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Examining the Effects of Noise and Task Dependent Performance in Prosody Perception in Autistic Individuals

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By

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ABSTRACT

Objective: It is known that autistic individuals have enhanced abilities in pitch discrimination and tend to excel in low-level tasks requiring lower cognitive processing. On the other hand, noise is a distracting factor in many areas of life, including prosody perception. The studies presented in this thesis aimed to understand prosody perception through different levels of cognitive tasks and under the influence of speech background noise.

Methods: In total, 256 non-autistic and 39 high-functioning autistic adults participated in these studies. In the first study, participants were asked to listen to brief utterances conveying one of six universally accepted emotions (happy, sad, angry, surprise, disgust, fear) and match it to a corresponding facial expression at three levels of auditory babble background noise conditions; 0 dB, -3 dB and -6 dB. In the second study, participants were asked to complete a pitch discrimination task between 180-200 Hz. In addition, they were asked to listen to five basic emotional utterances (happy, sad, angry, surprise, neutral) and determine the direction of the utterance, as well as the emotion, conveyed in these statements to examine the effects of task-dependent performance.

Results: ANOVA results indicated that both autistic and non-autistic participants had similar performance in emotional recognition under all three noise conditions. In addition, a mixed ANOVA revealed no group differences in pitch discrimination, sentence direction identification and emotion recognition tasks. However, a significant effect of emotion was observed. It was found that some emotions are recognized more easily compared to other emotions in both autistic and non-autistic groups. In addition, ANOVA results showed that individuals who had music training performed better at pitch discrimination and emotion perception tasks but not in sentence direction tasks which asked participants to identify the direction of each utterance.

Conclusion: These findings suggest that high-functioning autistic adults may have intact prosody perception abilities yielding them to perform as well as non-autistic adults even under noise conditions. Some emotions are perceived more easily compared to others regardless of diagnosis. Music training may allow adults to discriminate the pitch of sweep tones and perceive emotions more correctly compared to those without music training.

DEDICATION

I dedicate this work to my son, Mirza. I love being his mother. It is through him that I get to rediscover the world and appreciate the beauty in little things.

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1. INTRODUCTION

1.1 Autism Spectrum Disorders (ASD)

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder characterized by the presence of repetitive and restricted behaviours, and deficits in social communication (American Psychological Association (APA), 2013). The latest edition of the *Diagnostic and Statistical Manual of Mental Disorders – 5th edition* (DSM-5) published in 2013, has merged Asperger's syndrome, childhood disintegrative disorder and pervasive developmental disorder under the general umbrella of Autism Spectrum Disorders (APA, 2013). This new definition is aimed to be more accurate in diagnosing ASD at an earlier age (Halfon & Kuo, 2013). Autism is a spectrum disorder, which means that even with a diagnosis of autism, there can be a wide range of autism symptomology including but not limited to intellectual and social ability and severity (Marco et al., 2012). Currently, there are no accepted biological tests for autism and diagnosis is based solely on behaviour (Abruzzo et al., 2015). ASD has no known single cause. Given the complexity and the varying symptoms, it is believed that both genetic and environmental factors play a role. For example, children with autistic fathers have a higher chance of being diagnosed with autism compared to children whose mothers are autistic (Brandler et al., 2018). In addition, parents who already have an older child diagnosed with autism are eight times more likely to have a second child diagnosed later in life when compared to unaffected families. In other words, one in five children with an older autistic sibling will also be diagnosed with autism (Shephard et al., 2017; Hansen et al., 2019). Over the years, scientists have identified hundreds of genes that contribute to serious deficits in communication, however this only accounts for 10-20% of ASD cases (Rylaarsdam & Guemez-Gamboa, 2019). Even though it is believed that 40-85% of autism risk is determined by genes, a study published by Hallmayer in 2011 on autistic twin pairs concluded that environmental factors play a 58% role in an autism diagnosis (Hallmayer et al., 2011; Rylaarsdam & Guemez-Gamboa, 2019). Some studies have linked autism to several factors during pregnancy; the mother's age, diet, medical conditions including the medicines she uses, as well as birth complications and the timing of the birth (Kolevzon, Gross, & Reichenberg, 2007). There are other studies which link folate deficiency in the mother's womb not only to autism but to other neural developmental disorders as well (Hoxha et al., 2021). Overall, there is no single root cause of autism, but a varying list of factors contribute to the complexity and variety of the individual cases.

According to the National Autism Spectrum Disorder Surveillance System (NASS) report published in 2018 by the Public Health Agency of Canada, one in 50 children are diagnosed with autism in Canada (Public Health Agency of Canada, 2019). In addition, one in every 32 boys and one in every 125 girls are diagnosed with autism, making ASD four times more prevalent in boys than girls (Public Health Agency of Canada, 2019). The overall prevalence of autism has been increasing over the years making it one of the most common childhood neurodevelopmental disorders (Siu & Weksberg, 2017).

The symptoms of ASD persist lifelong even though they may improve over time with intervention (Elder et al., 2019). ASD is characterized by three domains according to DSM-5: impaired communication, impaired reciprocal social interaction, as well as restricted, repetitive and stereotyped patterns of behaviours or interests (APA, 2013). Because of the disorder's limitations, an increasing number of people encounter challenges in many areas of life, including social communication. It has been shown in previous studies that autistic individuals have a hard time recognizing emotional auditory and visual cues which leaves them stranded in communicating with others (Rump et al., 2009). For example, despite the increasing prevalence worldwide, adults with autism have the lowest rate of employment when compared to other disabilities (Fellow, 2016). In one study, Walsh and colleagues (2014) found that employment enhances the overall well-being of a person including their cognitive functioning and quality of life. However, 50% of autistic youth remain unemployed two years after finishing high school, while numbers are different for non-autistic youth (Fellow, 2016). The main obstruction in long-term success with employment is caused by communication impairments. Successful emotional communication has two factors: nonverbal vocalizations (such as a laugh) and speech prosody (Kamiloğlu et al., 2021). However, it is shown that autistic individuals have a hard time processing emotional prosody in speech (Fellow, 2016). These deficits create obstacles for an effective communication during the interview process and with other colleagues at the workplace. Unfortunately, they frequently hinder progress at work and may even result in termination (Fellow, 2016).

Furthermore, autistic individuals may struggle with sensory processing. Although sensory hyper- and hypo-responsiveness are not exclusive to autism, it appears to be more common in autistic people than in those with other developmental impairments (Leekam et al., 2007). Noting that auditory processing differences are the most common sensory processing differences in ASD, hyperacusis, or reduced tolerance to sound, is highly frequent in the ASD population (Danesh et al., 2021). One study conducted by Khalfa and colleagues found that autistic children identified sounds greater than 40 dB in intensity as being loud when compared with non-autistic children (Khalfa et al., 2004). For reference, a library whisper is about 30 dB and a normal conversation is about 50 dB. These impairments in social communication and the influence of everyday factors such as noise make it difficult for many autistic individuals. With the increasing prevalence of autism in the general population, it is important to understand the underlying mechanisms that lead to these impairments.

In addition to the impairments caused by the diagnosis, research shows that autistic individuals tend to excel in certain visual and auditory tasks where attention to detail and non-verbal abilities are required (Baron-Cohen et al., 2009). It is widely accepted that autistic individuals use a bottom-up approach in their perception of the world (Amso et al., 2013). This means that local elements are perceived and processed first rather than global elements (Mottron & Burack, 2001). This is thought to account for the exceptional performance of autistic individuals in tasks that require attention to detail. For example, despite struggling in social communication and prosody perception, scientific evidence suggests that autistic individuals excel in simple auditory tasks such as tone discrimination (Baron-Cohen et al., 2009). However, this ability does not translate into the detection of prosodic information or the development of language, even though both abilities require the detection of pitch-related differences (Eigsti & Fein, 2013). Despite many studies which have previously examined prosody perception in neurotypical individuals and several studies conducted with autistic individuals, there haven't been any studies up to date which investigated the influence of external factors commonly found, such as noise, on the successful perception of prosody. To account for these difficulties faced by autistic individuals in social contexts, a meaningful understanding of these perceptual processes is required.

The studies presented in this document attempted to explore how prosody perception, a crucial part of social communication, differs between autistic and non-autistic individuals. In addition, it also investigated the influence of external factors such as noise and performance related to the task in the perception of prosody.

1.2 Prosody in Autistic and Non-Autistic Individuals

Prosody is the rhythm, intonation and stress of speech which provides important information on the word beyond its literal sentence meaning (American Psychological Association, 2014). Effective communication depends on the correct perception of prosody, and individuals who have trouble communicating, such as autistic people find prosody perception challenging (Scheerer et al., 2020). Prosody has different components which are all important in correctly perceiving or conveying information in spoken communication. These are pragmatic functions such as the use of stress and intonation, grammatical functions and affective functions (Couper-Kuhlen, 1986). Stress, one of the pragmatic functions, can be used to indicate an important or contrastive word. For example, "I asked for a NON-DAIRY coffee". The stress on NON-DAIRY indicates that coffee containing dairy was served (Halliday, 1967). By varying the rhythm of speech and the relative prominence of words or syllables, it is possible to distinguish between stressed and non-stressed words. Intonation on the other hand is used to differentiate the utterance type while rising intonation can be used to indicate that a response is required at the end of a word or sentence, or a falling intonation usually suggests the end of the sentence (Couper-Kuhlen, 1986). Segmenting utterances, a grammatical function, can indicate where the uncertainty lies. A speaker's volume, speech rate, and pitch rate are altered in affective functions to portray their feelings. (McCann & Peppé, 2003). Prosody allows individuals to perceive information beyond a word's literal meaning including the emotional information in speech (APA, 2014). There are six universally recognized emotions: happiness, fear, anger, sadness, disgust and surprise (Ekman, 1992) and four basic emotions: happiness, fear, anger, and sadness. (Jack et al., 2014). Depending on the emotion being conveyed, the prosodic characteristic of one's speech changes.

Neurotypical and autistic individuals differ in their ability in prosody perception abilities. These differences can be observed as early as infancy. Neurotypical infants are shown to possess the ability of prosody perception early in life. Even at birth, it has been observed that newborns can distinguish languages based on their rhythmic differences (Nazzi et al., 1998). Moreover, very early in toddler years, neurotypical kids can recognize the stress pattern of their native language when compared with other languages (Jusczyk et al., 1993). Neurotypical toddlers can also use the dominant stress patterns of their own native language to segment their own spoken words (Jusczyk et al., 1999). Moreover, it is shown that neurotypically developing infants as young as 8-10 months old have a neural basis to detect facial expressions and tone of voice (Arai et al., 2011). In comparison, autistic individuals differ very early on with this skill. Babies learn to distinguish the mood of the person talking by picking up on auditory cues and matching them to their faces (Paquette-Smith & Johnson, 2016). Parents often tend to communicate with infants using infant-directed speech (IDS). IDS is characterized by a slower rate, more variable prosody and the use of simpler sentences (McMurray et al., 2013). The acoustic cues and prosodic features of IDS vary according to the caregivers' intentions, and IDS has been proven to be an effective way to communicate with pre-verbal younger children (Saint-Georges et al., 2013). However, studies show that autistic infants do not show the expected preferences for IDS over other auditory stimuli when compared to their neurotypical peers (Paul, 2007). About 20% of the siblings of autistic children meet the criteria for the disorder by the time they reach three years old (Ozonoff et al., 2016). Due to this, many studies use infant siblings as a methodological approach to study early markers of ASD. This allows for the study of specific behaviours under controlled settings. These studies follow the siblings of autistic children, or commonly referred as high-risk children, from early infancy to 2-3 years of age when the child can be officially diagnosed. Based on this, in 2013 Droucker and colleagues examined high-risk siblings at six, eight, 12 and 18 months for biases to infant-directed speech. They measured the time infants looked at the pictures (face or checkerboard) while listening to two infant-directed and two adult-directed speech passages. They found that the assessment at 12 months was a predictor for expressive speech abilities at 18 months and high-risk and low-risk siblings showed differences in their preferences. Low-risk infants who are infants with no older autistic sibling showed a higher preference for faces with the infant-directed speech in comparison to the high-risk infants (Droucker et al., 2013). In addition, in another study, high-risk autism infants were found to have difficulty recognizing prosodic differences in their mothers' speech when compared with low-risk infants (Quigley et al., 2016). This shows that difficulty in the perception of prosodic cues is related to autistic traits and can be observed very early in infancy. Furthermore, a neurotypically developing child will master the art of perceiving emotions just by prosody in speech by the time they are seven to nine years old (Kalathottukaren & C Purdy, 2017). This skill, which allows children to comprehend sarcasm, will overtime improve with the ability to distinguish irony by age nine and will be used in everyday communication (Glenwright & Pexman, 2010). However, children with autism display differences in prosody perception in this stage of development as well. In a study conducted by Scheerer and colleagues (2020) found that despite being able to correctly recognize affective prosodic information and match it with corresponding emotion, children with high-functioning autism were not able to match the prosodic information with correct visual representations as well as their neurotypical counterparts. The researchers suggested that despite having intact recognition abilities, children with autism may have difficulties utilizing emotional information in social contexts (Scheerer et al., 2020). In studies conducted with adults, there are contradicting findings on whether or not autistic adults can recognize prosody correctly. In a study conducted by Globerson and colleagues in 2016 showed that despite performing poorly in recognizing both vocal and visual emotions, autistic adults performed as well as non-autistic adults in pragmatic prosody tasks. Moreover, a comparative study between autistic children and adults found that the perception of prosody difficulties are more prominent in children and diminishes towards normalcy in adults (Charpentier et al., 2018).

The observed differences in perception of prosody can also be seen in the production of prosodic speech as well. Individuals with ASD have a difficult time producing intended changes in their speech (Diehl & Paul, 2013). In fact, they are often said to have a monotonous and inappropriately stressed way of talking; not being able to produce proper prosody that goes along with their intentions (Shriberg et al., 2001). A study conducted in 2017 by Hubbard and colleagues found that listeners were able to identify emotional speech produced by autistic participants more easily, yet they rated it less natural (Hubbard et al., 2017). In studies that required matching the correct emotional voice clips with the associated facial expressions, autistic children and adults performed significantly poorer than their neurotypical peers (Hobson, 1986; Eack et al., 2014). However, in a study done by Colaberson and colleagues, they found no significant difference between high-functioning autistic children and their neurotypically developing peers on receptive tasks of lexical stress and affective prosody (Grossman et al., 2010). In contrast, in a study consisting of a larger number of participants, Pepe and colleagues found that in comparison to their neurotypically developing peers, high-functioning autistic children showed significant impairment in all of the prosody tasks including phrasing and imitation (Peppe et al., 2011).

Overall, most of the current literature agrees that autistic individuals have impairments in both recognizing and producing correct prosody in communication. They further have a harder time recognizing and correctly identifying emotions both vocally and visually when compared to neurotypical individuals. Unfortunately, real-world distractions like noise in prosody perception have not yet been taken into consideration in any studies that are currently available. Consequently, results from these studies do not fully reflect back to the autistic population as everyday life does not take place in controlled lab settings. Therefore, more studies to understand the influence of external factors in prosody perception are needed and the studies presented in this thesis will aim to investigate these factors.

1.3 Noise and ASD

Sensory sensitivities are common in autistic individuals (Asperger, 1944). In fact, sensory sensitivities are included in the diagnostic criteria for autism (APA, 2013). Even though not everyone on the wide spectrum of autism may experience this, the prevalence of sensory sensitivities is estimated to be 60-95% in the ASD population (Schauder & Bennetto, 2016). In addition to this high prevalence, research shows that increased sensory sensitivity has been linked to more repetitive behaviours and social difficulties (Deschrijver et al., 2016). Increased *sound* sensitivity is one of the most commonly reported sensitivities for autistic people (Haesen et al., 2011). A meta-analysis estimated that 50-70% of individuals on the spectrum occasionally have experienced diminished sound tolerance in their lives (Williams et al., 2020; Williams et al., 2021). The increased tolerance to sounds has a significant contribution to functional impairments (Jones et al., 2020; Law et al., 2016). For autistic individuals, some noises may be annoying, and loud noises can even feel painful (Elwin et al., 2012). Combined noises, such as multiple people talking, can be too overwhelming (Robertson & Simmons, 2015). Many parents and caregivers report that their children refrain from participating in family, school or sports activities due to strong reactions to sounds (Hussein et al., 2019). Although auditory sensitivities are common and have a large impact on autistic individuals, there is not enough data to support any recommendations, whether behavioural or pharmaceutical, to treat or lessen the severity of this symptom (Fung et al., 2012). One of the reasons for this is the fact that there is little known about the underlying mechanisms of this impairment. Literature shows that autistic people habituate to noise slower and have lower auditory detection thresholds compared to neurotypically developing individuals (Kuiper et al., 2019). Habituation is defined as the diminishing behavioural or emotional response that results from repeated stimulation (Rankin et al., 2009). In other words, over time the body tends to learn not to physiologically respond to familiar stimuli (McDiarmid et al., 2017). Due to a lack of, or slower habituation in autistic individuals, certain stimuli can lead to sensory overload or hyper-reactions (Jamal et al., 2021). In 2022, Jamal and colleagues recorded EEG data of 13 autistic and 22 neurotypical youth on habituation to visual and auditory repeated stimuli. As expected, they found that neurotypical youth exhibited habituation over the course of the experiment. On the other hand, the autistic youth did not show a reduction between the first and the last event-related potential (ERP) or in other words recorded brain response. In fact, some of the autistic participants had increased ERP over time, meaning instead of getting used to the stimuli over time as expected, they became more aroused over time from the repeated stimuli (Jamal et al., 2021). This was similar to what Guiraud found with 9-month-old high-risk infants. They found that in comparison to low-risk infants, high-risk infants showed little to no difference between the first and the last ERP recorded during a sensory habituation task, showing little to no habituation (Guiraud et al., 2011). When compared with neurotypical individuals, autistic people are thought process a greater amount of auditory information simultaneously, which may result in an overload. This can be used explain the difficulty of habituation in autistic individuals (Brinkert & Remington, 2020). This auditory distractibility is thought to correlate with noise sensitivity (Belojević et al., 1992). However, at this point, this relationship needs more exploration to be supported.

Another theory for sensory overload in autistic individuals is the lowered thresholds for sound detection (Williams et al., 2021). For example, the human ear can detect frequencies between 20-20,000 Hz, and most speech is between 100 and 4,000 Hz (National Institute of Health, 2007). However, a study done by Khalfa and colleagues found that 63% of the autistic group had lower discomfort levels for pure tones below 80 dB (Khalfa et al., 2004). For reference 70 dB could be identified as the sound of a dishwasher or a shower and 60 dB would be similar to the intensity of a conversation in an office. In another study done by Demopoulos and Lewine, they investigated the thresholds for speech stimuli and found that 37% of their autism group had lowered thresholds at least one standard deviation below the neurotypical group (Demopoulos & Lewine, 2016). These findings suggest that autistic individuals may have a harder time navigating under noisy or what they perceive to be noisy situations. However, the distracting or masking role of noise during emotional perception is yet to be investigated.

In addition to a general sensitivity to sounds, literature shows that people on the spectrum react differently to different types of sounds (Rotschafer, 2021). Misophonia, which is sensitivity to selective sounds (e.g., chewing, sniffling etc.), is described as an inappropriate emotional response to "trigger" sounds even at low levels (Brout et al., 2018; Claiborn et al., 2020). These auditory triggers elicit both an emotional (e.g., disgust, anger, fear etc.) and a physical response (e.g., muscle tension, abdominal discomfort etc.) from the person with the disorder (Jager et al., 2020; Kumar et al., 2017). A qualitative study conducted by Landon and colleagues (2016) asked 10 autistic adults about their experiences with sounds and the reasons behind their discomfort or distress to some sounds. They found that participants rated sharp, loud and high-pitched sounds to be most distressing and some sounds to elicit strong emotional reactions regardless of the sound level (Landon et al., 2016). They also found that autistic individuals are more easily distracted by noises even in relatively quiet conditions. It is interesting to note that when the misophonic person produces these triggering sounds, they do not seem to elicit a response. (Potgieter et al., 2019). In addition, they also seem to elicit less of a response when the sounds are produced by a toddler or an adult with a cognitive impairment in opposition to when they are experienced in a familiar context (Jager et al., 2020; Potgieter et al., 2019). Aside from the discomfort, literature shows that autistic individuals also have a harder time focusing on their primary task when certain sounds are present in the background at different signal-to-noise ratios (Alcántara et al., 2004). Signal to noise ratio (SNR) is a measure that indicates the desired level of the signal, in this case sound, to the level of the background noise (Welvaert & Rosseel, 2013). A positive value of SNR typically indicates that the level of the signal is higher than the noise and a negative value indicates that the signal level is lower than the noise level. A study done by Dunlop and colleagues (2016) asked autistic and neurotypical participants to identify three target words under two different background noise conditions: multi-speaker babble condition, and speech-weighted noise condition. The task involved five blocks with 20 trials each and SNR of 1 dB, 3 dB, -1 dB, -3 dB, -5 dB and -7 dB. They found that individuals with autism had a significantly harder time discriminating speech in the multi-speaker babble condition and performed no differently than the neurotypical participants in the speech-weighted noise condition. They also had the hardest time discriminating the target words at the -5 dB sound-to-noise ratio in the multi-speaker babble condition (Dunlop et al., 2016). In another study done by Russo and colleagues, they investigated the speech-evoked responses in quiet and background noise conditions in autistic and neurotypical children. They found that the responses from autistic children had delayed timing in both conditions when compared to the neurotypical children, making noise an additional difficulty in perceiving the target information (Russo et al., 2009). In addition to controlled laboratory settings, it was found that autistic children have a harder time and lowered performance in the classroom without any controlling measures for the noise (Schafer et al., 2013).

