Physiological Arousal and Social Linguistic Perception in Children with Autism Spectrum Disorders

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ABSTRACT

Previous research suggests that social and communicative impairments in individuals with ASD may be related to difficulties in processing social linguistic information. Processing such information may be more difficult for individuals with ASD because they experience increased arousal in social situations. The objective of this study was to determine whether differences in arousal exist during social linguistic perception in children with ASD, when compared to arousal levels during perception of social non-linguistic and non-social non-linguistic stimuli. Potential influences of social anxiety and emotion were also explored. Nineteen children with ASDs and 19 typically developing children participated. Skin conductance responses (SCR) were used to measure arousal. Children with ASD were found to display increased SCRs to social stimuli when compared to non-social stimuli. No significant differences in SCRs were found between emotional and neutral stimulus conditions. Social anxiety was not related to differences in SCRs to social versus non-social stimuli.

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INTRODUCTION

Autism Characteristics

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by impairments in social and communicative domains (American Psychiatric Association, 2013). Research by Bebko, Weiss, Demark, and Gomez (2006) suggests that social and communicative impairments in individuals with ASD may be related to difficulties in processing social linguistic information. Specifically, Bebko et al. (2006) found that children with ASD displayed atypical perception of *temporal synchrony* when stimuli were social linguistic in nature. Perception of temporal synchrony between audio and visual components of the stimuli was measured using the Preferential Looking Paradigm: a paradigm in which two identical video clips are presented at the same time but only one of the video clips is synchronized in time with the audio output of the stimulus. Participants are considered to recognize temporal synchrony when they display non-random, preferential looking towards one of the two video clips, rather than the random 50:50 looking patterns that one would expect from chance. Bebko et al. (2006) found that children without a diagnosis of ASD displayed non-random preferential looking patterns across all conditions. Children with ASD performed similar to controls when stimuli were non-social non-linguistic in nature (e.g., a ball rolling and falling); however, for social linguistic stimuli (e.g., clips of women telling stories) only participants with ASD responded with no clear preference for temporally synchronized audio and visual information. Synchronization in time is an important cue in our association of relevant information and subsequent context-dependent interpretations of ambiguous situations. A lack of preference for temporally synchronized social linguistic stimuli may be indicative of sensory processing abnormalities. Importantly, a lack of preference for temporally synchronized social linguistic stimuli is also likely to lead to impaired interpretations of real-world social scenarios. The processing of social linguistic stimuli may be more difficult for individuals with ASD for several reasons, including pre-existing difficulties in processing language (Lord & Luyster, 2009), attention deficits (Keehn, Muller and Townsend, 2013), and increased arousal in social situations (Kylliainen & Hietanen, 2006).

Emotions

In addition to the linguistic, attentional, and arousal deficits often found in individuals with ASD, impairments in emotional perception are also common. Although these emotional impairments are not likely to play a role in impaired task performance in the Bebko et al. (2006) study, they do relate to the potential real-world applicability of any research on social impairments in this population. Most social interactions involve some degree of emotion and emotion itself is inherently social in nature.

Our appraisals of the emotions of others are largely context dependent (Anderson et al., 2008) and individuals with ASD have been shown to experience difficulty in filtering and sorting the information that they are bombarded with in terms of relevance (Rump, Giovannelli, Minshew, & Strauss, 2009). This is not surprising considering that Bolte and colleagues (2009) claim that the ability to recognize the emotional state of others requires the ability to divide attention and focus gaze on relevant information such as the information contained in the eyes, brow and mouth. This concept relates to the Bebko et al. (2006) study because recognizing temporal asynchrony would benefit similarly from the ability to divide and direct attention to the relevant information contained in these different areas of the face.

Studies of emotion processing impairments in ASD have tended to yield inconsistent results. Some studies have found individuals with ASD to be impaired in emotion perception (Golan, Baron-Cohen, & Golan, 2008; Gross, 2004; Rieffe, Terwogt, & Kotronopoulou, 2007;

Rump et al., 2009) while others have suggested that the ability to identify and understand emotions is intact in individuals with ASD, even though it may not necessarily be employed in everyday interactions (Rieffe, Terwogt, &Stockman, 2000; Uljarevic & Hamilton, 2013). Potential reasons that emotional perception may be impaired in some situations and not others relate back to the difficulty that individuals with ASD sometimes have in recognizing what cues may be relevant to interpreting the stimulus. For example Smith et al. (2010) propose that exaggerated emotional expressions provide individuals with ASD with the clear, unambiguous featural cues they rely on when processing emotion. In real life, however, many of the expressions that are vital to our understanding of other people are subtle and fleeting expressions of emotion. These subtle changes in emotional expression can often be ambiguous; therefore, accurate appraisal of such emotions requires the incorporation of contextual information. In fact, both Atkinson (2009) and Anderson and colleagues' (2008) provide evidence that the mapping of facial expressions to emotion categories can be influenced strongly by bodily and scene context, even at early stages of perception.

Impairments in emotional perception in ASD appear to be related to impairments in pragmatic skills (Wang & Tsao, 2015). Pragmatic abilities relate to one's ability to disambiguate meaning through contextual cues (Groen, Zwiers, van der Gaag, & Buitelaar, 2008). Pragmatic abilities can be subdivided into pragmatic language abilities and non-linguistic pragmatics (Groen et al., 2008), which include the interpretation of emotions and appraisals of the emotions of others (Anderson et al., 2008). Pragmatic language abilities refer to the ability to disambiguate meaning, structure coherent discourse, and understand irony (Groen et al., 2008). Since pragmatic abilities are related to both language and emotions (Anderson et al., 2008) it should not be surprising that language ability has been found to be significantly predictive of emotional understanding in children (Cutting & Dunn, 1999; de Rosnay & Harris, 2002; Pons, Lawson, Harris, & de Rosnay, 2003). Despite the fact that emotions are not directly implicated in the Bebko et al., (2006) study, their relationship to language and social information processing in general necessitate their consideration in discussions of social linguistic impairments in children with ASD.

Language Impairments

Although symptomatic presentation of ASD is variable, the delay of language acquisition is a common feature of the disorder and can often be the first recognized symptom. In fact, ASD was formerly thought to be primarily a language disorder (Lord & Luyster, 2009). Although some individuals with this disorder acquire language at an age comparable to that of their typically developing (TD) peers, these individuals may still present with impairments in language comprehension. For example, deficits in pragmatic language abilities are pervasive and usually lasting in ASD, even in highly verbal individuals (Lord & Luyster, 2009).

Pragmatic language impairments relate to difficulties in the ability to disambiguate meaning and to understand irony and implied meaning. Prosodic elements of speech are often related to linguistic communication of emotion. For example, Bemis, Grossman, Skwerer, and Tager-Flusberg (2010) describe affective prosody as a speaker varying the pitch and rate of an utterance to indicate his or her emotional state. Hubbard and Trauner (2007) found that although their ASD participants were able to process pitch, they were had difficulty correctly labelling the emotion of a speaker based on the prosodic elements of the speaker's utterances. Hubbard and Trauner suggest that this discrepancy may be because individuals with ASD missed other cues, such as the amplitude and duration of utterances, which also carry information about the intended emotion of the speaker. Gibbon, McCann, O'Hare, Peppe, and Rutherford (2006) report variable findings in the literature concerning the ability of individuals with ASD to understand affect as expressed by voice quality, intonation, and paralinguistic features. They argue, however, that the conflict in the findings may be the result of methodological difficulties because the literal interpretation of language and difficulty understanding metaphor in ASD indicate a consistent and pervasive impairment in this sphere.

Banerjee, Brooks, and Ploog (2009) propose that the prosodic impairments in ASD result from atypical attention to relevant information. They employed a forced-choice paradigm where participants were simultaneously presented with two sentences and reinforced for the selection of one over the other. Possible sentences included both statements and questions and prosodic inputs differed between the two as is typical in the common expression of the English language. Specifically, statements had a relatively flat prosodic contour, with a slight drop in pitch at the end of the statement whilst questions had a slight rise in pitch at the end of the pre-verbal noun and a greater rise in pitch at the end of the question. Children were not told which choice would be reinforced and were not told that reinforcement was only based on the *content* of the statement and not the prosodic input. When prosodic inputs matched the statement and question, both children with ASD and their TD peers presented with similar learning trajectories and were more likely to continue to select the choice that had previously been reinforced. However, the researchers found that when they varied the prosodic input of the reinforced stimulus – for example, if the sentence “Tom threw a ball” is the reinforced stimulus but prosodic input varies such that the stimulus is sometimes presented as “Tom threw a ball!” and sometimes as “Tom threw a ball?” - children with ASD paid equal attention to incongruent prosodic inputs as well as the content of verbal utterances, and failed to learn that the prosodic input was irrelevant. TD children tended to pay more attention to content suggesting that they were prioritizing linguistic features when the situation provided simultaneous stimulus choices offering conflicting information. The TD children displayed more efficient processing of linguistic information because, unlike the children with ASD, they were able to filter out the irrelevant conflicting information. These results are surprising considering the tendency of children with ASD to process language literally and their decreased tendency to attend to prosodic information. However, the results of the Banerjee, Brooks, and Ploog (2009) study may still be considered to support the idea that difficulties in processing language may play a role in the impaired task performance on social linguistic trials found in the Bebko et al., study. Similar to the Banerjee, Brooks, and Ploog (2009) paradigm, the Bebko et al., (2006) study added a layer of difficulty to the basic task of social linguistic perception. Similar to the manner in which the Banerjee, Brooks, and Ploog (2009) study varied prosody in their experimental task, the Bebko et al. (2006) study varied the temporal synchrony of the audiovisual stimulus. An inability to prioritize what aspects of the linguistic stimuli to attend to when conflicting information is provided, as was demonstrated by participants with ASD in the Banerjee, Brooks, and Ploog (2009) study, is likely to play a role in impaired performance on social linguistic trials in the Bebko et al., (2006) study.

Attention Deficits

Another factor that may lead to the poor performance of children with ASD on the social linguistic trials of the Bebko et al., (2006) study may be the attentional impairments that are often observed in individuals with the disorder. Impairments in attention may affect task performance in two ways: decreased attention to relevant information and increased attention to irrelevant information. Results of the Bebko et al., (2006) study suggest that impaired performance on the task may be due to individuals with ASD displaying decreased attention to the synchronization of the audio and visual components of the stimuli when the stimuli were social linguistic in nature.

Visual attention is particularly important for the development of our social information processing skills and the two have been found to be strongly related in TD individuals (Wagner, Luyster, Yim, Tager-Flusberg, & Nelson, 2013). In day-to-day interactions, attending to facial features such as the mouth and eyes can provide valuable contextual information regarding the intention of the speaker. In the Bebko et al., (2006) study, attending to features such as the mouth and eyes can also provide the participant with information regarding the lack of synchrony between the audio linguistic output and the visual stimulus. Speer, Cook, McMahon, and Clark (2007) found that, for social dynamic stimuli (clips of people interacting), individuals with ASD differed from TD individuals in regards to the amount of time they attended to certain facial features. Therefore, impaired performance by children with ASD on the social linguistic trials may have been affected, in whole or part, by impairments in attention, rather than pragmatic language difficulties alone. Furthermore, neuroimaging research on individuals with ASD suggests that both written and spoken language comprehension deficits in individuals with ASD may, in fact, arise from impairments in domains of higher cognitive processing such as attentional networks (Groen et al., 2008; Lord & Luyster, 2009; Norbury, 2005).

