Emotion, Sensory Processing, and Prosody in Neurotypical and Autistic Young Adults

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Brigham Young University

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Emotion, Sensory Processing, and Prosody in Neurotypical and Autistic Young Adults

Annika Henderson

A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of
Master of Science

Garrett Cardon, Chair
Shawn Nissen
Terisa Gabrielsen

Department of Communication Disorders
Brigham Young University

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ABSTRACT

Emotion, Sensory Processing, and Prosody in Neurotypical and Autistic Young Adults

Annika Henderson
Department of Communication Disorders, BYU
Master of Science

There is a paucity of research regarding autistic adults, yet as autistic individuals grow to adulthood, they are often met with several barriers because of their differences from the neurotypical (NT) population. Given the demands of adult social interaction, some of the social difficulties experienced by autistic adults are likely related to emotion processing and prosody function. With sensory processing differences added as a diagnostic criterion for autism within the last decade, an investigation into its relationship with emotional processing, another marked difficulty for this population, is warranted. There are logical connections between sensory processing, emotion, and prosody, such that an individual is required to detect the slight variations in pitch, stress, and pausing of prosody and have a typical and functional understanding of emotion to be able to comprehend the full meaning behind the prosodic cues of a speaker. Additionally, a speaker needs to understand these same sensory and emotional aspects in order to express typical prosody and have their full message, spoken and unspoken, be received by the listener. Thus, we hypothesized that there would be positive relationships between emotion, sensory processing, and prosody difficulties, and that sensory processing would act as a mediator between emotion and prosody. This study involved an online survey ($n = 639$) and an in-person component ($n = 51$) of NT and autistic young adults aged 18-27. Participants completed questionnaires and behavioral measures related to emotion, sensory processing, and prosody. Results revealed positive relationships between the three constructs and that sensory processing (especially auditory processing) was, indeed, a mediator between emotion and prosody. An exploratory analysis between males and females revealed no difference in prosody perception or production but differences in the role emotion plays in the above model between the sexes. This study provides a potential bridge between the NT and autistic communities and clinical implications for working with autistic individuals or those who express autistic traits.

Keywords: emotion, sensory processing, prosody, autism
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DESCRIPTION OF THESIS STRUCTURE AND CONTENT

This thesis, *Emotion, Sensory Processing, and Prosody in Neurotypical and Autistic Young Adults*, is written in a hybrid-format which incorporates elements of a traditional thesis and a journal publication. This thesis is written in accordance with standards set by the McKay School of Education and Brigham Young University.

The literature review is included in Appendix A. Appendix B contains the Institutional Review Board (IRB) approval letter, and Appendix C contains the IRB-approved consent form given to participants.
Introduction

Autism Spectrum Disorder

Autism spectrum disorder (ASD) is a neurodevelopmental condition characterized by difficulties in restricted and repetitive behaviors (RRBs) and social interaction (American Psychiatric Association [APA], 2022). Sensory processing difficulties have also been recently added to the diagnostic criteria for ASD in the Diagnostic and Statistical Manual for Mental Disorders, Fifth Edition, Text Revision (DSM-5-TR; APA, 2022). Additionally, recent studies have shown that the prevalence of ASD is on the rise, having increased from one in 59 children to one in 36 (Baio et al., 2018; Maenner et al., 2023). These high numbers are significant when considering the dearth of information about autistic adults and their needs as well as the limited resources available to them. They are also predictive of the needs for adult services within the next decade.

Though much has been learned and many advances have been made regarding ASD over the past decade, there is still a great deal that remains not well understood. Among these issues are many pertaining to autistic adults, since most research efforts have focused on children. It is imperative that research include all age groups to best serve the autistic population across the lifespan. This research may help autistic individuals avoid “the cliff,” or the abrupt cessation of services after the age of either 18 or 21. The cliff has an abjectly negative effect on these individuals, as services are stopped at a time when they are potentially needed the most (Hendren, 2021; Laxman et al., 2019). Indeed, research about autistic adults has the potential to improve policies that currently put them at a severe disadvantage. The current study intends to add to the adult-centered literature in efforts to provide answers to critical research questions so these individuals can receive the needed support.
Many of the issues that autistic children experience also apply to autistic adults. Three examples of such difficulties include atypical sensory processing, struggles with emotional processing, and atypical prosody. These characteristics can be challenging for anyone who experiences them. This may include not only autistic adults, but also adults who express varying degrees of autistic traits. The broad autism phenotype (BAP; De Groot & Strien, 2017; Maxwell et al., 2013) is a model that suggests that everyone exhibits some degree of autistic traits and that these traits fall on a spectrum of severity. The BAP model posits that the dichotomy of NT or autistic is an unrealistic oversimplification of the variety of humanity. Whether an adult has been diagnosed with ASD or expresses autistic traits, the challenges of adulthood may be a reality for neurodivergent individuals with and without diagnoses. Specifically, adults may experience difficulties related to life scenarios that are endemic in adulthood, such as establishing and maintaining employment, friend and family relationships, and stable and independent living, among others. Since the processing of one’s own and others’ emotions requires accurate sensory processing and is reflected in one’s prosody, we submit that investigating the relationship between these three factors may shed light on atypical emotion processing, a hallmark characteristic of autism. Thus, the current study aims to understand group differences in and relationships between emotional processing, sensory processing, and prosody in autistic and neurotypical (NT) adults.

Emotional Processing

Emotional processing is a complex phenomenon—a fact that may be especially true in autism. One of the major contributors to this is the fact that autistic individuals often struggle to integrate information from multisensory channels, limiting their capacity to accurately perceive emotions (Zhang et al., 2022). The challenge of multisensory integration may play a role in
emotional processing, which is not fully understood in young autistic children (Berkovits et al., 2017). In many cases, autistic individuals have difficulties regulating their emotions (Gross & Jazaieri, 2014; Mazefsky et al., 2014; Weiss et al., 2014; White et al., 2014), often using less productive emotional regulation strategies when compared to neurotypical people (Bruggink et al., 2016; Jahromi et al., 2012; Konstantareas & Stewart, 2006). Unfortunately, far less is known about emotional processing in autistic adults. Additionally, autistic individuals experience and express their emotions differently than neurotypical peers (Cai et al., 2020). For instance, the neurotypical population uses more emotional regulation strategies to regulate negative emotions than autistic individuals (Cai et al., 2020). Further, parents of autistic children reported that their children expressed more negative than positive emotions, even though when these same autistic children reported on their emotional state via daily journaling, the frequency of negative and positive emotions mirrored that of neurotypical children (Capps et al., 1993; Samson et al., 2015). Also, autistic traits are linked to higher rates of alexithymia, or difficulty with understanding and expressing one’s emotions (Cameron et al., 2014; Maisel et al., 2016; South & Rodgers, 2017). It is highly likely that alexithymia contributes heavily to the struggles of autistic individuals in processing emotions—their own and those of others. For example, alexithymia has been implicated in this population’s restricted ability to accept one’s own emotions and to appropriately express empathy to others (Cai et al., 2020; South & Rodgers, 2017). In sum, emotional processing is often very different for autistic individuals when compared to their neurotypical counterparts. Sometimes, these differences lead to difficulties in various aspects of life.
Prosody

Pitch, intensity, and duration are all components of the suprasegmental language feature of prosody (Eigsti et al., 2012). Prosody plays a significant role in everyday communication (Panagos & Prelock, 1997; Roach, 2000; Shriberg et al., 2001). For example, in spoken language, prosody can be used to relay grammatical information, as in determining whether an utterance is a statement or a question (Eigsti et al., 2012). Prosody can also relay affective information, revealing the emotions of the speaker (Eigsti et al., 2012). Speakers regularly use variations in loudness, duration, pitch, intonation, rhythm, and stress to convey meaning (Lehiste, 1970; Shriberg et al., 1990). However, autistic individuals often have great difficulty producing and perceiving such prosodic features (Kargas et al., 2016).

It has been frequently noted that autistic speakers tend to use abnormal prosody during verbal communication (Eigsti et al., 2012), including atypical employment of stress, pitch, and rhythm (Paul, Augustyn, et al., 2005; Paul et al., 2008; Paul, Shriberg, et al., 2005; Shriberg et al., 2001). Interestingly, some have shown that prosody atypicalities can persist for autistic individuals over time (Eigsti et al., 2012). When studying autistic individuals and prosody, Grossman et al. (2010) found that their subjects could use the stress patterns of word pairs to correctly identify the meaning of each word, but when asked to produce the word pairs themselves, their productions were notably different, being longer and slower compared to their neurotypical peers. In other words, the main deficit found in autistic children and adolescents was stress production.

Conversely, Kargas et al. (2016) found that autistic adults were less accurate in detecting syllable stress, even if the group of participants was relatively homogenous. They also found that atypical stress perception was related to atypical speech production in this population (Kargas et
al., 2016). Hubbard et al. (2017) found that autistic individuals produced and perceived prosody in irregular ways, leading listeners to rate their speech as more unnatural than neurotypical peers. Interestingly, Gebauer et al. (2014) discovered mostly typical neurological activity in autistic individuals when listening to utterances with affective prosody relaying a certain emotion, but these individuals rated the emotions as less intense than neurotypical people did. In contrast, a study by Rosenblau et al. (2017) found differing neural activation regarding brain regions and level of intensity in autistic and neurotypical groups when listening to affective prosody. Additionally, the autistic group in this study exhibited decreased accuracy in emotional prosody recognition. Both these neurophysiologic studies have interesting ties to the aforementioned atypical emotional processing in the autistic population. In short, the literature demonstrates prosodic deficiencies in both production and perception have been linked to the autistic population.

In conjunction with atypical emotion processing, prosodic perception and production differences can negatively affect communication and social interactions (Grossman et al., 2010; Holbrook & Israelsen, 2020). To date, there has been much debate in the literature about how autistic individuals understand and produce typical prosody (Eigsti et al., 2012; see paragraph above). This is a critical area in need of further study because autistic individuals are already at high risk of mental illness (e.g., depression, anxiety) and social isolation (Cai et al., 2020; Garfinkel et al., 2016). Difficulty understanding the nuances or underlying meaning and emotion of a speaker’s words has great potential to complicate a social situation. For example, communication breakdowns can lead to withdrawal from social situations (Heinrich et al., 2016; Smith & Kampfe, 1997). These communication breakdowns can occur because of imprecise understanding and/or use of prosodic cues. Thus, autistic people’s ability to process emotions
can affect their social functioning, particularly with neurotypical counterparts. Prosody of autistic speakers has been strongly linked with how others perceived their social and communicative abilities and deficits (Eigsti et al., 2012; Grossman et al., 2010). Additionally, prosody has been found to be one of the highest contributors (and barriers) to the social and vocational prospects of this population (Eigsti et al., 2012). These studies demonstrate that the prosodic deficits in autistic individuals may be indicative of their social functioning and acceptance. The connection and understanding between neurotypical and autistic populations are likely hindered by prosody perception and production differences. In fact, prosody may be a window into the emotional processing capacities of an individual and may be a way to measure emotional understanding. Prosody between autistic males and females is an area of particular interest in current research that is not always conclusive. Autistic females have been shown to possess more empathetic qualities, more advanced emotional understanding, and more brain activity when processing complex emotions—characteristics which may contribute to their use and understanding of prosody (McGillivray & Evert, 2018; Mulcahy et al., 2019; Rosenblau et al., 2017). However, overall, the literature is lacking in differentiating between the prosody of autistic males and females.

**Sensory Processing in Autism**

Autistic individuals often exhibit atypical sensory processing. In fact, over 90% of autistic children express such traits (Chang et al., 2014; Green et al., 2015; Marco et al., 2011). These deficits may result in sensory behaviors that are either hypersensitive, hyposensitive, or sensory seeking, although studies show that a child can exhibit each of these behavioral patterns in different sensory modalities or at different times (Baranek, 2002; Baranek et al., 2006; Ben-Sasson et al., 2007). For example, an autistic individual may perceive that a quiet sound is much
louder than it might be typically perceived and proceed to cover their ears because the auditory sensation is physically painful to them. On the other hand, an autistic individual may not respond to a sound in the environment because they perceived it to be much quieter than it was or didn’t attend to it as others might. Furthermore, autistic individuals who have sensory seeking tendencies crave sensory input and might spin or touch an object repeatedly, solely to experience the sensation of doing so. Also, it is extremely common for autistic people to have difficulties with multisensory integration. This may be due to an inability to effectively process and filter various simultaneous sensory signals (O'Neill & Jones, 1997) or to selectively attend to one of the signals (Marco et al., 2011; Matsuzaki et al., 2014). For example, if an autistic person were to walk into a room with flashing lights, loud music, various aromas, and people dancing, the combination of the various visual, olfactory, and auditory signals might be overwhelming for them.

Due to numerous factors, such as the heterogeneity of sensory processing in autism and difficulty in designing tasks that appropriately examine complex neurosensory systems, to date, the mechanisms of sensory processing atypicalities in autism remain elusive (Marco et al., 2011). Sensory behaviors are widely thought to arise from atypical brain structure, function, and/or connectivity (Cardon et al., 2017; Chang et al., 2014; D’Mello & Stoodley, 2015; Jassim et al., 2021; Lau et al., 2020; Marco et al., 2011; Rosenblau et al., 2017). For example, Green et al. (2013) and Green et al. (2015) found that certain brain regions of autistic individuals, such as the amygdala, were hyperreactive to sensory information, compared to control groups. While such studies have elucidated some of the potentially important neurobiological underpinnings of sensory processing, much work is still needed to fully understand these phenomena. The
behavioral correlates and impacts of atypical sensory processing are still under investigation as well.

Sensory processing abnormalities can make many aspects of life difficult for autistic individuals. For instance, affected individuals may avoid certain scenarios because of their sensory characteristics, limiting their social interactions and relationship development. Simple activities of daily life like grocery shopping or going to a restaurant might be more miserable than enjoyable with the variety of smells, sights, and sounds. Academically, focusing in class may prove challenging with the host of other sensory information, such as background noise of whispering, the whirring of fans, or an uncomfortable tag on their shirt. The realities and frustrations of this population’s sensory processing deficits can extend into all spheres of life.

One of the strongest correlates of atypical sensory processing in autism is anxiety—i.e., those who experience heightened sensory processing difficulties also tend to exhibit more severe anxiety (South & Rodgers, 2017). In fact, the relationship between sensory processing and anxiety has been shown to be mediated by both intolerance of uncertainty and alexithymia (Maisel et al., 2016; Moore et al., 2022; South & Rodgers, 2017; Wigham et al., 2015). The latter suggests an interrelationship between sensory processing, anxiety, and emotional function. Thus, the mutual relationship of anxiety and sensory processing issues may significantly contribute to other characteristic behaviors of autism, such as emotional processing difficulties and abnormal prosody.