A study done by Schafer and colleagues reported that the speech in noise perception capacity of autistic children is half of their neurotypical peers in the classroom (Schafer et al., 2013). Moreover, studies have found that improving the SNR in the classroom positively impacts the performance of autistic students (Schafer et al., 2014; Van Der Kruk et al., 2017). Methods to improve SNR include, but are not limited to, using a frequency modulation system, such as a microphone worn by the teacher and transmitting his/her voice directly into the students' ears (Rance et al., 2014; Schafer et al., 2016). This allows the student to focus on speech produced by the teacher without requiring the filtering of the classroom noise. Another method included installing sound-absorbent walls and halogen lightning, which positively affected and improved the children's performance and engagement in the classroom as well as increased attention (Kinnealey et al., 2012).

Finally, despite everything that is known about the difficulty of perception and processing of information in noisy settings, there is little known about prosody perception under such conditions. The studies in this thesis will attempt to explore the relationship, if any, between prosody perception and noise for those who are autistic.

1.4 Pitch Discrimination

Pitch is a subjective measure of the sound that is perceived by the human observer (Helmholtz & Hermann, 1954). Frequency on the other hand is the number of waves per second that the sound repeats itself. Even though pitch and frequency are closely related or often used interchangeably, they are not identical. For example, a small change in frequency does not always change the pitch of the tone.

Pitch discrimination is the ability to recognize the changes in the frequency of a given note (Radocy & Boyle, 2003; Stanutz, 2009). Pitch discrimination requires the listener to first hear the presented note, then keep it in the working memory to make a successful comparison to detect any differences (Jiang et al., 2013). In controlled laboratory settings, a healthy adult can detect changes as little as 3 Hz between pitches (Backus 1969). In addition, an article by Crawford (2008) argues that healthy adults can in fact detect changes as low as 1-2%.

Absolute pitch (AP) on the other hand, also known as perfect pitch, is the ability to identify or produce a tone at a particular pitch in the absence of a reference or an external pitch (Parncutt & Levitin, 2001; Takeuchi & Hulse, 1993). AP possessors, the people who carry this ability, vary in their accuracy. They can identify 70-100% randomly selected piano tones within a semi-tone of the targeted note, whereas non-AP possessors can only do that 40% of the time (Lockhead & Byrd, 1998; Miyazaki, 1988). One in 10,000 people in neurotypical communities are thought to possess AP, making it a rare ability (Profita et al., 1988). It is currently unknown if AP is a genetic trait or can be learned (Brady, 1970; Crozier, 1997). Another theory about AP suggests that it is a disinhibitory process. It is inherited in everyone, but as maturation occurs, the ability diminishes (Bossomaier & Snyder, 2004). A study completed in 2008 supports this theory. Saffran & Griepentrog found that 8-month-old infants relied on track patterns of absolute pitches rather than relative pitches in a tone-sequence statistical learning task. Adult listeners on the other hand primarily tracked relative pitch cues for the same task (Saffran & Griepentrog, 2001). In contrast to this theory, a study found that some musicians who have particular musical training before the age of five to seven during their preoperational period can facilitate the development of AP later in life (Chin, 2003). The preoperational period is also the time when the left hemisphere experiences a growth spurt. In addition, research shows that people with music training can obtain optimal or nearly optimal pitch discrimination abilities when compared to those with no musical training (Micheyl, Delhommeau, Perrot, & Oxenham, 2006). Together these findings suggest an advantage of musical training in pitch perception.

In autistic populations, the prevalence of AP is found to be much higher than the non-autistic populations (Brown et al., 2003). A case study in 2008 found that the autistic adult subject with AP had more success in discriminating the pitch of the speech sound when compared to a matched non-autistic adult with AP (Heaton, Davis, & Happé, 2008). However, it is often observed that both autistic and non-autistic individuals, tend to perform better in discriminating the pitch in single tones compared to discriminating the pitch in speech sounds (Heaton, Hudry, Ludlow, & Hill, 2008). In addition, it is suggested that autistic children have an enhanced ability in not only detecting the differences in pitch between single tones, but they also have a better memory in detecting pitch differences in melodic sounds (Stanutz, Wapnick, & Burack, 2014). Lastly, a suggests that this superiority in pitch discrimination can be predicted with an increased ability in non-verbal reasoning signifying that auditory performance is related to non-verbal reasoning rather than verbal abilities in autistic individuals (Chowdhury et al., 2017).

A new growing literature argues that most of the differences observed in the pitch discrimination or possession of absolute pitch ability is specific to a sub group of *autistic* individuals diagnosis rather than on *Asperger's* or *high-functioning* diagnosis (Bonnel et al., 2010). However, the latest diagnostic criteria for ASD has merged both of these diagnoses into a single one (APA, 2013). This merging of the diagnoses is thought to account for disagreements in the literature regarding the pitch discrimination abilities of autistic individuals. However, these inconsistencies in findings and disagreements in literature also make it difficult to understand the underlying mechanisms responsible for these observed differences. Since successful communication depends on various cues, including being able to detect pitch differences in speech, it is important to understand how these processes are different in autistic individuals, if they are indeed different at all.

1.5 Local Processing Bias in Autistic Individuals

As explored in the previous section, autistic individuals tend to outperform neurotypical individuals on tone discrimination tasks (Stanutz et al., 2014). However, this does not necessarily translate into superior speech processing abilities (Rotschafer, 2021). In fact, previous studies show that performance is task dependent in autistic individuals (Bertone, Mottron, Jelenic, & Faubert, 2005). To establish an understanding of how autistic individuals outperform in relative to non-autistic people on various tasks, it is important to recognize how sensory perception takes place in an autistic brain. Even though individuals with ASD excel in low-level tasks that do not require higher cognitive processing, such as tone discrimination, they also tend to have a harder time processing speech and/or more complex sounds (Lepistö et al., 2005). In general, a low-level task can be defined as a task that requires the processing of the most basic elements of a stimulus (Chowdhury et al., 2017). This can include discriminating between the two tones of an auditory stimulus or recognizing simple elements of a visual stimulus. In contrast, a higher-level task requires greater efforts not only to simply identify but also to incorporate, operate and make sense of patterns derived from low-level information (Chowdhury et al., 2017). High-level processing is a necessary tool for people to navigate the sensory world and depends on the ability to distinguish the whole or detailed characteristics of a stimulus. It is yet to be established if these impairments in autistic individuals are caused by a lack of social interest or abnormalities in neural networks (Lepistö et al., 2005). For example, neurotypical individuals tend to first process the global elements rather than the local elements, such as seeing a forest rather than seeing trees. This is known as the *global precedence effect* (Simmons et al., 2009). On the contrary, autistic individuals have trouble incorporating low-level-stimuli to form complex global percepts (Chowdhury et al., 2017). The *enhanced perceptual functioning* (EPF) theory proposed by Mottron & Burrack (2001) attempts to explain the atypical perception processes of autistic individuals. The EPF suggests that the enhanced ability of autistic individuals in processing auditory and visual stimuli is due to the priority of perceptual processes rather than higher-order cognitive or social processes (Mottron & Burack, 2001). Despite what may seem like contradicting findings in the literature regarding the perceptual abilities of autistic individuals in complex and simple tasks, the EPF argues that they are consistent and all stem from the origin that autistic individuals tend to process local elements first (Mottron, Dawson, Soulières, Hubert, & Burack, 2006). A study done by Nayar and colleagues provides support for this theory. Nayar and colleagues (2017) asked 28 autistic and 22 non-autistic children between the ages of seven and 13 to match solid models to two illusory alternatives while tracking their eye gaze. They found that autistic children had decreased gaze to the center of the solid shape, indicating a reduced global perception (Nayar, Voyles, Kiorpes, & Martino, 2017). In another study, Guy and colleagues (2019) tested 41 autistic and 42 neurotypical children and youth between the ages of six and16 on a Navon task which consisted of four hierarchical letters where a large (global) letter was made out of small (local) versions of the same (consistent) or different (inconsistent) letter. They then asked participants to identify the global or local aspects respectively. They found that autistic children displayed increased local-to-global interference, meaning that they showed a slower detection of global targets (large letters) in the presence of inconsistent local letters (large letters made out of different smaller letters) (Guy, Mottron, Berthiaume, & Bertone, 2019). This finding suggests that instead of a impaired global perception, autistic people may be more *inclined* to process local information regardless of presence of global information. In support of this theory, Koldewyn et al., (2013) found that when faced with hierarchical local-global stimuli, autistic children prefer to report local properties of the stimulus. However, when instructed, their ability to report the global aspects remain intact. The authors suggest that these findings may support the claims that autistic individuals show a *disinclination* and not a *disability* in global processing although more research in this area is needed (Koldewyn, Jiang, Weigelt, & Kanwisher, 2013). In addition, even though many autistic individuals display enhanced abilities in discriminating pure tones, when faced with more complex sounds such as speech, they tend to show impairments. Lepisto et al., (2005) in an ERP study found that autistic children showed enhanced abilities in pitch-discrimination but showed impairments in orienting to speech sounds compared to non-speech sounds, implying deficits in social orienting which is a higher-level task (Lepistö et al., 2005).

This phenomenon of preference for local to global elements in autistic individuals can be further observed in the learning of everyday tasks. For example, in autism interventions, such as applied behaviour analysis (ABA), common everyday tasks such as brushing teeth are taught by teaching the child each step individually known as backwards or forward chaining. In backward chaining, as the name suggests, the sequence of behaviours is taught in reverse order meaning the last step of the target behaviour is taught first (Woods & Teng, 2002). For example, for the target behaviour of brushing teeth, the child will first learn to brush their teeth independently before moving on to the one previous step which would be applying toothpaste to the toothbrush. To keep the child motivated to learn, they will receive the final reinforcer after the successful completion of each step every time. It is observed that autistic children learn these single, local steps more effectively in comparison to other learning methods that include learning the target as a whole (Rayner, 2011). After mastering each step, the child then can successfully practice the target behaviour independently.

Despite the number of studies about performance differences in perceptual tasks, the origin of these abilities remains only partially understood. The EPF model suggests that these abilities stem from atypical autistic behaviours in development. For example, it is well-established that autistic children display an atypical engagement with sensory stimuli; hyper-/hyposensitivity or fascination (Ben-Sasson et al., 2009; Boyd et al., 2010; Leekam et al., 2007; Posar & Visconti, 2018). In a study done by Watling and White, the parent reports for 40 children between the ages of three and six with showed a variety of deficits in sensory processing abilities in autistic children when compared to neurotypical children (Watling, Deitz, & White, 2001). In a separate study, Mottron et al., (2007) found that when an inanimate object was shown, autistic children engaged in a *lateral glance* with their heads turned away from or towards the object or directly staring ahead while their pupils focused on the stimulus in the corner of their eyes. The researchers suggest that this behaviour may be an early innate attempt to filter and optimize excessive information (Mottron et al., 2007). In addition, findings from brain imaging studies consistently indicate that autistic individuals display atypical brain activity in performing tasks and perceptual, social abilities (Chung & Son, 2020). These studies reflect the fact that autistic individuals display enhanced activation of the visual-perceptual regions of the brain such as the temporal occipital regions and reduced activation in higher-order regions such as the frontal regions (Kaplan-Kahn et al., 2021). These suggest autistic individuals process information rather superficially and locally than incorporating the more complex social elements. Aside from atypical activation in brain regions, some studies also suggest that autistic brains have both excessive and under connectivity in some brain regions which can lead to these atypical observations (Keehn et al., 2013; Schipul et al., 2011).

Finally, it is evidently accepted in the scientific community that autistic individuals have greater ability in local processing, including pitch discrimination tasks when compared to non-autistic individuals (Bonnel et al., 2003). However, there are little to no known studies which have actually investigated the role of performance related to the level of cognitive processing required for the task. To successfully understand the way lower and higher level processes differ in autistic individuals, it is important to first distinguish if successful performance is dependent on the complexity of the stimuli or the complexity of the expectation in the task. However, many studies only focus on one or the other, failing to provide a complete understanding of the matter. In this thesis, a complexity comparison of the complexity of the task in relation to emotion perception will be explored.

1.6 The Current Study & Research Questions

In an effort to understand prosody perception in autism in a wider context, findings from two separate studies will be presented in this document. The first study, *Prosody Perception with Background Noise in Individuals with Autism,* will explore the implications of background noise made from inaudible conversations, an everyday factor, in the perception of speech prosody. Although prosody perception has been examined in both the autistic and non-autistic populations in previous research, there is a paucity of research examining affective prosody perception in speech with background noise. In this study, autistic and non-autistic participants were asked to identify the emotion in semantically irrelevant sentences solely based on their prosodic characteristics under three different levels of background noise and to match them to correct visual representations. The noise consisted of multi-speaker incoherent babble sounds. The noise levels were either higher, equal or slightly higher than the speech stimuli to see if these changes have any effect on perceiving the correct emotion. This study hoped to extend the previous research in a number of ways. First, as discussed in earlier chapters, several studies have looked into the implications of different types of noises in perceiving information. Even though many studies have concluded that human speech as a distraction had the largest effect on one's attention (Rosen et al., 2013), there have been no studies that have specifically looked into prosody perception with human speech as background noise. Thus, more extensive research in this area is needed. Second, common noises usually do not conform to a constant level of volume, especially in public spaces. Studying the effects of the same type of noise in different sound levels will allow insight into neural processes that differentiate autistic individuals from the rest of the neurotypical population. Lastly, findings from this study will allow a better understanding of a second step involved in emotional processing: matching auditory stimulus to visual stimulus. Individuals receive some of the information in a conversation from speech and some from facial expressions (Xu, Yang, Tan, & Zhang, 2017). Due to difficulties with both of these processes, autistic individuals face disadvantages in interpreting the emotional state and intentions of others (Leppänen & Nelson, 2006; Tanaka et al., 2012). Therefore, in this study, in addition to the correct identification of emotion in the speech, correct identification of facial expression was also investigated by requesting participants to match the two together.

The second study, *Prosody Perception and Task Dependent Performance in Autistic Individuals* investigated performance differences on global and local levels of tasks in autistic and non-autistic individuals. Specifically, this study presented the same stimuli and asked two different questions requiring two different levels of cognitive functioning. Although many studies have tested pitch discrimination tasks in both non-autistic and autistic populations before, there are no studies to date that have looked at task-dependent performance in the same stimulus. In addition, in this study, participants were presented with confidence ratings after each response. Some studies suggest that differences in pitch discrimination and task discrimination may happen in individuals specifically diagnosed with autism and not with individuals diagnosed with Asperger's Syndrome (Bonnel et al., 2010). Asperger's Syndrome, or previously known as high-functioning autism. Many individuals with Asperger's have an above-average IQ and are advanced in the use of spoken communication (Hayashi, Kato, Igarashi, & Kashima, 2008). However, like the rest of the ASD population, they also experience difficulties with social complexities such as emotional communication. Unfortunately, much of the autism research is done by the contribution of high-functioning autistic individuals as the impairments caused by the disorder make it too difficult for low-functioning individuals to complete tasks requiring focused attention and comprehension as presented in this document. This lack of representation of the autism spectrum often leads to inconsistencies in findings. To anticipate these discrepancies, this study requires confidence ratings after each response. Even if the autistic participant sample may have developed coping mechanisms to meet the social demands, the confidence they present in understanding these demands may be different. This means that when responding to tasks that require the processing of the local elements and are recognized as low-level tasks, autistic participants should have a higher level of confidence. If the task requires global processing and is recognized as a high-level task, then autistic participants are expected to have more difficulties in processing and their confidence level regarding their responses should be lower. It is expected that despite possible similarities the results may offer, some differences can be observed in the confidence the two populations may feel in completing each task. Even though autism persists lifelong, learning social skills may have taken place for high-functioning autistic adults despite not being innate. Based on this, confidence ratings attempted to explore the confidence of autistic adults in social demands, expecting them to be different from the non-autistic adults.

Finally, the following research questions were addressed during this paper:

Study 1: ***Prosody Perception with Background Noise in Individuals with Autism***

1. How do autistic individuals differ in comparison to non-autistic individuals in identifying emotions with different levels of background noise?

Study 2: ***Prosody Perception and Task Dependent Performance in Individuals with Autism***

1. How are autistic individuals different in comparison to non-autistic participants in identifying pitch differences in tones? Do they feel more confident about their responses?
2. Do autistic and non-autistic people show any differences in performance in identifying the direction and the conveyed emotion of a sentence? Are the confidence levels in their responses dependent on the cognitive demands of the task?

1.7 Research Hypotheses

Study 1: ***Prosody Perception with Background Noise in Individuals with Autism***

This study has two hypotheses:

1. Autistic participants will have a harder time recognizing affective prosody across all noise conditions when compared to non-autistic participants.

2. Autistic participants will have a harder time recognizing affective prosody as the noise level increases compared to non-autistic participants.

Study 2: ***Prosody Perception and Task-Dependent Performance in Autistic Individuals***

This study has three hypotheses:

1. It is hypothesized that autistic participants will perform better in identifying the pitch direction in comparison to non-autistic participants. They will also be more confident in their responses.
2. Autistic and non-autistic participants will differ in their responses for sentence directions and participants with autism will be more confident in their responses.
3. Autistic participants will perform worse in identifying the emotion in speech when compared to the non-autistic participants and be less confident in their responses.

2. PROSODY PERCEPTION WITH BACKGROUND NOISE IN INDIVIDUALS WITH AUTISM

2.1 METHODS

2.1.1 Participants

In this study**,** 196 non-autistic (NASD) and 21 autistic (ASD) participants were recruited. One of the autistic participants also had epilepsy so their data was excluded from the analysis. Literature suggests that epilepsy and autism share common genes and symptomology which would have made it difficult to identify the effects of each disorder in the study tasks (Lee et al., 2015). There were 159 females, 31 males and six individuals who identified as other for the non-autistic participants, and 12 females, five males and three individuals who identified as other for the autistic participants. All of the autistic participants were officially diagnosed by a psychiatrist. The age range was 18-46 for the non-autistic participants with a mean age of 19.91 and a standard deviation of 3.45. For autistic participants, the age range was 18-45 with a mean age of 23.19 and a standard deviation of 7.17 (see Table 1). None of the participants had received any behavioural intervention such as Applied Behaviour Analysis (ABA) therapy except for one participant who had received it for less than a year. Their data was not excluded. None of the participants suffered from hearing loss and/or were diagnosed with global developmental delay. Participants were recruited through the Wilfrid Laurier University PREP system, online community and various autism centers. Participants signed informed consent before beginning the study and were provided with a Debriefing Statement after study completion. Participants were added to a $100 CAD draw if they wished for compensation. The official documents can be viewed in Appendix A.