Attention is thought to mediate neuronal firing by selectively inhibiting neurons that are firing in response to irrelevant stimuli in order to limit interference with the individual's processing of relevant stimuli (Iriki, Tanaka, & Iwamura, 1996; Taylor, Hartley, & Taylor, 2006). EEG studies in individuals with ASD have found extensive evidence of cortical dysregulation (Hughes, 2008) which suggests that, in individuals with ASD, attentional systems may be failing to efficiently regulate cortical activity. Keehn, Muller and Townsend (2013) hypothesize that early attentional dysfunction in ASD may result in atypical development of social communicative abilities. Attentional difficulties are not considered to be core deficits of ASD; however, they are often noted as associated clinical features. Children with ASD tend to have difficulty selectively attending to important stimuli and ignoring distractions, particularly in the domain of social interaction (Hughes, 2008). In social scenarios this would suggest that individuals with ASD may have difficulty filtering contextual information when processing language. Norbury (2005) proposes that the failure to process meaningful linguistic context may arise from one or more of the following reasons: a failure to access or activate relevant information, a failure to integrate relevant information, or inefficiency in suppressing irrelevant information. All three reasons proposed by Norbury (2005) implicate attention in the processing of linguistic context: attention is necessary to coordinate cognitive resources and thus facilitate the encoding of relevant information from our environment (Carter et al., 2009; Norbury, 2005; Ward, 2010).

The idea that attentional impairments in ASD may be responsible for both impaired task performance in the Bebko et al. (2006) study and linguistic impairments in ASD in general is supported by Frith's (1996) Weak Central Coherence (WCC) theory of ASD. Frith's theory ascribes both social and language deficits in ASD to higher-order cortical dysregulation in this population (Frith, 1996). Frith proposes a distinction between global versus detailed perceptual processing and suggests that in ASD the core deficits are due to a failure to integrate local details into a global entity. An example of local details within a global entity would be the shape and positioning of the eyes, lips, and a nose within a face (global). Differences in the shape and positioning of these local details relative to one another and relative to the rest of the face can provide the observer with important information on the affect and social intentions of the owner of the face. WCC, or deficits integrating these local details into the larger global entity, may result in the observers missing out on this key information because they are processing each feature (i.e., the eyes, lips and nose) individually. Burnette et al. (2005) found that WCC was related to pragmatic language impairments among children with ASD. They suggest that different aspects of social information processing, such as extracting the meaning of context-dependent language, require the integration of local and global entities, and impaired integration of cortical information in ASD is thought to be the result of inadequate cortical connectivity.

Frith's (1996) WCC theory of ASD is supported by research that suggests individuals with ASD display reduced functional connectivity and reduced regional integration between frontal and parietal cortices (Carter et al., 2009; Hughes, 2008). The frontal and parietal cortices have both been implicated in unimodal and crossmodal attention, as well as higher order cognitive control (Coull, Frith, Frackowiak, & Grasby, 1996; Han et al., 2004; Miller & Cohen, 2001; Vohn et al., 2007). Specifically, the parietal cortex is implicated in storage of spatial information in working memory and the anterior frontal cortex has been associated with switching of attention between percepts and maintaining higher order and abstract mental representations of task contingencies (Carter et al, 2009). Miller and Cohen's (2001) guided activation hypothesis suggests that the prefrontal cortex is specialized for the representation and maintenance of task-relevant information or "context". These context representations mediate cognitive control through interactions that provide top-down biasing that modulates the flow of information in other brain systems (Carter et al, 2009). Carter et al. suggest that impairments in cognitive control may be related to the existence of attention deficit symptoms in ASD. This would suggest that inappropriate connectivity, resulting in reduced cognitive control, may lead to the attentional deficits described in individuals with ASD. Impaired task performance on the social linguistic trials of the Bebko et al., (2006) study may thus be influenced by attention deficits that appear to be present in individuals with ASD at a neurological level.

Arousal and Attention

Attention networks are inherently tied to arousal networks such that attention can be conceptualized as the focusing of more general activation of arousal networks. Pop-Jordanov & Pop-Jordanova (2009) define arousal as "general activation of the mind which results from the person's interaction with the environment" as equated with the general operation of consciousness (S71). Such "general activation" can be understood as random firing of neurons in the brain which are always present, even in the absence of external stimuli. This "general activation" or arousal is localized to more specific regions of the brain when one becomes more conscious of specific stimuli. For example, visual stimuli might increase general activation in the areas of the brain associated with the processing of visual information. This increase and focusing of "arousal" or "general activation" becomes known as "attention". Pop-Jordanov and Pop-Jordanova (2009) define attention as "the active or passive focussing of consciousness upon an experience" (pp. S71). Attention and arousal networks are thus thought to interact (Fimm, Willmes, & Spijkers, 2006) and arousal is thought to modify the allocation of attentional resources (Lane, Chua, & Dolan, 1999) and modulate attentional focus (Fernandes, Koji, Dixon, & Aquino, 2011; Vogt et al., 2008). This is particularly true for stimuli with inherent significance for survival (Lane, Chua, & Dolan, 1999) such as social stimuli.

Anderson, Pratt, and West (2009) suggest that, in TD individuals, faces act as motivationally significant stimuli because they provide both socially and biologically relevant information. As a result of this, they propose that faces influence the orienting and capture of attention. The results of their study demonstrate visual prior entry effects: a measure of initial attentional deployment. These effects, reflecting attentional capture, were found when using both schematic and realistic human faces as stimuli. Though the results of studies such as this suggest that arousal has a facilitatory effect on attention, research by Schimmack (2005) and McConnell and Shore (2011) suggests that *hyper*arousal can interfere with visual attention. This is particularly relevant for the present study because individuals with ASD have been found to display differences in arousal at both resting state (Eilam-Stock et al., 2014) and in response to some stimuli that are social or emotional in nature (Hubert, Wicker, Monfardini, & Deruelle, 2009; Kylliainen et al., 2012; Stagg, Davis, & Heaton, 2013) when compared to TD individuals.

Social Anxiety and Arousal

Research suggests that individuals with ASD often present with social anxiety symptoms above and beyond the social skill impairments that are core deficits of the disorder (Gillot, Furniss, & Walter, 2001; Kim, Szatmari, Bryson, Streiner, Wilson, 2000; Kuusikko et al., 2008). Social anxiety in ASD has been found to be related to atypical neural activation (Kleinhans et al., 2010) and physiological arousal (Stagg, Davis & Heaton, 2013) when viewing faces (Kleinhans et al., 2010,2013). Specifically, hyperarousal in social situations is related to the presence of social anxiety symptoms in individuals with ASD (Kleinhans et al., 2010; Kuusikko et al., 2008). Hyperarousal is likely to make social interactions aversive to the individuals experiencing these symptoms (Doherty-Sneddon et al. (2012) and can therefore reduce their motivation to interact and receive social information. In fact, a critical review of the literature by Rogers and Ozonoff (2005) suggests that the lack of interest in faces often observed in individuals with ASD may result from abnormal levels of arousal.

Although Vogt et al. (2008) found that arousing stimuli are attended to for longer periods of time by TD individuals the opposite may be true for individuals with ASD. Research by

Doherty-Sneddon et al. (2012) suggests that, in individuals with ASD, increased social arousal may result in *over*-stimulation which, in turn, results in lower rates of attendance to arousing stimuli. They propose that this over-stimulation causes individuals with ASD to withdraw and avert eye-gaze in order to manage or sustain cognitive resources. It is possible, then, that impairments in arousal regulation (i.e. due to social anxiety) may subsequently exacerbate existing difficulties in social linguistic processing. The practice of averting eye-gaze in order to avoid over-stimulation may also result in individuals with ASD missing important environmental cues during linguistic processing thus exacerbating pragmatic difficulties. As individuals with ASD have been found to display atypical arousal when presented with social stimuli (Kaartinen et al., 2012; Kylliainen & Hietanen, 2006) it is possible that arousal played a role in task performance in the Bebko et al. (2006) study. In fact, Bebko et al., (2006) found that children with ASD were more likely to look away from complex linguistic stimuli than TD children and children with other developmental disabilities. Interestingly, however, they found an inverse relationship between language ability and looking away behaviour such that children with decreased language abilities looked away from the screen more often, when the stimulus involved complex language. A similar pattern was found for simple linguistic stimuli, although this relationship was not significant. If we refer back to the theory proposed by Doherty-Sneddon et al. (2012), it is possible that for children with ASD in the Bebko et al., study, increased arousal in the social trials (possibly due to social anxiety) may have led to increased averted eye-gaze for this group. According to the theory by Doherty-Sneddon et al. (2012) this averted eye gaze is likely due to their need to conserve cognitive resources in order to process the linguistic aspects of the stimuli, particularly as the complexity of the linguistic stimuli increases.

Neural Correlates

Although, as stated above, impairments on social linguistic trials of the Bebko et al., (2006) study may be due to deficits in linguistic processing, deficits in attention, and deficits in arousal modulation, the present study focused on measuring arousal. The explicit measurement of language was deemed to be unnecessary because the potential role of language is accounted for in the design of the present study (to be described in more detail below). Furthermore, due to the relationship between attention and arousal at the neural level, measuring arousal may also indirectly provide information on how attention factors into social linguistic processing in individuals with ASD.

Neural Correlates of Arousal

Cerebral modulation of sweat gland activity is mainly attributed to the hypothalamic areas, especially the paraventricular and posterior nuclei (Boucsein, 1992). These regions of the hypothalamus receive input from other cortical areas such as the amygdala and other components of the limbic system. Depending on the type of information received, the hypothalamus is then able to participate in the innervation of sweat gland activity by means of sudomotor fibres that descend via hypothalamic-reticular-spinal sympathetic pathways (Boucsein, 1992).

Inputs from the amygdala and other areas of the limbic system to the hypothalamus are important for the regulation of autonomic function (Blumenfeld, 2010). Children with ASD have been found to have a larger amygdala than TD children; and amygdala size in toddlers with ASD has been found to be correlated with the severity of social and communication impairments (Schumann, Barnes, Lord, & Courchesne, 2009). A review on the neurobiology of ASD by Schultz (2005) provides reports of atypical neural activation in the amygdala when children with ASD view faces. Schultz (2005) suggests that these results implicate the amygdala in the social deficits found in ASD. Due to strong amygdala-hypothalamic connections this atypical activation of the amygdala in response to faces is likely to result in atypical autonomic arousal responses in individuals with ASD. These atypical autonomic arousal responses, in turn, may be related to the presence of social anxiety symptoms often observed in individuals with ASD (Gillot, Furniss, & Walter, 2001; Kim, Szatmari, Bryson, Streiner, Wilson, 2000; Kuusikko et al., 2008). Social anxiety in ASD has, in fact, been found to be specifically related to atypical activation in the amygdala (Kleinhans et al., 2010; Schultz, 2005) as well as increased physiological arousal (Stagg, Davis & Heaton, 2013) when viewing faces (Kleinhans et al., 2010).