**Interrelationships Between Emotion, Prosody, and Sensory Processing**

The relationship between sensory processing, emotional processing, and prosody in autistic adults has yet to be studied. There are, however, logical interactions between the three constructs. First, integral to successful emotional processing is the ability to analyze several
pieces of sensory information and isolate the most salient aspects, a marked area of difficulty for autistic individuals (Cardon et al., 2017; Marco et al., 2011; Thye et al., 2018; Zhang et al., 2022). To a significant degree, the emotional status of a speaker is conveyed via prosodic cues within a conversation. Thus, one of the most important pieces of sensory input in social contexts is prosody. Atypical perception of prosodic cues could lead to misunderstandings between conversation partners. From a developmental perspective, such misunderstandings throughout early life could affect emotion understanding of others and self. Additionally, atypical sensing and understanding of one’s own emotions could contribute to differences in prosody production. A functional understanding of emotions must be established in order to comprehend and appropriately respond to the overt or covert emotion of a spoken message.

Atypicalities in each of these three constructs can lead to the substantially increased difficulty to develop social relationships for the autistic population, perhaps especially with their neurotypical peers (Milton, 2012). Due to many autistic individuals’ difficulty integrating sensory information (e.g., facial expressions, tone of voice and intonation, posture, and gestures), autistic individuals may have difficulty understanding the underlying meaning of what has been said in some conversations. Further, atypical emotional processing may only serve to exacerbate certain situations, as many may not understand the implied emotions of the message. These communication breakdowns (and their often-regular recurrence) could lead to social withdrawal, superficial relationships, and feelings of isolation. Such negative experiences could hinder an autistic individual’s ability to learn social cues and decrease their desire to engage socially and their ability to appropriately do so (e.g., using exaggerated or restricted prosody because of an impaired sensory feedback system). As a central component of this study, it is proposed that sensory processing may serve as the mediator between emotional processing and prosody. For
example, how an individual experiences emotion affects how they engage with their environment, including if they seek out or avoid sensory stimulation. Conversely, sensory experiences can contribute to one’s emotions (e.g., overwhelmed from noisy situations or content from the sensation of spinning). Additionally, sensory processing may affect the perception and production of prosody due to an atypical sensory system, including an impaired auditory feedback loop.

Statement of the Purpose

Given the above, we aimed to examine the interrelationship between emotion processing, sensory processing, and prosody both within and between groups of autistic and neurotypical adults. We hypothesized that each of these three constructs would differ significantly between autistic and neurotypical samples and would be correlated with each other, both within these groups and dimensionally across groups. Ultimately, we also expected that sensory processing would mediate the relationship between emotional processing and prosody, especially in autistic subjects.

Method

The current study was comprised of two phases. In phase one, participants completed a series of questionnaires via an online platform, and then a random selection of the survey respondents were invited to participate in phase two of the study. Phase two included two additional questionnaires and both expressive and receptive prosody behavioral measures. Analyses were completed to determine the accuracy of our hypotheses. A full description of the methods and data analyses is explained below.
Participants

Participants were recruited for two phases in the current study. Survey respondents from phase one included 624 NT (200 male, 424 female) and 15 autistic (nine male, six female) young adults, aged 18-27. Subjects for phase two were randomly selected from those who signaled a continued interest in participating in the study. Participants for phase two included 40 NT (18 male, 22 female) and 11 autistic adults (six male, five female), aged 18-27. These individuals were recruited from local universities, trade schools, autism-associated groups, schools, and other organizations via word of mouth, university-based research recruitment efforts, social media, and flyers/emails sent to previous research subjects who provided permission to do so. We administered measures of autistic traits (see below) in addition to self-reports of autism diagnosis. All measures of autistic traits were consistent with the self-report of each autistic participant. We excluded individuals with a history of any neurological disease (including traumatic brain injury), as well as those with hearing and/or significant uncorrected vision loss. All procedures were approved by the Institutional Review Board of Brigham Young University, included appropriate consent, confidentiality, and data storage methods, and were in accordance with the declaration of Helsinki.

Materials

We asked the participants to fill out a series of questionnaires to measure sensory processing, emotional processing, and autistic traits. We invited our participants to complete the Adolescent/Adult Sensory Profile (AASP; Brown & Dunn, 2002) and the Glasgow Sensory Quotient (GSQ; Robertson & Simmons, 2012). Both measures have been used to assess sensory hypo- and hyperfunction, and sensory seeking behaviors, across different modalities. The AASP is a 60-item self-report measure used for autistic individuals aged 11 and older. It assesses six
different modalities: taste/smell, movement, visual, touch, auditory, and activity level (Brown & Dunn, 2002). The GSQ is a 41-item self-report questionnaire and is normed for neurotypical individuals. It reports on seven different modalities (visual, auditory, gustatory, olfactory, tactile, vestibular, and proprioceptive), and answers are provided on a scale of ‘Never—Rarely—Sometimes—Often—Always’ (Robertson & Simmons, 2012). Cronbach’s alpha for this questionnaire was found to be $\alpha = 0.935$, and Guttman’s Split-Half technique demonstrated $r = 0.929$ (Robertson & Simmons, 2012).

To assess emotion regulation, the participants were asked to complete self-report form of the Behavior Rating Inventory of Executive Functions—Adult Version (BRIEF-A; Roth et al., 2005), a 75-item self-report measure for adults aged 18-90. The BRIEF-A was shown to have excellent reliability with a sample of individuals with traumatic brain injury (TBI; Waid-Ebbs et al., 2012). Participants were also asked to then provide the name and contact information of a trusted friend or family member. A member of the research team later reached out to this individual and completed the informant report of the BRIEF-A with them over the phone. This provided opportunities to compare self-report measures to those completed by a close other. Although the BRIEF-A is an executive function measure, it provides insight into how an adult processes emotion in everyday life, a component of executive function and a major construct in this study. To further assess emotional processing, participants were also asked to complete the Empathy Quotient (EQ; Baron-Cohen & Wheelwright, 2004), a 60-item (20 of which are control items) self-report questionnaire to measure participants’ ability to understand and interpret others’ emotions. A scale of ‘Definitely Agree—Slightly Agree—Slightly Disagree—Definitely Disagree’ is used to answer each item. The EQ is intended for adults with intelligence within the normal limits. Test-retest reliability for the EQ is $r = 0.97$ (Baron-Cohen & Wheelwright, 2004).
Participants also completed the Toronto Alexithymia Scale (TAS-20; Bagby et al., 1994). The TAS-20 is a 20-item self-report measure for adults that assesses three domains of emotional understanding: difficulty identifying feelings, difficulty describing feelings, and externally-oriented thinking. A Likert scale of ‘Strongly disagree—Disagree—Neither agree nor disagree—Agree—Strongly Agree’ is used to answer each item. The TAS-20 has good internal validity ($\alpha = 0.81$) and test-retest reliability ($0.77, p < 0.01$), with no items demonstrating a skewed distribution (Bagby et al., 1994).

To assess autistic traits, we asked participants to fill out both the Autism Quotient (AQ; Baron-Cohen et al., 2001) and the Social Responsiveness Scale—Second Edition (SRS-2; Constantino & Gruber, 2012). Both the AQ and the SRS-2 are frequently utilized in autism research (Berkovits et al., 2017; Cai et al., 2020; Garfinkel et al., 2016; Maisel et al., 2016; Wigham et al., 2015). The AQ consists of 50 items and is a self-report measure for adults of autistic traits. A scale of ‘Definitely Agree—Slightly Agree—Slightly Disagree—Definitely Disagree’ is used to answer each item. It has been shown to have excellent test-retest reliability (Baron-Cohen et al., 2001). The SRS-2 is composed of 65 items and measures social behaviors and autistic tendencies. Answers are provided using a scale of ‘1 = Not True, 2 = Sometimes True, 3 = Often True, 4 = Almost Always True.’ It has a self-report form for adults aged 19 and above. Psychometrics for the SRS-2 are excellent, including a sensitivity and specificity of 0.92 each and an internal consistency ranging from 0.94 to 0.96 for the three age ranges (Bruni, 2014).

Various measures were used to target prosody. In order to create a score for prosody for the participants from phase one, we selected items from the SRS-2 that were related to both expressive and receptive prosody and summed them to create a prosody score (Pr-SRS-2). The
Following questions were used for this score: “When people change their tone or facial expression, I usually pick up on that and understand what it means;” “I get overly loud without realizing it;” and “I tend to talk in a monotone voice (in other words, less inflection of voice than most people demonstrate).” For phase two of the study (i.e., in-person portion), we employed two behavioral tasks to assess understanding (perception) and use (expression) of prosody. First, we audio- and video-recorded participants as they maintained a 10-minute conversation with a conversational partner (see procedures below). Possessing the speech, language, and mental capacities to hold a conversation for 10 minutes was used as an inclusion criterion. Later, a group of three trained research assistants listened carefully to the recording of the participant’s conversation and came to a consensus for a rating of their prosodic features in speech (see below for a description of the rating techniques). Further, we used the Reading the Mind in the Voice Test – Revised (RMV-R; Golan et al., 2007) to assess participants’ understanding of the correlation between prosody and complex emotions. This test has 25 items with four multiple choice options for each item (one correct, three foils). Each item is composed of a spoken utterance from a BBC film. The participant was asked which complex emotion best matched the prosodic features of the spoken utterance. Participants were scored based on how many of the 25 items they answered correctly (i.e., identified the correct emotion). Psychometrics for the RMV-R include a power score of $1–\beta = 0.998$ and test-retest reliability of $r = 0.8$; the test also accurately identified 90% of autistic participants (Golan et al., 2007).

Data Collection and Procedures

Participants first provided implied consent and filled out the AQ, SRS-2, GSQ, EQ, and TAS-20 online and submitted their answers virtually (phase one of the study). A random sample of the survey respondents, controlled for age and sex, were then asked to come in person to
complete additional questionnaires and prosody behavioral measurements. Once present for their appointment, they were asked to provide contact information for a close friend or family member whom we later contacted and with whom we completed the informant form of the BRIEF-A over the phone. Upon completion of the questionnaires and the behavioral tasks, the participant was compensated for their time via cash or course credit.

After receiving consent, research team members held a 10-minute conversation with each participant to elicit a speech sample to analyze. These conversations included topics such as introductions, majors/minors in school, families, future plans of employment, and hobbies. These interactions were audio- and video-recorded using a video camera mounted on a tripod in the corner of the room and a microphone attached to a laptop. Adobe Audition software (Adobe, 2023) was used to record the conversation. Participants then either completed the AASP and the self-report form of the BRIEF-A or completed a receptive prosody behavioral task. The order of was alternated to avoid bias. To measure receptive prosody, members of the research team explained the RMV-R test to the participants and answered any questions. The participant was provided with a paper to mark their answers in a multiple-choice format, a list of definitions for each of the emotion words, and a list of the spoken utterances for each item on the RMV-R. The research assistant then played each item on the RMV-R only once, waited for the participant to mark their answer, and then played the next item. This continued until all 25 items were played. Speakers attached to the laptop were utilized to play each item.

Scoring of the behavioral measures for prosody was composed of two parts. First, to score the conversational sample, three members of the research team who were not involved in that participant’s in-person portion of the study, watched and rated the 10-minute audio recording of the participants’ conversation independently. The rating was adapted from item A-2
of the Autism Diagnostic Observation Schedule—Second Edition (ADOS-2), one of the principal assessments for diagnosing autism (Lord et al., 2012). We used the scoring system from this item of the ADOS-2, in that a score of 0 signified no abnormalities in intonation, volume, rhythm, or rate. A score of 1 signified a little variation with either a monotone or exaggerated voice. A score of 2 signified speech that is clearly abnormal for a variety of reasons (refer to item A-2 on the ADOS-2 for a more complete explanation of scoring). When scoring the participants’ expressive prosody, the research team provided notes regarding their rationale for each score. A consensus score of at least two out of the three research assistants was then assigned to the participant. The members of the research team were trained on this scoring system before scoring participants’ prosody. The next phase of prosody scoring involved calculating how many items the participants correctly answered (i.e., they chose the correct emotion) on the RMV-R to find their final score.

**Data Analysis**

To test between-group differences on sensory processing, emotional processing, and prosody, we carried out Mann-Whitney U-Tests (see Figure 1) between the autistic and neurotypical participants on the total scores of the AASP, GSQ, BRIEF-A, EQ, TAS-20, item A-2 on the ADOS-2, and RMV-R. In addition, we conducted similar analyses when comparing between-group differences based on gender—i.e., we compared autistic males and females to their neurotypical counterparts.

To examine the relationships between pairings of our constructs of interest, we computed Spearman Rank Order correlations between total scores of every combination of the AASP, GSQ, BRIEF-A, EQ, TAS-20, item A-2 on the ADOS-2, and RMV-R (see Figure 1). Additionally, we carried out similar correlations for males and females separately, controlling for
age. Furthermore, we statistically compared the strength of these associations between males and females using a general linear model approach.

To test our hypothesis that the relationship between emotional processing and prosody is mediated by sensory processing (see Figure 1), we first carried out mediation analyses with the GSQ/AASP-auditory scores as the mediator, the TAS-20 as the x-variable, and the ADOS-2/prosody score as the y-variable. Because these analyses only explained the mediation in the online sample, we also carried out exploratory mediation analyses with the TAS-20 as the mediator, the GSQ as the x-variable, and the Pr-SRS-2 as the y-variable because the alexithymia was shown to be a mediating factor in the male/female analysis.

Results

Our results are delineated below, organized by type of analysis, study phase (i.e., Phase 1—online survey; Phase 2—in-person), and relationships between the three constructs.

Between Group Differences

Phase 1: Online Survey

When we compared the total scores on measures of interest between the NT (n = 624) and autistic (n = 15) groups, all total scores were significantly different. For example, emotion differed between the groups as measured by the TAS-20 ($U = 7800.50, p < 0.001$) and EQ ($U = 641.50, p < 0.001$). Sensory processing was also different between the groups as measured by the GSQ ($U = 7262.00, p < 0.001$). Prosody also showed a difference between the NT and autistic groups as measured by the Pr-SRS-2 ($U = 8048.50, p < 0.001$). In addition to total scores, we performed a planned between group comparison of the auditory subtest score from the GSQ, which also revealed a significant difference between autistic and NT adults ($U = 6571.50, p = 0.008$). These comparisons can be seen in Table 1.
**Phase 2: In-Person**

When we compared the total scores on measures of interest between the NT (n = 40) and autistic (n = 11) groups in our in-person sample, most were significantly different. For instance, emotion differed between the groups as measured by the SR-BRI ($U = 344.50, p = 0.004$). Sensory processing differed between the groups as measured by the four quadrant scores of the AASP—low registration ($U = 362.00, p = 0.001$), sensation seeking ($U = 70.00, p < 0.001$), sensory sensitivity ($U = 352.50, p = 0.002$), and sensation avoiding ($U = 395.00, p < 0.001$). Expressive prosody also differed between the NT and autistic groups as measured by the ADOS-2 prosody score ($U = 285.00, p = 0.01$). These comparisons can be seen in Table 2.