Table 1: Participant characteristics

Group	Age	Gender
ASD	18-45	12 Females
(*n*=20)	*M*=23.19	5 Males
	SD=3.45	3 Other
NASD	18-46	159 Females
(*n*=196)	*M*=19.91	31 Males
	SD=3.45	6 Other

2.1.2 Measures

Before beginning the experiment, each participant was asked to complete a Demographics Questionnaire, The Autism Quotient (AQ) and the Multidimensional Social Competence Scale (MSCS). The Demographics Questionnaire asked questions about ethnicity, gender and age in addition to obtaining information about any diagnoses and/or impairments. The AQ is a 50-item self-report questionnaire with a 4-point selection scale of *definitely agree, slightly agree, slightly disagree, and definitely disagree* (Baron-Cohen, 2001). The AQ was used to assess the individual's standing on the autism scale with a value over 32 typically used as the cut-off to suggest clinical levels of autistic traits. MSCS (Yager & Iaoracci, 2013) is a 77 item self-report questionnaire with a 5- point-scale from *not true or almost never true*, *rarely true*, *sometimes true*, *often true*, to *very true or almost always true* which was used to assess the individual social standing on the autism scale. The MSCS has seven domains which are Social Motivation, Social Inferencing, Demonstrating Empathetic Concern, Social Knowledge, Verbal Conversation Skills, Non-Verbal Conversation Skills and Emotional Regulation. Score on the MSCS ranges from 77 to 385 with lower scores indicating poorer social competence skills. The questionnaires, as well as scoring keys, can be viewed in Appendix A.

2.1.3 Apparatus & Stimuli

The study was completed online and *Testable* (testable.org) was used to create and conduct the experiment. *Testable* is an online platform that can be used to design various behavioural experiments and surveys and collect data. The results along with the signed consent forms were uploaded onto the Cloud, an internet storage associated with Testable. The experiment took approximately one hour to complete. Participants were suggested to wear headphones to limit any distractions. The experiment utilized 36 trials, each approximately three seconds long. In each trial, the participants listened to the following sentence "The dogs are sitting by the door" from the *Ryerson Audio-Visual Database of Emotional Speech and Song* (RAVDESS). RAVDESS is an open-access database of emotional speech and songs with gender-balanced productions of emotional statements in a North American accent (Livingstone & Russo, 2018). Each vocalization was produced by actors expressing six universally accepted emotions: *anger, disgust, happy, sad, fear, surprise*. Half of the stimuli selected from this database were recorded by female voice actresses and the other half were recorded by male voice actors. Six pairs of auditory stimuli were presented with one of the happiness-sadness, anger-disgust, fear-surprise visual stimulus pairs from *Karolinska Directed Emotional Faces* (KDEF) database. KDEF is an open-access database of 4900 pictures of human facial expressions (Lundqvist et al., 1998). Each emotion in the selected pair was vocalized by the same actor and each auditory stimulus was paired once with the visual stimuli. The auditory emotional stimuli were presented at three different levels of sound-to-noise ratios: at 0 dB which meant equal loudness of the stimuli and the babble noise, -3 dB for slightly louder noise than the stimuli and -6 dB being the loudest noise condition. The noise presented was incoherent speech babble sounds. Each emotion was presented twice in each noise condition. Participants were asked to match the auditory stimulus with one of the presented emotional visual pairs (Figure 1). The correct answer was always presented in the options. The list of all stimuli used from these databases can be viewed in Appendix B

Figure 1: Experimental design example

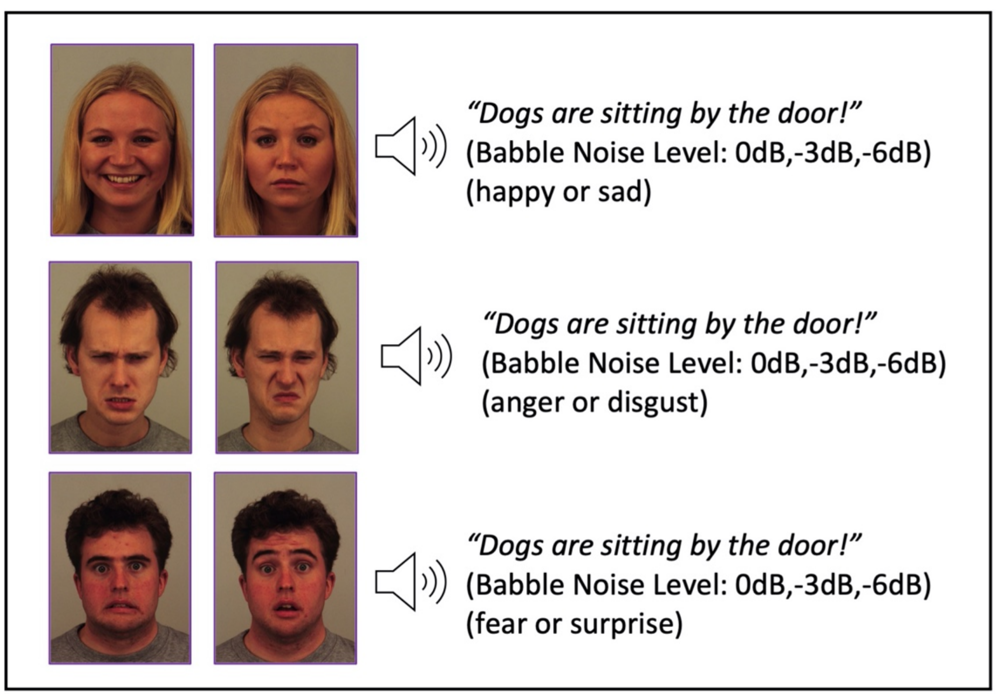


Figure 1 shows the experimental task with each line representing a single trial, with the presentation of two pictures representing a pair of emotions (happy-sad, anger-disgust, fear-surprise). In each trial, the auditory stimulus was heard with one speech babble noise condition: 0dB, -3dB or -6dB. Each visual representation was used only once with the auditory stimulus. The correct response was always available.

2.2 RESULTS

For all of the statistical analyses, JASP 0.16.1 was used as the statistical tool.

2.2.1 AQ and MSCS

An independent samples t-test was conducted to assess the diagnostic differences in AQ and MSCS scores. It was found that ASD and NASD individuals significantly differed in their AQ scores ($t(214)=-8.81$, $p < 0.01$, $\eta2=-2.07$). Autistic participants had more autistic traits ($M=34.40$, $SD=6.05$) than non-autistic participants ($M=19.40$, $SD=7.36$).

It was also found that the two groups significantly differed in six categories of the MSCS and in the overall test score. The autistic participants had lower scores indicating less social competency in all domains compared to non-autistic participants (see Table 2).

Table 2: MSCS scores across autistic and non-autistic participants

	ASD Mean / SD / Score Range	NASD Mean / SD / Score Range	*t*	*p*	*Cohen's d*
Total Score	226.10 31.67 146-286	283.60 31.67 198-354	7.73	<.001*	1.82
Social Motivation	27.85 6.96 15-39	39.01 6.98 21-54	6.81	<.001*	1.60
Social Inferencing	28.80 7.68 15-44	41.65 6.83 21-55	7.92	<.001*	1.86
	34.85	40.76			

Empathetic Concern	5.31	4.37	5.65	<.001*	1.33
	24-46	30-52			
Social Knowledge	39.85	46.65	5.05	<.001*	1.19
	6.08	5.83			
	25-48	26-55			
Verbal Conversation Skills	28.45	39.07	5.93	<.001*	1.39
	9.36	7.44			
	11-45	14-54			
Nonverbal Conversation Skills	32.45	40.40	5.83	<.001*	1.37
	5.32	5.86			
	23-41	23-51			
Emotion Regulation	33.85	35.96	1.45	0.149	0.34
	7.02	6.12			
	21-46	19-49			

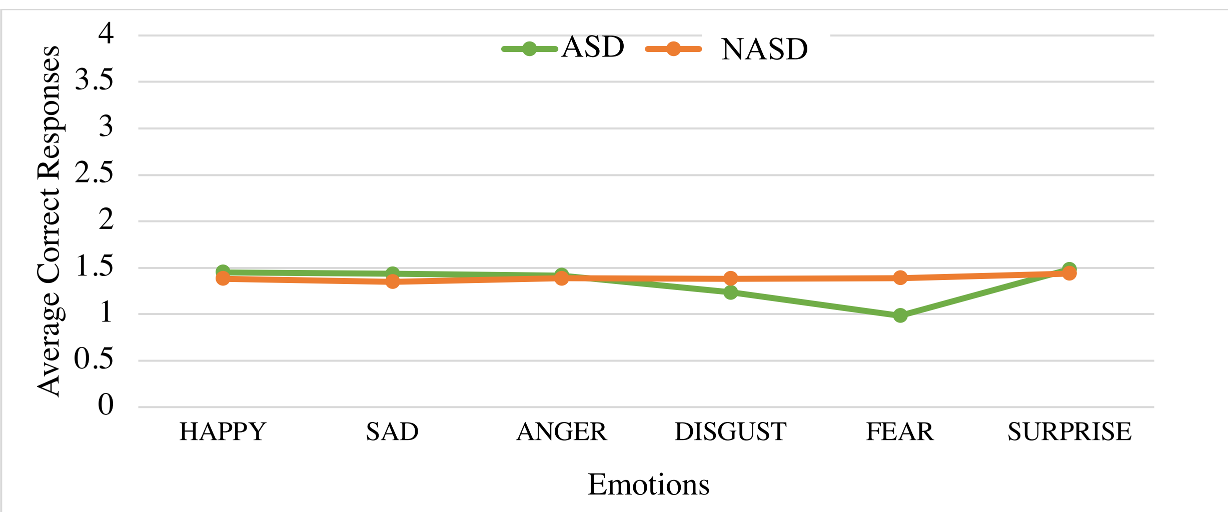
In addition, a linear regression analysis was conducted to determine if AQ and MSCS scores could predict performance in the experimental task. No significant relationship was found between the AQ scores and the task performance ($F(1,214)=1.47$, $p=0.227$, $R^2<.01$). On the other hand, MSCS scores were found to be a significant predictor of task performance ($F(8,205)=7.88$, $p<.001$) with an R^2 of .48. Out of the seven categories of the MSCS, *Social Motivation* ($\beta=-.44$, $p=.008$) and *Verbal Conversation Skills* ($\beta=-.38$, $p=.02$) were identified as the significant contributing factors for the predictor relationship between test scores and task performance.

2.2.2 Emotions and Noise Level

A mixed measures analysis of variance (ANOVA) was conducted on a 2 (diagnosis: ASD, NASD) x 3 (genders: female, male, other) x 6 (emotions: happy, sad, anger, disgust, fear, surprise) x 3 (noise levels: 0 dB, -3 dB, -6 dB) design. All within-group effects can be viewed in Appendix C. Homogeneity tests revealed that normality was violated. However, due to uneven numbers of groups and high variability within groups, no further steps were taken. ANOVAs are known to be adequately robust against normality violations, including in unequal group sizes. (Blanca et al., 2017).

The main effect of *diagnosis* (F(1,210)=0.93, p=.336, η^2<.001) and *emotion* (F(5,2100)=0.86, p=.508, η^2=.001) were not significant. In addition, a non-significant two-way interaction was established between *diagnosis* and *emotions* (F(1,5)=1.02, p=0.404, η^2=.001), suggesting that both groups of participants identified all six emotions similarly (see Figure 2). However, an independent samples t-test revealed that the emotion of *fear* was significantly different at the noise level of -6 dB across autistic participants and non-autistic participants (t(214)=2.25, p=.026). Autistic participants had a harder time recognizing the emotion of *fear* at -6 dB noise level (M=1.15, SD=0.75) when compared with NASD participants (M=1.48, SD=0.61; see Figure 2).

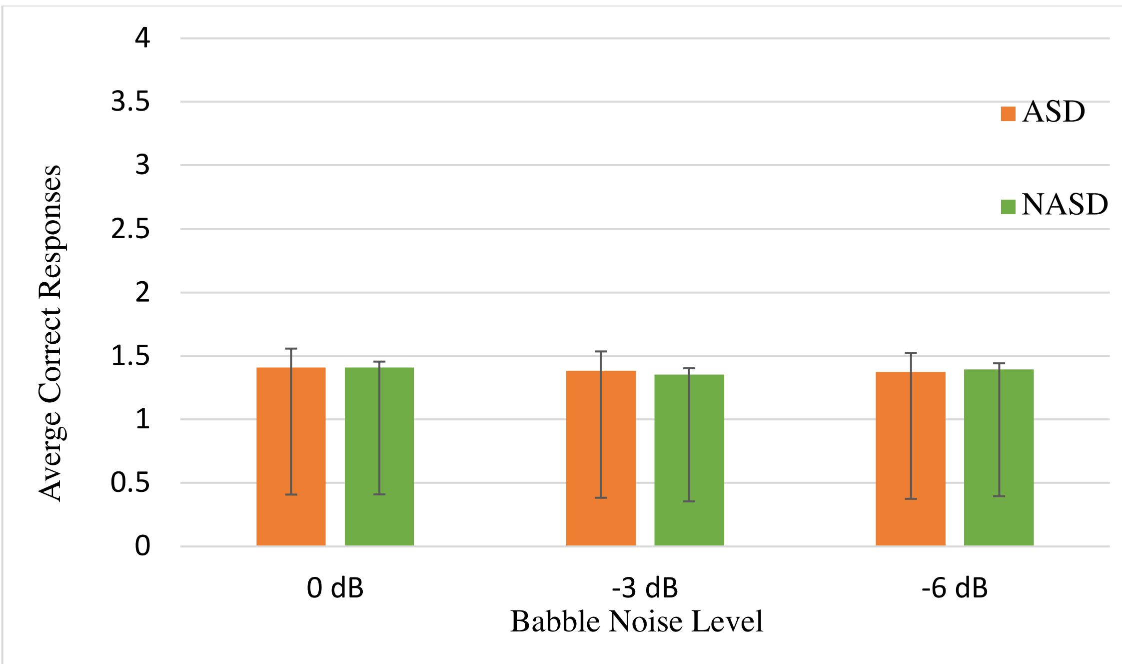
Figure 2: Average number of correctly identified of emotions across autistic and non-autistic participants



Moreover, the main effect of *noise level* (F(2,2100)=0.49, p=.290, η^2<.001) and the interaction between *diagnosis* and *noise level* did not reveal a significant two-way relationship

($F(2,1)=0.40$, $p=0.668$, $\eta^2<.001$) indicating that both groups performed similarly across all noise conditions (see Figure 3). Lastly, a marginal non-significant three-way relationship was observed between *diagnosis, emotion, and noise level* ($F(1,10)=1.70$, $p=0.075$, $\eta^2=.004$). This finding revealed that the two populations marginally differed in identifying the six universally accepted emotions under three noise conditions.

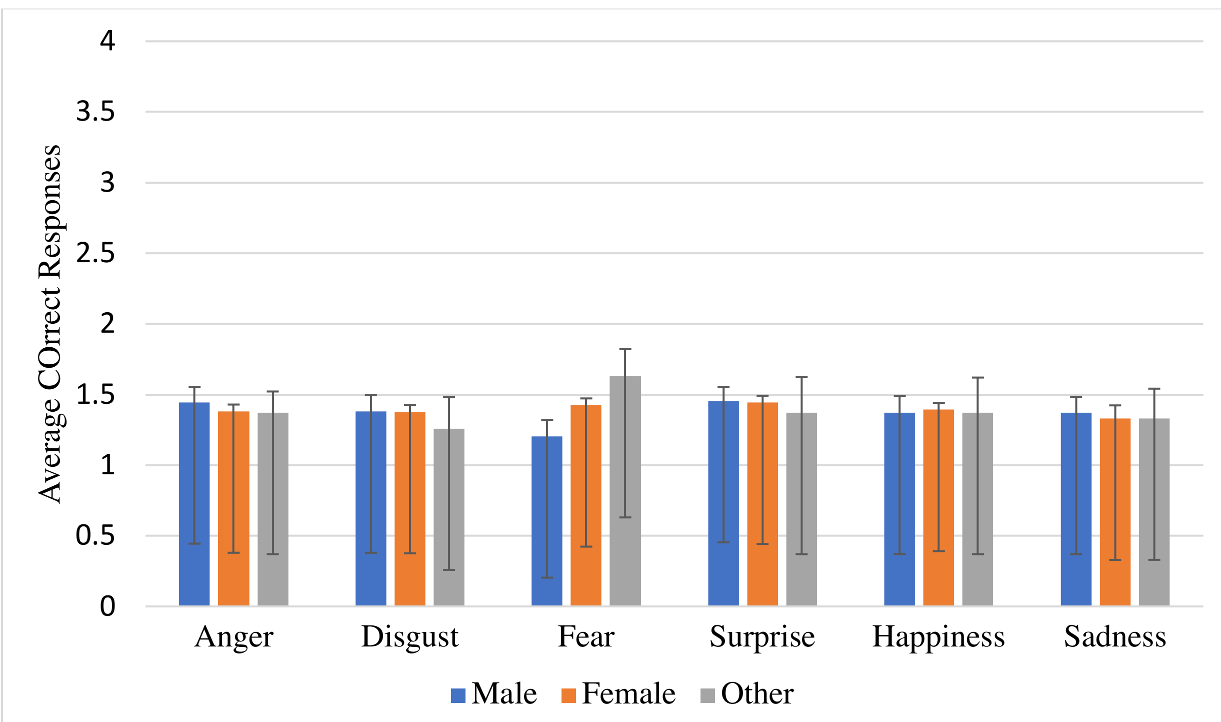
Figure 3: Average correct responses across three different noise levels for autistic and non-autistic participants



2.2.3 Gender

A main effect of gender was not observed ($F(2,210)=1.90$, $p=0.152$, $\eta^2=.002$) meaning *females, males* and participants who identified as *other* performed similarly on the experimental task. In addition, genders across diagnoses performed similarly, yielding a marginally non-significant two-way between-subjects interaction between *gender* and *diagnosis* ($F(2,210)=2.44$, $p=0.089$, $\eta^2=.002$). There was also a non-significant two-way interaction between *gender* and *noise level* ($F(2,4)=1.10$, $p=0.355$, $\eta^2=.001$), meaning all genders showed similar performance across the three noise levels. A significant two-way interaction was found between *gender* and *emotions* (F(2,10)=2.77, p=.002, η^2=.007). Post hoc tests revealed several significant differences between groups. Out of the four maximum possible correct answers, *females* overall performed better in identifying the emotion *happy* (M=1.39, SD=0.66) on average when compared with *males* identifying *fear* (M=1.20, SD=0.70). In addition, *females* were better at identifying *sad* (M=1.33, SD=0.66) and *fear* (M=1.42, SD=0.64) when compared to males identifying *fear*. Once again, males had a harder time identifying *fear* in comparison to identifying *anger* (M=1.44, SD=0.65). Lastly, people who identified as other performed better at identifying *fear* (M=1.63, SD=0.57) when compared with males identifying *fear* (see Figure 4).

Figure 4: Average emotion recognition across genders



In addition, a significant three-way interaction was found between *gender, diagnosis* and *emotion* (F(2,10)=2.31, p=.011, η^2=.006). Post hoc analysis revealed *ASD males* had significantly lower scores in identifying *fear* (M=0.733, SD=0.59) when compared to *female ASD* participants in identifying the emotion of *sad* (M=1.58, SD=0.60). In addition, *NASD* *females* were also observed to be significantly better at identifying *fear* (M=1.42, SD=0.64) and *surprise* (M=1.43, SD=0.64) in comparison to *ASD males* identifying *fear*. Similarly, when compared with *ASD males* identifying *fear, ASD* participants identified as *other* were better at identifying *fear* (M=1.89, SD=0.33) and f*emale ASD* participants were better at identifying *surprise* (M=1.64, SD=0.59). Lastly, once again *ASD males* had a harder time identifying the emotion of *fear* when compared with *NASD males* identifying *surprise* (M=1.46, SD=0.58).

Lastly, a significant four-way interaction of *diagnosis* x *gender* x *emotion* x *noise level* was not observed ($F(20,2100)=0.60$, $p=.089$, $\eta^2=.007$).