Atypical arousal also has the potential to interfere with the allocation of visual attention through saccadic eye movements. The directing of visual attention toward relevant visual stimuli through saccadic eye movements is an important aspect of gathering of visual information. Cortical regions implicated in this ability include the superior colliculi, pretectal area, and pulvinar (Blumenfeld, 2010). These regions communicate with the parietotemporo-occipital cortex and frontal eye fields in order to direct visual attention accordingly (Blumenfeld, 2010). Arousal networks from the locus coerulus of the brain stem to the lateral geniculate nucleus of the thalamus and to the inferior parietal cortex have also been implicated in modulating attentional processing of visual signals (Fimm, Willmes, & Spijkers, 2006). Although the results of the Fimm, et al. (2006) study suggest that arousal has a facilitatory effect on visual attention, as stated earlier, research by Schimmack (2005) and McConnell and Shore (2011) suggests that hyperarousal can interfere with visual attention instead.

Interestingly, not only do individuals with ASD present as hyper-aroused in response to social stimuli but they also display hypo-arousal states at rest in comparison with their TD peers (Eilam-Stock, 2014). Furthermore, abnormal arousal levels have been developmentally associated with abnormal perception of novel information, reduced attention to social information, restricted and repetitive behaviours, over-focused attention, and reduced efficiency of executive control abilities: all symptoms commonly seen in individuals with ASD (Keehn, Muller, & Townsend, 2013).

Current Study

The goal of the present study was to extend the findings of Bebko et al. (2006) by exploring the relationship between arousal and social linguistic perception in individuals with ASD and TD controls. Specifically, the goal of this study was to determine whether differences in arousal exist during social linguistic perception in children with ASD, when compared to arousal levels during perception of social non-linguistic and non-social non-linguistic stimuli. Additionally, I measured arousal in the same conditions for TD children and compared responses of TD children to children with ASD. This was done to allow me to determine the degree to which children with ASD differ from their peers. Although it is possible that attention may have played a role in task performance in the Bebko et al., (2006), teasing apart the isolated influences of attention and arousal was beyond the scope of this study. Furthermore, as discussed earlier, arousal is so inherently tied to the allocation of attention at a neural level that the measurement of arousal alone is incredibly informative and can provide insight into the role that attention may play in social linguistic perception as well.

Due to the increased levels of social anxiety observed in individuals with ASD and the relationship between anxiety and arousal that I noted earlier, I also explored whether differences in arousal during the perception of social stimuli are related to symptoms of social anxiety.

Finally, in order to increase the real-world applicability of the findings and gain insight into the role that emotions play in social perception, I explored whether arousal differs during social perception when positive or negative emotional expressions are being observed.

Design

In order to further explore whether linguistic processing impairments that are common to individuals with ASD were responsible for poor task performance in the Bebko et al. (2006) study, in an additive design, an additional social, but non-linguistic condition was added. The additional condition allowed me to separate the social and linguistic aspects of the social linguistic stimuli used in the original Bebko et al. (2006) study. Due to the fact that language is challenging for individuals with ASD, it is difficult to determine whether impaired task performance in social linguistic trials is primarily due to language or due to social impairments on a broader scale. The separation of social and social linguistic stimuli in the present study attempted to tease that relationship apart. The social non-linguistic condition still retained an "oral" component (i.e., non-speech sounds made using the mouth) to allow me to more confidently determine whether the presence of language specifically - as opposed to oral sounds in general - results in differences in arousal in individuals with ASD.

As previously alluded to, individuals with ASD have also been found to have difficulty detecting and interpreting emotion (Hubert et al., 2009; Riby, Whittle, Doherty-Sneddon, 2012). Because of my interest in social perception in ASD and because most common conversational exchanges in the real world also include some degree of emotional expression, two emotional conditions were also added to the present study. The social non-linguistic emotional "happy" and "sad" conditions were added to allow for the exploration of any effect that positive or negative emotion may have on the relationship between social perception and arousal.

The resulting experimental design contained five conditions (Figure 1): non-social non-linguistic (NSNL), social non-linguistic oral (SNLO), social non-linguistic happy (SNLH; positive emotion), social non-linguistic sad (SNLS; negative emotion), and social linguistic (SL). These five conditions allowed me to separate out social, linguistic, and emotional aspects of social linguistic processing in order to determine which aspects lead to different arousal responses in individuals with ASD when compared to TD children. The NSNL condition differs from the SNLO condition through the addition of purely "social" information. A difference in arousal responses between these two conditions is thus expected to reflect a difference in the cognitive processing of purely social information, when compared to non-social information. Similarly, the SNLO condition differs from the SL condition through the addition of purely "linguistic" information and the SNLO condition differs from the SNLH and SNLS conditions through the addition of purely "emotional" information.

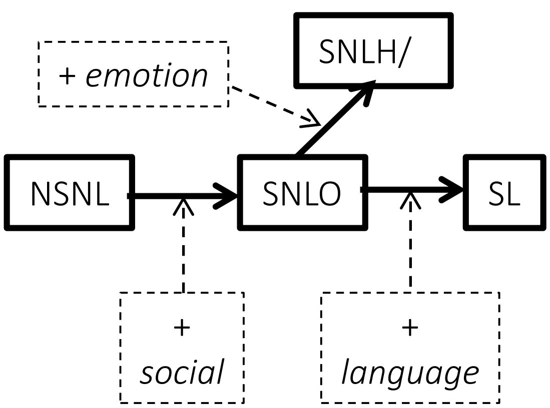

Figure 1: *Diagram of the five experimental conditions detailing how they fit into the subtractive design of the experiment. NSNL = non-social non-linguistic, SNLO = social non-linguistic oral, SL = social linguistic, SNLH = social non-linguistic "happy" (positive emotion), SNLS = social non-linguistic "sad" (negative emotion).*

For the purposes of analysis examination of differences between the five conditions was divided into two exploratory pathways. The first (Figure 2, see Results section) addressed my primary research question and explored the relationship between non-social non-linguistic stimuli, social non-linguistic oral stimuli, and social linguistic stimuli. This allowed me to determine whether arousal responses of children with ASD differ in response to social and/or linguistic aspects of perceived stimuli when compared to the responses of TD children. The second exploratory pathway (Figure 4, see Results Section) explored social non-linguistic stimuli and determined whether arousal differs in response to positive and/or negative emotional aspects of perceived stimuli when compared to neutral social non-linguistic stimuli. Comparison of the responses of children with ASD and those of TD children allows for the ability to determine the degree to which the two groups differ in their responses to neutral and emotional social non-linguistic stimuli. Individuals with ASD have been found to display different autonomic responses to pleasant and unpleasant social stimuli (Cohen, Masyn, Mastergeorge, & Hessl, 2015) and their subjective ratings of their arousal when viewing positive and negative emotional pictures also differ (Bolte, Feineis-Matthews, & Poustka, 2008). Research in this area is scarce; however, what research exists suggests that separate analysis of positive and negative emotion can provide more meaningful information regarding the relationship between arousal and non-linguistic social emotional perception.

In line with previous research (Kylliainen et al., 2012; Mathersul, McDonald, & Rushby, 2013a; Stagg, Davis & Heaton, 2013), I expected that children with ASD would display differences in arousal when the non-social condition was compared to the social conditions (i.e., social linguistic, social non-linguistic oral) because the social conditions contain faces and direct eye gaze. Furthermore, I expected that children with ASD would significantly differ from TD children in their responses to social stimuli.

This study is the first of its kind to look at arousal responses to social, linguistic, and emotional stimuli in tandem. Due to the exploratory nature of the proposed study I did not formulate a directional hypothesis regarding expected differences in arousal between the social linguistic, social non-linguistic and social non-linguistic emotional conditions for children with ASD. However, I determined that, if significant differences in arousal were found between the social linguistic and social non-linguistic conditions, these differences in arousal would be expected to indicate that impaired perception of temporal synchrony during social linguistic trials may be related to language processing difficulties in children with ASD. Similarly, significant differences in arousal between the social non-linguistic condition and the non-social non-linguistic condition, without significant differences between the social linguistic and social non-linguistic conditions, would suggest that impaired perception of temporal synchrony during social linguistic trials is primarily related to the social nature of the stimuli. In other words, the assumption in the present study was that, if increased arousal – and subsequent impairments in task performance - in social linguistic trials of the Bebko et al., (2006) study were in response to the social nature of the stimuli, levels of arousal would be similar between the two conditions. However, if language adds a layer of difficulty to social perception for individuals with ASD then I expect levels of arousal between the two conditions to be significantly different.

Finally, due to the relationship between social anxiety and arousal, the present study explored whether ratings of social anxiety symptoms in the child's day-to-day life are related to arousal responses to different types of social stimuli.

The present study attempted to answer the following research questions:

1. Compared to TD children, do children with ASD differ in the magnitude of their physiological responses to non-social and social stimuli?
2. Compared to TD children, do children with ASD differ in the magnitude of their physiological responses to linguistic and non-linguistic social stimuli?
3. Compared to TD children, do children with ASD differ in the magnitude of their physiological responses to emotional and unemotional social stimuli?

a. Does the valence of the emotion portrayed play a role in the arousal response to the stimuli?

4. Is social anxiety in ASD associated with differences in arousal in response to social stimuli?

METHODS

Participants

Participants in the ASD group were recruited from families that had participated in previous research with the Children's Learning Projects lab at York University. Additional participants in the ASD group were recruited through the Special Needs programs of two school boards in Cincinnati, Ohio. TD participants were recruited through friends and family. Participants were 19 children with an ASD and 19 TD children. All participants with ASD were previously diagnosed by a psychologist or psychiatrist according to DSM-IV-TR or DSM-5 criteria and were required to provide a copy of their diagnostic report to confirm diagnosis.

Participants with ASD fell within the age range of 7 years 3 months to 17 years 4 months (M_{age}=12.61, SD=2.88) and were comprised of 74% males. This sex bias is typical in this population as ASD is approximately four times more prevalent in males than it is in females (Centers for Disease Control and Prevention, 2010). Intellectual testing took place on the same day as the experimental task and was either conducted by myself or another trained member of the research team. The intellectual functioning of participants with ASD fell within the range of 87 to 123 (M_{IQ}=105.58, SD=11.92). TD participants fell within the age range of 7 years 5 months to 18 years 7 months (M_{age}=12.63, SD=3.05) and were comprised of 32% males. The intellectual functioning of TD participants fell within the range of 87 to 121 (M_{IQ}=103.79, SD=9.67). The groups were individually matched as closely as possible on chronological and mental age. IQ was matched within 15 points (1 standard deviation) and age was matched within one year and 3 months (18 out of 19 participants were matched within 6 months). Although the groups were not matched on sex the potential effects of sex were tested for and not found to be significant (see Results section for more detail). To confirm that there were no significant differences between the groups *t*-tests were completed comparing the chronological and mental age of the two groups. No significant differences were found between the groups on either of these variables (p_{age}=.930, p_{IQ}=.287).

All participants were verbal, native English speakers. All participants possessed normal or corrected-to-normal hearing and vision and, other than a diagnosis of ASD, participants had no known neurological issues, such as epilepsy or brain injury. Participants were instructed to refrain from consuming caffeine (e.g., coke) for two hours prior to testing, as per recommendations by Barry, Clarke, Johnston, and Rushby (2008).