Once again, we completed planned comparisons of variables that were important to our hypotheses. For example, both measures of auditory processing (i.e., AASP-auditory and GSQ-auditory) were significantly different between the NT and autistic participants (AASP-auditory: $U = 377.50, p < 0.001$; GSQ-auditory: $U = 341.00, p = 0.005$). In addition, the communication subscore of the SRS-2 ($U = 427.00, p < 0.001$) and our Pr-SRS-2 ($U = 342.00, p = 0.005$) were significantly different between the groups.

**Within Group Correlations**

**Phase 1**

We observed several notable correlations between couplings of our various measures of emotion, prosody, and sensory processing (see Table 3; see Figure 2). For instance, emotion and sensory processing showed significant association—scores on the TAS-20 were significantly and positively correlated with those from the GSQ ($r = 0.455, p < 0.001$). Additionally, there was a significant, albeit weak, negative correlation between the EQ and GSQ ($r = -0.296, p < 0.001$). We found that emotion and prosody were also significantly correlated. For instance, Pr-SRS-2
was negatively correlated with the EQ ($r = -0.57, p < 0.001$) and positively related to the TAS-20 ($r = 0.42, p < 0.001$). Finally, sensory processing and prosody were shown to be significantly correlated. That is, results revealed a significant positive correlation between the GSQ total score and Pr-SRS-2 ($r = 0.425, p < 0.001$). In addition, autistic traits as measured by the AQ total score were significantly correlated with Pr-SRS-2 ($r = 0.497, p < 0.001$). Significant relationships were also found when autistic traits were used as a covariate (see Table 4).

**Phase 2**

**Emotion and Sensory Processing.** Emotion and sensory processing were correlated across most measures of these constructs. For example, the behavior regulation index from the self-report BRIEF-A (SR-BRI) was significantly associated with the low registration ($r = 0.618, p < 0.001$), sensory sensitivity ($r = 0.561, p < 0.001$), and sensation avoiding ($r = 0.460, p < 0.001$) scores on the AASP. Furthermore, the TAS-20 also demonstrated a moderate to strong positive correlation to these same three scores from the AASP—low registration ($r = 0.478, p < 0.001$), sensory sensitivity ($r = 0.446, p = 0.001$), and sensation avoiding ($r = 0.569, p < 0.001$). In contrast, the TAS-20 demonstrated a weaker negative correlation with the sensation seeking score on the AASP ($r = -0.387, p = 0.005$). The TAS-20 exhibited a strong positive correlation with an additional measure of sensory processing, GSQ total score ($r = 0.585, p < 0.001$).

**Emotion and Prosody.** Results demonstrated that emotion and prosody tended to demonstrate an inverse relationship. For example, receptive prosody, as measured by the RMV-R, showed a negative correlation with the SR-BRI ($r = -0.30, p = 0.03$) as well as the EQ ($r = -0.30, p = 0.04$). Expressive prosody, as measured by each participant’s ADOS-2 score from the conversational sample, was also weakly and negatively correlated with the TAS-20 ($r = -0.28, p$
Other couplings of our measures of prosody and emotion were not significantly correlated.

**Prosody and Sensory Processing.** While some aspects of sensory processing were not significantly correlated with prosody, interestingly, processing in the auditory modality was. One example of this pattern was observed with expressive prosody (ADOS-2) which was positively correlated with the auditory processing score on the AASP ($r = 0.30, p = 0.03$). While not sensory processing, one of our measures of general autistic traits, the AQ total score, was also significantly correlated with Pr-SRS-2 ($r = 0.64, p < 0.001$).

**Mediation Between Constructs**

We originally hypothesized a mediatory role of sensory processing between emotion and prosody (see Figure 3). Indeed, our data supported this hypothesis, in that GSQ total score was a mediator between the TAS-20 and Pr-SRS-2 (see Figure 4). That is, the association between TAS-20 and GSQ scores was significant ($\beta = 0.79, p < 0.001$). Similarly, GSQ and Pr-SRS-2 were also significantly related ($\beta = 0.03, p < 0.001$). The direct effect of TAS-20 on Pr-SRS-2 was also significant ($\beta = 0.04, p < 0.01$). Indirect effects in this model were tested using bootstrapping methods (5,000 samples). The bootstrapped standardized indirect effect was 0.02, which fell within the 95% confidence interval, suggesting that the model was significant. Similar effects were observed in our smaller, in-person sample, but did not remain significant when autistic traits (AQ total score) was used as a covariate.

**Analysis of Sex-Based Differences**

We conducted an exploratory analysis to determine possible differences between males and females, due to variations in expression of autistic traits, emotion, prosody, and sensory processing between the sexes.
**Between Group Differences**

We used Mann-Whitney U tests to evaluate differences between males ($n = 208$) and a random sample of females ($n = 210$) in the total scores of the various measures, as well as several subtests related to our hypothesis. Overall, there were significant differences in the GSQ total score ($U = 17452.00$), GSQ-hypersensitivity subscore ($U = 15462.50$), GSQ-auditory subscore ($U = 17006.00$), and the EQ total score ($U = 16664.50$) between males and females ($p < 0.001$ for all). Notably, no significant differences were found in measures of prosody between males and females. Similar results were not observed in our in-person sample, suggesting an effect of sample size.

**Within Group Correlations**

**Phase 1.** There were distinct differences between males and females in correlations between several factors, with the males exhibiting stronger correlations in some measures and females demonstrating more robust correlations in others. For instance, males presented with a stronger correlation between the EQ and Pr-SRS-2 ($r = -0.538$, $p < 0.001$) and the Pr-SRS-2 and the AQ ($r = 0.497$, $p < 0.001$). Males also demonstrated higher correlations between the TAS-20 and the AQ ($r = 0.541$, $p < 0.001$), the GSQ total score ($r = 0.476$, $p < 0.001$), and the Pr-SRS-2 ($r = 0.428$, $p < 0.001$). On the other hand, females demonstrated enhanced relationships in other measures, including the Pr-SRS-2 and GSQ total score ($r = 0.380$, $p < 0.001$), the AQ and GSQ total score ($r = 0.429$, $p < 0.001$), the EQ and GSQ total score ($r = -0.235$, $p < 0.001$), and the GSQ-hypersensitivity score and Pr-SRS-2 ($r = 0.337$, $p < 0.001$).

**Phase 2.** Males demonstrated higher correlations between the AASP-auditory score and ADOS-2/prosody score ($r = 0.491$, $p = 0.015$), as well as between the TAS-20 and the AQ ($r = 0.682$, $p < 0.001$). In contrast, females presented with stronger associations between the TAS-20
and the ADOS-2/prosody score ($r = 0.424, p = 0.027$), the TAS-20 and AASP-auditory score ($r = 0.449, p = 0.019$), and the AASP-auditory score and AQ ($r = 0.591, p = 0.001$).

**Mediation Between Constructs**

Mediation analysis results suggested a significant mediating role of emotion on the relationship between sensory processing and prosody that differed between males and females in both the online and in-person samples. In a sample from the online survey respondents ($n = 422$), the TAS-20 mediated the relationship between the GSQ and Pr-SRS-2 in males ($n = 206; \text{model: } r = 0.45, p = 0.000$) and females ($n = 216; \text{model: } r = 0.51, p = 0.000$). This effect persisted when AQ was used as a covariate. Most notably, however, in the in-person sample, alexithymia (TAS-20) was a significant mediator between scores on the AASP-auditory subtest and ADOS-2/prosody scores in females only (see Figure 5). More specifically, the relationship between AASP-auditory and TAS-20 scores was statistically significant ($\beta = 0.83, p = 0.05$). In contrast, the relationship between TAS-20 and ADOS-2/prosody scores did not reach significance ($\beta = 0.12, p = 0.14$). The direct effect of AASP-auditory on ADOS-2/prosody was also non-significant ($\beta = 0.04, p < 0.01$). The bootstrapped (5,000 samples) standardized indirect effect was 0.09, which fell within the 95% confidence interval, pointing to overall significance of the model. This mediation effect was decreased when AQ was used as a covariate, even in females.

**Discussion**

**Overview**

In the present study, the main findings included significant correlations between emotion, sensory processing, and both expressive and receptive prosody for both NT and autistic participants. Additionally, we found that sensory processing played a mediating role between emotion and prosody, although the mediation model looked slightly differently for male and
females. Interestingly, analyses demonstrated that autistic traits seem to have significant influence on the correlations between these three constructs but different degrees of influence when comparing males and females. These findings will be discussed further below and compared to the current literature.

**Emotion and Sensory Processing**

Results of this study demonstrated a positive correlation between emotion and sensory processing, in agreement with our hypothesis. This finding aligns with the literature, in that a key component of emotional processing is receiving, analyzing, and synthesizing multiple pieces of sensory information simultaneously. Autistic individuals often demonstrate difficulty with this process (Cardon et al., 2017; Marco et al., 2011; Thye et al., 2018; Zhang et al., 2022). While the literature provides insight into this issue, a full understanding of multisensory processing and emotion is still elusive. Based on this study’s findings and those from the literature, we emphasize the likelihood that there is a higher-order cognitive component, such that autistic individuals may struggle to attend to and process the sensory aspects of more complex and nuanced elements of social communication, such as prosody (Baum et al., 2015; Kawakami et al., 2020; Martínez et al., 2020). For example, Kawakami et al. (2020) found a significant negative correlation between autistic traits and length of a temporal binding window when analyzing multisensory information. In other words, the greater degree of autistic traits, the increased difficulty with multisensory temporal processing. This may have implications on aspects of prosody which rely on temporal processing (e.g., pause). Further, differences in right hemisphere connectivity are often implicated in autism, which is the cortical hemisphere primarily responsible for prosodic interpretation and expression (Cardon et al., 2017; Mitchell et al., 2003). These cortical and cognitive differences may play a role in social contexts, including
interpreting prosody and highlight the likely relationship between sensory processing and prosody.

Autistic individuals also commonly exhibit difficulty with emotional regulation (Gross & Jazaieri, 2014; Mazefsky et al., 2014; Weiss et al., 2014; White et al., 2014) and present with higher rates of alexithymia (Cameron et al., 2014; Maisel et al., 2016; South & Rodgers, 2017). In light of our findings, perhaps these emotional differences are also associated with the difficulty many autistic individuals demonstrate with filtering and interpreting multiple aspects of their sensory environment. For example, if an autistic individual feels bombarded with sensory information (e.g., distracting background noises, bright lights, uncomfortable clothing), then they may demonstrate difficulty regulating their emotions in an adaptive manner because they might feel too overwhelmed to process all the information at once and plan a regulating response. If an individual feels at peace, they might have more mental energy to appropriately devote to attending to salient sensory aspects in their environment and responding in a more typical manner. Moreover, autistic individuals often demonstrate a decreased ability to identify and interpret internal signals related to affective information, also known as interoception. That is, they have difficulty processing the sensory information from within oneself to understand their own feelings (Garfinkel et al., 2016; Mulcahy et al., 2019). This affective variation is likely linked to the higher rates of alexithymia in the autistic population (Garfinkel et al., 2016; Mulcahy et al., 2019; South & Rodgers, 2017). Difficulty with interoception may lead autistic individuals to process emotion-related sensory cues differently than NT peers which could result in the misinterpretation of other’s emotions. Thus, differences in sensory processing of both external and internal signals could be associated with difficulties processing one’s own and others’ emotions. Findings from the current study suggest that the more typical the participants’
emotional processing skills were, the better they could process incoming sensory information, and vice versa. However, it should be noted that this effect was not necessarily divided along diagnostic lines. Rather, some pertinent correlational findings in the present study approached these relationships from a dimensional perspective.

**Emotion and Prosody**

Speakers can convey both grammatical and affective information via prosody (Eigsti et al., 2012). Our findings showed a significant, mostly negative, correlation between emotional processing and expressive/receptive prosody. For instance, participants who demonstrated more typical expressive prosody also showed increased ability to empathize and decreased alexithymia overall. Previous research has shown that autistic individuals often have difficulty producing and perceiving nuanced prosodic features (Kargas et al., 2016; Paul, Augustyn, et al., 2005; Paul et al., 2008; Paul, Shriberg, et al., 2005; Shriberg et al., 2001), and connections between alexithymia and prosody are found in the literature. One example from Goerlich-Dobre et al. (2014) suggested that those with alexithymia demonstrated reduced neural signals that were linked to interpreting prosody in speech. Moreover, Rosenblau et al. (2017) found diminished neural signals in autistic individuals when processing affective prosodic cues. In the present study, increased autistic traits were associated with both heightened emotional and prosodic differences, thus corroborating previous research conducted in this field. These findings suggest that emotion and prosody may be closely linked and that supports offered in one realm may result in improvement in the other.

There has been some debate about whether atypical perception or production of prosody is more characteristic of autistic individuals. For example, Kargas et al. (2016) averred that autistic adults demonstrated increased difficulty with receptive prosody, as shown by trouble
distinguishing syllable stress. On the other hand, Grossman et al. (2010) found that expressive prosody was more atypical in autistic individuals as evidenced by unusually long productions. Further, Hubbard et al. (2017) found that listeners rated autistic individuals’ prosody production as less typical when compared to NT peers. Similarly, our study found that listeners rated autistic participants’ prosody production as less typical, even when raters were blind to the diagnoses of participants. While the current study did not reveal a statistically significant difference in prosodic perception between neurotypical and autistic participants, there was a trend toward significance. We suspect that this effect might be related to sample size. Thus, future studies in this area with larger samples of autistic participants are warranted.

**Sensory Processing and Prosody**

Overall, we also found significant relationships between sensory processing and prosody. First, sensory hyposensitivity was shown to be negatively correlated with expressive prosody, underscoring the logical connection of perception and production. In other words, an individual can better utilize prosodic cues to relay affective or grammatical information when they can accurately perceive the slight tonal and inflectional variations in everyday speech (Gebauer et al., 2014; Zhang et al., 2022).

Auditory processing, specifically, was found to play a key role in the relationship of sensory processing and prosody. Auditory processing and expressive prosody were negatively correlated in the general group of participants as well as in the autistic participants who were involved in phase two. In other words, difficulty with auditory processing was connected to less typical expressive prosody. Lin et al. (2015) suggests that autistic individuals demonstrate a decreased capacity to make and adjust motor plans (including speech) in anticipation of external sensory factors (e.g., to plan to speak louder in a noisy environment) and that they rely mostly on
auditory feedback from already-spoken utterances to adjust these plans. This reduced feedback system would limit and slow the natural self-correction process of prosodic expression. In addition to the anatomical variations in the right hemisphere of the brain (Cardon et al., 2017; Mitchell et al., 2003) as previously mentioned, several others have posited that there are possible anatomical differences in the cerebellum as well, a brain structure critically important for adjusting and fine-tuning motor plans, in NT and autistic individuals (Cardon et al., 2017; D’Mello & Stoodley, 2015; Kern, 2002). Such a difference would impact the cortical feedback of all sensory modalities, not only auditory input. If an individual presented with differences in the auditory feedback system from birth, they would likely demonstrate difficulty modulating their prosodic perception and expression throughout development and, potentially, across the lifespan. Furthermore, such an individual might struggle to process and interpret prosodic cues from others which would further affect prosodic processing and development. Studies have shown significant differences in prosodic perception and expression between NT and autistic children, adolescents, and adults (Grossman et al., 2010; Kargas et al., 2016; Peppé et al., 2011; Shriberg et al., 2001). Research has noted that autistic individuals often present with atypical auditory processing (O’Connor, 2012; Rapin & Dunn, 2003; Williams et al., 2021), which may be related to the ubiquity of differences in expressive and receptive prosody. Our study contributes to the literature by underlining the importance of the auditory modality when investigating the interrelationship of sensory processing and prosody.