3. STUDY 2: PROSODY PERCEPTION AND TASK-DEPENDENT PERFORMANCE IN INDIVIDUALS WITH AUTISM

3.1 METHODS

3.1.1 Participants

Seventy-seven participants were recruited for this study. One participant indicated that they were not diagnosed but two of their immediate family members were autistic. Their results were excluded from the analysis as the literature suggests immediate family members are likely to differ from the neurotypical population, even if they are not diagnosed themselves (Messinger et al., 2013). One other participant said they thought they were autistic but were not officially diagnosed. Their data were also excluded as they were not officially diagnosed. Out of the remaining 75 participants, 56 participants were non-autistic (NASD) and 19 participants were autistic (ASD). The diagnosis was self-reported along with the information about the year of diagnosis and the diagnosing clinician. None of the autistic participants had received any behavioural intervention, had hearing impairments and/or were diagnosed with global intellectual delay. In addition, 21 of the 75 total participants indicated that they had official music training. There were 46 females, nine males and one participant who identified as other for the non-autistic participants. The age range was 18-45 with a mean age of 23.26 and a standard deviation of 6.84. For the autistic participants, there were 10 participants who identified as female, four who identified as male and five who identified as other. The age range for autistic participants was 17-53 with a mean age of 27.21 and a standard deviation of 10.51 (see Table 4). Fifteen participants from the NASD group and six participants from the ASD group indicated that they had official musical training. Participants were recruited from the Waterloo region community, the Wilfrid Laurier PREP system, social media and the online community. Each participant signed an informed consent form before beginning the experiment and received a debriefing statement after completing the study (see Appendix A for a list of study documents). Participants were compensated by an entry for a $100 draw prize.

Table 4: Participant characteristics

Group	Age	Gender	Musical Training
ASD	17-53	10 Females	13 Females
(n=19)	M=27.21	4 Males	1 Male
	SD=10.51	5 Other	1 Other
NASD	18-45	46 Females	3 Females
(n=56)	M=23.26	9 Males	2 Males
	SD=6.84	1 Other	1 Other

3.1.2 Measures

Each participant was asked to fill out a demographics questionnaire and the Autism Spectrum Quotient (AQ) (Baron-Cohen, 2001) before beginning the experiment. In the demographic questionnaire, participants were asked about diagnosis, medical conditions and any musical training or if they play an instrument. The AQ was used to evaluate the participants' overall standing on the autism spectrum (see Appendix A).

3.1.3 Apparatus & Experimental Design

The study was designed and conducted on *Testable* (testable.org). Participants were asked to wear headphones throughout the duration of the study. The study was approximately one hour long and consisted of three tasks. The first task consisted of 20 sweep tones ranging from 180-220 Hz with a center value of 200 Hz. Sweep tones are typically sine waves that smoothly vary in frequency from high to low or low to high. The direction of sweep tones was either going down to 180 Hz from 200 Hz at every even value or going up to 220 Hz from 200 at every two Hz (see Figure 5). In summary, in each trial, the sweep tones started at 200 Hz and ended at another value between 180-220 Hz. These values were determined based on literature and previous pilot work conducted in the lab. Participants were asked to identify the direction of the sweep tones and select UP for tones that ended higher or select DOWN for tones that ended lower. After each response, participants were asked to rate their confidence level as either *not confident, somewhat confident, confident,* or *very confident*.

Figure 5: Sweep tone values for Task 1 with a center value of 200 Hz

In the second task, participants were asked to identify the ending direction again. However, this time instead of sweep tones, emotional utterances from the *Emotional Speech Database* (ESD) were used. ESD is an open-access database that consists of 350 utterances spoken by 10 native English and 10 native Chinese speakers and covers five emotions (anger, happy, sad, neutral, and surprise) with more than 29 hours of recorded data (Zhou et al., 2022). Out of 35000 recordings, a random 100 recordings were selected. Each utterance was approximately 3.4 seconds long. Half of these utterances were recorded by one male actor, actor #20, and the other half were recorded by a female actress, actress #16. None of the 100 utterances were repeated and each was a unique statement (The list of all stimuli used from this database can be found in Appendix B). Each participant received a randomized selection of 20 utterances from the total selected 100 utterances, equally produced by each gender and containing equal numbers of each emotion. They were then asked to identify if the utterance pitch was ending going UP, DOWN or FLAT. After each response, they were asked to rate their confidence on a 4-level confidence scale of *not confident, somewhat confident, confident,* or *very confident*.

In the final task, participants received a random 20 utterances from the same 100 recordings used in the second task. However, this time they were asked to identify the emotion carried in the utterance by the corresponding word options. The options were *happy, sad, fear, surprise* and *neutral* as the literature suggests aside from the six universally accepted emotions (Ekman, 1992), four of them are identified as basic emotions (Gu et al., 2019). Each participant received four representations of the five emotions, half produced by a female and the other produced by a male. After each trial, participants were also asked to rate their confidence for their responses either as *not confident, somewhat confident, confident,* or *very confident*.

3.2 RESULTS

3.2.1 AQ

An independent samples *t*-test was conducted to see the diagnostic differences in AQ scores across the two groups. It was revealed that ASD and NASD individuals significantly differed in their AQ scores ($t(73)=-8.25$, $p < 0.01$). Autistic participants scored higher than NT individuals in comparison (see Table 5).

Table 5: AQ scores across autistic and non-autistic participants

	ASD	NASD	*t*	*p*
AQ Mean	34.42	19.21		
SD	6.54	7.07	-8.25	<.001

Score Range	21-43	6-38

A linear regression analysis was conducted to see if AQ scores could predict performance. It revealed that AQ scores could marginally predict confidence ratings associated with up sweep tones ($F(1,73)=3.91$, $p=.052$) with an $R^2=.05$ and an adjusted $R^2=.04$ and could significantly predict confidence ratings associated with down sweep tones ($F(1,73)=4.38$, $p=.040$) with an $R^2=.06$ and an adjusted $R^2=.04$. However, it was not a significant predictor in performance for pitch discrimination (up: $p=.911$, down: $p=.457$), sentence direction identification (up: $p=.769$, down: $p=.922$, flat: $p=.558$) or emotion recognition tasks (happy: $p=.724$, sad: $p=.466$, neutral: $p=.081$, angry: $p=.589$, surprise: $p=.427$) nor with the confidence ratings associated with these tasks ($p>.05$).

3.2.2 Task 1: Sweep Tones Direction Identification and Confidence Ratings

3.2.2.a Sweep Tones Direction Identification, Confidence Ratings and Group Differences

A 2 (diagnosis: ASD, NASD) x 2 (sweep tones: UP, DOWN) mixed factorial ANOVA revealed that the two groups were indifferent in their performance for both up and down sweep tones with a non-significant between-subjects effect of *diagnosis* ($F(1,73)=3.16$, $p=.08$, $\eta^2=.03$). A non-significant effect of *sweep tones* was also found ($F(1,73)=0.01$, $p=.918$, $\eta^2<.001$) meaning that both up and down sweep tones were recognized similarly. In addition, a significant interaction of *diagnosis* x *sweep tones* was not observed ($F(1,73)=1.44$, $p=.234$, $\eta^2=.005$). The two groups also did not significantly differ in their confidence ratings for both up and down sweep tones as revealed by a 2 (diagnosis: ASD, NASD) x 2 (Confidence Ratings: UP, DOWN) mixed design with a non-significant between-subject effect of *diagnosis* ($F(1,73)=0.42$, $p=.521$, $\eta^2=.005$). Similarly, a non-significant effect of *confidence ratings* ($F(1,73)=0.25$, $p=.618$, $\eta^2<.001$) and an interaction of *diagnosis* x *confidence ratings* was also observed ($F(1,1)=0.21$,

p=.647, η^2<.001). However, as expected, participants with ASD did indeed score a higher number of correct responses (M=8.84, SD=3.04) when compared with NASD participants (M=7.68, SD=2.00) for up sweep tones. In addition, participants with ASD also scored higher for down sweep tones (M=8.53, SD=1.22) in comparison to NASD participants (M=8.05, SD=1.89). Lastly, ASD participants overall had slightly lower confidence ratings (M=27.158, SD=5.44) compared to NASD participants (M=27.96, SD=4.46).

3.2.2.b Sweep Tones Direction Identification and Musical Training

A 2 (musical training: yes, no) x 2 (sweep tones: UP, DOWN) mixed ANOVA revealed that participants who indicated that they had *musical training* performed significantly better in identifying the correct direction for sweep tones (F(1,73)=6.62, p=.012, η^2=.06). However, there was no significant effect of *sweep tones direction* (F(1,73)=0.12, p=.735, η^2<.001) and no significant interaction of *sweep tones direction and musical training* was observed (F(1,1)=0.72, p=.398, η^2=.001). In addition, a 2 (musical training: yes, no) x 2 (confidence ratings: UP, DOWN) mixed ANOVA design was conducted to see if participants with and without *musical training* differed in their of level confidence in identifying sweep tone directions. It was found that participants with *music training* were significantly more confident in their responses for sweep tones (F(1,73)=4.07, p=.047, η^2=.05). However, there was no significant effect of *confidence ratings* for either direction of tones (F(1,73)=0.033, p=.856, η^2<.001) or significant interaction between *confidence ratings* and *musical training* (F(1,73)=1.12, p=.293, η^2=.002).

3.2.2.c Sweep Tones Direction Identification and Gender

A 3 (gender: female, male, other) x 2 (sweep tones: UP, DOWN) mixed ANOVA revealed a main effect of *gender* on performance for the sweep tones direction identification task (F(2,72)=3.61, p=.032, η^2=.07). Further analysis revealed that individuals who identify as *other*

(*M*=8.42, *SD*=1.63) significantly identified the direction more accurately compared to *males* (*M*=6.92, *SD*=1.72) and *females* (*M*=8.30, *SD*=2.14). No main effect of *sweep tones* (F(1,72)=0.28, p=.595, η^2=.001) and no significant interaction of *gender* and *sweep tones* (F(2,72)=0.24, p=.788, η^2=.002) were observed. In addition, no significant main effects of *gender* (F(2,72)=0.08, p=0.925, η^2=.002) in *confidence ratings* or main effect of *confidence ratings* (F(1,72)=1.40, p=.241, η^2=.002) or interaction of *gender* and *confidence ratings* (F(2,72)=1.28, p=.283, η^2=.004) were observed.

3.2.3 Task 2: Utterance Direction Recognition and Confidence Ratings

3.2.3.a Assessing Utterance Characteristics

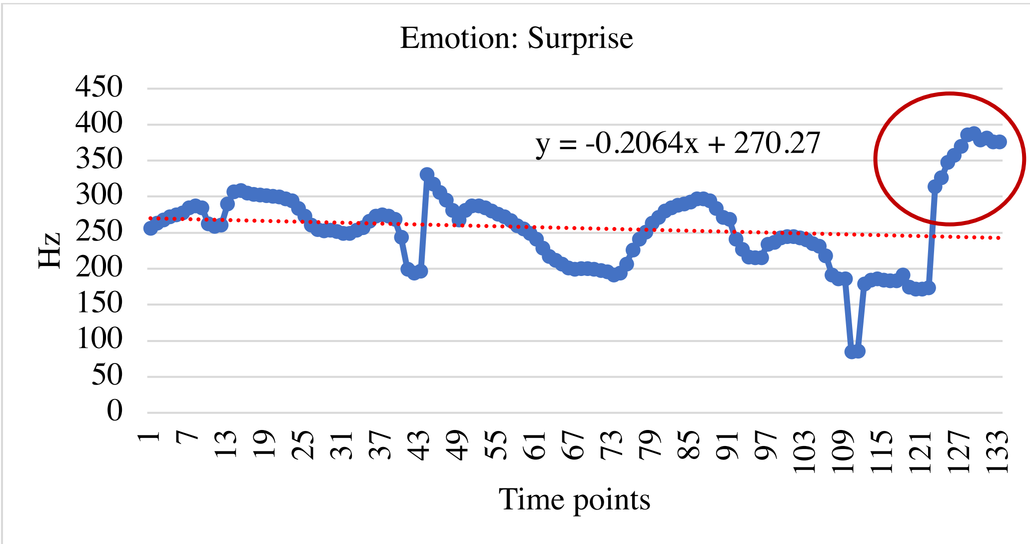
To assess the characteristics of the presented utterances, pitch values across the time duration of the 100 sentences were identified in Praat. Based on these values, the pitch slope for each utterance was calculated in Microsoft Excel 16.66.1. Graphs of slopes revealed that slope on its own was not enough to accurately determine the pitch direction ending of the utterances. Despite the common expectation to label negative slopes as going down, positive slopes as going up and slopes nearing zero as flat, inconsistencies in utterances grouped by emotions revealed that utterances had a large variability of slopes and direction endings (see Table 6). Moreover, a utterances with a negative slope could really end going up (Figure 6). To account for discrepancies in slope variabilities, the first 5% of the sentence pitch values were subtracted from the last 5% to see differences between the start and the end of utterances. Similar to slope values, 5% values also revealed high variability in their distribution across emotions (see Table 6).

In addition, a correlation analysis was conducted to see if there were any meaningful relationships between the participant responses in relation to slope and 5% values (see Tables 7-11; Appendix C). It was revealed that slope and 5% values were very weakly correlated with participant responses, if at all. Since speech stimuli with high variability within the sound itself and across the emotional spectrum were being used, no sentences were marked as up, down or flat. To avoid incorrect and inaccurate labelling of stimuli, we instead analyzed group differences in responses.

Table 6: Slope and 5% value characteristics for utterances

			SLOPE			
	MEAN	**STD**	**VAR**	**MIN**	**MAX**	**MEDIAN**
HAPPY	-0.93	1.00	1.00	-3.33	0.10	-0.43
SAD	-0.26	0.30	0.09	-1.30	0.08	-0.18
NEUTRAL	-0.25	1.33	1.76	-2.16	3.26	-0.39
ANGRY	-0.36	0.892	0.80	-2.37	1.16	-0.33
SURPRISE	0.59	1.13	1.27	-0.85	3.83	0.44
			5%			
	MEAN	**STD**	**VAR**	**MIN**	**MAX**	**MEDIAN**
HAPPY	-476.30	649.34	421641.60	-1755.70	813.26	-495.61
SAD	-149.06	269.64	72704.20	-811.63	450.13	-215.00
NEUTRAL	98.78	815.17	664504.80	-868.83	1800.87	-180.73
ANGRY	127.49	867.87	753189.30	-986.99	2143.12	-85.90
SURPRISE	792.07	756.83	572790.40	-365.81	2084.52	652.97

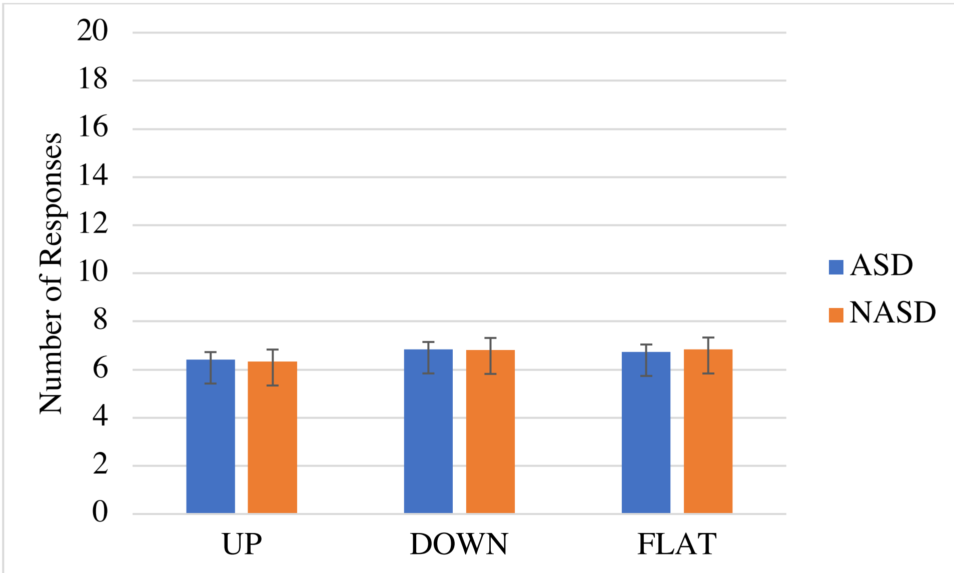
Figure 6: An example of a graphed utterance; pitch plotted against time showing a negative slope and an upwards ending



3.2.3.b Utterance Direction Recognition and Confidence Ratings

A chi-square test was run to determine if the two diagnostic groups differed in their decisions for direction responses. It was revealed that participants were only significantly different in their responses in identifying *happy* stimuli as *up*. For the four other emotions, a similar pattern was observed between the two groups in identifying the direction of the utterances ending based on its pitch as either *up, down or flat* (see Figure 7). An independent samples t-test revealed that the groups did not significantly differ in their *confidence ratings* ($t(73)=0.80$, $p=.424$) Contradictory to what was expected, it was found that NASD participants were more confident in this utterances direction task ($M=2.82$, $SD=0.52$) when compared to the ASD participants ($M=2.71$, $SD=0.54$).

Figure 7: Observed frequencies in utterance direction identification task across autistic and non-autistic participants



3.2.3.c Utterance Direction Recognition and Musical Training

A chi-square test was run to determine if individuals with official music training differed in their decisions for direction responses when compared with participants who indicated no musical training. It was revealed that the two groups made similar decisions and no significant differences were observed in their responses for identifying utterances as ending *up* (X2(7, *N*=75)=4.21, *p*=.756) *down* (X2(10, *N*=75)=14.75, *p*=.142) or *flat* (X2(10, *N*=75)=5.03, *p*=.889). An additional chi-square test indicated that participants with and without musical training also did not differ in their responses (*p*>.05) across any emotion categories, yielding similar decisions about sentence ending directions.

3.2.3.d Utterance Direction Recognition and Gender

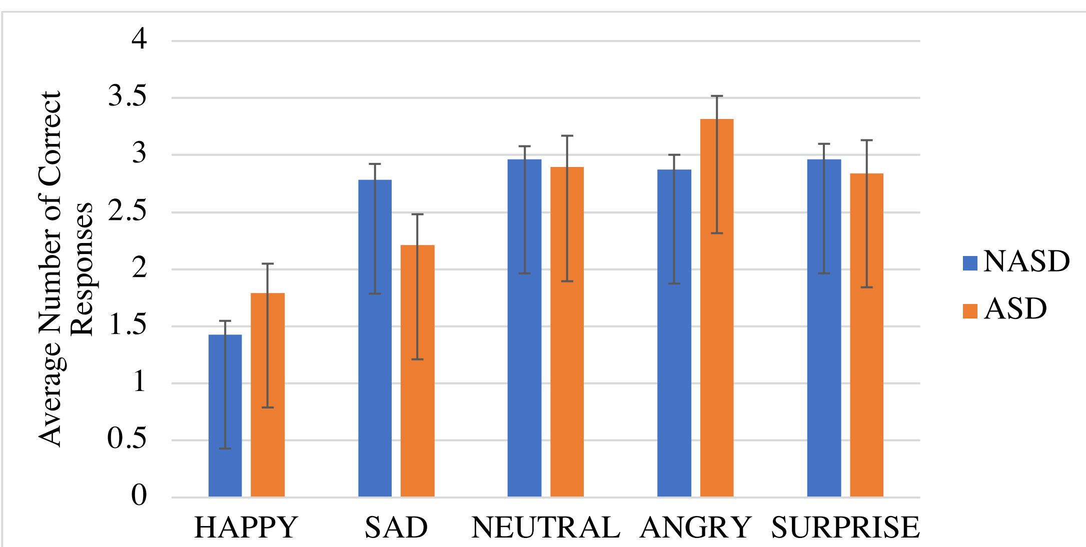
A chi-square test was run on overall responses to determine if *females, males* and individuals identifying as *other* differed in their decisions for utterance direction endings. It was revealed that participants marginally differed in identifying the utterances as *up* (X2(14,

N=75)=23.24, p=.056) and significantly did not differ in identifying utterances as ending *down* (X2=(20, N=75)=16.79, p=.666) or ending as *flat* (X2=(20, N=75)=15.19, p=.765). These results indicate that *females, males* and participants who identified as *other* made similar decisions about utterance direction endings.

3.2.4 Task 3: Emotion Recognition

A mixed measures ANOVA was conducted on a 2 (diagnosis: ASD, NASD) x 5 (emotions: happy, sad, neutral, angry, surprise) design. A significant within-subjects effect of *emotion* (F(1,292)=23.39, p<.001, η^2=.18) and *emotion x diagnosis* (F(1,4)=2.74, p=.029, η^2=.021) was observed. No significant between effects for *diagnosis* (F(1,73)=0.002, p=.962, η^2<.001) was observed meaning both groups performed similarly across emotions (see Figure 8). Further post-hoc tests on *emotion* revealed that compared to *happy* (M=1.52, SD=.094) emotions *sad* (M=2.64, SD=1.09), *neutral* (M=2.95, SD=.094), *angry* (M=2.99, SD=0.95) and *surprise* (M=2.93, SD=1.07) were more accurately recognized. *Sad* was also more correctly identified when compared to *angry*.