Table 1: Participant Characteristics

	ASD (*N* = 19)			TD (*N* = 19)		
	Mean	SD	Range	Mean	SD	Range
Age	12.61	2.88	7.30-17.39	12.62	3.05	7.53-18.68
IQ (WASI-II)	105.58	11.92	87-123	103.79	9.67	87-121

Stimuli

Stimuli consisted of 5-second video clips from five different conditions: social linguistic (SL), social non-linguistic oral (SNLO), social non-linguistic emotional – happy (SNLH), social non-linguistic emotional – sad (SNLS), and non-social non-linguistic (NSNL). Social linguistic stimuli portrayed women telling various stories and social non-linguistic oral stimuli portrayed women making non-speech sounds with their mouths (e.g., clicking tongue). Emotional stimuli portrayed women expressing emotions without using speech: social non-linguistic happy stimuli portrayed women laughing and social non-linguistic sad portrayed women crying. Finally, non-social non-linguistic stimuli were represented by clips of a game of Mousetrap® (Milton Bradley) - where a ball was seen and heard rolling through a maze - and clips displaying a close-up of a hand playing a piano.

Each social condition had four versions of the stimuli portrayed by two different actors: two different clips per actor. Similar to the social conditions, the non-social non-linguistic condition also had four versions of the stimuli portrayed using two different objects - the mousetrap and the piano – with two different clips per object. Each version of each condition was played twice during the experiment, resulting in a total of 8 presentations of each condition. Children were simply required to view the stimuli.

Measures

Spence Children's Anxiety Scale, Parent Version (SCAS-P)

The Spence Children's Anxiety Scale – Parent Version (SCAS-P; Spence, 1998) is a parent self-report measure designed to assess children's anxiety symptoms as they relate to anxiety disorders described in the fourth edition of the diagnostic and statistical manual of mental disorders (DSM-IV; APA, 1994). The SCAS-P was selected as an anxiety measure for this study because it was developed for use with children in this study's age range and produces subscale measures of anxiety that map onto anxiety disorders described in the DSM-IV. Other commonly used measures of anxiety, such as the revised Children's Manifest Anxiety Scale (Reynolds & Richmond, 1978), do not provide information on the occurrence or severity of anxiety symptoms as they relate to specific anxiety disorder categories in diagnostic classifications systems. Although the SCAS-P was developed based on DSM-IV classifications of anxiety disorders, which have since been superceded by the DSM-5, the measure was still thought to possess practical utility for this study because few changes exist between DSM-IV and DSM-5 categories of anxiety.

The SCAS-P consists of thirty-eight items that map onto specific symptoms of anxiety and one open-ended item that does not factor into the child's score. Six of the 38 items are meant to map onto obsessive-compulsive problems, 6 are meant to map onto separation anxiety, 6 onto social phobia, 6 onto generalized anxiety symptoms, 9 onto panic disorder and agoraphobia, and 5 items map onto fears of physical injury. Parents are asked to rate the frequency with which they believe their child experiences the symptoms on a 4 point scale that gives options for the parent to select "never", "sometimes", "often", or "always". Examples of items from the SCAS-P are "My child worries what other people think of him/her" and "My child feels afraid when (s)he has to talk in front of the class".

Research on the psychometric properties of the SCAS-P with parents of children with and without anxiety disorders (Nauta, Scholing, Rapee, Abbott, Spence, & Waters, 2004) demonstrates that the measure has good internal consistency (α= 0.89) and inter-rater reliability (r = .51-.73). The measure also displays strong convergent validity with the Child Behavioural Checklist (CBCL)-internalizing subscale (r = .55-.59). Agreement between parent and child self-report on the SCAS-P items varied in both the anxiety-disordered group (r = .41-.66) and TD group (r = .23-.60) with agreement being strongest on items that reflected observable behaviour.

Spence Social Worries Questionnaire, Parent Version (SWQ-P)

The SWQ-P specifically assesses symptoms of *social* anxiety in children and adolescents. Although the SCAS-P contains a social phobia subscale the SWQ-P was judged to be an important measure to include because items on the SWQ-P inquire about specific avoidance or worrying behaviours that may be indicative of social anxiety, rather than inferred thoughts and feelings. Due to the communication impairment that is a central diagnostic feature of ASD, parents may be less able to reliably report on their child's thoughts and feelings that may be indicative of social anxiety. Examples of items on the SWQ-P are "he or she avoids or gets worried about meeting new people" and "he or she avoids or gets worried about entering a room full of people".

The SWQ-P is comprised of 10 items and asks parents to rate the frequency with which their child experiences the symptoms described. Parents are asked to rate the frequency on a 3 point scale that gives options for the parent to select "not true", "sometimes true", or mostly true".

The SWQ-P has good internal reliability, with a Guttman split-half reliability coefficient of 0.93 and coefficient alpha of 0.94 (Spence, 1995). Both the SCAS-P and SWQ-P have been successfully used with parents of children and adolescents with ASD in past studies (Gillot, Furniss, & Walter, 2001; Magiati, Chan, Tan, & Poon, 2014).

Autism Diagnostic Observation Schedule, Second Edition (ADOS-2; Lord, Rutter, et al., 2012)

The ADOS-2 is a semi-structured measure for the observational assessment of ASD. Specifically, tasks that comprise the ADOS-2 are designed to provide opportunities for clinicians to observe behaviours that are characteristic of or are usually impaired in individuals with ASD; such as, communication, social interaction, play, and restricted and repetitive behaviours.

Research on the psychometric properties of the ADOS-2 demonstrates that the measure has strong predictive validity, good inter-rater reliability (Mean exact agreement ranging from 88.2% to 91.5% across different modules), and good test-retest reliability (intraclass correlations of .90) (Lord, Rutter, et al., 2012).

The ADOS-2 was administered by a trained and research-reliable member of the Children's Learning Projects lab to all participants in the ASD group in order to re-confirm diagnosis.

Wechsler Abbreviated Scale of Intelligence, Second Edition (WASI-II; Wechsler, 2011)

The WASI-II is a brief standardized intelligence test designed for children and adults aged 6-90. The WASI-II provides composite scores that estimate general intellectual ability in the areas of verbal comprehension and perceptual reasoning. Four subtests comprise the WASI-II: Block Design, Vocabulary, Matrix Reasoning, and Similarities. Scores on these measures are combined to form a Full Scale Intelligence Quotient (FSIQ) score. These four subtests are similar in format to their counterparts in other Wechsler intelligence tests and have been specifically selected for WASI-II because they have the highest loadings onto general intellectual functioning (*g*). These four subtests therefore provide a way to quickly estimate general cognitive functioning. Administration of the WASI-II can be further shortened by the selection of just two subtests – Vocabulary and Matrix Reasoning – to provide an even quicker estimate of general cognitive functioning. Scores on these two subtests are combined to produce an FSIQ-2 score. Administration time for the two-subtest form is approximately 15 minutes.

Due to limited time the two-subtest form of the WASI-II was used in this study. The measure was administered to participants in both the ASD and TD groups by myself or another trained member of the Children's Learning Projects lab. Scores on the WASI-II were used to match participants from the ASD and TD groups on mental age.

The WASI-II has good internal consistency, with strong split-half reliability scores for children aged 6-16 years on individual subtests (r = .87-.91) and composites (r_{VCI} = .96; r_{PRI} = .93). Split-half reliability scores are strong for both the two-subtest version used in this study (*r*

=.89), and the four subtest version (*r* =.96). Test-retest reliability is also strong for subtests (*r* = .79-.90) and composites (*r* = .87- .95). Test-retest reliability is strong for both the two-subtest and four subtest version of the test as well (both above .90). Interrater reliability is also high (*r* = .94-.99) (Wechsler, 2011). The WASI-II shows strong convergent validity with the Weschler Intelligence Scale for Children, Fourth Edition (*r* = .91) and the Weschler Adult Intelligence Scale, Fourth Edition (*r* =.92). Although relational scores are not reported for the Kaufman Brief Intelligence Test, Second Edition, the correlation was reported as being strong to very strong. Finally, there is a strong correlation of .94 between the two-subtest and four-subtest versions of the WASI-II suggesting that the use of the two-subtest version did not result in a significant loss of validity in FSIQ measurements (Irby & Floyd, 2013).

Skin Conductance Response

Differences in arousal between the different conditions were measured through the collection of Skin Conductance Responses (SCR). SCR refers to momentary changes in the electrical resistance of the skin reflecting the function of sweat glands controlled by the sympathetic nervous system (Andreassi, 2000). SCR may reflect stimulus-induced changes in arousal as well as the allocation of attention to stimuli over time (Mathersul, McDonald, & Rushby, 2013b) and has been interpreted to be a sensitive method for collecting psychophysiological data on stimulus-related arousal. SCR should be distinguished from Skin Conductance Level (SCL) or the tonic, slowly habituating level of electrical conductivity of skin. SCR, on the other hand, refers specifically to rapid phasic *changes* in skin conductivity (Braithwaite, Watson, Jones, & Rowe, 2013). SCR Data were recorded using PowerLab hardware (ADInstruments, 2004) connected to a Dell® personal computer, which sampled electrodermal activity at 1kHz.

Procedure

Parents were given an information letter (Appendix A) to read and were asked to sign an informed consent form (Appendix B). The procedure was explained to children in language appropriate to the child's age and all children were asked to sign an assent form (Appendix C). Participants were then seated approximately 50 cm in front of the computer screen and asked to adjust their seating position until comfortable. Participants were instructed to choose a comfortable seating position in which they would be able to sit for approximately 20 minutes with little movement. The palmar surface of the index and middle digits of the participant's non-dominant hand (assessed by asking participants) were cleaned using alcohol wipes. Two 2 cm x 2.5 cm stainless steel finger plate surface electrodes were then placed on the medial phalanges of the aforementioned digits and secured with Velcro straps. The index-middle finger combination is recommended for SCR measurement because those two fingers are situated on the same dermatome (an area of skin supplied by a single spinal nerve), and asynchronism of sweat glands which could affect SCR measurements is thus avoided (Boucsein, 1992). No recording gel was used with the electrodes in accordance with the guidelines provided by ADInstruments (2008). Participants were reminded to move as little as possible during the presentation of stimuli in order to avoid movement artefacts in the SCR data. Throughout the experiment the child was monitored for movement and associated disruptions in SCR signal were noted in their file. Trials with movement artefacts were then excluded from further analysis.

Following the attachment of electrodes participants were asked to relax and view a fixation cross on a computer monitor for two minutes in order to allow their SCR levels to stabilize. The cross changed colours every ten seconds to maintain the child's interest. Participants wore noise isolating headphones during stimulus presentation in order to standardize audio amplitude to a range of 50-60dB and minimize noise. The experiment consisted of a total of four blocks, each lasting approximately 4 minutes in length. Blocks were divided by short breaks that allowed the child to rest their eyes or readjust their seating position. The break between the second and third block lasted for 1 minute. The other two breaks lasted for 10 seconds. The entire experiment lasted approximately 20 minutes. Stimulus presentation order was pseudo-randomized such that each version of each condition was preceded and followed by every other version of each condition only once. For example, since every condition contained four different versions, version one of the social linguistic condition was only preceded by version two of the non-social non-linguistic condition only once. Each stimulus presentation was preceded by a fixation cross for an interstimulus interval (ISI) of three seconds.

