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Developmental Changes in Response to Music-evoked Emotion Among Children and Adolescents with Autism Spectrum Disorders

Kevin G. Stephenson
Brigham Young University

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Kevin G. Stephenson

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Mikle South, Chair
Jared Warren
Michael Larson

Department of Psychology

Brigham Young University

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ABSTRACT

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Kevin G. Stephenson
Department of Psychology, BYU
Master of Science

Significant symptoms of anxiety in individuals with autism spectrum disorder (ASD) may arise due to impaired emotion recognition. In light of reports showing ASD-specific developmental changes in amygdala volumes, we expanded a previous study of recognition of music-evoked emotions in ASD versus typical controls (CON). We explicitly compared both behavioral and psychophysiological response to music-evoked emotions of children (ages 8-11) and older adolescents (ages 16-18). A total of 91 participants (42 ASD) listened to segments of instrumental music that had been previously validated to evoke *happy*, *sad*, or *scary* emotional valence. We measured accuracy and reaction time while also collecting skin conductance response. The ASD group demonstrated reduced skin conductance response to the emotional music stimuli overall, compared to controls. The younger *child* groups, regardless of diagnosis showed greater physiological reactivity to *scary* stimuli than to the other emotions. Analysis of behavioral data demonstrated an interaction of age group and diagnostic group: for scary music, the older control group was more accurate than the younger control group while the opposite pattern was observed for the ASD group. These data suggest disrupted developmental trajectories for integrating physiological and cognitive cues in ASD. This lack of integration may underlie increased feelings of uncertainty and anxiety that are associated with more difficult and less adaptive decision making in ASD.

Keywords: autism spectrum disorder, music, anxiety, emotion, development

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Introduction

Autism spectrum disorder (ASD) is a neurodevelopmental disorder characterized by deficits in reciprocal social communication as well as restricted or repetitive movements and interests (American Psychiatric Association, 2013). In addition to core clinical symptoms of ASD there are a number of associated physical and emotional symptoms that can cause substantial functional impairment. For example, individuals diagnosed with ASD show high rates of comorbid anxiety that may generate as much or more distress as the hallmark autism symptoms. In a meta-analysis, van Steensel, Bögels, and Perrin (2011) found that around 40% of individuals with ASD had at least one comorbid anxiety disorder. Using a large sample of 1316 children and adolescents with ASD whose primary caregiver completed a Child Behavior Checklist. Specifically, Vasa et al. (2013) reported that 41% of ASD adolescents and 26% of school-aged children diagnosed with ASD met cut-off scores for a comorbid anxiety disorder, with subclinical symptoms present for an additional 13% of the adolescents and 26% of the younger children, respectively. Even twins of ASD children who themselves are unaffected by autism symptoms show increased symptoms of general anxiety, social anxiety, and panic symptoms, suggesting that anxiety may be part of a broader autism phenotype (Hallett et al., 2013).

Emotion Recognition in ASD

Such significant anxiety in ASD may arise in part as a result of fundamental deficits in emotion recognition. In a recent meta-analysis, Uljarevic & Hamilton (2013) report on 48 studies with over 900 participants with ASD engaging in emotion recognition tasks. Their results indicated that individuals with ASD do not perform as well as matched controls in either emotion matching or emotion labeling tasks, with an overall effect size of -.81 (reduced to -.4 when

estimating publication bias). Specifically, it is slightly more difficult for individuals with ASD to recognize fear compared to happiness. Uljarevic and Hamilton (2013) found no effects of age, IQ, or type of task (emotion matching vs. emotion labeling) on emotion recognition accuracy. However, the studies included in the meta-analysis only investigated emotions expressed by face and body. A recent study by Deschamps, Coppes, Kenemans, Schutter, and Matthys (2013) suggests that, overall, children with ASD have intact facial mimicry of happy, sad, fearful, and angry emotions compared to controls, while children with ASD with more severe symptoms show some deficits in mimicking fearful faces.

These frequent difficulties in emotion recognition and regulation have led researchers to investigate the relationship of amygdala dysfunction and ASD symptomatology. Adolphs, Baron-Cohen, and Tranel (2002) found that, when compared to healthy controls, individuals with uni- and bilateral amygdala damage show deficits in recognizing emotion when presented with static images of faces. In particular, they showed more severe deficits when asked to identify social emotions (e.g. flirtatious, guilty, etc.) compared to basic emotions (e.g. happy, sad, etc.). Adolphs et al. (2002) concluded that the overall emotion recognition deficits observed in patients with amygdala damage are similar to those in individuals diagnosed with ASD. Increased amygdala volume in autism is also associated with increased anxiety (Juranek et al., 2006). A seminal study by Schumann et al. (2004) suggested that ASD groups have abnormal age-related growth and connectivity of the amygdala, although there is considerable variability in specific findings across studies (see e.g., Ecker et al., 2012; Greimel et al., 2013). The common element seems to be disrupted connectivity between amygdala and other brain regions, rather than simply changes or differences in amygdala volume (Jou et al., 2011; von dem Hagen, Stoyanova, Baron-Cohen, & Calder, 2013).