Figure 8: Mean Performance in emotion recognition between autistic and non-autistic participants

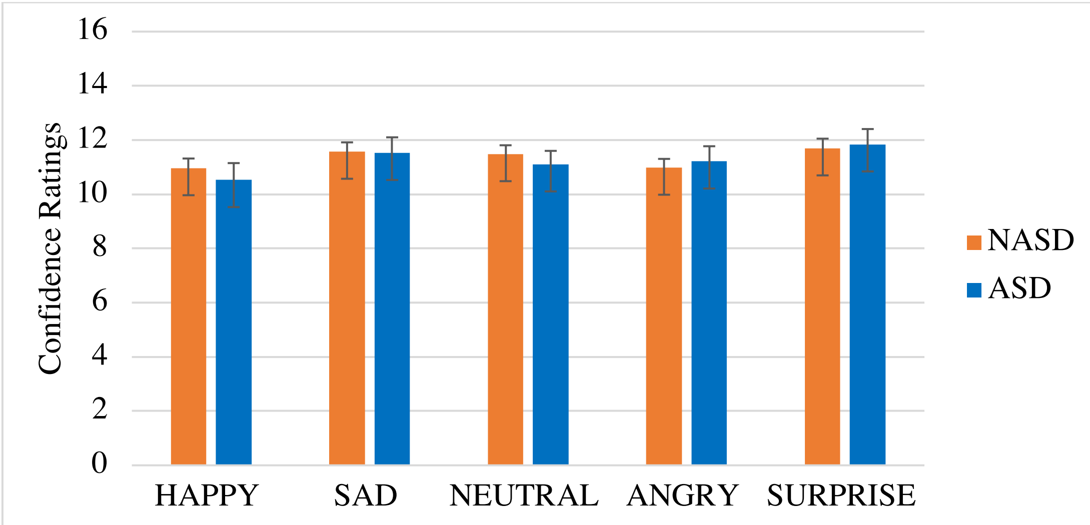


Post hoc tests also revealed significant differences in emotion recognition between the two groups. NASD participants had a harder time recognizing *happy* (*M*=1.43, *SD*=0.89) when compared with *sad* (*M*=2.79, *SD*=1.02), *neutral* (*M*=2.96, *SD*=0.85), *angry* (*M*=2.88, *SD*=0.96) and *surprise* (*M*=2.96, *SD*=1.01). NASD participants also had a harder time recognizing *happy* when compared with ASD participants across *neutral* (*M*=2.90, *SD*=1.20), *angry* (*M*=3.32, *SD*=0.89) and *surprise* (*M*=2.84, *SD*=1.26). ASD participants had a harder time recognizing *happy* (*M*=1.79, *SD*=1.13) when compared with *neutral*, *angry* and *surprise* in the ASD group and *sad, neutral, angry* and *surprise* in the NASD group. Lastly, ASD individuals performed better at identifying *angry* when compared to their success in *sad*. Overall, ASD group had better success recognizing *happy* and *angry* when compared to the NASD group.

3.2.4.a Emotion Recognition and Confidence Ratings

A non-significant main effect of *diagnosis* ($F(1,73)=0.03$, $p=0.869$, $\eta^2<.001$) was found for level of confidence through a mixed ANOVA on a 2 (diagnosis: ASD, NASD) x 5 (confidence ratings: happy, sad, neutral, angry, surprise) analysis. On the other hand, one significant within-subject effect for *confidence ratings* ($F(4,292)=4.93$, $p<.001$, $\eta^2=.015$) and one non-significant within subjects effects for *confidence ratings x diagnosis* ($F(4,292)=0.71$, $p=.587$, $\eta^2=.002$) were observed. Post-hoc tests for *confidence ratings* indicated that participants were more confident in their responses for *sad* (*M*=11.55, *SD*=2.53) and *surprise* (*M*=11.77, *SD*=2.55) when compared to their responses for *happy* (*M*=10.75, *SD*=2.68). Overall, participants with autism (*M*=11.24, *SD*=2.54) were slightly less confident when responding compared to the NT participants (*M*=11.34, *SD*=2.54) as expected despite being slightly more confident on their responses for *surprise* and *anger* (see Figure 9).

Figure 9: Confidence ratings across emotion recognition task in autistic and non-autistic participants



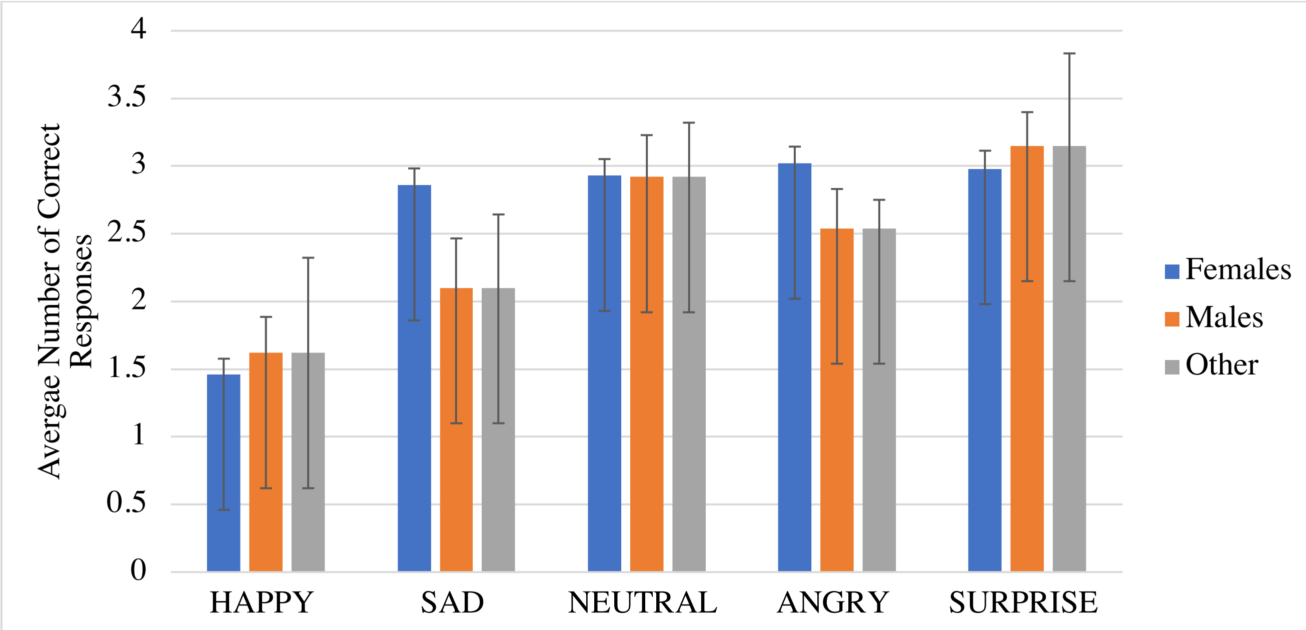
3.2.4.b Emotion Recognition and Musical Training

A 2 (musical training: yes, no) x 5 (emotion: happy, sad, neutral, angry, surprise) mixed ANOVA was conducted to determine if participants with and without *musical training* differed in their success in recognizing emotions. The results revealed that participants with *music training* (M=2.86, SD=0.90) significantly identified emotions more accurately ($F(1,73)=6.75$, $p=.011$, $\eta^2=.02$) compared to participants with no prior music training (M=2.51, SD=1.02). In addition, a significant effect of *emotion* was observed ($F(4,292)=23.80$, $p<.001$, $\eta^2=.19$). It was revealed that individuals with *musical training* were able to identify emotions *sad* (M=2.85, SD=0.85), *angry* (M=2.95, SD=0.92), *surprise* (M=3.19, SD=0.98) better than they were able to identify *happy* (M=1.95, SD=1.07). However, no significant interaction between *emotions* and *musical training* was observed ($F(4,292)=1.10$, $p=0.359$, $\eta^2=.009$).

3.2.4.c Emotion Recognition and Gender

Gender differences in emotion recognition were analyzed in a mixed ANOVA separately from the diagnosis analysis due to the small and uneven distribution of genders across the two groups in a 3 (gender: female, male, other) x 5 (emotion: happy, sad, neutral, angry, surprise) mixed ANOVA design. A main effect of *gender* was not observed ($F(2,72)=0.75$, $p=.475$, $\eta^2=.005$). A significant effect of *emotion* ($F(4,72)=14.55$, $p<.001$, $\eta^2=.12$) and a significant interaction effect of *gender* and *emotion* ($F(2,8)=3.12$, $p=.002$, $\eta^2=.05$) was observed. Post hoc tests showed that participants identified emotions from most accurate to least accurate as follows: surprise, anger, neutral, sadness, and happiness. In addition, *females* identified *happy* ($M=1.46$, $SD=0.87$) less accurate when compared to identifying *sad* ($M=2.93$, $SD=0.912$), *neutral* ($M=2.98$, $SD=1$) and *angry* ($M=3.02$, $SD=0.92$). *Females* also had a harder time identifying *happy* when compared to *males* identifying *neutral* ($M=2.92$, $SD=1.12$), *angry* ($M=2.54$, $SD=1.05$) and *surprise* ($M=3.15$, $SD=0.90$). *Females* also identified *happy* less accurately when compared to people who identified as *other* in recognizing emotions *neutral* ($M=3.17$, $SD=0.98$) and *angry* ($M=3.67$, $SD=0.52$). Lastly, *males* identified *happy* less accurately compared to *neutral* and *surprise* as well as compared to *females* recognizing *sad, neutral, angry*, *surprise* and compared to individuals identifying as other recognizing *angry* (see Figure 11).

Figure 10: Average recognition accuracy of emotions by gender



4. DISCUSSION

4.1 Summary and Revisiting the Hypotheses

In this thesis, findings from two different yet related studies examining prosody perception in youth and adults with or without autism have been presented. In both studies, each participant was asked to fill out questionnaires regarding their gender, official diagnoses, and hearing abilities in addition to their current autistic traits.

The first study, *Prosody Perception with Background Noise in Individuals with Autism,* investigated the effects of speech as a background noise at three different levels on perception of speech prosody. Research shows that among different noise types, such as construction noise, fans or household appliances, human speech is the most distracting noise type (Rosen et al., 2013). When there is speech noise in the background, people have a harder time focusing on the task at hand. However, despite this knowledge there were no studies which had investigated this phenomenon in prosody perception. To fill this gap, in this study the participants were tested across three different sound to noise ratios at -3dB, -6dB and 0 dB. These numbers were selected based on previous studies (Dunlop et al., 2016). The participants were asked to identify one of the six universal emotions: *happy, sad, angry, disgust, fear,* and *surprise* conveyed in an emotional sentence. Each emotion was presented twice within each noise condition. Participants identified the correct emotion in three emotional pairs: *happy-sad, angry-disgust, fear-surprise,* and matched it with the corresponding facial expressions. In a total of 36 trials, there were randomized even numbers of noise conditions presented. This study had two hypotheses:

1. **Autistic participants will have a harder time identifying emotions across all noise conditions when compared to non-autistic participants.**

A mixed factorial ANOVA has shown that autistic and non-autistic performed similarly in identifying emotions across all conditions. A significant difference was observed only in the identification of the emotion *fear* with autistic participants having a harder time in the -6 dB condition when compared with the non-autistic participants by a t-test. The null hypothesis was accepted.

2. **Autistic participants will have a harder time recognizing emotions as the noise level increases compared to non-autistic participants.**

Null hypothesis was accepted as a significant difference in performance across three noise levels between the groups was not observed through a mixed factorial ANOVA.

The second study *Prosody Perception and Task Dependent Performance in Individuals with Autism,* aimed to investigate the performance difference between the low-level and high-level tasks in prosody perception in speech. Literature suggests that individuals with autism tend to excel in low-level processing and have a harder time with tasks requiring high-level processing

(Mottron & Burack, 2001). Participants were asked to complete three tasks requiring low or high-level cognitive processing to examine this. To assess low-level processing, participants were asked to identify the direction of 20 sweep tones with a central tone of 200 Hz. The sweep tones ranged from 180-220 Hz. These numbers were obtained through pilot testing in the lab. In the second task, participants were asked to identify the ending direction of 20 randomized emotional sentences with four basic emotions: *happy, sad, angry,* and *surprise* in addition to *neutral*. Despite being emotional sentences, the task required participants to focus on local elements of the stimuli which was the pitch direction of the sentence, making it a low-level task. In the last task, participants were asked to identify the emotion conveyed in 20 randomized sentences requiring higher cognitive processing. Both task two and task three utilized the same set of 100 emotional sentences with a random selection of 20 sentences presented in each task. After each trial across tasks, participants were asked to rate their confidence in their responses. This study had three hypotheses:

1. **It is hypothesized that autistic participants will perform better in identifying the pitch direction in comparison to non-autistic participants. They will also be more confident in their responses.**

A mixed factorial ANOVA revealed that the performance difference between autistic and non-autistic participants was marginally significant. However, as expected autistic participants did indeed score more correct responses when compared to non-autistic participants. It was also found that autistic participants were slightly less confident in their responses yet a significant difference was not obtained. The null hypothesis was accepted.

2. **Autistic and non-autistic participants will differ in their responses to sentence directions and autistic participants will be more confident in their responses.**

A chi-test revealed that both autistic and non-autistic participants had similar patterns of responses in classifying the direction of emotional sentences. As such, the null hypothesis was accepted. In addition, a significant difference was not observed in confidence ratings for responses between the two groups. However, non-autistic participants were more confident in their responses compared to autistic participants.

3. **Autistic participants will perform worse in identifying the emotion in speech when compared to the non-autistic participants, and be less confident in their responses.**

A mixed measures ANOVA revealed that the two groups were not significantly different in emotion recognition. However, a significant main effect of *emotions* and an interaction of *emotions* and *diagnosis* was observed. Both groups of participants had the hardest time recognizing *happy* when compared with the rest of the emotions. In addition, it was revealed that two groups did not significantly differ in their confidence levels when identifying the emotions. Null hypothesis was accepted. Interestingly, autistic participants identified angry and happy more correctly when compared with the non-autistic group, despite a non-significant difference.

4.2 Interpretation of the Results

4.2.1 Pitch Discrimination Task

Literature suggests that autistic individuals excel in low-level tasks and use a local first approach to perceiving their environment (Mottron & Burack, 2001). This means autistic individuals tend to process single elements of sensory cues first and work their way up, rather than perceiving the target as a whole (Mottron & Burack, 2001). Enhanced perceptual theory suggests that despite many contradicting findings in the literature about sensory perception in individuals with autism, they all support the same notion that bottom-up processing is prioritized in individuals with autism (Mottron & Burack, 2001). However, despite an unnatural preference for processing local elements first, autistic individuals seem to possess the ability to recognize global elements if they consciously shift their focus (Guy et al., 2019). Based on this theory, it was hypothesized that autistic individuals would be able to identify the direction of sweep tones more accurately when compared to non-autistic participants in this study. However, a marginally significant difference was observed between the groups for this task. Even though autistic participants did indeed have a higher average of correct number of responses, it was not enough to elicit a significant difference. This can be due to several reasons. First, previously done studies argue that enhanced ability of pitch discrimination or sometimes known as the absolute pitch is a unique characteristic of autistic individuals and not for people diagnosed with Asperger's syndrome or previously known as high-functioning autism (Bonnel et al., 2010). These two previously distinct disorders were combined under the Autism Spectrum Disorders in the latest and fifth edition of the *Diagnostic and Statistical Manual of Psychiatric Disorders* in 2013 (Halfon & Kuo, 2013). Despite sharing common diagnostic criteria, previously known as Asperger's syndrome was diagnosed on the basis that individuals displayed less or milder symptoms of autism, average or advanced intelligence and no language delays (Hosseini & Molla, 2022). However, these language abilities do not directly translate into advanced social skills in this group of people. Individuals with Asperger's syndrome still struggle to fit in and often have a hard time with social communication (Hosseini & Molla, 2022). Out of the 19 autistic volunteers who participated in this study, only three indicated that they were diagnosed with Asperger's syndrome. However, given the age range of the participants, most of them were also diagnosed after 2013, making it impossible to differentiate between the two diagnoses. However, it is an unfortunate acceptance that most autism research takes place with the participation of high-functioning autistic individuals. High-functioning autism is a term commonly used for individuals on the autism spectrum who are able to read and write, complete daily tasks independently and have verbal communication abilities. Therefore, it is highly likely that the majority of the participants may fit into the criteria of Asperger's syndrome or the term for high-functioning autism providing consistency of findings from this study with the previous literature.

Second, the lack of a significant difference can be due to the range of pitches presented in sweep tones. In this study, participants were asked to identify the direction of sweep tones ranging between 180-220 Hz. These values were chosen based on pilot studies in the lab from a range of 100 Hz-1000 Hz. However, another contributing factor to the selection of these values was to make them consistent with the rest of the study in terms of speech stimuli. Most speech produced by males falls between 60-180 Hz and falls between 160-300 Hz for females (Re et al., 2012). To test the specific outcomes of task-related performance, the elimination of any possible contributing factors was attempted to keep the study consistent. Since the rest of the tasks in this study involved speech stimuli produced evenly by both males and females, a pitch range of 180-220 Hz was utilized for sweep tones for consistency. Studies which have observed significant differences between non-autistic and autistic individuals often utilized pitch ranges between 500-1500 Hz or used single tones instead of continuous sounds like sweep tones (Bonnel et al., 2003). This may account for the lack of differences observed in this study. In addition, since the pitch range used for this study fell within the range of speech stimuli, it may have given participants an advantage in familiarity making it easy to detect pitch discrimination for both groups.

Lastly, in a study done by Heaton et al (2008), words and non-sense words were used to assess pitch discrimination ability. In a separate study done by Stanutz et al. (2014), melodic memory and pitch discrimination in autistic individuals was assessed. Both of these studies concluded that individuals with autism outperformed non-autistic participants in melodic memory and pitch discrimination (Heaton, Hudry, et al., 2008; Stanutz et al., 2014). However, in both of these studies, the participants were children between the ages of 7-13 instead of adults like in this study. Similar to many developmental differences between non-autistic and autistic individuals, enhanced pitch ability may be more prominent in younger kids. As the individual gets older, it may fall back into the typical range as pitch discrimination abilities have been associated with language delays in children with autism (Eigsti & Fein, 2013).

4.2.2 Direction Identification in Emotional Utterances

One of the aims of this thesis was to investigate performance differences between non-autistic and autistic individuals based on the level of the task. This was achieved by presenting the participants with conceptually complex stimuli, such as emotional sentences, and demand low-level processing by asking the pitch direction of the sentence endings. It was hypothesized that individuals with autism and non-autistic individuals would show differences in their responses. Since it was a low-level task, autistic participants were also expected to feel more confident in their responses. However, this relationship was not significant in the present study and therefore was not consistent with previous research. The previous literature suggests that people have a harder time recognizing the pitch direction of speech sounds when compared to single tones (Heaton et al., 2008). However, a significant difference was observed in classifying *happy* emotional sentences. Most of the autistic participants identified *happy* sentences as ending going *up* whereas most non-autistic participants identified it as going *down*. This difference may be attributed to the physical properties of the *happy* stimuli. In 100 possible emotional sentences across five emotions, *happy* stimuli had one of the largest variances in their slopes despite having a negative average slope. The two groups of participants may have received a different range of stimuli as all trials were randomized. For the rest of the emotional sentences, a similar pattern was observed between the two groups. This may suggest that there is an interference of emotional information regardless of the question being asked for the completion of the task for both autistic and non-autistic individuals.

Moreover, it was expected that literature suggests an enhanced ability in pitch discrimination, autistic participants could have felt more confident in their responses for this task. However, in opposition to what was hypothesized, autistic participants also had less confidence in their responses. Once again, this may be due to the possible interference of the emotional information in the utterances with the purpose of the task which was to simply identify the ending direction. Research suggests that both non-autistic and autistic individuals have a harder time discriminating pitch differences in speech sounds compared to single tones (Heaton, Hudry, et al., 2008). This may account for the lack of differences between the two groups as this task may have been equally difficult for both groups of participants. Another reason for these findings may be due to the habituation differences in the two groups. It is agreed that autistic individuals have a harder time habituating to stimuli leading to overstimulation (Jamal et al., 2021). This means if the number of trials was more than 20, over time a difference may have been observed between non-autistic and autistic participants. Over time, it could have been expected that non-autistic participants would habituate to the emotional information and be able to focus solely on the direction of the task over time whereas this phenomenon wouldn't be expected in the autistic participants. However, since emotional information as a distractor has not been studied extensively previously, this theory may need more exploration.