SCR Analysis

Chart 5 software (ADInstruments, 2004) was used for the recording and preliminary assessment of the SCR data. The amplitude of the SCR is the most reliable measure of arousal that can be extracted from SCR data. The standard method for determining SCR amplitude defines SCR amplitude as the *difference* between the skin conductance value at its peak and the skin conductance value at the preceding trough (Boucsein, 1992). SCRs in the present study were computed according to the standard criteria using the largest deflection during a 4 s window beginning 1 s after the onset of a stimulus serving as a measure of autonomic response to that stimulus. This time frame was selected because SCR responses have been shown to have an onset latency of 1 second and it may take up to 3 seconds for a SCR to reach its peak (Boucsein, 1992). The minimum amplitude criterion was set to 0.01 microSiemens (μS) so that trough-to-peak amplitude changes smaller than this value were not considered to be significant. Minimum criterion thresholds for SCRs typically fall within the range of 0.01-0.05μS with smaller values becoming more and more common as advances in technology and precision increase (Braithwaite, Watson, Jones, & Rowe, 2013).

ISIs in this study were considered too short (3 seconds) to ensure that the SCR returned to baseline prior to the presentation of the next stimulus. For ISIs this short, many researchers, including Benedek and Kaernbach (2010a,b), recommend that the SCR data undergo a mathematical correction in order to adjust the data for the potential of overlapping SCRs. A continuous decomposition analysis was applied to the data using Ledalab software (Benedek & Kaernbach, 2010a) in Matlab. Benedek and Kaernbach, (2010a) provide a detailed explanation of the continuous decomposition analysis correction procedure. Similar methods of correcting SCRs for potential overlap have been proposed by several researchers (Alexander et al., 2005; Bach, Flandin, Friston, & Dolan, 2010; Green, Kragel, Fecteau, & LaBar, 2014; Lim et al., 1997; Williams et al., 2001) and have been used on different populations including individuals with a diagnosis of panic disorder (Wise, McFarlane, Clark, & Battersby, 2009), cerebral palsy (Leung & Chau, 2014), and anxiety- and depression-prone persons (Dibbets, van den Broek, & Evers, 2015).

Despite the added analytical steps required, the shortening of ISIs has many benefits, including shortened experiment time which, in turn, allows for the ability for an increased number of stimulus repetitions and supports the maintaining of rapport with participants. Additionally, because movement can interfere with SCR measurements trials with movement artefacts were excluded from analysis. In anticipation of the necessity of deleting some trials multiple presentations of the stimuli from each condition were judged to be necessary and shortened ISIs provided a viable way to increase the number of stimulus presentations without excessively lengthening the duration of the experimental task. Children with ASD also tend to have sensory sensitivity and can sometimes be resistant to having foreign objects (such as SCR electrodes) attached to their body. Lengthy ISIs would increase the amount of time during which the child would have to experience this discomfort and as a result, the shortening of ISIs was judged to be highly beneficial in the context of the present study.

After trials were excluded due to movement artefacts ASD participants retained a mean of 87.5% of their data (range: 72.5% to 100%) and TD participants retained a mean of 91.3% of their data (range: 75% to 100%).

For each individual, outliers were identified for each condition as SCR values that fell outside the interquartile range for that individual's data points in that specific condition. Analyses were run once with and without outliers excluded. Results did not significantly differ so results are presented below for the dataset in its entirety, without the exclusion of any outliers.

RESULTS

For each participant, a mean SCR value was calculated for each condition. Mean SCRs of the ASD group were generally higher and showed greater variability than those of the TD group (Table 2).

Table 2: Mean SCR in each condition by group

Table 2. Mean SCR (μS) in each condition by group.

		Range	*M*	*SD*
ASD (*N*=19)	NSNL	.05 – 12.40	2.04	2.84
	SNLO	.07 - 14.95	2.64	3.74
	SL	.07-15.33	2.51	3.56
	SNLH	.06 -19.03	2.80	4.49
	SNLS	.05 - 15.21	2.44	3.69

	NSNL	.01 - 8.53	1.16	1.99
	SNLO	.07-5.23	1.02	1.50
TD	SL	.07 - 4.74	.97	1.31
(*N*=19)	SNLH	.05 -6.76	1.11	1.87
	SNLS	.05 - 6.58	1.15	1.84

NSNL = non-social non-linguistic, SNLO = social non-linguistic oral, and SL = social linguistic

Social Linguistic Perception

In order to answer my first and second research questions, I compared mean SCR values of the NSNL, SNLO, and SL conditions with one another. The relationship between these three conditions is portrayed in Figure 2.

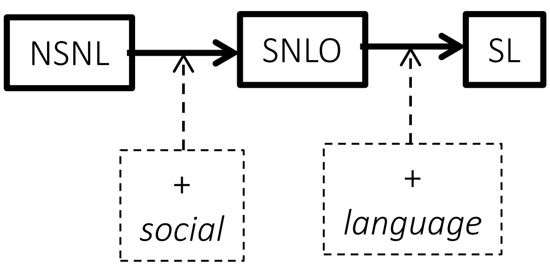

Figure 2: *Diagram of the first pathway of analysis intended to explore the relationship between social and social linguistic processing. Analysis explored mean differences in SCR between the different conditions in order to determine whether the addition of "social" and/or "linguistic" features to the stimuli led to differences in arousal. NSNL = non-social non-linguistic, SNLO = social non-linguistic oral, and SL = social linguistic.*

A 3 (condition) x 2 (group) repeated measures ANOVA was conducted to determine whether differences in SCR exist between NSNL, SNLO, and SL conditions when children with ASD are compared to TD children. Mauchly's test of sphericity indicated that the condition variable violated the assumption of sphericity. The degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, $\varepsilon = .67$. The main effects of group and condition were not significant ($p_{group} = .119$, $p_{condition} = .403$). The overall interaction between condition and group was borderline significant $F(1, 2.01) = 3.85$, $p = .058$, $\eta_p^2 = .097$. It is possible that, due to the modest sample size of the present study (N=38), limited statistical power may have played a role in limiting the significance of my findings. Graphical representation of mean differences in group SCR by condition reveal clear differences between the groups (see Figure 3), with means for the ASD group nearly double the means of the TD group or greater.

Post hoc comparisons revealed that while mean SCR during the NSNL trials did not significantly differ when children with ASD were compared to TD children, $t(36)=1.11$, $p = .392$, the two groups significantly differed in their mean SCR during the SNLO trials $t(36)=1.76$, $p = .045$. Differences between the groups in mean SCR during the SL trials approached significance $t(36)=1.76$, $p = .072$. The TD group's mean SCRs do not appear to differ greatly among the three conditions suggesting that neither social nor social linguistic perception affect arousal in TD children any more than perception of stimuli in general. For the ASD group however, mean SCRs are greater during the presentation of social stimuli (SNLO and SL conditions) when compared to mean SCRs during the presentation of non-social stimuli (NSNL condition). There does not appear to be a large difference in mean SCR during social non-linguistic oral versus social linguistic stimulus presentations, suggesting that social *linguistic* perception does not affect arousal in individuals with ASD any more than social perception in general (see Table 2 for mean SCR values).

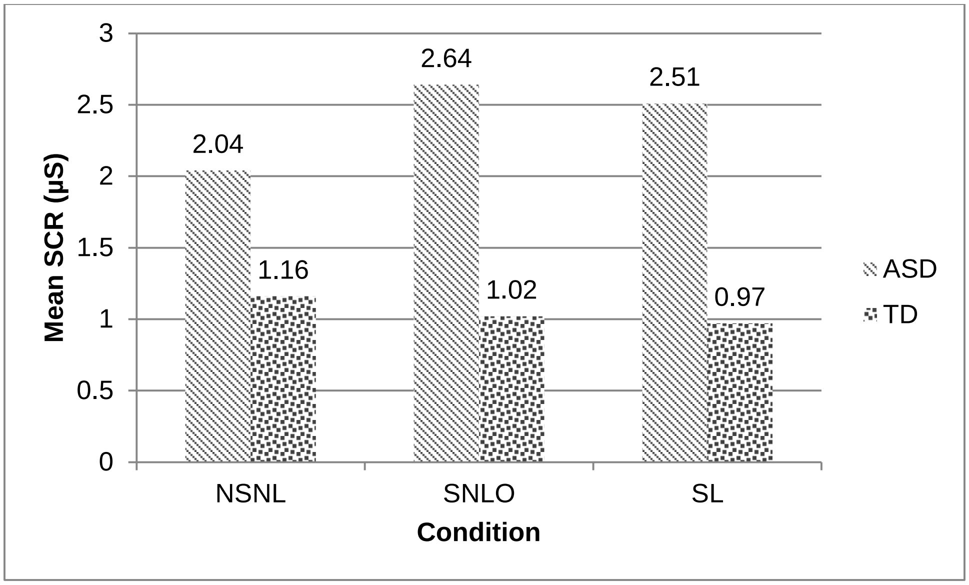

Figure 3: *Mean SCR (µS) for each group by condition. NSNL = non-social non-linguistic, SNLO = social non-linguistic oral, and SL = social linguistic. Differences in mean SCR between the groups for the SNLO condition were significant (p = .045) and differences between the groups for the SL condition approached significance (p = .072).*

Emotional Perception

In order to answer my third research question, I compared mean SCR values of the NSNL, SNLO, SNLS and SNLH conditions with one another, paying particular attention to the three social conditions but maintaining the presence of the non-social condition as a point of comparison. The relationship between these four conditions is portrayed in Figure 4.

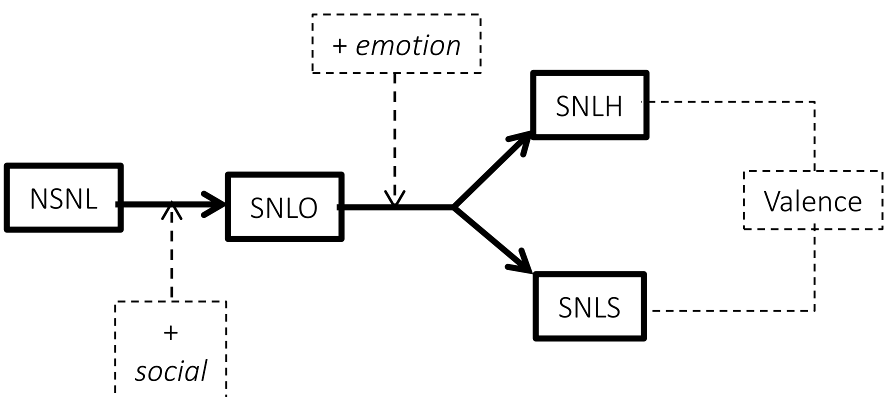

Figure 4: *Diagram of the second pathway of analysis intended to explore the relationship between social and social emotional processing. Analysis explored mean differences in SCR between the different conditions in order to*

determine whether the addition of "social" and/or "emotional" features to the stimuli led to differences in arousal. The model also allows for the exploration of the potential effects of emotional valence on arousal.

A 4 (condition) x 2 (group) repeated measures ANOVA was conducted to determine whether differences in SCR exist between NSNL, SNLO, SNLH and SNLS conditions when children with ASD are compared to TD children. Mauchly's test of sphericity indicated that the condition variable violated the assumption of sphericity. The degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity, $\varepsilon = .76$. There were no significant main effects or interactions; however, it is possible that limited power due to the modest sample size of the present study may have limited the significance of my findings.