**Differences in Sensory Processing, Emotion, and Prosody Between Males and Females**

There were several noteworthy findings when comparing male and female results from the current study. For instance, males and females differed on several items, especially hypersensitivity and empathy (consistent with Cardon et al., 2023), but did not differ in prosody
scores. This suggests that males and females perceive and express prosody in similar ways overall. On the other hand, several sex-based differences in correlational patterns existed in the current study, particularly from the larger sample in phase one. For instance, prosody was a common factor in correlations for males, significantly relating to emotion, autistic traits, and alexithymia. For females, sensory processing was a more common variable, correlating with emotion, autistic traits, and prosody. Additionally, females demonstrated higher rates of hypersensitivity to sensory input. Although females in this group were both autistic and NT, there is an interesting connection to results found by Osório et al. (2021) that female autistic children present with much higher rates of atypical sensory processing. This trend appears to continue across the lifespan, as Lai et al. (2011) found that female autistic adults presented with increased sensory sensitivities when compared to male autistic adults. Overall, females seem to have lower thresholds for sensory information when compared to males.

Ultimately, mediation analyses carried out separately in our groups of males and females showed that the relationship between sensory processing and prosody was mediated by emotion (particularly alexithymia), primarily in females. Our data suggest that sensory processing is associated with alexithymia which predicts prosody performance in females. This is a notable finding, given that this was the smallest sample for which there was a significant mediation, it was only in females, and it contained a task-based measure as opposed to only questionnaire data. The importance of alexithymia in this mediation may be a sex-specific effect. Additionally, while autistic traits seem to be a factor in this mediating relationship, their influence appears to be stronger in males (i.e., the mediation was eliminated in males when controlled for autistic traits). Overall, it seems that our males and females differed along constructs that mirror previous studies—sensory subtypes and EQ—but not general autistic traits (Cardon et al., 2023; Osório et
al., 2021; Schneider et al., 2013). This suggests that males and females present with more similar levels of autistic traits than would be expected by the current diagnostic ratios (i.e., 3.8:1; Maenner et al., 2023). However, males and females seem to have different profiles/expression of autism-related traits. Our mediation model supports this, showing that the mediatory effect of emotion on the relationship between sensory processing and prosody is most significant/present in females, while general autistic traits seem to be more impactful on the same model in males.

**Autistic Traits**

In the current study, it is important to note that while many of the aforementioned results are pertinent to those with a diagnosis of ASD, the majority of our participants, especially in the online sample, did not have such a diagnosis. Thus, we highlight here that many of the same relationships found among autistic persons also exist in the neurotypical population or may vary continuously across diagnostic lines. Results from the current study support the theory of the broad autism phenotype and dimensional or hybrid approaches to understanding autistic traits (De Groot & Strien, 2017; Maxwell et al., 2013). One example of such findings was observed in the mediation analysis. Though our mediation models’ effects were reduced when a measure of autistic traits was used as a covariate, in most cases, they remained significant. This finding suggests that even when we controlled for autistic traits, the relationships of other traits germane to the current study continued to exhibit strong associations, even when the majority of the sample was neurotypical. Therefore, as interested parties use the information presented herein to support autistic people, they might also consider how these findings apply to neurotypical individuals who exhibit difficulties in sensory processing, prosody, and emotion function.
Limitations and Further Research

While the present study demonstrated significant relationships between the three constructs—emotion, prosody, and sensory processing—further research is warranted to target an increased sample size of autistic individuals, particularly for in-person, task-based measures. Thus, taken together, our data support a mediatory role of sensory processing between prosody and emotion. Further research could distinguish what other factors are involved in the relationship between emotional processing and prosody. Future research could also modify the prosody measures used to determine generalization of the findings. For instance, more fine-grained measures of prosody may elucidate additional important effects.

Our current findings should be interpreted cautiously due to a limited sample size for phase two and of autistic adults. The lack of an IQ measure is an additional limitation. Although measuring the participants’ IQ is currently underway, it is not reported or included in the present study. Therefore, the effect that IQ has on the relationships of these three constructs is not yet determined.

Practical Implications

There are implications for stakeholders (especially clinicians) from the current study. First and foremost, developing a more complete understanding of the prosodic abilities of autistic adults can contribute to more meaningful relationships between the autistic and neurotypical communities as the focus switches from how something was said, to what was said. Additionally, as we understand the nature and degree of prosodic deficits in the autistic population, resources can be created, gathered, and distributed to local communities to improve these deficits and decrease the number of miscommunications and missed opportunities. Finally, prosody has been found to be one of the highest contributors (and barriers) to the social and vocational prospects of
the autistic population (Eigsti et al., 2012). As prosody is improved and/or prosodic differences are better understood, autistic individuals may experience fewer barriers in typical adulthood (e.g., creating relationships, maintaining employment). Speech-language pathologists (SLPs) may be the best qualified professionals in helping autistic adults perceive and express more typical prosody. The current study, and others related to prosody, can play a major role in providing evidence-based care to autistic adults who seek to adjust their prosodic perception and expression. As we better understand how autistic adults currently understand and use prosody, we can provide more specific and effective means of treatment. As prosody improves, social and vocational opportunities may open more readily to autistic individuals. Furthermore, as SLPs target prosody with autistic individuals, the current study suggests potential gains might be had in emotional and/or sensory processing as well because of the significant correlation between these three constructs. Ultimately, the current study can contribute to a more meaningful lifestyle for adults, particularly autistic adults.

There are additional implications from the current study, particular for autistic females. These findings may influence practitioners and stakeholders in that knowledge of the unique characteristics of autism in females could aid them in serving/supporting females who express high degrees of autistic traits. Specifically, those who attempt to support prosody function in females may consider the influence of emotion and sensory processing in their efforts, as opposed to focusing solely on prosody itself. Furthermore, since prosodic characteristics may be unique in females, this factor may be considered more heavily during female diagnostics.

**Conclusion**

With the prevalence of autism on the rise, it has become paramount to expand the research regarding autistic adults. In doing so, these individuals and their caregivers can receive
the necessary knowledge and resources needed to navigate through adulthood, which comes with a unique set of challenges and opportunities, including developing relationships and gaining employment. Sensory processing, emotional understanding, and the perception and production of prosody all have implications related to the success and ease of entering adulthood for autistic individuals. However, there was a dearth of information in the literature regarding the correlation between these three factors. The current study investigated the relationship between these three constructs, including the possibility that sensory processing served as a mediator between emotion and prosody. In this study, we hypothesized that there would be positive correlations between emotion, sensory processing, and prosody and that sensory processing acted as the mediator between emotion and prosody. The data from the current study reveal that positive relationships do, in fact, exist between the three constructs. Additionally, sensory processing (particularly auditory processing) plays a mediating role in the relationship of emotion and prosody, and this holds true for both NT and autistic adults. However, autistic traits played a larger role in the mediation analysis for males, whereas emotion, especially alexithymia, was a more significant factor for females. On the other hand, there was no difference found in prosody perception or production between the sexes.

Together, these findings provide insight into the prosodic tendencies and correlates thereof in autistic adults which could help bridge the gap between the autistic and NT communities. In addition, SLPs and other stakeholders may find that targeting prosody with autistic individuals, or others who present with autistic traits, might also improve the sensory and/or emotional processing capabilities of clients and vice versa. Ultimately, prosody is a valuable component to consider in research as well as clinical settings when interacting with
autistic adults and those with autistic traits, particularly due to the complexity of adulthood and the vast array of possibilities and challenges it brings.
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[https://doi.org/10.1016/j.jaac.2019.05.033](https://doi.org/10.1016/j.jaac.2019.05.033)

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https://doi.org/10.1023/a:1025850431170


## Tables

### Table 1

*Demographics and Scores of Phase 1 Participants*

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<th>NT&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Autistic</th>
<th>$U$-value</th>
<th>$p$-value</th>
</tr>
</thead>
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<tr>
<td>$n$</td>
<td>624</td>
<td>15</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Male / female</td>
<td>200 / 424</td>
<td>9 / 6</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Mean age M / F</td>
<td>21.6 / 20.3</td>
<td>22.2 / 20.8</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>EQ&lt;sup&gt;b&lt;/sup&gt;</td>
<td>$M = 47.41$ SD = 11.78</td>
<td>$M = 23.40$ SD = 10.28</td>
<td>641.50</td>
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<tr>
<td>TAS-20&lt;sup&gt;c&lt;/sup&gt;</td>
<td>$M = 48.93$ SD = 10.43</td>
<td>$M = 62.93$ SD = 10.96</td>
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<td>GSQ&lt;sup&gt;d&lt;/sup&gt;</td>
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<tr>
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<td>$M = 20.33$ SD = 4.07</td>
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<tr>
<td>Pr-SRS-2&lt;sup&gt;f&lt;/sup&gt;</td>
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<tr>
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<td>$M = 14.57$ SD = 9.09</td>
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<td>AQ&lt;sup&gt;h&lt;/sup&gt;</td>
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*Note.* <sup>a</sup> Neurotypical. <sup>b</sup> Empathy Quotient. <sup>c</sup> Toronto Alexithymia Scale. <sup>d</sup> Glasgow Sensory Quotient. <sup>e</sup> Glasgow Sensory Quotient: Auditory Subscore. <sup>f</sup> Prosody score from select items of the Social Responsiveness Scale – Second Edition. <sup>g</sup> Social Responsiveness Scale – Second Edition: Communication Subscore. <sup>h</sup> Autism Quotient.
### Table 2

**Demographics and Scores of Phase 2 Participants**

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<th>p-value</th>
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<td>n</td>
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<td>11</td>
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<td>–</td>
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<td>Male / female</td>
<td>18 / 22</td>
<td>6 / 5</td>
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<td>–</td>
</tr>
<tr>
<td>Mean age M / F</td>
<td>21.9 / 20.9</td>
<td>22.2 / 21.0</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>EQ&lt;sup&gt;b&lt;/sup&gt;</td>
<td>M = 51.23 SD = 11.47</td>
<td>M = 23.73 SD = 10.93</td>
<td>21.00</td>
<td>&lt; 0.001</td>
</tr>
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<td>TAS-20&lt;sup&gt;c&lt;/sup&gt;</td>
<td>M = 46.50 SD = 9.03</td>
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<td>Sr-BRI&lt;sup&gt;d&lt;/sup&gt;</td>
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<td>Ir-BRI&lt;sup&gt;e&lt;/sup&gt;</td>
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<td>M = 56.20 SD = 12.52</td>
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<td>AASP – Low registration&lt;sup&gt;f&lt;/sup&gt;</td>
<td>M = 30.35 SD = 6.58</td>
<td>M = 39.36 SD = 8.07</td>
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<td>M = 51.08 SD = 6.28</td>
<td>M = 40.91 SD = 7.94</td>
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<tr>
<td>AASP – Sensory sensitivity&lt;sup&gt;h&lt;/sup&gt;</td>
<td>M = 34.38 SD = 7.00</td>
<td>M = 44.64 SD = 11.19</td>
<td>352.50</td>
<td>0.002</td>
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<tr>
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<td>M = 49.64 SD = 11.29</td>
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<td>AASP – Auditory&lt;sup&gt;j&lt;/sup&gt;</td>
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<td>M = 36.91 SD = 7.16</td>
<td>377.50</td>
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<td>GSQ&lt;sup&gt;k&lt;/sup&gt;</td>
<td>M = 47.18 SD = 16.47</td>
<td>M = 70.82 SD = 29.04</td>
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<td>NT</td>
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<td>U-value</td>
<td>p-value</td>
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<tr>
<td>GSQ – Auditory</td>
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<td>$SD = 3.42$</td>
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<td>RMV-R</td>
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<td>$SD = 4.29$</td>
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*Note.*  
/a Neurotypical.  
/b Empathy Quotient.  
/c Toronto Alexithymia Scale.  
/e Informant Report of the Behavioral Regulation Index from the BRIEF-A.  
/f Adolescent/Adult Sensory Profile (AASP): Low registration subscore.  
/g AASP: Sensation seeking subscore.  
/h AASP: Sensory sensitivity subscore.  
/i AASP: Sensation avoiding subscore.  
/j AASP: Auditory subscore.  
/k Glasgow Sensory Quotient (GSQ).  
/l GSQ: Auditory subscore.  
/m Reading the Mind in the Voice – Revised.  
/p Prosody score from select items of the Social Responsiveness Scale – Second Edition.  
/q Autism Quotient.
Table 3

Partial Correlations of Behavioral Measures – Phase 1

<table>
<thead>
<tr>
<th></th>
<th>GSQ</th>
<th>EQ</th>
<th>AQ</th>
<th>SRS-2-Comm</th>
<th>TAS-20</th>
<th>Pr-SRS-2</th>
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</tr>
<tr>
<td>GSQ(^a)</td>
<td>1</td>
<td>(r = -0.296^{**})</td>
<td>(r = 0.472^{**})</td>
<td>(r = 0.518^{**})</td>
<td>(r = 0.455^{**})</td>
<td>(r = 0.425^{**})</td>
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<tr>
<td></td>
<td></td>
<td>(p &lt; 0.001)</td>
<td>(p &lt; 0.001)</td>
<td>(p &lt; 0.001)</td>
<td>(p &lt; 0.001)</td>
<td>(p &lt; 0.001)</td>
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<td>EQ(^b)</td>
<td>1</td>
<td>(r = -0.563^{**})</td>
<td>(r = -0.656^{**})</td>
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<tr>
<td></td>
<td></td>
<td>(p &lt; 0.001)</td>
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<td>(p &lt; 0.001)</td>
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<td>AQ(^c)</td>
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<td>(p &lt; 0.001)</td>
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<td></td>
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<td>(p &lt; 0.001)</td>
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<tr>
<td>TAS-20(^e)</td>
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<td>(r = 0.420)</td>
<td>(p &lt; 0.001)</td>
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<tr>
<td>Pr-SRS-2(^f)</td>
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</table>