4.2.3 Emotion Recognition

It was found that autistic participants performed similarly to non-autistic participants in the emotion recognition task leading to no significant performance differences between the two groups. However, participants with autism had a higher number of correct responses in identifying *happy* and *angry* compared to the non-autistic participants. This was a very interesting find as the literature suggests that individuals with autism have a harder time visually recognizing *angry, disgust* and *surprise* and require intensified facial cues to perceive it correctly (Choi et al., 2016; Keating et al., 2022; Nagy et al., 2021). However, in this case, individuals with autism not only recognized *angry* and *happy* more correctly, but they were also more confident in their responses to *angry* and *surprise* but not in recognizing *happy* compared to non-autistic participants. These findings may suggest that visual and auditory stimuli pathways can be processed differently despite being connected. Despite needing more intensified cues to correctly identify these emotions visually, autistic participants were able to outperform non-autistic participants in the auditory task of emotional recognition. On the other hand, there have been studies which link oxytocin deficiency in autistic individuals especially in childhood, to an increased negative perception of emotions and social contexts (Freeman et al., 2018; John & Jaeggi, 2021). Research shows that people tend to focus on the mouth region for joyful emotions and tend to focus on the eyes for sad emotions (Schurgin et al., 2014). A study investigating the effects of oxytocin on emotion perception found that a single dose of intranasal oxytocin spray shifted eye gaze for emotion perception from mouth to eyes in autistic individuals leading to a more accurate perception of emotions visually (Le et al., 2020). In addition, Domes and colleagues (2014) found that a single dose of intranasal oxytocin endorses an amygdala reaction and promotes facial emotion recognition in adults with Asperger's syndrome. Therefore, presumed oxytocin deficiency in autistic adults may be correlated with higher recognition of negative stimuli as observed in this study.

Previous studies argue that most autistic individuals, despite being known to have a harder time recognizing emotions compared to non-autistic individuals, will have intact abilities in identifying basic emotions as showcased in this study (Icht et al., 2021). However, as the emotions get more complex such as *envy*, *boredom*, or *jealousy,* differences in the autism group can be more easily observed (Kleinman et al., 2011; Golan et al., 2006). This may suggest that a possible difference, if any, between autistic individuals and non-autistic individuals in prosody perception may lie within the recognition of more complex emotions rather than basic emotions.

Lastly, it is good to note that despite what is known about multimodal perception, research on emotional perception typically focuses on visual stimuli and visual cues (Parada-Cabaleiro et al., 2020). Therefore, the success of autistic individuals leading to no significant differences between groups observed in this study may be attributed to the processing of the auditory pathway in the absence of visual cues. This may mean individuals with autism had to solely relay on auditory information to make their decisions, instead of visual cues leading to a successful identification of emotions as well as their non-autistic counterparts.

4.2.4 Noise and Emotional Prosody

Participants with and without autism performed similarly across all noise conditions in emotional prosody perception. It was expected that autistic participants would have a harder time as the noise levels increased. The only difference was observed in the recognition of *fear* which aligns with the previous literature. Previous studies suggest that individuals with autism have a harder time recognizing the emotion of *fear* (Tell et al., 2014). However, this difference was only observed at the -6 dB condition, which was the loudest noise condition. This may suggest that some diagnostic differences can be observed under higher levels of stress across the spectrum of autism.

Research shows that autistic individuals have a very hard time filtering out noise and functioning in noisy conditions (Kuiper et al., 2019). In fact, sensory sensitivities are included in the diagnostic criteria for autism (APA, 2013). However, other than the observed difference of recognition of fear in the -6 dB condition, both groups were able to recognize emotions in a very similar fashion. Several factors may have contributed to this outcome. Firstly, in this study, in addition to the noise in the background, participants were asked to match the emotional voice clips with a corresponding emotional facial expression. A combination of visual and auditory cues may have made it easier for both groups to comprehend the emotion of the task, especially since emotional databases use exaggerated representations. Typically, people depend on multiple sensory channels to make complete assessments of a situation or a subject, including emotional perception (Gerdes et al., 2014). Having both of these cues may have complimented the emotion being conveyed despite the noise conditions.

Secondly, the signal-to-noise ratios utilized in this task were 0 dB, -3 dB and -6 dB. This means the signal-to-noise ratio was equal in condition 0 dB, the noise was slightly higher in the -3 dB condition, and the noise was considerably higher than the signal in the -6 dB condition. Despite the considerable amount of noise, both groups performed very similarly. This may be due to the type of noise present in the trials which were incoherent overlapping speech sounds produced by several individuals. Even though research suggests that human speech is the most distracting noise type (Rosen et al., 2013), noise becomes a distractor only when it interferes with the information that is targeted (Kolbeinsson et al., 2022). However, the noise in this task was speech babble and not actual speech or emotional noise. Therefore, the noise may not have had a great impact on masking the target stimuli. It would be of interest to replicate this study with more complex speech noise to see if the same lack of difference between groups is still observed.

Lastly, since the participants consisted of high-functioning autistic adults, suggested by the completion of the tasks independently, they may have utilized coping mechanisms to help them navigate their everyday life. Most autism-related differences can be observed in early development (Tanner & Dounavi, 2021). However, through proper behavioural therapy or corrected external input, individuals with autism may learn skills to control most of their diagnosis-related symptoms even though this does not make their autism disappear. This learned improvement in behaviour may even be observed in brain recordings revealing the correction of previously atypical neural connections (Dawson et al., 2012). Research suggests that with noise, in general, non-autistic individuals have a harder time perceiving emotion, but this phenomenon seems to decrease with age (Parada-Cabaleiro et al., 2020). Whether or not this pattern can be observed in autistic individuals is yet to be investigated. However, based on previous literature it is appropriate to assume a similar age-related learning to noise in individuals with autism to explain the indifference between the groups in the emotion perception tasks.

4.3 Musical Training

Previous literature suggest that music training enhances cognitive and verbal abilities in children (Miendlarzewska & Trost, 2014). This is due to the fact that listening to music requires perceptual abilities including being able to discriminate the pitch and its effective structural components (Miendlarzewska & Trost, 2014). In addition, music, similar to other sounds, depends on working memory as it unfolds over time (Bella et al., 2013; Peretz et al., 2005). Based on this previous knowledge, research suggests that individuals who have music training can often perform better in pitch discrimination tasks (Bianchi et al., 2016; Flagge et al., 2021). Similarly in this study, it was observed that individuals with music training indeed had a higher number of correct responses in determining the direction of sweep tones, regardless of the ending direction (up or down). In addition, it was observed that individuals who indicated that they had official music training also identified emotions more accurately. This finding also aligns with previous studies as newly emerging research outlines an association between prosody perception in speech and musical training (Good et al., 2017). However, a significant difference between individuals with and without music training was not observed for the sentence direction tasks. Both groups had similar responses in identifying the pitch ending of emotional sentences. A study done by Du & Zatorre (2017) argue that music training implicated better speech encoding in both auditory and speech encoding regions, including improving perception in noise conditions. Based on these results, it would have been expected that participants with music training perform better on sentence direction task as well however, this was not the case. This may be due to the dispersion of choices in this task. The pitch discrimination tasks required participants to identify whether or not pitch was ending going *up* or *down*. However, on the sentence direction tasks, participants had to choose from one of three options. In addition to *up* and *down*, *flat* was also included as one of the options. Since this tasks utilized emotional speech as the stimuli rather than pure tones, inclusion of *flat* as one of the options was thought to be more inclusive. However, the addition of this third option, may have contributed to dispersion of responses which may have been different if it was just a choice between *up* or *down*. In fact, scientific literature suggests that most level tones tend to be perceived as going down (Schouten, 1985), forcing participants to disperse their responses. In addition, the majority of the autistic participants had music training when compared to non-autistic participants. The lack of diagnostic differences in the previously explored sections may be due to the musical training of the autism group.

4.4 Conclusions

In conclusion, this thesis uncovered important information about the way perception of prosody takes place amongst autistic and non-autistic individuals. It showcased the differences in how universally accepted six basic emotions are perceived. Most importantly, it gathered information that autism is a wide-ranging spectrum disorder with various weaknesses and strengths embedded within its extensive net by showcasing that some autistic individuals can perceive prosody as well as non-autistic individuals despite social difficulties. As shown in previous studies, the enhanced pitch perception may be unique to autistic individuals rather than those with high-functioning autism or Asperger's syndrome. In addition, musical training has a positive impact on the pitch and emotional perception. It was discovered that participants with musical training had greater success in discriminating the pitch of sweep tones and recognizing emotions, but not in discriminating the tone direction of emotional sentences. This finding provides support to the previous literature about musical training and enhanced ability in pitch discrimination. Based on the findings from these studies, it is evident that a combination of sensory pathways including auditory and visual may be used to make judgements in emotional perception and prior musical training has an influence on prosody perception. Autistic adults in these studies were able to comprehend the six basic emotions as well as non-autistic adults, and noise only becomes a distraction when it interferes with the target information regardless of its levels.

In summary, this thesis offers an in-depth understanding of prosody perception with environmental acoustic influences and raises some good questions about performance differences between autism subgroups.

4.5 Limitations

This study presents some limitations. Many studies investigating autism-related impairments face difficulties in participant recruitment. The ratio of autism within Canadian society is 1:50, which despite being more available compared to other developmental disorders, still poses a difficulty in recruitment. Even though the experiments in this study had a greater ratio of autistic participants compared to social reality, it still resulted in unbalanced and small sample sizes which may have led to some unobserved differences in the results. In addition, since autism is a spectrum disorder, a variety of symptomology in differing severities are observed within the diagnosis. Therefore, low-functioning autistic individuals with severe impairments would not be able to complete the tasks in these studies without proper support. Due to this most if not all of the autistic group is made up of high-functioning autistic individuals, who are defined as those who are independent and verbal limiting the possible differences that might have been present with a more diverse autistic group. Moreover, most of the autism group consisted of individuals with music training which may have given them an advantage in the successful completion of the experimental tasks. Lastly, due to the COVID-19 pandemic, many research activities have been forced to eliminate participant interactions. With the studies taking place online, there is always the risk of participants completing the tasks in a disruptive environment despite being instructed to complete them with headphones and limited distractions.

4.6 Future Directions

Findings from these studies suggest that there may be various differences between the autism subgroups that affect the way prosody is perceived. It would be the natural next step to repeat this study with a more defined and diverse autistic group in larger numbers. In addition, it was revealed in these studies that the six basic emotions: *happy, sad, angry, disgust, surprise,* and *fear* are perceived as easily by autistic individuals as it is perceived by non-autistic individuals. Substituting the basic emotions with complex emotions would help in identifying any possible differences between the groups in prosody perception. Lastly, these studies established that nonsense speech noise could be easily disregarded. Altering the noise type from nonsense speech to meaningful speech or even emotional speech to see masking or interference effects on information in perception could yield possible differences and further the understanding in the field.

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APPENDIX A

REB #7052

Prosody Perception in Speech with Background Noise in Individuals with Autism - Wilfrid Laurier University Informed Consent Statement

Prosody Perception in Speech with Background Noise in Individuals with Autism

Principal Supervisor: Dr. Jeffery Jones, Professor, Cognitive Neuroscience of Communications Lab, Department of Psychology, Wilfrid Laurier University

Co-investigators: Zehra Sasal (Master's student) and Victoria Caranfa (Undergraduate student), Department of Psychology, Wilfrid Laurier University

The purpose of this study is to investigate how individuals with Autism Spectrum Disorder (ASD) process prosody (i.e., changes in intonation, stress, rhythm, etc. of speech) and facial expressions of emotions compared to those who are not on the spectrum. The researchers are Laurier undergraduate and graduate students Victoria Caranfa and Zehra Sasal in the Psychology Department working under the supervision of Dr. Jeffery Jones.

INFORMATION

You are invited to participate in this study, which will take approximately 60 minutes to complete online. For this experiment you will be asked to listen to various vocal clips depicting a certain emotion and compare the sound clips with facial expressions depicting the same and different emotions. During this experiment you should wear headphones and have the volume at an adequate level to hear the sound clips. The results of this study will allow us to investigate how well individuals can distinguish and match different emotions.

You will be asked to complete a demographics questionnaire, along with the multidimensional social competence scale and the autism quotient to assess your standing on the autism spectrum.

Approximately 100 participants (16 to 80 years of age) are being recruited from a variety of sources for this study. We are recruiting participants both with and without ASD. Participants must not have a significant hearing impairment, a seizure disorder and/or require the use of a hearing device.

RISKS

There is a possibility you may experience auditory sensitivity/overstimulation during the experiment. You may also experience boredom due to the repetition involved in the experiment. These feelings are normal and should be temporary. The task will occur interactively, which will reduce the risk of boredom. If you become too sensitive to the auditory noise you may exit the study or lower your volume at any time. Please note that you may choose to end the study at any time. If you experience any negative feelings that persist or worsen as a result of participating in this study, please contact the researchers. Alternatively, Laurier students may contact the Student Wellness Centre (Waterloo Students: wellness@wlu.ca, 519-884-0710 x3146. Brantford Students: lbwellnesscentre@wlu.ca, 519-756-8228 x5803).

BENEFITS

As a participant in this study, you may benefit by learning how experimental research is conducted in cognitive psychology. The information obtained in this study will provide important information on how individuals with autism process emotional auditory and visual stimuli. Several childhood and adult communication disorders including ASD are thought to be linked to a failure in the mechanisms that relate prosodic intonations of speech and emotional recognition. Understanding the sensory representations supporting emotional recognition will aid the development of treatments for these forms of communication disorders.

CONFIDENTIALITY

The study takes place online via Testable. During transmission over the Internet, confidentiality of data cannot be guaranteed. The data will be transferred to a secure Cloud by Testable. Each participant in this experiment will be assigned a participant ID code that will be attached to their data. The only way this ID will be associated with the participant is on their consent form, which will be stored on a password-protected computer accessible to Dr. Jeffery Jones, Zehra Sasal, and Victoria Caranfa. The email contact information the participants may choose to provide for the draw prize, learn results or to hear about other studies will be collected with the data. However, this information will be removed from the data immediately and stored separately to keep all data anonymous. During this experiment participants' answers will be recorded. However, the answers will not be stored with personal information, nor will they be associated with the participant in any way other than their ID code and date of collection. Upon completion of data collection, any identifying information, including the ID code and Laurier email (required to assign PREP credits), will be destroyed by Jeffery Jones by June 1st, 2022. The consent forms will be maintained until July 1, 2029. The de-identified electronic data will be retained indefinitely by Dr. Jeffery Jones, and may be analyzed as part of a separate project (i.e., secondary analysis). Victoria Caranfa and Zehra Sasal will delete the data from their personal computers on June 1st, 2022. No names will be attached to any publications associated with this study.

COMPENSATION

Laurier students will receive 0.5 PREP credits for participation. If they choose to withdraw from the study, they will still receive the same amount of PREP credits. Other ways to earn PREP credits are participating in other studies and completing a critical review of a journal article. Visit the psychology website for more information:
https://students.wlu.ca/programs/science/psychology/research/psychology-research-experience-program.html

You will be entered in a $100 dollar prize (i.e., e-transfer) draw upon completion of the study if you choose to provide your email for this purpose. The odds of winning are estimated to be 1 in 100, and the winner will be notified by June 1, 2022. If you withdraw from the study, you may still choose to be entered into the draw.

Any compensation received related to the participation in this research study is taxable. It is the participant's responsibility to report the amount received for income tax purposes and Wilfrid Laurier University will not issue a tax receipt.

CONTACT

If you have questions at any time about the study, procedures, or the draw, or you experience adverse effects as a result of participating in this study you may contact the researchers, Dr. Jeffery Jones (phone: 519-884-0710, ext. 2992 or email: jjones@wlu.ca), Zehra Sasal (email: sasa5250@mylaurier.ca), or Victoria Caranfa (email: cara8300@mylaurier.ca).

This project has been reviewed and approved by the University Research Ethics Board at Wilfrid Laurier University (REB #7052), which is supported by the Research Support Fund. If you feel that you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Jayne Kalmar, Chair, Wilfrid Laurier University Research Ethics Board, (519) 884-0710, ext. 3131 or email REBChair@wlu.ca.

PARTICIPATION

Your participation in this study is voluntary; you may decline participation without penalty. If you withdraw from the study, your data will not be transcribed or coded, nor used in the analyses of the study and your data will be destroyed. Please note that after data collection is complete and identifiers are removed, we will not be able to remove your data. You have the right to omit any question(s)/procedure(s) you choose or withdraw from the study completely at any time without penalty or loss of benefits to which you are otherwise entitled.

FEEDBACK AND PUBLICATION

The results of this research might be published/presented in a thesis, course project report, book, journal article, conference presentation, class presentation. Your data will be reported only as part of a group mean in this and any other publications that may arise from this research (i.e., you will not be publicly identified). The findings may also be made available through Open Access resources. If you would like to receive a final summary of results from this study please include your email address below. Feedback will be emailed to you following the completion of data collection by June 1, 2022.

We recommend that your print or save this form for your records.

CONSENT

I have read and understand the information in this form and agree to participate in this study.

I consent [Click here to begin the study]
I do not consent [Click here to exit]

REB #7052

Prosody Perception in Speech with Background Noise in Individuals with Autism - Wilfrid Laurier University Debriefing Statement

Principal Investigator: Dr. Jeffery Jones, Cognitive Neuroscience of Communications Lab, Department of Psychology, Wilfrid Laurier University

Student Researchers: Zehra Sasal, Victoria Caranfa, Department of Psychology, Wilfrid Laurier University

You have successfully participated in a study that continues research in an area of prosody and emotion processing. Here is a summary of the study and the research topic:

Autism spectrum disorder (ASD) is one of the most common neurodevelopmental disorders and is diagnosed in 1 of every 68 children. It is characterized by social and communication deficits that can impede optimal functioning in day-to-day life. Due to the impairments that come with the disorder, an increasing number of individuals tend to face difficulties in many areas of life including social communication. It is shown in previous studies that individuals with ASD have a hard time recognizing emotional auditory and visual cues which makes it difficult for them to communicate effectively with others. Individuals with ASD also have difficulty perceiving and expressing emotions.

Prosodic changes in speech (i.e. changes in intonation, stress, rhythm, etc.) provide important information on the word beyond its literal meaning in a sentence, which people with autism often cannot connect to vocal or facial emotionality. Prosody has different components which are all important in correctly perceiving or conveying information in spoken communication. A non-autisticly developing child will master the art of perceiving emotions just by prosody in speech by the time they are 7-9 years old, while individuals with autism show differences very early on in how they perceive emotions. High risk autism infants were found to have difficulty recognizing prosodic differences in their mothers' speech when compared with low-risk infants. In this project we aimed to understand if the participants could distinguish different basic emotions in relation to a voice clip depicting that emotion. We also added a background noise consisting of a multi-speaker babble to the voice clips to see if it had any effect on the perception of the depicted emotion.

The purpose of the additional questionnaires was to determine where you fall on the autism spectrum. We also aim to use the results of this study to investigate the prosody and emotion processing system in individuals with ASD. In order to utilize your data to compare to individuals with ASD, we required scores on the ASD quotient to demonstrate that our non-autisticly developed population scores differently than our ASD population.

Understanding the mechanisms supporting prosody and emotion processing will aid the development of treatments for many forms of communication disorders. This knowledge will also be valuable to clinicians who regularly must differentiate normal vocal changes that occur during development from true pathologic vocal conditions that affect children.

Potential risks you may have encountered while participating in this study are auditory fatigue and boredom. All these feelings are normal and should be temporary. If any of these feelings persist, please contact the researchers (contact information provided below).

You will be notified if you won the prize draw and be emailed a summary of the results found in this study if you indicated YES in the consent form by June 1, 2022. Your email will not be kept by the researchers past June 1, 2022 and will be securely deleted. If you have any questions, you may contact the researchers involved in this study (Dr. Jeffery Jones at (519) 884-0710, extension 2992, or jjones@wlu.ca, Zehra Sasal at sasa5250@mylaurier.ca and Victoria Caranfa at cara8300@mylaurier.ca).

This study has been reviewed and approved by the Wilfrid Laurier Research Ethics Board (REB #10012193). If you have any questions or concerns over ethical issues in this experiment, you may contact Dr. Jayne Kalmar, Chair, Wilfrid Laurier University Research Ethics Board, (519) 884-0710, ext. 3131 or email REBChair@wlu.ca.