In order to better understand amygdala contributions to autism, researchers have utilized multimodal approaches for investigating emotion recognition. Nonetheless, to date the majority of studies have relied on emotional faces as stimuli (Daly et al., 2012; Kennedy & Adolphs, 2012; Song & Hakoda, 2012; Tanaka et al., 2012; Wong, Beidel, Sarver, & Sims, 2012). Far fewer studies have employed the use of nonsocial stimuli in assessing the ability of individuals with ASD to correctly identify emotions. South et al. (2008) found that nonsocial emotion recognition may be intact in ASD when using tasks such as the Snake in the Grass, Mere Exposure, Affective Word Memory, and the Iowa Gambling Task. The results of that study suggest that emotional processing errors may be specifically linked to socially-derived situations, in particular with faces. However, more research using nonsocial stimuli is needed.

Emotion Recognition of Music in ASD

One of the fundamental societal roles of music is to express emotions (Juslin & Sloboda, 2001). Recent neuroimaging results have shown common areas of activation for specific emotions such as fear across various emotion modalities including faces, vocalizations, and music (e.g., Aube, Angulo-Perkins, Peretz, Concha, & Armony, 2014; see review in Koelsch, 2014). Behavioral reports likewise highlight the role of the amgydala in processing sad and scary music. Patient S.M., who has complete bilateral amygdala atrophy without damage to surrounding areas in the temporal lobes, showed impaired ability to recognize sad and scary music while her ability to recognize happy music was intact. She also judged scary music as less intense than controls (Gosselin, Peretz, Johnsen, & Adolphs, 2007).

Research in emotion and music has also investigated the impact of musical stimuli on a range of psychophysiological measures including heart and pulse rate, biochemical responses, and skin conductance response (SCR) among others. These psychophysiological studies have

shown that music is a viable stimulus for eliciting emotional responses in typically developing individuals. Evidence suggests that music causes changes in the autonomic nervous system (ANS) that are thought to be correlated with emotion (Larsen, Berntson, Poehlmann, Ito, & Cacioppo, 2008).

There have been an increasing number of studies using musical stimuli to investigate the amygdala theory of autism (see Baron-Cohen et al., 2000), which posits atypical amygdala function to be one of the major neural regions associated with social and emotional deficits observed in autism. Bhatara, Quintin, Heaton, Fombonne, and Levitin (2009) found that children and adolescents with ASD have difficulties judging the expressivity of musical excerpts, rating mechanical excerpts the same as expressive music, while controls rate them as different. Quintin, Bhatara, Poissant, Fombonne, and Levitin (2011) investigated a simpler task in ASD, similar to the musical paradigm as the one used with Patient S.M. (Gosselin et al., 2007). Quintin et al. first validated musical clips for the same target emotions (happy, sad, scary, and peaceful) as the Gosselin et al. study. All of the clips had good interrater agreement, as reported in Quintin et al. (2011). The music clips ranged in duration from 30s to 50s and were presented in randomized order for each participant. Participants rated the intended emotion by selecting one of four line drawings of emotional faces (with the name of the emotion written next to the drawing) after each excerpt. They then rated the intensity of each clip using a 32cm continuous scale ranging from slightly intense (0) to very intense (1).

In a sample of 26 children and adolescents (ages 10-19) diagnosed with ASD, Quintin et al. (2011) found that children and adolescents with ASD were not significantly different than age-matched controls at recognizing the four emotions, after controlling for IQ. The ASD group showed similar accuracy as well as intensity ratings compared to controls. In light of evidence

suggesting developmental differences in the rate of amygdala growth, however (see Schumann et al., 2004), it is possible that the developmental course of emotion recognition in ASD differs from typical trajectories. Thus the first objective of our study was to expand the Quintin et al. (2011) study by including two separate age groups in order to better understand the impact of age on emotion recognition in ASD, specifically for fearful stimuli associated with amygdala activation (Adolphs et al., 2002).

Another aim of our present study was to utilize psychophysiological measures of arousal as another objective test of response to music. Previous studies of atypical amygdala function (Gosselin et al., 2007) and ASD (Bhatara et al., 2009; Quintin et al., 2011) have solely used subjective ratings of perceived intensity and did not incorporate any physiological measure of ANS arousal. Having both behavioral and physiological measures of intensity will help determine if perception of internal states correlate with physiological arousal in children and adolescents with ASD. SCR is minimally invasive and easy to administer and has been frequently used as a dependent variable in music emotion studies (Khalfa, Roy, Rainville, Dalla Bella, & Peretz, 2008; Lundqvist, Carlsson, Hilmersson, & Juslin, 2009; Roy, Mailhot, Gosselin, Paquette, & Peretz, 2009); we therefore utilized SCR in the current experiment to better understand perceived and actual ANS arousal in ASD compared to controls.