Note. \(^a\) Glasgow Sensory Quotient. \(^b\) Empathy Quotient. \(^c\) Autism Quotient. \(^d\) Social Responsiveness Scale – Second Edition: Communication Subscore. \(^e\) Toronto Alexithymia Scale. \(^f\) Prosody score from select items of the Social Responsiveness Scale – Second Edition. \(^{**}\) Correlation is significant at the 0.01 level (2-tailed).
Table 4

Partial Correlations of Behavioral Measures: Controlled for Autistic Traits – Phase 1

\[ n = 639 \]

<table>
<thead>
<tr>
<th></th>
<th>GSQ</th>
<th>EQ</th>
<th>TAS-20</th>
<th>Pr-SRS-2</th>
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<tr>
<td>GSQ\textsuperscript{a}</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( r = -0.041 )</td>
<td>( r = 0.299^{**} )</td>
<td>( r = 0.249^{**} )</td>
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</tr>
<tr>
<td></td>
<td>( p = 0.297 )</td>
<td>( p &lt; 0.001 )</td>
<td>( p &lt; 0.001 )</td>
<td></td>
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<tr>
<td>EQ\textsuperscript{b}</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>( r = -0.258^{**} )</td>
<td>( r = -0.404^{**} )</td>
<td></td>
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</tr>
<tr>
<td></td>
<td>( p &lt; 0.001 )</td>
<td>( p &lt; 0.001 )</td>
<td></td>
<td></td>
</tr>
<tr>
<td>TAS-20\textsuperscript{c}</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>( r = 0.242^{**} )</td>
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<td>( p &lt; 0.001 )</td>
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<tr>
<td>Pr-SRS-2\textsuperscript{d}</td>
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<td></td>
<td></td>
<td></td>
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</tbody>
</table>

\textit{Note.} \textsuperscript{a} Glasgow Sensory Quotient. \textsuperscript{b} Empathy Quotient. \textsuperscript{c} Toronto Alexithymia Scale. \textsuperscript{d} Prosody score from select items of the Social Responsiveness Scale – Second Edition. **Correlation is significant at the 0.01 level (2-tailed).
Figures

Figure 1

Analyses and Correlations Performed in the Current Study

ANOVA – NT vs. ASD
- ADOS-2/prosody + RMV-R
- BRIEF-A (self- and other-report) + EQ + TAS-20
- AASP + GSQ
- AQ + SRS-2

Correlations
- ADOS-2 + RMV-R / BRIEF-A + EQ + TAS-20
- BRIEF-A + EQ + TAS-20 / AASP + GSQ
- ADOS-2 + RMV-R / AASP + GSQ

Mediation

[Diagram showing mediation relationships between variables such as BRIEF-A, EQ, TAS-20, AASP, GSQ, ADOS-2, and RMV-R]
Figure 2

Scatter Plots of Correlations of Various Pairings of Constructs of Interest: Sensory Processing—Emotion (A), Prosody—Emotion (B), and Prosody—Sensory Processing (C) From Phase 1
Figure 3

*Theoretical Mediation Model*

![Diagram showing the theoretical mediation model with arrows indicating the relationships between Sensory processing, Emotional processing, and Prosody.](image)

Figure 4

*Mediation Analysis – Phase 1*

![Diagram showing the mediation analysis for Phase 1 with statistical details and beta coefficients.](image)
Figure 5

Female Mediation Analysis – Phase 2

![Diagram showing the relationship between Alexithymia (TAS-20), Auditory Processing (ASP-Auditory), and Expressive Prosody (ADOS-Prosody).]

- **Alexithymia (TAS-20)**
  - $\beta = 0.83^*$
  - Model:
    - $r=0.55$
    - $r^2=0.30$
    - $p=0.003$
    - Upper CI=0.89
    - Lower CI=0.04

- **Auditory Processing (ASP-Auditory)**
  - $\beta = 0.12$

- **Expressive Prosody (ADOS-Prosody)**
  - $\beta = -0.06$
**APPENDIX A**

**Annotated Bibliography**


*Introduction*: Communication is a crucial part of life, and when breakdowns happen, it can lead to a decrease in well-being. This study wanted to understand the differences in communication style of older and younger adults. The literature has also shown that older individuals have decreased emotional perception in speech, which limits their interactions. For this purpose, this study sought to compare emotion perception in speech in young adults and older adults, particularly their ability to detect emotion from prosodic and semantic cues, any failure to selectively attend to one cue and not the other, and how both groups integrate the two types of channels (prosody vs. semantics).

*Method*: 40 healthy and neurotypical participants were recruited for both groups (younger and older adults; 80 total participants), half male and half female for each group. The Hebrew version of the Test for Rating of Emotions in Speech (T-RES) was used, measuring anger, sadness, fear, and happiness. Two sets of 24 sentences each were validated and used for this study. Participants were tested individually, and there were three parts to a session: rating the semantics, rating the prosody, and general rating.

*Results*: Results showed that, while both older and younger adults could correctly identify emotions when prosodic and semantic information was congruent, younger adults gave more weight to the prosodic features of the spoken stimuli whereas older
adults considered prosody and semantics relatively equal, but with a slight tendency to lean more into semantics. Both older and younger adults were unable to fully separate the two channels (prosody and semantics), exhibiting an inability to selectively attend to one while ignoring the other.

Relevance to current work: This article explores the age-related differences between younger and older adults in relation to their understanding of prosody and semantics in spoken sentences. Most importantly, it explains how neurotypical younger adults (around 25 years old), albeit natives of Israel, understand prosody and how much prosody impacts their interpretation of spoken stimuli. The current study can use this article to loosely compare the target population (young adults with ASD) with neurotypical adults in terms of their prosodic understanding.


Introduction: This study sought to determine the validity of a new test, the Test for Rating of Emotions in Speech (T-RES), when measuring the roles of semantics and prosody in discerning emotion in speech. There has been some ambiguity regarding these two factors in communication, so this study aimed to clarify the confusion.

Method: Eighty young adults (52 female, 28 male) participated in this study, and they were all undergraduate students at a university. These participants completed a self-report survey for health and demographics. They listened to 48 sentences that contained affective information presented in either prosodic or semantic channels. Each participant
was tested individually and completed a Likert scale rating the speaker’s emotion after listening. There were three main sections: attending specifically to the emotions portrayed from the semantic information, from the prosodic elements, and from the sentence generally.

**Results:** Ultimately, this study found three conclusions: first, that when the semantic and prosodic elements matched the same emotion, the participants rated it the highest; second, that participants could not successfully meaningfully ignore one of the channels (i.e., they paid some attention to both); and third, prosody is a more important factor when gleaning affect from speech. Additionally, the T-RES proved to be a simple, easy-to-follow protocol for these tasks.

**Relevance to current work:** This article was helpful in that it had three ideas for ways to measure prosody in speech (the FAB, DANVA2, and the T-RES), and it enumerated the advantages and disadvantages of each. Additionally, this article bolstered previous findings that prosody plays a critical role in helping listeners identify the emotion behind speech. This is significant for the current research, as prosody will likely be an important construct to the present study with adolescents and young adults with and without ASD.


**Introduction:** This article emphasizes the relative lack of understanding regarding emotional regulation in young, preschool/early elementary aged children with ASD even though emotional regulation is a marked difficulty. Children with ASD experience more
emotional dysregulation when compared with neurotypical peers. Interestingly, the authors noted that emotion regulation is not often used in autism research, as problematic behaviors are highlighted instead. The authors argue that it would be more helpful and efficient to target emotional regulation (the root of the problem) rather than simply addressing behavioral issues (the consequences of the problem). This study investigated the emotional regulation abilities of children between the ages of 4-7 and which characteristics are most closely associated with emotional regulation and dysregulation.

**Method:** A total of 108 individuals participated in this study, composed of autistic children and their caregivers. The participants were assessed three times across two years. Participants were recruited through local efforts, schools, websites, and events. The participants completed several assessments and questionnaires including the Emotion Regulation Checklist (ERC), the Child Behavior Checklist 1 1/2 - 5 and 6 - 18 (CBCL), the Social Skills Improvement System (SSIS), the Wechsler Preschool and Primary Scales of Intelligence, 3rd Edition (WPPSI-III), the Comprehensive Assessment of Spoken Language (CASL-2), the Social Responsiveness Scale (SRS), and the Autism Diagnostic Observation Schedule (ADOS-2).

**Results:** Results from this study demonstrated consistency through the various measurements that analyzed emotional regulation. Additionally, they found that emotional regulation was "highly correlated with measures of children’s autism symptomatology, social skills, and behavioral functioning" (Berkovits et al., 2017, p. 74). Notably, a child's emotion regulation scores were stable throughout the study, but those children who improved in emotional regulation also had improved social skills a year later. This finding suggests that if emotional regulation is not targeted and not improved,
social skills will suffer, but interventions can prove helpful in improving emotional regulation and, relatedly, social outcomes.

Relevance to current work: This study contributed much to the current study because it detailed emotional regulation abilities. Even though this particular study was focused on younger children, it stated that, generally, emotional regulation scores were stable, suggesting that these patterns may persist throughout the lifetime without direct intervention. Additionally, it was interesting that the authors noted that behavioral issues were more commonly emphasized in children with ASD even though emotional dysregulation is probably at the root of these difficulties. The present study will incorporate some aspect of emotional regulation, and this study provided helpful background information to the experience of children with ASD.


Introduction: Because there are so many uncertainties and so many questions regarding emotional regulation, the authors of this study investigated whether emotional regulation could be effectively measured and if it was helpful to do so. They hypothesized that the incidence rate of significant emotional dysregulation would be high in adults with ADHD and that it would be linked to morbidity and dysfunction.

Method: The authors conducted a study comprised of 441 adults who had ADHD and who were between the ages of 18-55. They completed a series of assessments and questionnaires, including an interview and completing the Adult ADHD Self-Report
Scale, the Behavior Rating Inventory of Executive Function—Adult version, the Social Responsiveness Scale, the adult self-report, the Barkley Emotional Dysregulation Scale, and the Quality of Life Enjoyment and Satisfaction Questionnaire.

Results: Results from this study determined which of the participants had high- or low-level DESR, and these various participants were then compared. Comparisons demonstrated that people with higher level DESR were more likely to be taking medications. The authors also found that people with higher DESR presented with decreased executive functioning abilities, social skills, and were less equipped for everyday functioning. Notably, these patients with higher level DESR had significantly lower quality of life.

Relevance to current work: Although this study involved individuals with ADHD, it used a valuable resource to operationalize/quantify emotional regulation; they used the Barkley Emotional Dysregulation Scale. This is the most important contribution to the present study. This emotional regulation scale will be examined and, if needed, it could be modified to use with individuals with ASD. Additionally, the authors explained the impact that these participants with ADHD experience due to DESR. These impacts should be taken into consideration in the present study when interacting with individuals with ASD who potentially have difficulties with emotional regulation.


Introduction: Adolescence is a time where friend relationships become more important, and thus social skills are crucial. However, the authors point out that not all youth,
particularly teenagers, are successful in forming and maintaining meaningful relationships with others. It has been noted that individuals with ASD have lower emotional intelligence (EI), both in ability EI and trait EI. Importantly, emotional intelligence can effectively predict social functioning. This study compared emotional intelligence in autistic and NT adolescents to better understand social/emotional needs of these populations at this formative time period.

Method: 25 youth with ASD (18 males and 7 females) and 25 without ASD (14 males and 11 females) met criteria for participating in this study (Boily et al., 2017, p. 285). The parents of these individuals completed two questionnaires: a demographic questionnaire about their child and the Social Communication Questionnaire (SCQ) that measured the social and communicative abilities of their child. The youth participants completed more questionnaires: the Wechsler Abbreviated Scale of Intelligence (WASI) to measure IQ, the BarOn Emotional Quotient Inventory: Youth Version, Short form (BarOn EQ-i: YV(S)) to measure TEI, and the Mayer–Salovey–Caruso Emotional Intelligence Test–Youth Research Version (MSCEIT-YRV) to measure AEI.

Results: The authors noted that this study is an exploratory one and that results should be understood in that light. It was observed that, generally, autistic participants presented with poorer emotional intelligence in several domains when compared to their NT peers. These results explain this population's difficulties in social situations. Interestingly, autistic subjects did not significantly differ from controls on self-reported social abilities although their scores were slightly lower than the norms, and they performed well on the subtest about perceiving emotions. This latter performance may be explained by the facial expressions being presented as static rather than dynamic as well
as the fact that the participants did not have a time limit when studying the faces which might have led to higher rates of success.

Relevance to current work: This research study by Boily et al. (2017) contributed to the current study by examining the emotional intelligence of youth with ASD. The current study will focus on adolescents with ASD and compare them to neurotypical adolescents, and this study provided an appropriate framework for that. It was demonstrated that youth with ASD have lower emotional intelligence which contributes, at least in part, to their social deficits. However, it was noted that emotional intelligence can be targeted and improved through intervention which may be a source of hope for this population. The current study will also incorporate other potential constructs (sensory processing, IU, anxiety), and it was beneficial to understand the emotional foundation that adolescents with ASD may be starting with.


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Introduction: This article investigated the relationship between executive function, sensory deficits, and repetitive behaviors in individuals with ASD, as well as the predictors of RRBs in autism. Evidence shows that individuals with ASD often have atypical sensory processing issues (hyposensitive, hypersensitive, or sensory seeking), and they often engage in repetitive behaviors. The authors suggest that the link between these two autistic traits exists in executive function. However, they concede that evidence is ambivalent as to the relation between repetitive behaviors and executive functions, but
the authors maintain that it is vital to investigate the role of executive function in this relationship in autism.

Method: 61 children with ASD and 64 typically developing children participated in this study. All participants were recruited through the University of North Carolina Autism Research Registry as well as nearby clinics. Participants completed the Repetitive Behavior Scale-Revised, the sensory questionnaire, and the Behavior Rating Inventory of Executive Function to assess repetitive behaviors, sensory deficits, and executive functioning.

Results: Results showed that the ASD group scored significantly higher than the typically developing group on all subtests and overall scores for each of the assessment measures. Additionally, caregivers reported that high-functioning autistic children demonstrated more RRBs, atypical sensory processing, and executive functioning issues. A correlation was also found between sensory processing difficulties and repetitive behaviors as determined by their RBS-R score. In contrast, no relationship was found between executive functioning and sensory deficits in individuals with ASD, suggesting that executive function is not the decisive link between sensory processing and RRBs.

Relevance to current work: This article referenced potential relationships between executive functioning, sensory deficits, and repetitive behaviors. The current study may involve some aspect of executive functioning, and this article provided a framework for options for the study (as well as excluded other options). Additionally, the current article will incorporate sensory processing abilities in individuals with ASD which this article also touches on.

**Introduction:** Humans experience a vast array of emotions, and we want to experience positive feelings so we regulate negative ones. There are, of course, several methods of emotional regulation, some of which increase or decrease the current emotion, whether positive or negative. It has been frequently noted that individuals with ASD often have difficulties regulating their emotions, using less adaptive regulating strategies than NT peers. Additionally, it has been observed that individuals with ASD experience and express their emotions differently than neurotypical peers. This study investigated how the use of a variety of emotional regulation strategies coupled with psychological well-being impacted the moods of individuals with and without ASD.