REB #7114

Perception of Emotional Prosody and Task Dependent Performance in Individuals with Autism – Informed Consent Statement Wilfrid Laurier University

Principal Supervisor: Dr. Jeffery Jones, Professor, Cognitive Neuroscience of Communications Lab, Department of Psychology, Wilfrid Laurier University

Co-investigators: Zehra Sasal (Master's student)

The purpose of this study is to investigate how individuals with autism spectrum disorder (ASD) process pitch differences (i.e., changes in pitch, stress, rhythm, etc. of speech) in non-speech and speech sounds compared to those who are not on the spectrum. The researcher is Laurier graduate student Zehra Sasal in the Psychology Department working under the supervision of Dr. Jeffery Jones.

INFORMATION

You are invited to participate in this study, which will take approximately 60 minutes to complete online. For this experiment you will be asked to listen to various tone sweeps and identify the direction of which the tone ends in addition to identifying the direction and emotion of various speech aduio clips. During this experiment you should wear headphones and have the volume at an adequate level to hear the sounds. The results of this study will allow us to investigate the role pitch plays in conveying prosodic information and task dependent performance in individuals with autism.

In addition, you will also be asked to complete a demographics questionnaire and the autism quotient questionnaire.

Approximately 100 participants (16 to 80 years of age) are being recruited from various sources for this study. We are recruiting participants both with and without ASD. Participants must not have a significant hearing impairment, a seizure disorder and/or require the use of a hearing device.

RISKS

There is a possibility you may experience auditory sensitivity/overstimulation during the experiment. You may also experience boredom due to the repetition involved in the experiment. These feelings are normal and should be temporary. The task will occur interactively, which will reduce the risk of boredom. If you become too sensitive to the auditory noise you may exit the study or lower your volume at any time. Please note that you may choose to end the study at any time. If you experience any negative feelings that persist or worsen as a result of participating in this study, please contact the researchers. Alternatively, Laurier students may contact the Student Wellness Centre (Waterloo Students: wellness@wlu.ca, 519-884-0710 x3146. Brantford Students: lbwellnesscentre@wlu.ca, 519-756-8228 x5803).

BENEFITS

As a participant in this study, you may benefit by learning how experimental research is conducted in cognitive psychology. The information obtained in this study will provide important information on how individuals with autism can detect differences in pitch within a given sound to better understand mechanisms of prosody in addition to task dependent performance differences. Several childhood and adult communication disorders including ASD are thought to be linked to a failure in the mechanisms that relate prosodic intonations of speech and emotional recognition. Understanding the sensory representations supporting emotional recognition will aid the development of treatments for these forms of communication disorders.

CONFIDENTIALITY

The study takes place online via Testable. During transmission over the Internet, confidentiality of data cannot be guaranteed. The data will be transferred to a secure Cloud by Testable. Each participant in this experiment will be assigned a participant ID code that will be attached to their data. The only way this ID will be associated with the participant is on their consent form, which will be stored on a password-protected computer accessible to Dr. Jeffery Jones and Zehra Sasal. During this experiment participants' answers will be recorded. However, the answers will not be stored with personal information, nor will they be associated with the participant in any way other than their ID code and date of collection. The email contact information the participants may choose to provide for the draw prize will be collected with the data. However, this information will be removed from the data immediately and stored separately to keep all data anonymous. Upon completion of data collection, any identifying information, including the ID code will be destroyed by Jeffery Jones by December 31, 2022. The consent forms will be maintained until July 1, 2029. The de-identified electronic data will be retained indefinitely by Dr. Jeffery Jones, and may be analysed as part of a separate project (i.e., secondary analysis). Zehra Sasal will delete the data from their personal computer on December 31, 2022. No names will be attached to any publications associated with this study.

COMPENSATION

Wilfrid Laurier University students will receive 0.5 PREP credits for their participation. Other ways to earn PREP credits are participating in other studies and completing a critical review of a journal article. Visit the psychology website for more information: https://students.wlu.ca/programs/science/psychology/research/psychology-research-experience-program.html

You will also be entered in a $100 dollar prize (i.e., e-transfer) draw upon completion of the study if you choose to provide your email for this purpose. The odds of winning are estimated to be approximately 1 in 100, and the winner will be notified by December 31, 2022.

Any compensation received related to the participation in this research study is taxable. It is the participant's responsibility to report the amount received for income tax purposes and Wilfrid Laurier University will not issue a tax receipt.

CONTACT

If you have questions at any time about the study, procedures, or you experience adverse effects as a result of participating in this study you may contact the researchers, Dr. Jeffery Jones (phone: 519-884-0710, ext. 2992 or email: jjones@wlu.ca) or Zehra Sasal (email: sasa5250@mylaurier.ca).

This project has been reviewed and approved by the University Research Ethics Board at Wilfrid Laurier University (REB #7114), which is supported by the Research Support Fund. If you feel that you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Jayne Kalmar, Chair, Wilfrid Laurier University Research Ethics Board, (519) 884-0710, ext. 3131 or email REBChair@wlu.ca.

PARTICIPATION

Your participation in this study is voluntary; you may decline participation without penalty. If you withdraw from the study, your data will not be transcribed or coded, nor used in the analyses of the study and your data will be destroyed. Please note that after data collection is complete and identifiers are removed, we will not be able to remove your data. You have the right to omit any question(s)/procedure(s) you choose or withdraw from the study completely at any time without penalty or loss of benefits to which you are otherwise entitled.

FEEDBACK AND PUBLICATION

The results of this research might be published/presented in a thesis (i.e., Masters thesis for Zehra Sasal), course project report, book, journal article, conference presentation, class presentation. Your data will be reported only as part of a group mean in this and any other publications that may arise from this research (i.e., you will not be publicly identified).

We recommend that you print or save this form for your records.

CONSENT

I have read and understand the information in this form and agree to participate in this study.

I consent [Click here to begin the study]

I do not consent [Click here to exit]

REB #7114

Perception of Emotional Prosody and Task Dependent Performance in Individuals with Autism – Debrfiefing Statement Wilfrid Laurier University

Principal Supervisor: Dr. Jeffery Jones, Professor, Cognitive Neuroscience of Communications Lab, Department of Psychology, Wilfrid Laurier University

Co-investigators: Zehra Sasal (Master's student)

The purpose of this study is to investigate how individuals with autism spectrum disorder (ASD) process pitch differences (i.e., changes in pitch, stress, rhythm, etc. of speech) in non-speech and speech sounds compared to those who are not on the spectrum. The researcher is Laurier graduate student Zehra Sasal in the Psychology Department working under the supervision of Dr. Jeffery Jones.

Debriefing Statement

You have successfully participated in a study that continues research in an area of prosody and emotion processing. Here is a summary of the study and the research topic:

Autism spectrum disorder (ASD) is one of the most common neurodevelopmental disorders and is diagnosed in 1 of every 68 children. It is characterised by social and communication deficits that can impede optimal functioning in day-to-day life. Due to the impairments that come with the disorder, an increasing number of individuals tend to face difficulties in many areas of life including social communication. It is shown in previous studies that individuals with ASD have a hard time recognizing emotional auditory and visual cues which makes it difficult for them to communicate effectively with others. Individuals with ASD also have difficulty perceiving and expressing emotions.

Prosodic changes in speech (i.e. changes in pitch, stress, rhythm, etc.) provide important information on the word beyond its literal meaning in a sentence, which people with autism often cannot connect to vocal or facial emotionality. Prosody has different components which are all important in correctly perceiving or conveying information, including the different levels of pitch which is important in identifying different emotions in spoken communication. A typically developing child will master the art of perceiving emotions just by prosody in speech by the time they are 7-9 years old, while individuals with autism show differences very early on in how they perceive emotions. High risk autism infants were found to have difficulty recognizing prosodic differences in their mothers' speech when compared with low-risk infants. In this project we aimed to understand if the participants could distinguish a specific aspect of prosody, pitch, in various tone sweeps.

The purpose of the additional questionnaires was to find out how things like age, musical training and other factors such as autism predict performance on perceiving emotion in speech.

We aim to use the results of this study to find out the significance of pitch in conveying prosodic information and if performance is task dependent for autistic individuals.

Understanding the mechanisms supporting prosody and emotion processing will aid the development of treatments for many forms of communication disorders. This knowledge will also be valuable to clinicians who regularly must differentiate normal vocal changes that occur during development from true pathologic vocal conditions that affect children.

Potential risks you may have encountered while participating in this study are auditory fatigue and boredom. These feelings are normal and should be temporary. If any of these feelings persist, please contact the researchers (contact information provided below). Laurier students may contact the Student Wellness Centre (Waterloo Students: wellness@wlu.ca, 519-884-0710 x3146. Brantford Students: lbwellnesscentre@wlu.ca, 519-756-8228 x5803).

If you have questions at any time about the study, procedures, or the results, or you experience adverse effects as a result of participating in this study you may contact the researchers, Dr. Jeffery Jones (phone: 519-884-0710, ext. 2992 or email: jjones@wlu.ca), or Zehra Sasal (email: sasa5250@mylaurier.ca).

This project has been reviewed and approved by the University Research Ethics Board at Wilfrid Laurier University (REB #7114), which is supported by the Research Support Fund. If you feel that you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. Jayne Kalmar, Chair, Wilfrid Laurier University Research Ethics Board, (519) 884-0710, ext. 3131 or email REBChair@wlu.ca.

A summary of the results will be available by December 31, 2022 and if you are interested in knowing more, you can contact the researchers from the provided information above.

We recommend that you print or save this form for your records.

Demographics Questionnaire-REB #7052

1. Date of birth: (MM/YYYY)

____

2. Gender:

____

3. Primary language spoken at home:

____

4. What is your family's cultural or ethnic background? (e.g., Italian, Métis, Korean)

____

5. What is your official diagnosis?

   o Autism Spectrum Disorder
   o Asperger's Syndrome
   o Other
   o NA

6. If you selected "other" for the question above, please specify:

____

7. Where and by whom were you diagnosed? (If not applicable, please leave blank)

____

8. When were you diagnosed? (If not applicable, please leave blank)

____

9. Have you ever been provided with a diagnosis of "global developmental delay" or "intellectual disability"?

   o Yes
   o No

10. Have you been given any additional diagnoses?

o Yes

o No

11. If you answered yes, please list all additional diagnoses. (If not applicable, please leave blank)

____

12. Do you have any other medical conditions? (e.g. seizures, Tourette's syndrome etc.)

o Yes

o No

13. If you answered yes, please list any other medical conditions. (e.g. Epilepsy, Tourette's syndrome etc.)

____

14. Do you take any prescription medications regularly?

o Yes

o No

15. If you answered yes, please list the prescription medications you regularly take.

____

16. Have you ever received any ABA/IBI or took part in autism intervention programs?

o Yes

o No

17. If yes to previous question, at what age did you start ABA/IBI? (If not applicable, please leave blank)

____

18. If you ever received any ABA/IBI how many years did you receive it for? (If not applicable, please leave blank)

____

19. Do you suffer from hearing loss and/or use a hearing device?

- o Yes
- o No

Demographics Questionnaire - REB #7114

Do you wish to be included in a $100 prize draw?

o Yes
o No

If you have answered yes to the above question, please provide your email:

____

Date of birth: (MM/YYYY)

____

Gender:

Gender Fluid
Man
Nonbinary
Trans man
Trans woman
Two-Spirit
Woman

Primary language spoken at home:

____

What is your family's cultural or ethnic background? (e.g., Italian, Métis, Korean)

____

Do you have an official diagnosis?

- o Autism Spectrum Disorder
- o Asperger's Syndrome
- o Other

If you selected "other" for the question above, please specify:

____

Where and by whom were you diagnosed? (If not applicable, please leave blank)

____

When were you diagnosed? (If not applicable, please leave blank)

____

Have you ever been provided with a diagnosis of “global developmental delay” or “intellectual disability”?

o Yes
o No

Have you been given any additional diagnoses?
o Yes
o No

If you answered yes, please list all additional diagnoses. (If not applicable, please leave blank)

____

Do you have any other medical conditions? (e.g. seizures, Tourette’s syndrome etc.)
o Yes
o No

If you answered yes, please list any other medical conditions. (e.g. Epilepsy, Tourette’s syndrome etc.)

____

Do you take any prescription medications regularly?
o Yes

o No

If you answered yes, please list the prescription medications you regularly take.

____

Have you ever received any ABA/IBI or took part in autism intervention programs?

o Yes

o No

If yes to previous question, at what age did you start ABA/IBI? (If not applicable, please leave blank)

____

If you ever received any ABA/IBI how many years did you receive it for? (If not applicable, please leave blank)

____

Do you play any instruments?

o Yes

o No

Do you have any official music training?

o Yes

o No

Do you suffer from hearing loss and/or use a hearing device?

o Yes

o No

Autism Quotient

		Definitely agree	Slightly agree	Slightly disagree	Definitely disagree
1.	I prefer to do things with others rather than on my own.			1	1
2.	I prefer to do things the same way over and over again.	1	1		
3.	If I try to imagine something, I find it very easy to create a picture in my mind.			1	1
4.	I frequently get so strongly absorbed in one thing that I lose sight of other things.	1	1		
5.	I often notice small sounds when others do not.	1	1		
6.	I usually notice car number plates or similar strings of information.	1	1		
7.	Other people frequently tell me that what I've said is impolite, even though I think it is polite.	1	1		
8.	When I'm reading a story, I can easily imagine what the characters might look like.			1	1
9.	I am fascinated by dates.	1	1		
10.	In a social group, I can easily keep track of several different people's conversations.			1	1
11.	I find social situations easy.			1	1
12.	I tend to notice details that others do not.	1	1		
13.	I would rather go to a library than a party.	1	1		
14.	I find making up stories easy.			1	1
15.	I find myself drawn more strongly to people than to things.			1	1

16.	I tend to have very strong interests which I get upset about if I can't pursue.	1	1		
17.	I enjoy social chit-chat.			1	1
18.	When I talk, it isn't always easy for others to get a word in edgeways.	1	1		
19.	I am fascinated by numbers.	1	1		
20.	When I'm reading a story, I find it difficult to work out the characters' intentions.	1	1		
21.	I don't particularly enjoy reading fiction.	1	1		
22.	I find it hard to make new friends.	1	1		
23.	I notice patterns in things all the time.	1	1		
24.	I would rather go to the theatre than a museum.			1	1
25.	It does not upset me if my daily routine is disturbed.			1	1
26.	I frequently find that I don't know how to keep a conversation going.	1	1		
27.	I find it easy to "read between the lines" when someone is talking to me.			1	1
28.	I usually concentrate more on the whole picture, rather than the small details.			1	1
29.	I am not very good at remembering phone numbers.			1	1
30.	I don't usually notice small changes in a situation, or a person's appearance.			1	1
31.	I know how to tell if someone listening to me is getting bored.			1	1
32.	I find it easy to do more than one thing at once.			1	1
33.	When I talk on the phone, I'm not sure when it's my turn to speak.	1	1		
34.	I enjoy doing things spontaneously.			1	1

35.	I am often the last to understand the point of a joke.	1	1		
36.	I find it easy to work out what someone is thinking or feeling just by looking at their face.			1	1
37.	If there is an interruption, I can switch back to what I was doing very quickly.			1	1
38.	I am good at social chit-chat.			1	1
39.	People often tell me that I keep going on and on about the same thing.	1	1		
40.	When I was young, I used to enjoy playing games involving pretending with other children.			1	1
41.	I like to collect information about categories of things (e.g. types of car, types of bird, types of train, types of plant, etc.).	1	1		
42.	I find it difficult to imagine what it would be like to be someone else.	1	1		
43.	I like to plan any activities I participate in carefully.	1	1		
44.	I enjoy social occasions.			1	1
45.	I find it difficult to work out people's intentions.	1	1		
46.	New situations make me anxious.	1	1		
47.	I enjoy meeting new people.			1	1
48.	I am a good diplomat.			1	1
49.	I am not very good at remembering people's date of birth.			1	1
50.	I find it very easy to play games with children that involve pretending.			1	1

MSCS

Scoring: Add all the sores, the marked statements are reverse coded.

Instructions: For each item, circle the number that best describes your behavior in the past six months.

1 = Not True or Almost Never True 2 = Rarely True 3 = Sometimes True
4 = Often True 5 = Very True or Almost Always True

Many of the items may seem similar to one another, but your response on each one is very important. If you are unsure of an item, please put your best estimate.

1 = NOT TRUE OR ALMOST NEVER TRUE 2 = RARELY TRUE 3 = SOMETIMES TRUE
4 = OFTEN TRUE 5 = VERY TRUE OR ALMOST ALWAYS TRUE

*1. I prefer to spend time alone (e.g., I am most content when left on my own).	1 2 3 4 5
2. I enjoy meeting new people.	1 2 3 4 5
3. I easily recognize unfriendly actions. For example, I know when someone is making fun of me in a mean-spirited way. Or, I recognize when a peer is pressuring me to do something I shouldn't or don't want to do.	1 2 3 4 5
4. I disagree with people without fighting or arguing.	1 2 3 4 5
5. I apologize after hurting someone (without being prompted or told to).	1 2 3 4 5
*6. I talk "over" people in conversations (e.g., interrupt a lot, don't wait for others to finish speaking).	1 2 3 4 5
*7. I shift conversations to my favourite topic or interest.	1 2 3 4 5
*8. I talk about the same things over and over ("get stuck" on certain topics).	1 2 3 4 5
9. I am sensitive to the feelings and concerns of others.	1 2 3 4 5
10. I initiate friendly social "chit-chat" with people (e.g., ask about what's new with other person, talk about the weather or events). These are casual conversations that often have no specific purpose.	1 2 3 4 5
11. I do not offer to help people (unless asked or told to).	1 2 3 4 5
*12. I have trouble joining conversations appropriately (e.g., I may interrupt or "butt in" without waiting for a good time to join in; or, I may start talking about a topic of interest to me regardless of the ongoing conversation).	1 2 3 4 5
*13. I misread social cues.	1 2 3 4 5

*14. I stay in the "background" in group social situations (e.g., keep to myself, may not be noticed).	1 2 3 4 5
15. I am patient (e.g., when waiting).	1 2 3 4 5
16. I express concern for others when they are upset or distressed (e.g., may ask "are you alright?" or ask if they need anything).	1 2 3 4 5
17. I look people in the eye when talking to them.	1 2 3 4 5
*18. I get frustrated easily.	1 2 3 4 5
19. I ask people questions about themselves or their lives (e.g., how they are, what they've been up to).	1 2 3 4 5
*20. I give compliments to people.	1 2 3 4 5
*21. My emotional responses tend to be extreme (e.g., I might be extremely angry or frustrated in response to relatively small problems).	1 2 3 4 5
*22. I avoid talking to people when possible (e.g., look, move, or walk away).	1 2 3 4 5
23. My facial expressions are easy to read.	1 2 3 4 5
24. I can tell when people are joking.	1 2 3 4 5
25. I stay calm when problems come up.	1 2 3 4 5
26. I know about the latest trends for my age (e.g., in clothes, music, tv shows/movies, music).	1 2 3 4 5
*27. I am indifferent or "oblivious" to people who are upset (or in distress).	1 2 3 4 5
28. I pick up on subtle hints and indirect requests. For example, I would understand that when someone asks "Can you reach that book?", they are asking me to pass it to them. In other words, I can "read between the lines" when others are talking.	1 2 3 4 5
*29. My smiles seem forced or awkward.	1 2 3 4 5
30. I appear visibly upset when I see people suffering (in real life or on tv/film).	1 2 3 4 5
31. I act appropriately for my age in public (e.g., restaurants, movie theatres, libraries, doctor's waiting rooms, etc).	1 2 3 4 5
32. I use eye contact to get other people's attention (e.g., to start a conversation, ask a question).	1 2 3 4 5
33. I change the volume of my voice depending on where I am (e.g., quiet at the library, movies but louder when outside or at a sporting event).	1 2 3 4 5
34. I show a range of facial expressions (e.g., embarrassed, guilty, surprised, disgusted, pleased).	1 2 3 4 5
*35. I smile appropriately in social situations (e.g., if given a compliment, greeting someone, in response to someone smiling at me).	1 2 3 4 5
*36. I act out when angry or upset (e.g., yell at, hit, or shove people).	1 2 3 4 5