Post hoc comparisons revealed that while mean SCR during the SNLS trials did not significantly differ when children with ASD were compared to TD children, differences in mean SCR during the SNLH trials approached significance $t(36)=1.51$, $p = .071$. The SNLH condition also contained the greatest amount of variability in mean SCR for the ASD group (Table 2). Figure 5 displays mean SCR for the two groups during the four conditions.

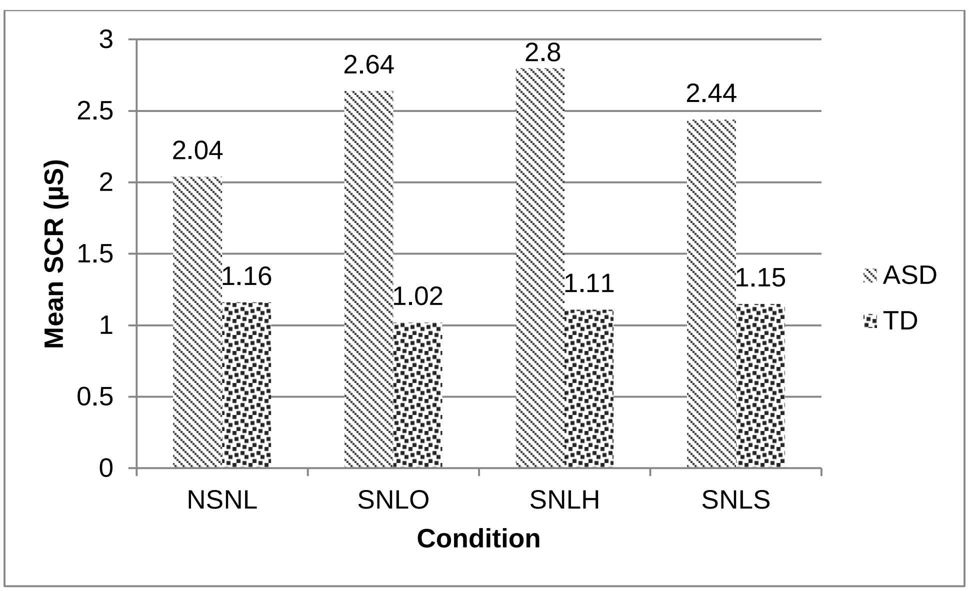

Figure 5: *Mean SCR (µS) for each group by condition. NSNL = non-social non-linguistic, SNLO = social non-linguistic oral, SNLH = social non-linguistic "happy" (positive emotion), and SNLS = social non-linguistic "sad" (negative emotion). For the ASD group, SCRs were greatest during the SNLH condition and lowest during the*

presentation of NSNL condition. Differences in mean SCR between the groups during the SNLH trials approached significance (p = .071).

Social Anxiety

Children with ASD had significantly greater overall scores on the Spence Children's Anxiety Scale (SCAS-P) $t(36) = 2.91$, $p = .048$ than TD children as well as significantly higher scores on the Panic Attack $t(36) = 2.029$, $p = .041$, Social Phobia $t(36) = 2.472$, $p = .014$, and Obsessive Compulsive $t(36) = 2.999$, $p = .001$ subscales (see Table 3). The mean of scores obtained by children with ASD on the SCAS-P were far more similar to means obtained by anxiety-disordered children than typically developing children using the same measure in the Nauta et al. (2004) study. Children with ASD also had significantly higher scores on the Social Worries Questionnaire (SWQ-P), $t(36) = 3.387$, $p = .014$ (Table 3) when compared to TD children.

Table 3: Mean scores on the Spence Children's Anxiety Scale (including subscale scores) and the Social Worries Questionnaire

	ASD (*N*=19)			TD (*N*=19)		
	Range	*M*	*SD*	Range	*M*	*SD*
SCAS-P Overall Score	4-68	29.42	17.61	2-53	15.53	11.09
SCAS-P Panic Attack Subscale	0-15	4.16	4.54	0-15	1.53	3.37
SCAS-P Separation Anxiety Subscale	0-15	4.11	3.86	0-7	2.47	2.34
SCAS-P Physical Subscale	0-15	4.37	3.22	0-8	3.26	2.54
SCAS-P Social Phobia Subscale	0-18	6.79	5.12	0-8	3.53	2.63
SCAS-P Obsessive	0-12	4.32	3.65	0-8	1.42	2.09

Compulsive Subscale						
SCAS-P Generalized Anxiety Subscale	1-12	5.68	3.50	1-10	3.32	2.38
Social Worries Questionnaire	0-19	9.42	5.95	0-14	3.89	3.90

Note. Potential scores on the Spence Children's Anxiety Scale range from 0 – 114 with higher scores indicating the endorsement of more anxiety symptoms. The maximum potential scores for each of the subscales of the SCAS-P are as follows: Panic Attack and Agoraphobia (max = 36), Separation Anxiety (24), Physical Injury Fears (20), Social Phobia (24), Obsessive Compulsive (24), Generalized Anxiety (24). The maximum potential score that a child could receive on the Social Worries Questionnaire is 20 with higher scores indicating greater social anxiety.

Anxiety scores and, more specifically, social anxiety scores in this sample conformed to expectations of increased anxiety in children with ASD when compared with TD children as found in the literature (e.g., Gillot, Furniss, & Walter, 2001; Magiati, Chan, Tan, & Poon, 2014). In order to determine whether increased social anxiety in ASD is related to increased arousal during the perception of social stimuli all four social conditions were averaged together and a difference score was created that subtracted the mean SCRs of all the social conditions (SNLO, SL, SNLH, and SNLS) from the non-social condition (NSNL). Spearman's rho was then calculated to determine the degree to which social anxiety scores were related to differences in arousal responses between social and non-social stimuli. Analyses were run using both the SCAS-P Social Phobia subscale and the SWQ-P as measures of social anxiety. Results of the correlation analysis were not statistically significant suggesting that social anxiety did not play a role in moderating SCR differences between social and non-social conditions. As a follow-up analysis, four additional difference scores were created by subtracting each of the social conditions from the non-social condition separately. The difference between mean SCRs in the NSNL and SL conditions was found to be significantly related to social anxiety scores on the

SCAS-P Social Phobia subscale ($r_s = .728$, $p < .001$) and the SWQ-P ($r_s = .524$, $p = .021$) for the TD group only.

Sex Differences

Due to the differences in sex ratios between the two groups (74% males in the ASD group versus 32% males in the TD group) all analyses were re-run using sex as a factor instead of group and re-run again using both sex and group as factors. No statistically significant differences or interactions were observed.

DISCUSSION

The present study extended the findings of Bebko et al. (2006) by exploring the relationship between arousal and social linguistic perception in individuals with ASD. Additionally, I explored the impact that viewing positive and negative emotions may have on arousal and the relationship between social anxiety and SCR during social trials. There is limited research in the area of physiological indicators of social linguistic and social emotional perception in children with ASD. Few studies have measured SCR in children with ASD and none have attempted to use this measure of arousal to determine whether differences in arousal exist between different categories of social stimuli. This study found evidence of differences in arousal responses to social versus non-social stimuli when children with ASD were compared to TD children. However, no differences were found in arousal responses to emotional stimuli compared to neutral stimuli in either the ASD or TD group.

Overall, the literature on physiological arousal in individuals with ASD is mixed; with some studies reporting evidence of hypoarousal in this population and others reporting hyperarousal instead. For example, research by Bal et al. (2010), Hirstein, Iversen, &

Ramachandran (2001), Kylliainen & Hietanen (2006) provides evidence of hyperarousal in individuals with ASD in response to faces while research by Hubert, Wicker, Monfardini, and Deruelle (2009) provides evidence for hypoarousal in individuals with ASD in response to happy and angry faces during an emotion perception task. Interestingly, Blair (1999) found children with ASD displayed atypical heightened SCRs to the distress of others but were hyporesponsive to threatening stimuli.

In general, the results of the present study provide evidence of hyperarousal in individuals with ASD. Children with ASD in this study displayed higher SCRs than their TD peers in response to all five stimulus types (NSNL, SNLO, SL, SNLH, and SNLS). Specifically, in response to the four social stimulus conditions (SNLO, SL, SNLH, and SNLS) mean SCRs of the ASD group were more than double those of the TD group and in the remaining non-social condition the mean SCR of the ASD group was close to double that of the TD group. Interestingly, however, the ASD group also displayed greater variability in their SCRs. Standard deviations for SCRs in the ASD group were more than twice as large as the standard deviations for the TD group in all four social conditions and close to twice as large as the TD group's in the non-social condition. This variability in SCRs (the rapid phasic changes in skin conductivity) in children with ASD has been reported in other studies and may be related to variability in baseline SCL (the tonic, slowly habituating level of skin conductivity) of individuals with ASD.

Research on resting-state arousal, or spontaneous fluctuations in SCL at rest, suggests that individuals with ASD can be divided into two subgroups: individuals with high resting-state arousal levels and individuals with low resting-state arousal levels (Mathersul et al., 2013b; Schoen, Miller, Brett-Green, & Hepburn, 2008). Barry and Sokolov (1993) provide evidence that SCRs are directly influenced by SCL and, when individuals with ASD are divided into these two groups based on their resting-state arousal, the groups have been found to display significantly different SCRs in response to non-social environmental stimuli (Schoen et al., 2008) and social stimuli (Mathersul et al., 2013b). It is possible that the increased variability in the SCRs of the ASD group in this study may be related to subgroups within the ASD group that differ in resting state arousal and, consequently, differ in the magnitude of their SCRs to different stimuli. Unfortunately, this study did not examine resting-state arousal in a manner comparable to the methods found in the literature; however, in future research it would be interesting to determine whether SCRs elicited by the different conditions in this study differ when the ASD group is divided into subgroups based on resting-state arousal.

Social Linguistic Perception

In addition to the heightened and increased variability in SCRs observed in the ASD group, the children in this group also displayed a different pattern of responding to social and non-social stimuli when compared to the TD group. The first part of my analysis explored whether linguistic processing impairments that are common to individuals with ASD may be associated with poor task performance in the Bebko et al. (2006) study. Mean SCR values in both the social non-linguistic and social linguistic conditions were both greater than those of the non-social condition and the interaction between group and condition approached significance. Referring back to my experimental design (Figure 2), these results suggest that individuals with ASD experience increased arousal in response to the social aspects of the stimuli and not the linguistic. In terms of task performance in the Bebko et al. (2006) study this suggests that individuals with ASD may have been differentially responding to the social aspects of the social linguistic stimuli and not the linguistic aspects per se. The increased arousal displayed by the ASD group during the social trials in this study suggest that children with ASD may have been experiencing similar increases in arousal during the social linguistic trials of the Bebko et al. (2006) study as well. Even though arousal can facilitate task performance by increasing attention, hyperarousal can also inhibit performance. In fact research has found that hyperarousal during social interactions can make such interactions feel aversive (Doherty-Sneddon et al., 2012). This, in turn, can lead to the individual being less likely to attend to relevant information such as temporal synchrony.