**Method:** 24 individuals with ASD and 20 individuals without ASD participated in this study, but only the results from 23 individuals with ASD and 19 individuals without ASD were analyzed due to exclusion factors. The participants completed several questionnaires, including one to measure demographic information, the DSM-5 Cross-cutting Dimensional Scale (DSM-5 CROSS-D) to measure anxiety symptoms, the Patient Health Questionnaire-9 to measure depression symptoms, and the Warwick-Edinburgh Mental Wellbeing Scale (WEMWBS) to measure positive psychological wellbeing. Non-ASD participants also completed the short version of the Autism Spectrum Quotient to measure ASD traits, and the diagnosis for individuals with ASD was corroborated by
Module 4 of the Autism Diagnostic Observation Schedule-Second Edition (ADOS-2). All participants were trained on the app the authors used and were given an iPad to complete a brief survey three times each day for a few days on that app.

**Results:** Results showed that the ASD participants scored much higher on measures of autistic traits, anxiety, depression, and much lower on measures of wellbeing. For both ASD and non-ASD groups, both positive wellbeing and anxiety predicted mood, but interestingly, depression did not. Notably, it was found that there was no significant difference between the groups and which emotions they experienced. On the other hand, there was a significant link between group and how they modified their positive emotions, suggesting that NT individuals accept positive emotions more readily than autistic individuals. Further, those without ASD used more ER strategies to regulate negative emotions than participants with ASD.

**Relevance to current work:** This study was extremely fascinating. It dove into the topic of emotional regulation, specifically comparing how individuals with and without ASD regulated both positive and negative emotions. It is an accepted fact that individuals with ASD have deficits in emotional understanding, which leads to issues of control and management. In relation to the current study, Cai et al. (2020) commented briefly on the principle of alexithymia in individuals with ASD and how that potentially creates problems in the understanding, processing, and regulation of emotions. The authors also mentioned the ineffectiveness of using self-report measures to analyze alexithymia in this population for obvious reasons. An interesting avenue of research was pointed out to measure ER using contextual information since emotions are almost always derived from and depend on one's circumstances.

**Introduction:** Since sensory deficits was added as a criterion for diagnosis of autism spectrum disorder, it has become increasingly important to understand the neurological sources of these deficits. Cardon et al. (2017) set out to do just that. Citing several budding theories, the authors suggest that autistic traits can be explained "by deficits in distributed neurological networks, rather than single portions of the brain" (Cardon et al., 2017, p. 2). The purpose of this study is to analyze correlations between various sensory processing brain structures including the cerebellum and amygdala.

**Method:** A group of solely male participants, made up of both typically developing and those diagnosed with ASD, took part in this study. Using magnetic resonance imaging, Cardon et al. (2017) took measurements of the volume of various brain structures from the frontal, temporal, occipital, parietal cortices, amygdala, both cerebellar hemispheres, and conducted inter- and intragroup comparisons with these measurements.

**Results:** In short, Cardon et al. (2017) found that several structural differences between the ASD and TD group. Interestingly, the ASD group demonstrated increased connections within each hemisphere but decreased connections between the right and left hemispheres of the brain as well as decreased connections between the cortex and cerebellum. The typically developing group demonstrated the exact opposite. Additionally, the ASD group demonstrated several significant correlations with the amygdala; the TD group did not.
Relevance to current work: The ASD group in this study demonstrated that there are physical differences in the dimensions of various brain structures. These differences include interhemisphere variations and those within the amygdala and cerebellum. Potentially, these physical differences contribute to disparities in the ability to emotionally regulate between typically developing and ASD groups. If the source(s) of these disparities can be pinpointed, there are myriad implications as to how to best treat and temper these emotional vicissitudes.


Introduction: Pitch, intensity, and duration are all components of the suprasegmental language feature of prosody. In spoken language, prosody can be used to relay either grammatical information, as in if the utterance is a statement or a question, or affective or emotional information. It has been noted that abnormal prosody production has been implicated in autism and that this can significantly affect these individuals’ social and vocational outcomes. Interestingly, prosody tends to be consistent over time and is linked to autistic people’s social and communicative abilities. To date, there has been much debate in the literature about how individuals with ASD understand and produce appropriate prosody. This study sought to clarify this topic.

Method: 16 individuals with ASD (14 male) and 11 typically developing individuals (7 boys) participated in this study; all participants were between 9 and 17 years old. While in an MRI scanner, the participants listened to a set of pre-recorded sentences that were spoken by a female native English speaker. The sentences were all
declarative and three to five words long, and they were spoken with either a neutral or angry voice (affective prosody), with either a statement or question intonation (grammatical prosody). Participants were never told to attend to the prosody of the speaker.

**Results:** fMRI scans showed that for TD individuals, affective prosody is primarily processed in the left IFG. The ASD group, on the other hand, processed affective prosody in a variety of different brain regions, including the bilateral parahippocampal gyrus, the left globus pallidus, the right STG, the right MFG, and the precentral gyrus. Grammatical prosody, for the TD group, was processed entirely in the right STG whereas for the ASD group, it was processed again in several regions. These include the right anterior cingulate cortex, the right superior frontal gyrus, and the bilateral middle frontal gyrus. These findings illustrate that autistic individuals activated a lot more brain regions when interpreting prosody information, suggesting that it takes additional cognitive effort. This conclusion aligns with the fact that individuals with ASD perform better when explicitly told to attend to prosody which decreases the cognitive and attentional demands of the task.

**Relevance to current work:** This study was exceptionally helpful to the current study because it enumerated and elucidated which brain regions are employed for processing prosody in TD individuals and in those with ASD. This study marks significant differences between the two which is to be expected but helps shape the experimental design for the current study. Importantly, this study provides specific brain regions that can be measured using fMRI imaging.
Introduction: There is a significant correlation between ASD and anxiety, as several published works have pointed out. This review article mainly draws on the strong connection between sensory processing, autism, and anxiety, but it particularly three major contributors to the co-occurrence of anxiety in ASD: sensory dysfunction, alexithymia, and neurobiology. The authors argue that as we understand these concepts better, we can more effectively treat these individuals and their deficits.

Method: The authors studied 19 different types of research articles related to ASD, anxiety, sensory processing, and psychopathology. The articles were found by conducting a PubMed search of articles on these topics that were published in the last ten years; articles that were irrelevant or copied were disregarded.

Results: "Hyperarousal" and "hypervigilance" are often symptoms of anxiety, and these symptoms heighten any incoming sensory information, which plays into the abnormal sensory functioning of individuals with ASD. In other words, since individuals with ASD often are also diagnosed with anxiety, the hypersensitive nature of anxiety only serves to exacerbate the sensory overload cycle of those with ASD. Further, this link between anxious feelings and sensory processing difficulties for those with ASD may be due to a stronger neural connection to the amygdala.

The amygdala may not be the only brain structure that is vilified in this situation--the anterior insula, at least in part, is responsible for our abilities to understand and appropriately cope with our emotions; alexithymia is the inability to do so. Individuals
with ASD often experience alexithymia and thus struggle to understand emotions, both their own and others'. Interestingly, the oft-cited difficulties autistic individuals demonstrate regarding empathy is due to emotional processing, not social capabilities. Stated otherwise, one's ability to empathize has more to do with the depth of his/her emotional understanding than with his/her ability to interact with peers.

Individuals with ASD often have slight variations in their neuroanatomy compared to their typically-developing peers. In particular, there is increased activation in the auditory and visual cortices as well as the thalamus, which are all cranial regions related to interpreting sensory information. This may explain why these individuals experience lower sensory thresholds. Additionally, there is increased activation in emotional processing centers of the brain, particularly the amygdala, hippocampus, and prefrontal cortex. This might explain why these individuals have difficulty with alexithymia and emotional regulation.

_relevance to current work:_ This study touched on classic features of ASD--difficulties with sensory processing and emotional understanding, as well as the neuroanatomical differences that may explain these difficulties. In specifically enumerating various brain differences in individuals with ASD, this study helps bring about greater clarity on what one might see on an MRI scan. Also, in addressing sensory deficits and alexithymia, this article emphasized the importance to make research applicable to real-life individuals who live in a sensory- and emotion-filled world and ways that clinicians can engage in more effective treatment strategies.


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*Introduction:* Part of experiencing emotions is to attend to the internal signals of our bodies which is known as interoception. Important physiological changes for emotion processing and this process of interoception have been shown to stem from similar brain regions such as the ventral prefrontal, anterior cingulate and insular cortices, amygdala, ventral striatum and dorsal brainstem. The insula also plays a pivotal role in emotion processing. It has been noted that individuals with ASD have impairments in their ability to appropriately process emotions and that anxiety is a frequent comorbidity. These authors postulated that the emotional processing differences/difficulties in the autistic population may be due to difficulties with interoception, and that interoceptive abilities may be related to anxiety.

*Method:* Twenty adults with ASD (18 male, 2 female) and 20 neurotypical adults (18 male, 2 female) participated in this study. These participants took part in a heartbeat tracking task as well as a heartbeat discrimination task to assess their interoceptive accuracy (how accurate they were in counting their heartbeats without manually checking and if they were correct when identifying whether a tone was synchronous with their heartbeat. Afterwards, they completed a short survey to express how confident they were in their answers. Interoceptive abilities and anxiety were measured using various questionnaires and behavioral tasks.

*Results:* Results demonstrate that the ASD group scored much higher on the AQ and much lower on the EQ than the control group; the ASD group also had significantly higher anxiety scores. As the authors predicted, autistic individuals presented with lower
rates of interoceptive abilities, and this group also had higher interoceptive sensibility. A significant difference for interoceptive awareness was not found between the two groups. Notably, when subjects overestimated their interoceptive abilities on the heartbeat task, it was linked to higher anxiety scores. Severity of ASD and anxiety were positively correlated. Subjects’ interoceptive scores were independently linked to anxiety.

Relevance to current work: This research article was fascinating and related in myriad ways to the current study. Firstly, this study recruited adult participants (including some with ASD), which is somewhat less common in the literature. Additionally, the emphasis on emotion processing and how that related to anxiety was particularly relevant to the current study. The authors found significant links between the ability to understand one's internal state (they defined this as interoception) and emotional processing and anxiety. As one's ability improves to better attend to physiological processes, the more appropriately one can manage emotions. The better one can manage their emotions, the less anxious they will likely be. However, as the authors noted, interoception and emotional processing are not strengths for the ASD population, which makes anxiety the more likely to co-occur. The present study will emphasize some aspect of emotional processing/regulation and its connection to anxiety.


Introduction: Green et al. (2015) acknowledged that more research needed to be conducted regarding sensory over-responsivity (SOR) in individuals with ASD. Research
that has been done suggests that there are deficits relating to sensory gating and selective attention, suggesting that autistic individuals can easily become overstimulated, even by irrelevant input. Therefore, the authors set out to investigate responses to simultaneous tactile and auditory stimuli in autistic and NT youth to measure SOR. They hypothesized that SOR would be related to a decreased capacity to habituate to sensory input, especially in the amygdala and sensory cortices.

**Method:** Thirty-eight individuals participated in this study—half with ASD and half typically developing—from 9 to 17 years old. fMRI scans were taken as subjects were exposed to three environments: traffic sounds, a tactile task, and then both stimuli simultaneously. During this process, the participants were instructed to focus on a small cross throughout the examination. Brain activation over the duration of each repeated condition was averaged across the repeated trials, and habituation and neural connectivity were assessed.

**Results:** Ultimately, results showed that autistic youth demonstrated higher brain activation to mildly aversive sensory stimuli when compared to TD peers. There were no observed differences in brain activation in emotional processing areas between ASD and TD groups in the tactile task, but the insula and amygdala were more activated in the autistic group when demonstrating SOR symptoms. The largest difference observed between the ASD and TD group was in the simultaneous auditory and tactile task. The ASD group demonstrated increased brain activity (particularly in various sensory processing regions, the thalamus, and emotional processing regions like the amygdala and prefrontal cortex) than the TD group, who became accustomed to the input much
faster. The group of autistic individuals without SOR demonstrated similar habituation rates to the TD group.

Relevance to current work: This article was extremely relevant to the current study. It measured brain activity in both sensory and emotional processing regions while individuals with and without ASD were exposed to various stimuli. The current study will undertake to investigate the relationship, in part, between these regions in the brain. This article found that typically developing individuals habituate to external stimuli much more quickly than individuals with ASD, particularly those with heightened sensitivity. Importantly, the authors make a fascinating contribution to the current study in outlining the decreased connectivity between the amygdala and the prefrontal cortex, suggesting potential difficulties with emotional regulation.


Introduction: Prosody has been identified as an area of general weakness in individuals with ASD. This population's abnormal prosody contributes to the perception of their social deficits. The literature is conflicting on how individuals with ASD match prosody with emotions, both in perception and production, so Grossman et al. (2010) set out to address these discrepancies and use objective measures to analyze this population's prosodic abilities. By conducting three separate experiments, they hypothesized that individuals with high functioning autism (HFA) would perform similarly to their NT peers when identifying the affective component of a filtered sentence (removing semantic
information but maintaining prosody) and when identifying the meaning of ambiguous word pairs (such as hot dog or pick up) using lexical stress only. The authors also hypothesized that individuals with HFA would perform poorer than their peers when asked to produce lexical stress differences for the ambiguous word pairs.

Method: Sixteen children and adolescents with HFA and 15 neurotypical children participated in this study, comprised of three experiments. In their first experiment, the authors incorporated sentences with only prosodic information (semantic information was removed). Participants were then asked to identify whether the speakers were expressing happy, sad, or neutral emotions. In experiment two, participants were asked to only use lexical stress to identify the meaning of ambiguous word pairs. The third experiment used acoustic measures of stress (e.g., pitch, intensity, and duration) when the participants verbally filled in a missing word (illustrated and written in a notebook) as part of a story.

Results: For experiment 1, both groups performed better when the semantic information was included rather than when it was filtered out, and autistic and NT groups were both capable of determining the emotion in sentences from prosodic cues. The second experiment also revealed similar performance between the groups; no significant differences were found. The third and last experiment showed that individuals with HFA could successfully identify words from lexical stress. However, when producing the target word, their productions were significantly different, being longer, more effortful, and slower compared to the TD group. In other words, the main deficit found in children and adolescents with HFA was in stress production.

Relevance to current work: This article provided a couple measurement options for prosody—the Profiling Elements of Prosodic Systems in Children (PEPS-C) and the
Prosody-Voice Screening Profile. Additionally, it provided background on the abilities of those with ASD in interpreting and producing appropriate prosody, although the participants in this study were much younger than the population that will most likely be recruited for the current study.