*37. I talk "at" people (e.g., almost like I am giving a lecture).	1 2 3 4 5
*38. I go off track during conversations (e.g., I might change topics suddenly as if thinking aloud or reminded of something else; or, I might gradually get sidetracked or lose track of your original point).	1 2 3 4 5
39. I am concerned about people and their problems (e.g., talk to someone who is having a hard time).	1 2 3 4 5
*40. I am naïve (believe whatever I am told).	1 2 3 4 5
41. I get over setbacks or disappointments quickly.	1 2 3 4 5
*42. I need to be told or prompted to talk or interact with people.	1 2 3 4 5
43. I follow social "rules" around privacy (e.g., respect people's privacy when they are changing/ in the washroom; knock on closed doors instead of barging in).	1 2 3 4 5
*44. I get very anxious.	1 2 3 4 5
45. I can see things from another person's perspective.	1 2 3 4 5
*46. I have "melNTowns" (e.g., sudden outbursts, "blow ups" temper tantrums).	1 2 3 4 5
47. My expectations of friends reasonable. For example, I know that they have other friends or are not always available.	1 2 3 4 5
48. I offer comfort to people (e.g., to someone who is upset, not feeling well, hurt etc.). For instance, I may try to hug the person or provide a comforting object as a way of trying to make the other person feel better.	1 2 3 4 5
49. I use appropriate gestures when communicating with people (e.g., nodding/shaking head, waving goodbye, pointing at something interesting or far away, giving thumbs up, putting finger to lips for "be quiet", etc.).	1 2 3 4 5
50. I am good at taking turns in conversations (e.g., my conversations have age -appropriate levels of back-and-forth with each person getting a chance to talk; I respond appropriately to the other person's questions or statements).	1 2 3 4 5
*51. My facial expressions seem "flat" (e.g., my face may be like a "blank slate" or seem overly serious).	1 2 3 4 5
*52. I have trouble judging who is trustworthy (e.g., who to share secrets or personal information with).	1 2 3 4 5
53. I understand what makes a true friend.	1 2 3 4 5
54. I recognize when people are trying to take advantage of me.	1 2 3 4 5
55. I try to cheer people up (when they are down).	1 2 3 4 5
56. I give other people a chance to speak during conversations (e.g., pauses, asks them questions).	1 2 3 4 5
57. I seek out people to spend time with (e.g., friends, other people).	1 2 3 4 5

58. I understand the "social hierarchy" at school or work or in other settings (e.g., understand that teachers or supervisors are in a position of authority).	1 2 3 4 5
*59. I have trouble predicting what other people will do or how they will react.	1 2 3 4 5
60. I get very upset if things are not done your way.	1 2 3 4 5
*61. I dominate conversations so that it can be hard for others to "get a word in". For example, I might ramble on and on about a favourite topic of interest. I might also need reminders/prompting to let others speak.	1 2 3 4 5
*62. I sound the same (have the same tone and intonation in his/her voice) regardless of how I am feeling. In other words, it is hard to tell what I am feeling based on the way my voice sounds.	1 2 3 4 5
*63. I provide too much detail when talking about a topic (e.g., I might list a bunch of facts rather than expressing a main message or exchanging information).	1 2 3 4 5
64. I congratulate people when good things happen to them.	1 2 3 4 5
65. I initiate get-togethers with peers (e.g., call or email or text them to make plans).	1 2 3 4 5
66. I point at things when appropriate (e.g., to get another person to look at something far away).	1 2 3 4 5
*67. I do not pick up on the subtleties of social interaction.	1 2 3 4 5
*68. My emotions tend to be "all or nothing" ("all on" or "all off").	1 2 3 4 5
*69. I show little interest in people.	1 2 3 4 5
*70. I speak with a flat, monotonous tone of voice.	1 2 3 4 5
71. I understand that it is important to have good personal hygiene (e.g., smelling and looking clean).	1 2 3 4 5
72. I change my behaviour to suit the situation. For example, I might be more polite/ formal around authority figures like teachers or supervisors but be more casual around peers. As another example, I might change my way of speaking depending on who you are talking to (e.g., talk more simply to a younger child).	1 2 3 4 5
73. I dress appropriately for my age and social situation (e.g., dress up for formal events, wear more casual clothes on weekends, wear clothes that are generally considered acceptable by peers my age).	1 2 3 4 5
*74. I talk too much.	1 2 3 4 5
75. I hide my true feelings (when necessary) so that I don't come across as rude (e.g., I might hide feelings of disappointment when given a gift that I do not like or when someone breaks something of mine by accident).	1 2 3 4 5
76. I introduce myself to people (without being told to).	1 2 3 4 5
77. I understand when people are being sarcastic.	1 2 3 4 5

APPENDIX B

List of Stimuli: REB #7050

Each RAVDESS file was presented with a pair of KDEF stimuli.

RRAVDES FILE NAME	**KDEF FILES NAME**	
-3_03-01-03-01-02-01-10	AF01DIS	AF01ANS
-3_03-01-03-01-02-01-17	AF02HAS	AF02SAS
-3_03-01-04-02-02-01-05	AF03ANS	AF03DIS
-3_03-01-04-02-02-01-10	AF05DIS	AF05ANS
-3_03-01-05-01-02-01-02	AF10AFS	AF10SUS
-3_03-01-05-01-02-01-09	AF11ANS	AF11DIS
-3_03-01-06-01-02-01-02	AF17SUS	AF17AFS
-3_03-01-06-01-02-01-15	AF19SUS	AF19AFS
-3_03-01-07-01-02-01-05	AF26SUS	AF26AFS
-3_03-01-07-01-02-01-08	AF27DIS	AF27ANS
-3_03-01-08-02-02-01-20	AF28HAS	AF28SAS
-3_03-01-08-02-02-01-21	AF30ANS	AF30DIS
-6_03-01-03-01-02-01-04	AF34HAS	AF34SAS
-6_03-01-03-01-02-01-07	AM02AFS	AM02SUS
-6_03-01-04-02-02-01-11	AM03SUS	AM03AFS
-6_03-01-04-02-02-01-22	AM09DIS	AM09ANS
-6_03-01-05-01-02-01-01	AM11DIS	AM11ANS
-6_03-01-05-01-02-01-08	AM12AFS	AM12SUS
-6_03-01-06-02-02-02-12	AM15SAS	AM15HAS
-6_03-01-06-02-02-02-17	AM16HAS	AM16SAS
-6_03-01-07-02-02-01-17	AM18ANS	AM18DIS
-6_03-01-07-02-02-01-18	AM20AFS	AM20SUS
-6_03-01-08-01-02-01-02	AM21DIS	AM21ANS
-6_03-01-08-01-02-01-11	AM22SAS	AM22HAS
+0_03-01-03-02-02-01-02	AM23SAS	AM23HAS
+0_03-01-03-02-02-01-03	AM29HAS	AM29SAS
+0_03-01-04-01-02-01-06	AM30DIS	AM30ANS
+0_03-01-04-01-02-01-13	AM32HAS	AM32SAS
+0_03-01-05-01-02-01-03	AM33ANS	AM33DIS
+0_03-01-05-01-02-01-22	AM34AFS	AM34SUS

+0_03-01-06-01-02-01-02	BF09SUS	BF09AFS
+0_03-01-06-01-02-01-15	BF10SAS	BF10HAS
+0_03-01-07-01-02-01-02	BF13HAS	BF13SAS
+0_03-01-07-01-02-01-03	BF16AFS	BF16SUS
+0_03-01-08-01-02-02-07	BF27SAS	BF27HAS
+0_03-01-08-01-02-02-20	BM27AFS	BM27SUS

List of Stimuli: REB #7114

File Number	Sentence
0016_000083.mp3	Be off now as quick as you may!
0016_000168.mp3	I said you looked like an egg, sir.
0016_000179.mp3	Daisy creams with pink edges.
0016_000193.mp3	Please hire me after you.
0016_000222.mp3	Ask god to help you.
0016_000231.mp3	He told me that I ought to change.
0016_000240.mp3	Both side were softly curved.
0016_000281.mp3	He could not help doing so.
0016_000344.mp3	Lucy, a clever farmer.
0016_000345.mp3	A whirring noise was heard.
0016_000416.mp3	Shall we let Barbara in?
0016_000440.mp3	And they did push so!
0016_000448.mp3	Said the witch.
0016_000537.mp3	An hour out of GuildFord town.
0016_000548.mp3	I'd shoot myself. a pause.
0016_000574.mp3	Do you know the lid opens?
0016_000589.mp3	This is the way that snakes always talk.
0016_000598.mp3	In which piglet meets a elephant.
0016_000612.mp3	I believe you are one of them!
0016_000639.mp3	No, said piggy carelessly.
0016_000842.mp3	Wake now my merry tads!
0016_000856.mp3	The eye could not catch them.
0016_000859.mp3	Such tunes are joy to a dancing fay.
0016_000880.mp3	Toast from the bread fruit tree.
0016_000883.mp3	Fresh pain seized Paul's body.
0016_000895.mp3	A boat put out on the bay.
0016_000932.mp3	Will call her Lily, for short.
0016_000951.mp3	The ladybug told them proudly.

0016_001011.mp3	I am safe back again.
0016_001029.mp3	And his heart wagged with joy like a lamb's tail.
0016_001179.mp3	A large flat ferry boat was moored beside-it.
0016_001186.mp3	She has eaten the tapioca all of it.
0016_001235.mp3	The new born baby is stolen as we go.
0016_001240.mp3	And they were sandy yellow brownish all over.
0016_001244.mp3	Yes, I miss her.
0016_001342.mp3	She has a high voice.
0016_001347.mp3	How Tom and Jerry went to visit mister Sam.
0016_001353.mp3	I am loath to see him go.
0016_001385.mp3	But things haven't change yet.
0016_001387.mp3	But mom I'm not certain about.
0016_001453.mp3	He was still in the forest!
0016_001540.mp3	What an impetuous boy he is!
0016_001563.mp3	How they went to the mountains to eat nuts.
0016_001574.mp3	I pay half a crown a week extra.
0016_001605.mp3	Fear neither root nor sprout!
0016_001610.mp3	It weighs seven point five kilogram.
0016_001611.mp3	From each cake, there sprang a huge dog.
0016_001615.mp3	He likes dragons very much.
0016_001620.mp3	Her paw went into your eye?
0016_001629.mp3	The first year they sowed rye.
0020_000101.mp3	It's me piglet, help help!
0020_000106.mp3	I guess it's a choice feast.
0020_000144.mp3	We all see panda on TV or in the zoo.
0020_000158.mp3	it looks much better.
0020_000175.mp3	All this have we won by our labour.
0020_000188.mp3	Now quicker the fiddle went.
0020_000265.mp3	I've just shot a stag.
0020_000313.mp3	Give me a fine fat goose.

0020_000323.mp3	Why did I wake up!
0020_000338.mp3	Paul's teeth ached because of lemon.
0020_000405.mp3	A deafening chirruping rent the air.
0020_000498.mp3	And on the top of them, came Winnie, the cute bear.
0020_000499.mp3	My winding sheet!
0020_000514.mp3	His large mouth curled into a sneer.
0020_000549.mp3	Captain Tom receives an angry letter.
0020_000577.mp3	Born once every one hundred years, dies in flames!
0020_000614.mp3	Slam the doors and wedge them!
0020_000666.mp3	A thief in the night.
0020_000689.mp3	And be with you,Tom!
0020_000700.mp3	Do you have anything in mind?
0020_000787.mp3	A hippo lives in the zoo.
0020_000837.mp3	Let the glass globe be.
0020_000870.mp3	But if you hadn't done them.
0020_000872.mp3	I shall say good bye.
0020_000902.mp3	that sounds good.
0020_000961.mp3	After a while he perceived both giants.
0020_001000.mp3	Six was half way down the room.
0020_001001.mp3	I'm sure your friends can wait!
0020_001007.mp3	I owe them five hundred dollars.
0020_001010.mp3	Why it is just like the round egg which sounds thin.
0020_001101.mp3	Said the American to Chinese.
0020_001110.mp3	That I am a born nurse.
0020_001125.mp3	I'd far rather go without them than eat them!
0020_001131.mp3	And I never had a whooping cough why.
0020_001149.mp3	I've hit the wrong nose.
0020_001202.mp3	Guilty for what do you rule?
0020_001219.mp3	Sam waved his arm vaguely.
0020_001246.mp3	Clear are your eyes and bright your breath!

0020_001332.mp3	Alice I won't forget it again.
0020_001368.mp3	The name of the song is called haddocks.
0020_001497.mp3	Confess that you opened the thirteenth door.
0020_001566.mp3	They ate beef at the butcher shop.
0020_001581.mp3	First, issue a reward.
0020_001642.mp3	Give me your hand or I will cry harder than before.
0020_001654.mp3	She laughed.
0020_001656.mp3	I must have two to fetch and carry.
0020_001669.mp3	But show me now your map!
0020_001709.mp3	He owed mister Lawson, I can't tell you how.
0020_001714.mp3	Bob goes to a new school.
0020_001736.mp3	Over them swooped the eagles.

APPENDIX C

Within Subjects Effects for Noise Level X Diagnosis x Gender x Emotion for Study 1

Within Subjects Effects

Cases	Sphericity Correction	Sum of Squares	df	Mean Square	F	p	η^2
Noise Level	None	0.98	2.00	0.49	1.24	0.29	5.83e-4
	Greenhouse-Geisser	0.98	1.99	0.49	1.24	0.29	5.83e-4
Noise Level ∗ Diagnosis	None	0.32	2.00	0.16	0.40	0.67	1.90e-4
	Greenhouse-Geisser	0.32	1.99	0.16	0.40	0.67	1.90e-4
Noise Level ∗ Gender	None	1.74	4.00	0.43	1.10	0.36	0.001
	Greenhouse-Geisser	1.74	3.98	0.44	1.10	0.36	0.001
Noise Level ∗ Diagnosis ∗ Gender	None	2.55	4.00	0.64	1.62	0.17	0.001
	Greenhouse-Geisser	2.55	3.98	0.64	1.62	0.17	0.002
Residuals	None	165.40	420.00	0.39			
	Greenhouse-Geisser	165.40	418.11	0.40			
Emotion	None	1.72	5.00	0.34	0.86	0.51	0.001
	Greenhouse-Geisser	1.72	4.88	0.35	0.86	0.51	0.001
Emotion ∗ Diagnosis	None	2.04	5.00	0.41	1.02	0.40	0.001
	Greenhouse-Geisser	2.04	4.88	0.42	1.02	0.40	0.001
Emotion ∗ Gender	None	11.09	10.00	1.11	2.77	0.00	0.001
	Greenhouse-Geisser	11.09	9.76	1.14	2.77	0.00	0.001

Emotion ∗ Diagnosis ∗ Gender	None	9.26	10.00	0.93	2.31	0.01	0.001
	Greenhouse-Geisser	9.26	9.76	0.95	2.31	0.01	0.006
Residuals	None	420.61	1050.00	0.40			
	Greenhouse-Geisser	420.61	1024.30	0.41			
Noise Level ∗ Emotion	None	2.91	10.00	0.29	0.70	0.73	0.001
	Greenhouse-Geisser	2.91	9.56	0.30	0.70	0.72	0.001
Noise Level ∗ Emotion ∗ Diagnosis	None	7.05	10.00	0.71	1.70	0.08	0.001
	Greenhouse-Geisser	7.05	9.56	0.74	1.70	0.08	0.001
Noise Level ∗ Emotion ∗ Gender	None	9.29	20.00	0.46	1.12	0.32	0.006
	Greenhouse-Geisser	9.29	19.11	0.49	1.12	0.32	0.006
Noise Level ∗ Emotion ∗ Diagnosis ∗ Gender	None	12.05	20.00	0.60	1.45	0.09	0.007
	Greenhouse-Geisser	12.05	19.11	0.63	1.45	0.09	0.007
Residuals	None	871.43	2100.00	0.42			
	Greenhouse-Geisser	871.43	2006.52	0.43			

***Note*. Type III Sum of Squares**

Table 7: Correlation of slopes and 5% values across each appearance with the participant responses for emotion happy

Pearson's Correlations									
Variable		**Slope 1**	**5% 1**	**Slope 2**	**5% 2**	**Slope 3**	**5% 3**	**Slope 4**	**5% 4**
Happy UP	Pearson's r	0.18	0.19	-0.2	0.01	0.04	-0.04	-0.12	0.12
	p-value	0.12	0.10	0.08	0.94	0.72	0.77	0.33	0.31
Happy DOWN	Pearson's r	-0.09	-0.04	0.08	-0.09	-0.13	0.10	0.05	-0.16
	p-value	0.43	0.71	0.51	0.43	0.26	0.41	0.70	0.18
Happy FLAT	Pearson's r	-0.04	-0.09	0.06	0.09	0.10	-0.07	0.04	0.08
	p-value	0.77	0.43	0.59	0.46	0.38	0.54	0.77	0.52

Table 8: Correlation of slopes and 5% values across each appearance with the participant responses for emotion sad

Pearson's Correlations									
Variable		**Slope 1**	**5% 1**	**Slope 2**	**5% 2**	**Slope 3**	**5% 3**	**Slope 4**	**5% 4**
Sad UP	Pearson's r	-0.04	-0.06	-0.10	0.22	-0.04	-0.18	-0.20	-0.29
	p-value	0.75	0.59	0.40	0.06	0.73	0.13	0.09	0.01
Sad DOWN	Pearson's r	-0.13	-0.31	-0.11	0.06	-0.23	-0.24	0.03	0.12
	p-value	0.27	0.01	0.33	0.63	0.05	0.04	0.80	0.23
Sad FLAT	Pearson's r	0.13	0.30	0.14	-0.12	0.22	0.28	0.04	-0.02
	p-value	0.26	0.01	0.24	0.29	0.06	0.02	0.75	0.88

Table 9: Correlation of slopes and 5% values across each appearance with the participant responses for emotion angry

Pearson's Correlations									
Variable		**Slope 1**	**5% 1**	**Slope 2**	**5% 2**	**Slope 3**	**5% 3**	**Slope 4**	**5% 4**
Angry UP	Pearson's r	0.13	-0.13	0.05	0.2	-0.08	-0.16	0.07	0.10
	p-value	0.26	0.25	0.67	0.09	0.49	0.16	0.55	0.42
Angry DOWN	Pearson's r	-0.22	-0.12	-0.10	-0.16	-0.03	0.08	-0.04	-0.09
	p-value	0.06	0.31	0.40	0.17	0.83	0.51	0.72	0.47
Angry FLAT	Pearson's r	0.07	0.28	0.04	-0.07	0.12	0.11	-0.04	-0.03
	p-value	0.58	0.02	0.74	0.53	0.30	0.39	0.73	0.82

Table 10: Correlation of slopes and 5% values across each appearance with the participant responses for emotion surprise

Pearson's Correlations									
Variable		**Slope 1**	**5 % 1**	**Slope 2**	**5% 2**	**Slope 3**	**5% 3**	**Slope 4**	**5% 4**
Surprise UP	Pearson's r	0.12	-0.26	0.21	0.15	-0.18	0.11	0.22	-0.13
	p-value	0.32	0.03	0.07	0.21	0.13	0.36	0.06	0.29
Surprise DOWN	Pearson's r	-0.05	0.14	-0.16	-0.05	0.31	-0.22	-0.14	0.27
	p-value	0.65	0.22	0.18	0.65	0.01	0.06	0.24	0.02
Surprise FLAT	Pearson's r	-0.13	0.26	-0.17	-0.17	-0.05	0.07	-0.20	-0.09
	p-value	0.28	0.03	0.15	0.14	0.69	0.58	0.08	0.44

Table 11: Correlation of slopes and 5% values across each appearance with the participant responses for emotion neutral

Pearson's Correlations									
Variable		**Slope 1**	**5% 1**	**Slope 2**	**5% 2**	**Slope 3**	**5% 3**	**Slope 4**	**5% 4**
Neutral UP	Pearson's r	-0.03	-0.10	0.22	0.25	-0.15	-0.08	-0.10	-0.04
	p-value	0.77	0.38	0.06	0.03	0.21	0.49	0.42	0.76
Neutral DOWN	Pearson's r	0.14	0.34	-0.28	-0.23	-0.04	0.03	-0.01	0.05
	p-value	0.22	0.003	0.02	0.05	0.71	0.80	0.90	0.66
Neutral FLAT	Pearson's r	-0.12	-0.27	0.16	0.09	0.11	0.01	0.06	-0.03
	p-value	0.31	0.02	0.19	0.42	0.34	0.93	0.61	0.79