Social Emotional Perception

The second portion of my analysis explored whether arousal differs during social perception when positive or negative emotional expressions are involved. In previous research (e.g., Cohen, Masyn, Mastergeorge, & Hessl, 2015) individuals with ASD have been found to demonstrate different autonomic reactions to pleasant and unpleasant stimuli so it was seen as important to include these conditions in my study in order to be able to compare the magnitude of reactions in the emotional conditions to those of the other three conditions. Although no significant differences in SCR between the two groups were found, examination of Figure 5 suggests that, while TD children exhibit relatively consistent SCRs across emotional and neutral conditions, children with ASD tended to exhibit greater SCRs to positive emotional stimuli than negative and neutral emotional stimuli. These results are consistent with those of other studies (Bolte, Feineis-Matthews, & Poustka, 2008; Cohen et al., 2015) and suggest that individuals with ASD experience greater increases in arousal when viewing positive emotions than TD children. Overall, although results of the analysis of social emotional perception did not reach significance, potentially owing to the modest sample size of this study, the results show similar trends with other studies and present meaningful differences between the ASD and TD groups when the data are examined in closer detail.

Social Anxiety

My analyses did not reveal a significant relationship between social anxiety and physiological responses to social stimuli. Physiological models of anxiety suggest that individuals with a diagnosis of an anxiety disorder are differentiated from the general population by intensified physiological responding (hyperarousal) to threatening stimuli (Weems, Zakem, Costa, Cannon, & Watts, 2005). It is possible that the non-threatening nature of my stimuli (i.e., recorded videos) may have been a factor in the results. Although social anxiety in individuals with ASD did not appear to be related to differences in mean SCR during observation of the social conditions when compared to the non-social condition it is possible that this may have been due to the relatively non-threatening nature of the task when compared to real-life social scenarios. Riby, Whittle, and Doherty-Sneddon (2012) found that, when compared to video-mediated communication, live faces elicited greater physiological responses in TD children. It is possible that in response to real social situations or live, as opposed to video-mediated, stimuli SCRs may show a stronger relationship with social anxiety scores.

Tsunoda et al., (2008) found that social anxiety was associated with unconscious SCRs to masked fearful faces but not masked happy faces. The authors hypothesize that high social anxiety is associated with unconscious emotional responses to fearful faces. They suggest that individuals with high social anxiety are more sensitive to markers of interpersonal threat and that fearful faces represent socially salient expressions with negative expression while happy faces represent social acceptance and positive affect. My social stimuli could easily be considered neutral or ambiguous; for example, in the SNLH condition which portrays clips of women laughing it is unclear why the woman is laughing as no context is given. Consequently, it is possible that individual differences in the manner in which participants process ambiguous social information may have affected their unconscious SCRs to different stimuli.

Hirsh and Clark (2004) propose that an information processing bias is evident when individuals are characterized by the manner in which they process information in a particular domain of cognition; such as memory or interpretation. Hirsh, Clark, and Mathews (2006) argue that biases in different domains of cognition influence and interact with one another to maintain disorders such as Social Phobia. It is possible that individual differences in social information processing biases may have been a factor in the results. For example, individuals who tend to interpret ambiguous situations in a negative manner may be more likely to interpret the video clips of women laughing as analogous to a threatening social situation (i.e., being laughed at or made fun of) while individuals who tend to interpret ambiguous situations in a more positive manner may be more likely to interpret the same stimuli as positive (i.e., indicative of social acceptance and shared enjoyment). It is possible, then, that cognitive biases may have played a role in confounding the findings on social anxiety in the present study, although this remains to be tested.

Interestingly, Mathersul et al. (2013b) found that when individuals with ASD were divided into subgroups based on their resting-state arousal levels, individuals with ASD in their low SCL group tended to rate faces more negatively than controls, whereas the individuals with ASD in the “typical” SCL group did not significantly differ from either the low SCL group or controls. Conversely, the typical SCL group tended to display significantly lower empathy than the control group whilst the low SCL group did not significantly differ from either the typical SCL group or controls. This research suggests that differences in cognitive or social information processing biases may be related to the potential differences in resting-state arousal described earlier. Unfortunately the literature on resting-state arousal in ASD is sparse and more research is needed to explore these differences further.

Finally, although SCR is considered a sensitive measure for data on stimulus-related arousal (Mathersul et al., 2013b) it is possible that a different physiological measure may have been more sensitive to measuring *anxiety*-related physiological changes. For example, Weems, Zakem, Costa, Cannon, and Watts, (2005) found heart-rate to be more closely related to anxiety than SCR.

Implications

The capacity to process social information is intimately related to our ability to form social connections and interact with other individuals. Success in these interactions is often dependent on our ability to integrate audiovisual information in order to provide context to our interpretations of social stimuli. An understanding of the physiological underpinnings of impaired performance in social situations for individuals with ASD has the potential to inform treatment interventions and potentially improve the capacity of individuals with ASD to interact with other individuals and be fully included in society. Knight, Petrie, Zuurmond, and Potts (2009) found that, although children with disabilities such as ASD expressed the desire to have friends and participate in social activities, they experienced high levels of social isolation and exclusion, particularly during school holidays. Similarly, other research has found that children with ASD participate less in social activities and have fewer friendships than their TD peers (Orsmond, Wyngaarden Krauss, & Mailick Seltzer, 2004; Solish, Perry & Minnes, 2010). The barriers to participation in activities with peers often include disability-related needs, such as poor communication and language comprehension skills, rather than lack of interest. Improved understanding of the nature of the social information processing deficit in ASD can help improve interventions by targeting the origins of the impairment along with the symptoms. For example, the current findings suggest that social interventions might be coupled with relaxation techniques to help individuals with ASD learn to minimize hyperarousal in social situations.

Limitations

The current study was the first to examine arousal during perception of dynamic displays of non-social, social non-linguistic, social linguistic, and social non-linguistic emotional stimuli. The findings presented here have extended the understanding of the impact of arousal, social anxiety, and language on social perception in children with ASD. However, the current study did have some limitations.

The main limitation of the current study was the small sample sizes that limited the power of my statistical analyses and may have limited the significance of my findings. Another limitation of the present study was that, due to the restriction of my sample to individuals without an intellectual disability, it is unclear to what degree my findings generalize to individuals with ASD who have an additional diagnosis of an intellectual disability.

Future Studies

Further research is needed to understand the relationship between arousal and social linguistic perception further. It is important that the research questions presented here be explored further through the use of larger sample sizes and different methods of physiological data collection. Specifically, it would be useful to use pupillometry in tandem with collection of SCR in order to tease apart the relationship between arousal and attention during social linguistic perception. Pupil dilation serves as a more direct indicator of visual attention and the collection of both pupil dilation data and SCR would allow us to more definitively state whether the increased arousal observed in the ASD group during the social conditions of this task had a facilitatory effect on social linguistic perception or not. For example, if increases in arousal were coupled with increases in pupil dilation (reflecting the allocation of attentional resources) it would suggest that increased arousal was likely having a facilitory effect on task performance through the increased allocation of attention. Conversely, if increased arousal was coupled with pupil constriction or “looking away” behaviours it would suggest that increased arousal may be aversive the ASD group, leading them to disengage from the stimulus causing the increased arousal (Doherty-Sneddon et al., 2012).

Due to the structural and functional neural abnormalities often observed in individuals with ASD it would be interesting to see whether these neural differences are related to differences in mean SCR between the different conditions in my task. Similarly, it would be interesting to determine whether neural abnormalities are related to task performance in the Bebko et al. (2006) study. Future studies could use fMRI data to explore this concept further.

Unlike the Bebko et al. (2006) study, the present study only presented participants with temporally synchronized stimuli. It would be interesting to observe the impact of temporal asynchrony on arousal responses and to determine whether arousal responses to the five different conditions in this study are differentially affected by asynchrony.

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List of Appendices

Appendix A.1: Sample Information Letter for Parents of Children with ASD

Physiological Indicators of Multisensory Processing

Dear Parent,

Purpose of the Study

The ability to integrate information across sensory modalities is important for interactions in the everyday world. This ability is impaired in children with ASD. One specific aspect of multisensory integration that is impaired in children with ASD is temporal processing. This impairment can lead to deficits commonly seen in ASD, such as problems with communication.

The current study will investigate the impact that temporal processing has on audiovisual integration in ASD using information gathered from pupillary responses (e.g., size of pupils in response to pictures) and galvanic skin response (amount of moisture on the skin). Both of these measures give an indication of the level of arousal or engagement during a given task. This information will be informative in understanding the processes that may be interfereing with successful multisensory integration in ASD.

What will Participation Involve?

This study will involve children between the ages of 5 and 18 years of age who have been diagnosed with an Autism Spectrum Disorder (ASD). In order to participate, individuals must: a) have at least a 2-year-old verbal ability in English and have measured intellectual skills in the range of mild cognitive impairment or above; b) normal or corrected-to-normal hearing and vision; c) no known neurological issues (epilepsy, brain injury, etc.), and d) a previous diagnosis of an ASD by a psychologist or psychiatrist according to DSM-IV-TR criteria. Children will be asked to watch a short video and some pictures that have been created specifically to understand how children attend to and understand what they see and what they hear. The images and video that children will see include a woman telling a story, a woman making voice sounds, a piano being played, and some animated cartoons. During the session, the child's eye movements will be video recorded and tracked using eye-tracking equipment. The child will also have two external electrodes attached to the index and ring finger of their non-dominant hand. These electrodes will measure changes in the child's skin conductance as a measure of galvanic skin response.

Along with this there will a cognitive (thinking) activity examining children's problem solving skills (e.g., working with puzzles) and a language-based activity. Additionally, the Autism Diagnostic Observation Scale (ADOS), a structured observation scale children and adults with ASD will be administered. Overall, the experiment should take no longer than one and a half hours for your child.

Parents will also be asked complete several questionnaires about a range of skills and characteristics of your child. These include thinking skills, self-control, communication and social skills, repetitive and sensory-type behaviors. An additional questionnaire will ask about

your experiences obtaining a diagnosis for your child and any previous diagnoses that may have been given. We will also ask you to provide a copy of the diagnostic report for clarification. Parent involvement should take approximately 60 to 90 minutes.
As a token of our appreciation, we would like to provide your child with a ($10-$20) gift card for participating in our study.

Are there any Risks Involved?

All of the parts of this study have been reviewed and there are no risks involved. All information that is collected will be kept strictly confidential to the fullest extent possible by law. To ensure confidentiality, paper data will be stored in a locked cabinet, and other data will be stored on an external hard drive in an encrypted file that will be kept at the Child Learning Projects Lab at York University. The lab is also locked and only accessible by project personnel. All children will be given a participant number by which they will be identified. Data and audio-video recordings will be stored for an extended period after the study to enable comparison and combination with data in future studies. Once all projects in this line of research have been completed, all data and recordings will be destroyed (paper materials will be shredded and video will be destroyed). In the event that the results are published or presented, only grouped data will be used to guarantee anonymity. Any individual or personal information will be kept confidential. Your child will be provided with a small gift in appreciation of their participation. In addition, we will offer modest compensation for your travel, parking or transit, if you choose. This study is being conducted under the supervision of Dr. James Bebko, a professor at York University and a Clinical Psychologist.

Withdrawal from the Study: Participation is completely voluntary, *you or your child can withdraw from the study at any time* and it will not affect any of the services that you may currently be receiving. If you decide to stop participating, you will still be eligible to receive the promised compensation for agreeing to be in this project. Your decision to stop participating, or to refuse to answer particular questions, will not affect your relationship with the researchers, York University, or any other group associated with this project. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.