**Introduction:** The anterior insula and the anterior cingulate gyrus have long been thought to play a significant role in both cognition and emotion. Interestingly, people with ASD present with abnormalities in these specific brain regions, but a direct link to these brain regions and autistic traits has yet to be determined. The triple model network, a theory on the interplay between three general cortical regions, offers a potential explanation of how these brain regions relate to ASD phenotypes as this theory "represents a common component of the pathophysiology of a variety of psychiatric disorders" (Hogeveen et al., 2018, p. 287). In this study, the authors undertake to assign a specific link between the dysfunction of one of the brain regions of the triple network model, the salient network (the anterior insula and the anterior cingulate gyrus), and "internalizing symptoms in ASD ("anxiety, depression, social withdrawal, and somatization") (p. 288). The authors hypothesize that, in individuals with ASD, the relationship between the three brain regions of the triple network model would be abnormal and that "aberrant SN [salient network] connectivity may promote internalizing by diminishing one’s insight into his or her own level of psychopathology" (Hogeveen et al., 2018, p. 288). The authors also established whether these abnormalities were a result of age in individuals with ASD.
Method: One hundred and twenty-one individuals were initially recruited to be part of this study, half with diagnosed ASD and half without, but only 102 fully participated after exclusion requirements. The parents of these individuals filled out a report measure and most of the subjects also completed a self-report measure. It was found that parent-reported items more closely aligned with clinician-reported "internalizing symptoms," highlighting "the suggestion that individuals with ASD possess limited insight into their own psychopathology" (Hogeveen et al., 2018, p. 288). The study subjects then participated in resting state fMRI scans.

Results: Results showed that indeed, individuals with ASD demonstrated higher levels of internalized symptoms when compared to the typically developing participants. Notably, the three brain regions in the triple network model showed increased connectivity that "spanned the entire... neural architecture but was localized to three specific connections" (Hogeveen et al., 2018, p. 290). One of those specific connections, the anterior insula (aINS) and the retrosplenial cortex (RSP), substantiated the authors' hypothesis that "greater aINS-RSP connectivity in individuals with ASD was associated with increased internalizing," particularly anxiety and depression symptoms, but a "correlation revealed that aINS-RSP connectivity was not associated with autism symptoms" (Hogeveen et al., 2018, p. 290). Additionally, another part of the authors' hypothesis was correct in that this "overconnectivity" between the aINS and the RSP "in individuals with ASD was associated with a tendency to underestimate one's own internalizing symptoms" (Hogeveen et al., 2018, p. 291).

Relevance to current work: This article was related to the current study because it explained critical cortical connections in individuals with ASD. It explained the triple
network model and gave substantial evidence to corroborate the theory's claim that three cortical networks are integrally related, particularly in individuals with ASD. The aINS-RSP connection may play a role in emotional regulation deficits in those with ASD, particularly since the connection leads to higher rates of anxiety-depression symptoms. Finally, the discussion of this article touched on alexithymia and how it correlates with the presence of anxiety in individuals with ASD; both alexithymia and anxiety are closely related to emotional regulation deficits in ASD. As the current study will investigate elements of emotional regulation in ASD, this aINS-RSP connection may prove helpful.


*Introduction:* One of the most defining characteristics of autism spectrum disorder (ASD) is impaired social functioning, including atypical prosody. The authors set out to understand the emotional prosody of adults with ASD. The aims of this study were to discover if there were any substantial differences in emotional prosody production between those with ASD and neurotypical controls, and how listeners would rate the naturalness of these productions.

*Method:* For the production part of the experiment, this study recruited 15 males with ASD between the ages of 21–42 and 15 neurotypical males between the ages of 18-26. Participants were asked to produce certain phrases in five different emotions: neutral, angry, happy, interested, and sad. This part of the experiment found that, while both groups used intensity to convey the various emotions, the productions of those with ASD
contained more intensity overall. Similarly, speakers with ASD produced longer phrases than the control group.

For the perception part of this experiment, the authors recruited 30 neurotypical listeners (20 females, 10 males) between 18-50 years old and 22 listeners with ASD (2 females, 20 males) between 18-43 years old. Some of the sentences from the first experiment were presented for this part of the study. Each participant listened to the phrases, made a judgment as to which emotion it was, and then rated its naturalness. Interestingly, the phrases produced by autistic speakers were accurately identified more often than those produced by TD speaker. Neurotypical listeners were significantly more accurate in discriminating which emotion the speaker was portraying than listeners with ASD. Both groups rated TD speakers as more natural overall.

**Results:** Overall, speakers with ASD produced phrases that were longer, had increased variability in pitch, and were louder than those produced by TD speakers. This finding contradicts previous findings in the literature that suggested individuals with ASD used flat or monotone voices. However, the authors conceded that perhaps a subset of individuals with ASD may use this type of voicing but are not included or represented in this study. The differences in affective prosody perceptions between the groups were "far less robust" compared to affective prosody productions, suggesting that "the expression of emotion and nonverbal cues" is an area of marked divergence from neurotypical individuals (Hubbard et al., 2017, p. 1999).

**Relevance to current work:** This study is extremely relevant to the current study, as it expounds on the affective prosodic features of adults with ASD compared to a TD control group. It compares the ability to produce and to perceive the emotional content in
spoken phrases produced by both groups. As prosody is one of the constructs of the current project, this study elucidates how adults with ASD produce and perceive the emotional salience of spoken language. The current study will expound on that even further by relating that ability to their capacity for social engagement and emotional processing.


*Introduction:* Autistic individuals often demonstrate atypical prosody production. This potentially impacts these individuals' ability to socialize in natural settings without judgment. Because of these possible implications, this study investigated the relationship between speech perception and production, and how this relationship affects social functioning in autistic individuals. Previous research has so far proven controversial. The authors of this study sought to clarify this issue.

*Method:* Forty-two participants were involved in this study—21 adults who had been diagnosed with ASD and 21 neurotypical adults (18 male, 3 female in each group). The authors note that the groups were not perfectly matched, but they ensured that no significant differences were a result of IQ differences. 10 four-syllable words that had stress on the first syllable were selected (e.g., AUditory) as were another set of 10 four-syllable words that had stress on the second syllable (e.g., caPAcity). These words were recorded correctly and then incorrectly by putting the stress on the wrong syllable (e.g., auDIitory, CApacity). In total, 40 stimuli words were recorded by a native British English
The participants were assessed using the ADOS and the Wechsler Abbreviated Scale of Intelligence and then they individually completed a syllable stress perception task. After being presented with two of the stimulus words, participants were asked to state whether the two words were the same or different (regardless of being correct or incorrect).

**Results:** Kargas et al., (2016) found four main results. First, adults with ASD were less accurate in detecting syllable stress; second, the autistic participants, although relatively similar, performed drastically different on the syllable stress perception task; third, poorer speech perception related to more atypical speech production in the autistic subjects; and fourth, “performance on the stress perception task was not significantly related to communicative ability in ASD” (Kargas et al., 2016, p. 211). Although it was demonstrated that deficits in prosodic perception are not the only factor in overall socializing skills, these findings corroborated others by showing that syllable stress is particularly difficult for this population.

**Relevance to current work:** This article is significant to the current study because it specifically studied adults with ASD (although their age range is much wider), and it expounded on specific weaknesses of this population in terms of prosody and stress. The current study will also investigate prosody in adults with ASD, and this article provides a baseline for how adults with ASD interpret prosodic information.

Introduction: Because of the consistent inconsistencies observed in neuroimaging studies with individuals with ASD, Lau et al. (2020) conducted this meta-analysis to discover any overlap between studies. This study focused on what previous articles had reported regarding the connection between the dorsal posterior cingulate cortex (PCC) and the ventromedial prefrontal cortex (VMPFC). This study aimed to focus on the PCC connectivity in autism. Importantly, the authors aver that "Findings from the current meta-analysis could provide insight into the development of brain connectivity biomarkers for classifying ASD" (p. 2).

Method: This study performed an online search of the MEDLINE/Pubmed databases and used keywords to find articles on this topic. After the authors screened for duplicates and robustness using a variety of methods, the authors found ten related and robust research articles. These studies together had a total of 501 participants, 264 with ASD and 237 without ASD.

Results: Eight out of the ten studies found decreased functional connectivity between the PCC and the VMPFC while the other two reported the opposite. No hyperconnectivity of the PCC was observed. Interestingly, the PCC and the VMPFC are the two centers in the default mode network. If this network has lower connectivity, some have proposed that the decreased cranial connectivity between the anterior and posterior regions may be a major components of both social and higher-order cognitive deficits in autism

Relevance to current work: This meta-analysis was relevant to the current study because not only did it address neuroanatomical differences in individuals with ASD as observed by resting state MRI, but it helped to describe the likely effects of those
anatomical differences. The current study will include conducting resting state MRI scans and can observe these brain structures in individuals with ASD. Additionally, the current study may focus on an aspect of emotional understanding and/or alexithymia, and this study provides a possible anatomical framework to base assumptions of the cause.

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*Introduction:* Individuals with ASD also frequently have concomitant anxiety. This research study sought to develop "a theory-driven model about the cognitive mechanisms that link ASD symptoms to anxiety," specifically intolerance of uncertainty (IU), alexithymia, and emotional acceptance (Maisel et al., 2016, p. 692). The authors predicted that IU would act as a mediator between ASD and anxiety, and that alexithymia and a lower emotional acceptance might also contribute to this relationship.

*Method:* This was a dual site study, with some research conducted in Utah and some research conducted in London. Seventy-six adults with ASD and 75 neurotypical individuals participated in this study. These participants were recruited at the two sites from online databases for research volunteers. The participants completed a vast array of questionnaires: the Autism Spectrum Quotient, the Intolerance of Uncertainty Scale-12, the Toronto Alexithymia Scale-20, the Five Facet Mindfulness Questionnaire-Nonreactivity, State Trait Anxiety Inventory Form-Y, and the Penn State Worry Questionnaire, and the Fear of Negative Evaluation Scale.
Results: Results from this study showed moderate to strong relationships between autistic traits, IU, alexithymia, and mindfulness. Specifically, "the relationship between autism symptoms and anxiety is mediated almost entirely by emotional acceptance, alexithymia, and IU" (Maisel et al., 2016, p. 696). However, emotional acceptance and alexithymia contribute most heavily to the relationship between ASD and anxiety; with these two constructs in the mix, "IU no longer served as a significant mediator for autism symptoms leading to anxiety" (Maisel et al., 2016, p. 697). In other words, "alexithymia and emotional acceptance directly predicted anxiety, while IU did not" (Maisel et al., 2016, p. 698).

Relevance to current work: This study is relevant to the current study because it investigated ASD and the connections to emotional understanding, particularly the link between alexithymia, emotional acceptance, and anxiety with ASD. It is beneficial to understand the significance and relationship of these three constructs, as well as IU, in regard to individuals with ASD. Alexithymia and emotional acceptance, because they more strongly predict anxiety, are perhaps more important for the current study and are possible areas for further research.


Introduction: The purpose of this study by Marco et al. (2011) was to examine the current literature on the neurophysiology of individuals with ASD, specifically analyzing sensory processing of both simple and complex information as well as what role attention plays throughout the process.
Main points: The authors synthesize the literary conclusions about how individuals with ASD process simple auditory, visual, and tactile stimuli. Regarding these simple sensory stimuli, the research is exceedingly mixed and sometimes even contradictory in terms of how these individuals process that information. It is important to consider the heterogeneity of the autistic population, and simple answers are not sufficient to explain all variability. In contrast, there are a selection of conclusions that apply to autistic individuals as a population regarding how they process complex sensory stimuli. These individuals may have difficulty interpreting, analyzing, and filtering sensory information from multiple modalities at once. Additionally, individuals with ASD often demonstrate deficits in the integration of sensory stimuli. Brain areas such as the prefrontal cortex, regions of the temporal lobe, and the cerebellum have all been identified as potentially contributing to this. These difficulties interpreting sensory information often result in attentional deficits in this population. This significantly limits a person's quality of life and their ability to interact with others.

Conclusion: This study suggests that these various differences in sensory processing of individuals with ASD result in typical, observable deficits of ASD such as language delay and emotional/facial interpretation. However, the authors concede that it is extremely difficult to come to substantial and definitive conclusions regarding the sensory processing mechanism of individuals with ASD due to the wide variety of autistic profiles.

Relevance to current work: This review provided synthesized information, particularly about the sensory processing capabilities of individuals with ASD. As the current study will also investigate (in part) the sensory deficits in individuals with ASD,
this review was helpful in identifying which areas of the brain might be involved, how these deficits affect communication, and how these various difficulties affect an individual's daily life. Notably, this article underlined again and again the significant heterogeneity of this population, which cannot be dismissed when working with these individuals.

https://doi.org/10.1007/s10803-021-05340-x

**Introduction:** Martínez-González et al. (2021) conducted a study to determine the relationship between four factors: social communication, emotion regulation, stereotyped behaviors, and self-injurious behaviors. This article also points out connections between restricted, repetitive behaviors and stress and anxiety as well as emotional regulation. Individuals with ASD who engage in restricted and repetitive behaviors are more likely to also engage in self-injuring behavior. Additionally, people with ASD often struggle to communicate appropriately in social circumstances.

**Method:** In this study, 239 participants were involved. These participants were recruited from various educational facilities and who were all diagnosed with ASD. Potential participants who exhibited comorbidities were excluded from this study. These participants each completed a sociodemographic questionnaire and then subtests of three other questionnaires (the Repetitive Behavior Scale-Revised, the Social Communication Questionnaire Form B, and the Social-Emotional Rating Scale: Leiter-R-Questionnaire).
Results: Martínez-González et al. (2021) found that there were no significant correlations between either age or gender with any of the factors analyzed with the exception of females engaging in self-injurious behaviors more frequently than males. It was discovered that social communication and self-regulation are very closely linked whereas engaging in self-injury was moderately related to stereotypic behaviors. Furthermore, better emotional regulation related to lower rates of self-injury, and better social communication was connected to fewer stereotypic behaviors.

Relevance to current work: This article provides critical knowledge about correlations of classic ASD traits. In particular, the authors expound on emotional regulation and its co-occurring counterparts (e.g., self-injury, social communication). The current study may look at (in part) how individuals with ASD emotionally regulate, and this article provides an ideal backdrop to possible quandaries. Additionally, this article suggests various questionnaires that may prove useful for the current study.

[https://doi.org/10.1007/s12144-009-9044-3](https://doi.org/10.1007/s12144-009-9044-3)

Introduction: This article examined emotional regulation strategies and their connection to one's well-being. Specifically, this was a preliminary study aimed to identify beneficial emotional regulation strategies, particularly using a model of emotional regulation in comparison with other already known models. The hypothesis posited that managing emotions during their genesis was more effective than managing emotions after their genesis.
Method: Seventy-three people participated in this study, all of whom were living in Australia. Their ages ranged from 18 to 78, and they were all purely volunteers who anonymously completed various questionnaires. The authors created an original, short questionnaire for this study relating to emotional regulation strategies, and they also used the Assessing Emotions Scale to assess emotional intelligence, the Life Satisfaction Scale to assess well-being, and the Gross and John Reappraisal and Suppression measures to further assess emotional regulation.

