience, 77*(1-2), 1-10.

Tomasello, M. (1995). Joint attention as social cognition. *Joint attention: Its origins and role in development*, 103-130.

Tomchek, S. D., & Dunn, W. (2007). Sensory processing in children with and without autism: A comparative study using the short sensory profile. *American Journal of occupational therapy, 61*(2), 190-200.

Tsatsanis, K. D., Rourke, B. P., Klin, A., Volkmar, F. R., Cicchetti, D., & Schultz, R. T. (2003). Reduced thalamic volume in high-functioning individuals with autism. *Biological psychiatry, 53*(2), 121-129.
Uddin, L. Q., & Menon, V. (2009). The anterior insula in autism: under-connected and under examined. *Neuroscience & Biobehavioral Reviews, 33*(8), 1198-1203.

Uljarević, M., Lane, A., Kelly, A., & Leekam, S. (2016). Sensory subtypes and anxiety in older children and adolescents with autism spectrum disorder. *Autism Research.*

Uvnäs-Moberg, K. (1998). Oxytocin may mediate the benefits of positive social interaction and emotions. *Psychoneuroendocrinology, 23*(8), 819-835.

Van Boxtel, J. J., & Lu, H. (2013). A predictive coding perspective on autism spectrum disorders. *Frontiers in psychology, 4*, 19.

Van de Cruys, S., de-Wit, L., Evers, K., Boets, B., & Wagemans, J. (2013). Weak priors versus overfitting of predictions in autism: Reply to Pellicano and Burr (TICS, 2012). *Iperception, 4*(2), 95-97. doi: 10.1068/i0580ic

Van Overwalle, F., Baetens, K., Mariën, P., & Vandekerckhove, M. (2014). Social cognition and the cerebellum: A meta-analysis of over 350 fMRI studies. *NeuroImage.* http://doi.org/10.1016/j.neuroimage.2013.09.033

Vandenbroucke, M. W. G., Scholte, H. S., van Engeland, H., Lamme, V. A. F., & Kemner, C. (2008). A neural substrate for atypical low-level visual processing in autism spectrum disorder. *Brain, 131*(4), 1013-1024. doi: 10.1093/brain/awm321

Vannetzel, L., Chaby, L., Cautru, F., Cohen, D., & Plaza, M. (2011). Neutral versus emotional human stimuli processing in children with pervasive developmental disorders not otherwise specified. *Research in Autism Spectrum Disorders, 5*(2), 775–783. http://doi.org/10.1016/j.rasd.2010.09.005

Venkataraman, A., Duncan, J. S., Yang, D. Y., & Pelphrey, K. A. (2015). An unbiased Bayesian approach to functional connectomics implicates social-communication networks in
Sensory and social impairments in ASD. *Neuroimage Clin*, 8, 356-366. doi: 10.1016/j.nicl.2015.04.021

Villalobos, M. E., Mizuno, A., Dahl, B. C., Kemmotsu, N., & Müller, R. A. (2005). Reduced functional connectivity between V1 and inferior frontal cortex associated with visuomotor performance in autism. *Neuroimage*, 25(3), 916-925.

von der Luhe, T., Manera, V., Barisic, I., Becchio, C., Vogeley, K., & Schilbach, L. (2016). Interpersonal predictive coding, not action perception, is impaired in autism. 371(1693). doi: 10.1098/rstb.2015.0373

Vouloumanos, A., & Curtin, S. (2014). Foundational tuning: how infants’ attention to speech predicts language development. *Cognitive Science*, 38(8), 1675–86. http://doi.org/10.1111/cogs.12128

Wallace, G. L., Budgett, J., & Charlton, R. A. (2016). Aging and autism spectrum disorder: Evidence from the broad autism phenotype. *Autism Research*.

Wallace, M. T., & Stevenson, R. A. (2014). The construct of the multisensory temporal binding window and its dysregulation in developmental disabilities. *Neuropsychologia*, 64, 105–123. http://doi.org/10.1016/j.neuropsychologia.2014.08.005

Wang, A. T., Lee, S. S., Sigman, M., & Dapretto, M. (2006). Neural basis of irony comprehension in children with autism: The role of prosody and context. *Brain*, 129(4), 932–943. http://doi.org/10.1093/brain/awl032

Wass, S. V., Jones, E. J., Gliga, T., Smith, T. J., Charman, T., & Johnson, M. H. (2015). Shorter spontaneous fixation durations in infants with later emerging autism. *Sci Rep*, 5, 8284. doi: 10.1038/srep08284

Waterhouse, L., Fein, D., & Modahl, C. (1996). Neurofunctional mechanisms in autism. *Psychological Review*, 103(3), 457–489. http://doi.org/10.1037/0033-295X.103.3.457
Weigelt, S., Koldewyn, K., & Kanwisher, N. (2012). Face identity recognition in autism spectrum disorders: a review of behavioral studies. *Neuroscience & Biobehavioral Reviews, 36*(3), 1060-1084.