Please read and sign the attached consent form indicating whether your child may or may not participate. Please feel free to ask me any questions or if you would like more information. Thank you for your interest and participation in this study, it is greatly appreciated!

Sincerely,

Magali Segers
Doctoral Candidate
xx
xx

Busi Ncube
Masters Candidate
xx
xx

Appendix A.2: Sample Information Letter for Parents of TD Children

Physiological Indicators of Multisensory Processing

Dear Parent,

Purpose of the Study

Two abilities are thought to help people interact socially: 1) attention (shifting your attention from one person or object to another); and 2) combining together what we see with what we hear (intersensory processing). Although these skills are important for making sense of the world around us, there has only been limited research on how they work together. We are asking for your and your child's assistance in a research study to look at how they work together and how they impact social understanding and communication.

A better understanding of the nature of these processes will help us better understand the course of development in children and adolescents.

What will Participation Involve?

This study will involve children between the ages of 5 and 18 years of age who have not been diagnosed with any developmental disabilities or neurological impairments (e.g., epilepsy, brain injury, etc.). In order to participate, individuals must: a) have at least a 2-year-old verbal ability in English and have intellectual skills in the range of mild cognitive impairment or above; b) normal or corrected-to-normal hearing and vision. Children will be asked to watch a short video and some pictures that have been created specifically to understand how children attend to and understand what they see and what they hear. The images and video that children will see include a woman telling a story, a woman making voice sounds, a piano being played, and some animated cartoons. During the session, the child's eye movements will be video recorded and tracked using eye-tracking equipment. The child will also have two external electrodes attached to the index and ring finger of their non-dominant hand. These electrodes will measure changes in the child's skin conductance as a measure of galvanic skin response.

Along with this there will a cognitive (thinking) activity examining children's problem solving skills (e.g., working with puzzles) and a language-based activity. Overall, the experiment should take no longer than one and a half hours for your child.

Parents will also be asked complete several questionnaires about a range of skills and characteristics of your child. These include thinking skills, self-control, communication and social skills, repetitive and sensory-type behaviors. An additional questionnaire will ask about your child's overall mental and physical health and development. We will also ask you to provide a copy of the diagnostic report for clarification. Parent involvement should take approximately 60 to 90 minutes.
As a token of our appreciation, we would like to provide your child with a ($10-$20) gift card for participating in our study.

Are there any Risks Involved?

All of the parts of this study have been reviewed and there are no risks involved. All information that is collected will be kept strictly confidential to the fullest extent possible by law. To ensure confidentiality, paper data will be stored in a locked cabinet, and other data will be stored on an external hard drive in an encrypted file that will be kept at the Child Learning Projects Lab at York University. The lab is also locked and only accessible by project personnel. All children will be given a participant number by which they will be identified. Data and audio-video recordings will be stored for an extended period after the study to enable comparison and combination with data in future studies. Once all projects in this line of research have been completed, all data and recordings will be destroyed (paper materials will be shredded and video will be destroyed). In the event that the results are published or presented, only grouped data will be used to guarantee anonymity. Any individual or personal information will be kept confidential. Your child will be provided with a small gift in appreciation of their participation. In addition, we will offer modest compensation for your travel, parking or transit, if you choose. This study is being conducted under the supervision of Dr. James Bebko, a professor at York University and a Clinical Psychologist.

Withdrawal from the Study: Participation is completely voluntary, *you or your child can withdraw from the study at any time* and it will not affect any of the services that you may currently be receiving. If you decide to stop participating, you will still be eligible to receive the promised compensation for agreeing to be in this project. Your decision to stop participating, or to refuse to answer particular questions, will not affect your relationship with the researchers, York University, or any other group associated with this project. In the event you withdraw from the study, all associated data collected will be immediately destroyed wherever possible.

Please read and sign the attached consent form indicating whether your child may or may not participate. Please feel free to ask me any questions or if you would like more information. Thank you for your interest and participation in this study, it is greatly appreciated!

Sincerely,

Magali Segers
Doctoral Candidate
xx
xx

Busi Ncube
Masters Candidate
xx
xx

Appendix B.1: Sample Consent Form for Parents of Children with ASD

Physiological Indicators of Multisensory Processing

By signing this form, I agree that I have read and understood the description of the study, and that I allow my child to participate. I understand that the information collected about my child during this study will remain completely confidential within the limits of the law and that we may choose to stop participating at any time. I understand that participation in this study will in no way affect any services that we are receiving now or in the future. I agree to have my child's participation and eye-movements video-recorded for purposes of later analyzing looking patterns.

Parent/Guardian Name (please print) ___________________________________

Parent/Guardian Signature _________________________ Date________________________

Relationship to the minor who is participating in this study:
____

Child's Name (please print): ____________________________________

Child's Date of Birth (d/m/y): ____________________________________

Child's current age (in years): _______________

Principal Investigator Signature_______________________ Date ______________________

Questions about the Research? If you have questions about the research in general or about your role in the study, please feel free to contact us using the contact information below. You may also contact my Graduate Program – the Psychology Department Graduate office at (xxx) xxx-xxxx. This research has been reviewed and approved by the Human Participants Review Sub-Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact the Sr. Manager & Policy Advisor for the Office of Research Ethics, 5th Floor, York Research Tower, York University (telephone xxx-xxx-xxxx or e-mail xx).

Magali Segers	Busi Ncube	Dr. James Bebko
Doctoral Student	Masters Student	Supervising Professor
York University	York University	York University

Additional Information *(please complete the following information)*

Child's first language_________________ Child's most frequently used language____________

By the age of **3**, was your child's language the same as typically developing children?

☐ YES ☐ NO

My child's hearing: Estimated test date____________________

☐ has not been tested
☐ has been tested and no problems were found
☐ has been tested and the following difficulties were found:
____

My child's vision: Estimated test date_____________________
☐ has not been tested
☐ has been tested and no problems were found
☐ has been tested and the following difficulties were found:
____

Has your child **ever** received Intensive Behavioral Therapy (IBI: at least 20 hours of behavioral therapy a week)? (Please note: This question is only to help us understand your child's previous experiences)
☐ YES ☐ NO

* Limited compensation for your travel, parking or transit is available, if you wish; would you like to receive $10.00 to partially cover these costs? ☐ YES ☐ NO

Would you like us to provide your child with a ($10.00-$20.00) giftcard? ☐ YES ☐ NO

1. Do you wish to receive a brief summary of the grouped findings of this study? (*Please note that it may be* <u>*12 months*</u> *after completion of the study before all the results have been analyzed*)
☐ YES ☐ NO

2. Are you willing to be contacted for participation in future studies (no obligation)?
☐ YES ☐ NO

If you answered **YES** to either of the two above questions, please provide:

Name: ____

Mailing Address:
____

Telephone: ___________________________ Email Address:_____________________

Appendix B.2: Sample Consent Form for Parents of TD Children

Physiological Indicators of Multisensory Processing

By signing this form, I agree that I have read and understood the description of the study, and that I allow my child to participate. I understand that the information collected about my child during this study will remain completely confidential within the limits of the law and that we may choose to stop participating at any time. I understand that participation in this study will in no way affect any services that we are receiving now or in the future. I agree to have my child's participation and eye-movements video-recorded for purposes of later analyzing looking patterns.

Parent/Guardian Name (please print) ___________________________________

Parent/Guardian Signature _________________________ Date________________________

Relationship to the minor who is participating in this study:
____

Child's Name (please print): ____________________________________

Child's Date of Birth (d/m/y): ____________________________________

Child's current age (in years): _______________

Principal Investigator Signature_______________________ Date
____

Questions about the Research? If you have questions about the research in general or about your role in the study, please feel free to contact us using the contact information below. You may also contact my Graduate Program – the Psychology Department Graduate office at (xxx) xxx-xxxx. This research has been reviewed and approved by the Human Participants Review Sub-Committee, York University's Ethics Review Board and conforms to the standards of the Canadian Tri-Council Research Ethics guidelines. If you have any questions about this process, or about your rights as a participant in the study, please contact the Sr. Manager & Policy Advisor for the Office of Research Ethics, 5th Floor, York Research Tower, York University (telephone xxx-xxx-xxxx or e-mail xx).

Magali Segers	Busi Ncube	Dr. James Bebko
Doctoral Student	Masters Student	Supervising Professor
York University	York University	York University

Additional Information ***(please complete the following information)***

Child's first language_________________ Child's most frequently used language____________

By the age of **3**, was your child's language the same as typically developing children? ☐ YES ☐ NO

My child's hearing: Estimated test date____________________

☐ has not been tested
☐ has been tested and no problems were found
☐ has been tested and the following difficulties were found:
____

My child's vision: Estimated test date_____________________
☐ has not been tested
☐ has been tested and no problems were found
☐ has been tested and the following difficulties were found:
____

Has your child **ever** received any type of remedial therapy in the past? (Please note: This question is only to help us understand your child's previous experiences)
☐ YES ☐ NO
If YES, please specify: ____

* Limited compensation for your travel, parking or transit is available, if you wish; would you like to receive $10.00 to partially cover these costs? ☐ YES ☐ NO

Would you like us to provide your child with a ($10.00-$20.00) giftcard? ☐ YES ☐ NO

1. Do you wish to receive a brief summary of the grouped findings of this study? (*Please note that it may be <u>12 months</u> after completion of the study before all the results have been analyzed*)
☐ YES ☐ NO

2. Are you willing to be contacted for participation in future studies (no obligation)? ☐ YES ☐ NO

If you answered **YES** to either of the two above questions, please provide:

Name: ____

Mailing Address:
____

Telephone: ___________________________ Email Address:______________________

Appendix C: Sample Assent Form

Physiological Indicators of Multisensory Processing

Why are we doing this study?

We are doing this research so we can find out more about how children and adults understand what they see and hear.

What will happen during the study?

If you decide to participate you will watch some videos of people talking and other videos without people in them. We will use a special computer to show us where you are looking. During the videos you will have two sensors wrapped around two of your fingers which will tell us how you are feeling while you're watching the videos. If you get uncomfortable, you can let us know and we will make sure that you get more comfortable. You can have your mom/dad stay with you in the room with you if you want, or they can wait outside. It will take about 15 minutes.

After that we will do some activities where we will ask you to build things, tell us about some words, look at some books, make a puzzle, and play with some toys. When we are finished you will be given a small gift.

Are there good or bad things about the study?

Most kids like to watch this video and think the study is fun. We don't think that there are any bad things about the study.

Who will know about what I said or did in the study?

If you are part of this study, your name will not be given to anyone. We won't tell anyone about what you said or did. We will not show the video of you to anyone and will erase the video once the results are of no more use for us. Also, we will destroy any papers that we used in the study.

Can I decide if I want to be in the study?

You can decide if you want to be in the study. It is O.K. if you do not want to be part of the study. It is O.K. if you say yes now and change your mind later. Your parents know about the study and have said that you can be in it. Please ask questions that you have at any time.

Assent:

The study has been explained to me. I know that I can ask questions about the study at any time. I know that I can decide to stop at any time. I have been told that all of the videos and other information collected will not be given to anyone. It will only be seen by the research team.

____________________________ ____________________________

NAME SIGNATURE