Results: Ultimately, the results demonstrated that managing emotions at their onset was much more effective than managing them afterwards. This was associated with higher rates of well-being and a better mood. Additionally, individuals with more developed emotional intelligence managed their emotions at the onset more frequently.

Relevance to current work: This article was most helpful for the current study because it included various materials for measuring emotional regulation. Since the current study will partly investigate emotional regulation in individuals with ASD, these materials are paramount in order to quantify/qualify how these individuals are managing the emotions within themselves.


Introduction: Individuals with ASD frequently exhibit classic symptoms of anxiety. As we better understand the details and underpinnings of these symptoms, we can provide more effective treatment for both disorders. This article specifically looks into sensory
dysfunction, alexithymia, and intolerance of uncertainty and their roles in anxiety in autism.

**Main Points:** This mini review article concluded that autistic individuals with more severely atypical sensory processing presented with higher rates of anxiety. Further, autistic individuals not only often experience anxiety but also frequently struggle understanding the vast range of human emotion. Finally, individuals with ASD often experience increased rates of intolerance of uncertainty. Each of these classic components of ASD are mediated by important structures within the brain.

**Relevance to current work:** This mini review designed a simple yet useful model that suggests that sensory dysfunction leads to difficulties with emotional regulation, which in turn leads to an intolerance of uncertainty. This natural flow of symptoms elucidates the complex nature of ASD characteristics. Also, this mini review suggested looking at potential therapy ideas for improving sensory integration. This would help halt the downward spiral from its onset for many individuals with ASD. Mindfulness-based therapy is one possible starting point for this type of therapy.


**Introduction:** This article scrutinized a new self-reporting questionnaire, the Sensory Perception Quotient (SPQ), specifically designed for adults with ASD and/or atypical sensory processing. Few questionnaires are currently published for adults; most are for children with ASD whose parents report on their functioning. Since sensory processing difficulties has emerged as a criterion for a diagnosis of autism spectrum disorder, there
is a dire need for a questionnaire that specifically addresses this deficit which the authors sought to create. Each of the five senses are addressed throughout the SPQ. This study set out to address the structure and validity of the SPQ, to identify if there were sensory processing differences between ASD and control groups based on the SPQ.

**Method:** In this study, there were 359 people, 196 with an ASD diagnosis and 163 without. Only those participants with a diagnosis from a competent professional were included. These participants were recruited voluntarily via an online autism platform. First, everyone provided their background information, then they completed the AQ. The participants' IQ was assessed using a brief, modified version of Raven's Progressive Matrices, and they completed the SensOR Scale. Finally, each participant filled out the sensory perception quotient (SPQ). Participants completed each of these measures online, and in whatever order they preferred and were free to log out between assessments.

**Results:** The results of this study indicated a high Cronbach's alpha, split-half reliability, and concurrent validity, suggesting impressive reliability for the SPQ assessment. Moreover, ASD and control groups differed significantly on total scores of the SPQ. Interestingly, females showed higher sensory sensitivity in both the ASD and control groups. Finally, there was correlation between the SPQ and the AQ between groups and within the ASD group.

**Relevance to current work:** This article analyzed the validity of a new questionnaire, the sensory perception quotient (SPQ), which is designed for people with ASD or sensory processing difficulties. In the current study, a questionnaire will be employed for participants to fill out about their own sensory processing experiences. This article provides a possible option for which questionnaire to use.

**Introduction:** Thye et al. (2018) outlines what autism spectrum disorder (ASD) is, noting the social deficits, restricted and repetitive behaviors (RRBs), and the sensory processing abnormalities that are characteristic of the disorder. The authors emphasize that there has been a surge of research conducted in recent years focused on sensory processing and ASD. The authors postulate that there is a greater connection between the social and sensory processing deficits in individuals with ASD. This article reviews studies to corroborate this claim.

**Results:** Thye et al. (2018) discuss the senses including vision, auditory processing, tactile processing, olfaction and gustation, and multisensory integration. The author also go into the neuroanatomical structures that control these sensory functions. In terms of their auditory processing, individuals with ASD have difficulty processing pitch and recognizing changes in prosody. Additionally, the authors found that individuals with ASD struggle to focus on more salient incoming sensory information. These differences in auditory processing result in decreased social skills for this population as they do not pick up on subtle pitch changes and as they have unnatural prosody. Individuals with ASD also present with difficulties in multisensory integration, including emotion recognition.

**Relevance to current work:** This article was highly relevant to the current study. Thye et al. (2018) discuss the sensory domains extensively and even included prosody
and emotion recognition and how they relate to social functioning. Additionally, Thye et al. (2018) enumerate the brain structures that relate to each of the sensory domains. The current study focuses on prosody, emotion, and the neural underpinnings of both, which this article discussed.


**Introduction:** Wigham et al. (2015) investigated what role intolerance of uncertainty (IU) and anxiety play in sensory processing difficulties and repetitive, restricted behaviors (RRBs) in individuals with ASD. Individuals with ASD often present with sensory processing abnormalities in that their experience is either heightened or is reduced, although studies show that an autistic individual can present with both at different times, even in the same modality. This hyper- or hyporeactivity to sensory input has been linked to anxiety in individuals with ASD which then may lead them to seek control over their environment by engaging in RRBs. Because these individuals may desire to control their environment and become anxious from change or uncertainty, they may exhibit intolerance of uncertainty.

**Method:** Parents of 53 autistic children were recruited for this study. These parents were asked to complete various questionnaires about their children's behaviors and characteristics using the following measures: the parent version of the Social Responsiveness Scale (SRS), the Wechsler Abbreviated Scale of Intelligence (WASI; measuring IQ), the Short Sensory Profile (SSP), the parent version of the Spence
Children’s Anxiety Scale (SCAS; measuring anxiety), the Intolerance of Uncertainty Scale-Parent Version (IUS-P; measuring IU), and the Repetitive Behaviour Questionnaire (RBQ).

**Results:** There were several noteworthy results from this study. First, as the authors predicted, a direct effect was found "from sensory under responsiveness to repetitive motor behaviours... and to insistence on sameness" (Wingham et al., 2015, p. 947). Similarly, another direct effect was found "from sensory over responsiveness to sameness behaviours" (Wingham et al., 2015, p. 949). Ultimately, this study found that "there is strong evidence for paths that involve IU and anxiety from both sensory under responsiveness and sensory over responsiveness to both repetitive motor and sameness behaviours" (Wingham et al., 2015, p. 949). These findings suggest that IU is the mediator between autistic traits and anxiety.

**Relevance to current work:** This research article contributed significantly to the present study as it touched on some of the major constructs of the current study such as IU, sensory processing, and anxiety. The results emphasize how sensory processing abnormalities contribute to IU, anxiety, and RRBs in individuals with ASD. Also, this research article provides several examples of questionnaires that could be used in the present study to measure any of the mentioned constructs.
Institutional Review Board Memorandum

Memorandum

To: Garrett Cardon

Department: BYU - EDUC - Communications Disorders

From: Sandee Aina, MPA, HRPP Associate Director
    Wayne Larsen, MAcc, IRB Administrator
    Bob Ridge, Ph.D., IRB Chair

Date: September 22, 2022

IRB#: IRB2022-340

Title: Sensory processing, prosody, and emotion in autism

Brigham Young University’s IRB has approved the research study referenced in the subject heading as expedited level, categories 6 and 7. This study does not require an annual continuing review. Each year near the anniversary of the approval date, you will receive an email reminding you of your obligations as a researcher. The email will also request the status of the study. You will receive this email each year until you close the study.

The IRB may re-evaluate its continuing review decision for this decision depending on the type of change(s) proposed in an amendment (e.g., protocol change that increases subject risk), or as an outcome of the IRB’s review of adverse events or problems.
The study is approved as of 09/22/2022. Please reference your assigned IRB identification number in any correspondence with the IRB.

Continued approval is conditional upon your compliance with the following requirements:

1. A copy of the approved informed consent statement and associated recruiting documents (if applicable) can be accessed in iRIS. No other consent statement should be used. Each research subject must be provided with a copy or a way to access the consent statement.

2. Any modifications to the approved protocol must be submitted, reviewed, and approved by the IRB before modifications are incorporated into the study.

3. All recruiting tools must be submitted and approved by the IRB prior to use.

4. All data, as well as the investigator's copies of the signed consent forms, must be retained for a period of at least three years following the termination of the study.

5. In addition, serious adverse events must be reported to the IRB immediately, with a written report by the PI within 24 hours of the PI's becoming aware of the event. Serious adverse events are (1) the death of a research participant; or (2) serious injury to a research participant.

6. All other non-serious unanticipated problems should be reported to the IRB within 2 weeks of the first awareness of the problem by the PI. Prompt reporting is important, as unanticipated problems often require some modification of study procedures, protocols, and/or informed consent processes. Such modifications require the review and approval of the IRB.
APPENDIX C

Consent Form

Consent to be a Research Subject

Title of the Research Study: Sensory processing, emotion, and prosody in autistic adults
Principal Investigator: Garrett Cardon
IRB ID#: IRB2022-340

Introduction

This research study is being conducted by Professor Garrett Cardon and research staff at Brigham Young University to determine the relationships between emotion, tone of voice, and understanding of sound and other sensory signals in autistic individuals. You were invited to participate because you are between the ages of 18-26, have a diagnosis of autism, and have no history of neurological disorder (including traumatic brain injury).

Procedures

If you choose to participate in this study, you will be asked to do the following:

- Answer questions about your emotions and how you deal with and understand sounds, sights, smells, tastes, and other sensory inputs.
- Have a short conversation with one of our team members. During this conversation, you will be video and audio recorded.
- Listen to recordings of other people reciting short sentences and answer questions about these recordings.

All research activities will take place at the John Taylor Building on the BYU campus in the principal investigator’s laboratory. We anticipate that your research appointment will last approximately 1 hour, but some participants may take longer to complete all testing. You will be given as much time as you need to familiarize yourself with the building, room, and personnel involved in the study, as well as breaks during the research activities.
**Risks/Discomforts**
There are no known significant risks involved in this research study, but there is always a possibility a small, unknown risk may exist to this or any test (i.e., discomfort related to questions or activities). However, we believe that we have taken reasonable precautions to ensure your safety. None of the questions we will ask are overtly distressing or meant to cause discomfort or offense. If you have any questions about your safety in this experiment, please feel free to discuss them with us at any time. There is a risk that people outside of the research team will see your research information. We will do all that we can to protect your information.

**Benefits**
There will be no direct benefits to you. However, this study is designed for the researcher to learn more about the social interaction styles of young adults. This study is not designed to treat any illness or to improve your health. We will not release any clinically un-interpretable results.

**Confidentiality**
Brigham Young University and the research team have rules to protect information about you. Federal and state laws including the Health Insurance Portability and Accountability Act (HIPAA) also protect your privacy. This part of the consent form tells you what information about you may be collected in this study and who might see or use it. We cannot do this study without your permission to see, use and give out your information. You do not have to give us this permission. If you do not, then you may not join this study.
We will see, use, and disclose your information only as described in this form. We will do everything we can to keep your records a secret. It cannot be guaranteed.

The use and disclosure of your information has no time limit. Data will always be stored on password protected computers, in filing cabinets in locked offices on the BYU campus, and/or with a secure cloud storage service (Box). You can cancel your permission to use and disclose your information at any time by writing to the study’s Primary Investigator, at the name and address listed below. If you do cancel your permission to use and disclose your information, your part in this study will end and no further information about you will be collected. Your cancellation would not affect information already collected in this study.

Garrett Cardon

Brigham Young University

Department of Communication Disorders

1190 N 900 E 130 TLRB

Provo, UT 84604
Both the research records that identify you and the consent form signed by you may be looked at by others who have a legal right to see that information. The participant’s name will immediately be replaced with an identifying code in order to protect your confidentiality. Other identifying information will only be used to make calculations (such as chronological age) or contact you, if you provide permission (see below), but will never be used in any publication, presentation, or other form of communication with anyone other than you.

Federal offices such as the Food and Drug Administration (FDA) that protect research subjects like you. People at the Brigham Young University Institutional Review Board (BYUIRB), the study investigator and the rest of the study team.

**Information about you that will be seen, collected, used, and disclosed in this study:**

- Name and Demographic Information (age, sex, ethnicity, address, phone number, etc.)
- Research Visit and Research Test records
- Diagnoses that have been given to you or your close family members, such as anxiety, Autism Spectrum Disorder (ASD), or Attention Deficit Hyperactivity Disorder (ADHD)

**What happens to Data that is collected in this study?**

The scientists on the research team work to discover new information about autism. The data collected from you during this study is important to this study and to future research. If you join this study:

- Both the investigators and any sponsor of this research may study your data
- Any product or idea created by the researchers working on this study will not belong to you.
- There is no plan for you to receive any financial benefit from the creation, use or sale of such a product or idea.

**Data Sharing**

We will keep the information we collect about you during this research study for analysis and for potential use in future research projects. If the study data contain information that directly identifies subjects: Your name and other information that can directly identify you will be stored securely and separately from the rest of the research information we collect from you.
De-identified data from this study may be shared with the research community, with journals in which study results are published, and with databases and data repositories used for research. We will remove or code any personal information that could directly identify you before the study data are shared. Despite these measures, we cannot guarantee anonymity of your personal data, though the above risks are likely more hypothetical than realistic.

**Compensation**

You will $10/hour via cash for your participation in this study. There will be no monetary cost to you for participating in this study.

**Participation**

Participation in this research study is voluntary. You have the right to withdraw at any time or refuse to participate entirely without any risk to you whatsoever.

**Questions about the Research**

If you have questions, concerns, or complaints, you can contact the Principal Investigator, Garrett Cardon, 303-241-6666, garrett.cardon@byu.edu or Annika Henderson, annika.slight@gmail.com

**Questions about Your Rights as Research Participants**

If you have questions regarding your rights as a research participant contact Human Research Protections Program by phone at (801) 422-1461; or by email: BYU.HRPP@byu.edu.
Statement of Consent

I have read, understood, and received a copy of the above consent and desire of my own free will to participate in this study.

Name (Printed): ____________________  Signature: ________________  Date: ____________

PERMISSION TO CONTACT FOR FUTURE RESEARCH STUDIES: Sometimes after a research project is finished, there are new questions that researchers need to ask and new research studies that need to be done. We would like your permission to contact you for participation in future studies that you may qualify for. We will not contact you unless you give us your permission.

_____ I agree to be contacted for future research studies that I/my children might be eligible for.

_____ I do not wish to be contacted in the future for any additional research studies.

If you agree to be contacted, please list an address, phone number, and email address where you can be reached:

Phone: ________________________________________________

Email: ________________________________________________