Weiss, S. J., Wilson, P., Hertenstein, M. J., & Campos, R. (2000). The tactile context of a mother’s caregiving: implications for attachment of low birth weight infants. *Infant Behavior and Development, 23*(1), 91-111.

Weiss, S. J., Wilson, P., Seed, M. S. J., & Paul, S. M. (2001). Early tactile experience of low birth weight children: Links to later mental health and social adaptation. *Infant and Child Development, 10*(3), 93-115.

Wermter, A. K., Kamp-Becker, I., Hesse, P., Schulte-Körne, G., Strauch, K., & Remschmidt, H. (2010). Evidence for the involvement of genetic variation in the oxytocin receptor gene (OXTR) in the etiology of autistic disorders on high-functioning level. *American Journal of Medical Genetics Part B: Neuropsychiatric Genetics, 153*(2), 629-639.

Wessberg, J., & Norrsell, U. (1993). A system of unmyelinated afferents for innocuous mechanoreception in the human skin. *Brain Research, 628*(1), 301-304.

Whitehouse, A.J.O., Bishop, D.V.M., 2008. Do children with autism “switch off” to speech sounds? An investigation using event-related potentials. Dev. Sci. 11, 516–24. doi:10.1111/j.1467-7687.2008.00697.x

Wiggins, L., Robins, D., Bakeman, R., & Adamson, L. (2009). Brief report: sensory abnormalities as distinguishing symptoms of autism spectrum disorders in young children. *Journal of autism and developmental disorders, 39*(7), 1087-1091.
Williams, J. H. G., Massaro, D. W., Peel, N. J., Bosseler, A., & Suddendorf, T. (2004). Visual-auditory integration during speech imitation in autism. *Research in Developmental Disabilities, 25*(6), 559–575. http://doi.org/10.1016/j.ridd.2004.01.008

Williams, J. H. G., Whiten, A., & Singh, T. (2004). A systematic review of action imitation in autistic spectrum disorder. *Journal of Autism and Developmental Disorders, 34*(3), 285–299. http://doi.org/10.1023/B:JADD.0000029551.56735.3a

Wilson, C. E., Brock, J., & Palermo, R. (2010). Attention to social stimuli and facial identity recognition skills in autism spectrum disorder. *Journal of Intellectual Disability Research, 54*(12), 1104-1115.

Wolpert, D. M., Miall, R. C., & Kawato, M. (1998). Internal models in the cerebellum. *Trends in Cognitive Sciences, 2*(9), 338–347. http://doi.org/10.1016/S1364-6613(98)01221-2

Wolpert, D., Doya, K., & Kawato, M. (2003). A unifying computational framework for motor control and social interaction. *Philos Trans R Soc Lond B Biol Sci, 358*(1431), 593–602. http://doi.org/10.1098/rstb.2002.1238

Wu, S., Jia, M., Ruan, Y., Liu, J., Guo, Y., Shuang, M., ... & Zhang, D. (2005). Positive association of the oxytocin receptor gene (OXTR) with autism in the Chinese Han population. *Biological psychiatry, 58*(1), 74-77.

Xavier, J., Vignaud, V., Ruggiero, R., Bodeau, N., Cohen, D., & Chaby, L. (2015). A multidimensional approach to the study of emotion recognition in autism spectrum disorders. *Frontiers in Psychology, 6*, 1–9. http://doi.org/10.3389/fpsyg.2015.01954

Yirmiya, N., Gamliel, I., Pilowsky, T., Feldman, R., Baron-Cohen, S., & Sigman, M. (2006). The development of siblings of children with autism at 4 and 14 months: Social engagement, communication, and cognition. *Journal of Child Psychology and
*Psychiatry, 47*(5), 511-523.

Yu, L., Fan, Y., Deng, Z., Huang, D., Wang, S., & Zhang, Y. (2015). Pitch Processing in Tonal-Language-Speaking Children with Autism: An Event-Related Potential Study. *Journal of Autism and Developmental Disorders, 45*(11), 3656–3667. http://doi.org/10.1007/s10803-015-2510-x

Zalla, T., Sav, A. M., & Leboyer, M. (2009). Stimulus-reward association and reversal learning in individuals with Asperger Syndrome. *Research in Autism Spectrum Disorders, 3*(4), 913–923. http://doi.org/10.1016/j.rasd.2009.03.004

Zaytseva, Y., Gutyrchik, E., Bao, Y., Pöppel, E., Han, S., Northoff, G., Welker, L., Meindl, T., & Blautzik, J. (2014). Self processing in the brain: A paradigmatic fMRI case study with a professional singer. *Brain and cognition, 87*, 104-108.

Zou, L. Q., Yang, Z. Y., Wang, Y., Lui, S. S., Chen, A. T., Cheung, E. F., & Chan, R. C. (2016). What does the nose know? Olfactory function predicts social network size in human. *Scientific reports, 6.*