Method

Participants

Approval for this study was obtained through the Brigham Young University Institutional Review Board. Parents provided written consent and participants provided written assent. We tested a group of high-functioning individuals with ASD and a neurotypical control group (CON). All participants in the ASD group had a diagnosis based on DSM-IV-TR criteria

and met research criteria for an ASD (scores > 7) according to the Modules 3 or 4 of the Autism Diagnosis Observation Schedule (ADOS; Lord et al., 2000), completed by the third author, a licensed clinical psychologist trained to research reliability on the ADOS. Typically developing control participants were recruited by word-of-mouth and flyers placed in the community and their parents reported no history of psychopathology or psychotropic medication use. All participants in the CON groups had parent-reported Social Responsiveness Scale scores below the cutoff for concern about autism (raw scores < 75) (see Constantino et al., 2003).

The study comprised a total of 91 participants. There were two distinct age groups: a *child* group of (total *n = 50,* ASD *n* = 24) ages 8-11 (*M* = 9.89, *SD* = 1.16); and an *adolescent* group (total *n* = 41, ASD *n* = 18) ages 16-18 (*M* = 16.71, *SD* = 1.02). All participants completed the Wechsler Abbreviated Scales of Intelligence. All IQ index scores were in the average range or above (Full Scale IQ *M* = 110.23, *SD* = 11.31) and there were no statistical differences in IQ scores between ASD and CON groups. As expected, the ASD participants in both age groups had significantly higher levels of autism symptoms as measured by the SRS. The ASD groups also had higher parent-reported anxiety and sensory sensitivity including auditory sensitivity (see Table 1).

Measures

This study was conducted as part of a larger battery of research tasks. All parents completed the Social Responsiveness Scale (SRS; Constantino et al., 2003) as a dimensional measure of autism symptoms; the Spence Children's Anxiety Scale-Parent Version *(*SCAS-P*;* Spence, 1998; Nauta, Scholing, Rapee, Abbott, Spence, Waters, 2004) as a measure of trait anxiety; and the Short Sensory Profile (SSP; McIntosh, Miller, & Shyu, 1999), which provides a

measure of sensory sensitivity including auditory sensitivity. Participants received monetary compensation at the conclusion of the full battery.

Task

The music-evoked emotion recognition task was largely based on the design by Quintin et al. (2011). However, we departed from their methodology in several specific ways. We used the identical musical stimuli for the *happy*, *sad*, and *scary* emotions but omitted the *peaceful* selections because of apparent confusion and ambiguity regarding this more complex emotion in the previous Quintin et al. study. Because pilot testing showed that the majority of skin conductance arousal occurred within the first few seconds of each musical excerpt--with little added information during the rest of the original length--we therefore also reduced the length of each musical excerpt to the first 20s of each clip in order to target this initial psychophysiological arousal while reducing the length of the task. Additionally, in the original Quintin et al. study, participants were able to skip the rest of each musical excerpt as soon as they knew which emotion the music was meant to convey. We chose to play each 20s segment in their entirety in order to have a standard length with which to compare each excerpt. Lastly, we added a modified self-assessment manikin (SAM; see Bradley & Lang, 1994) created for use in this study (see Supplemental Materials), in order to minimize the need for verbal ratings of emotion and intensity. The SAM was shown on the computer monitor and the participant responded using mouse clicks.

In order to measure a stable baseline skin conductance level, participants first completed a short task where they were asked to identify pictures of flowers from consecutive pairs of pictures on the computer monitor. After reading instructions on the monitor, participants listened to each musical segment (five for each emotion condition) presented in a randomized order.

After each segment the participants chose an emotion (happy, sad, or scary) using the SAM on the monitor. Specifically, participants were asked "How does this music make you feel?" A second 5-point intensity rating SAM (specific to the chosen emotion) followed, allowing participants to rate the intensity of each stimulus.

We collected SCR data during the baseline and music tasks using electrodes on the palmar surface of the middle and ring fingers of the left hand, centered around the top joint on each finger which were connected to the Biopac MP150 GSR-100C module (Biopac Systems, Inc., Goleta, California) at 250 Hertz. Data acquisition and analysis was done using AcqKnowledge software (Biopac Systems). We accounted for drift in the SCR data by using the Difference mathematical transformation included in the AcqKnowledge software. We analyzed the SCR data from each musical stimulus using the AcqKnowledge "area under the curve" function, and square root transformed the data to normalize the distribution.

Statistical Analysis

For each of the study variables (i.e., SCR, accuracy of emotion identification, and emotion intensity) we ran a 2 (diagnostic group) x 2 (age group) x 3 (emotion condition) repeated measures ANOVA. We then used Tukey's honest significant difference (HSD) post-hoc tests to analyze specific level differences of significant omnibus effects. Furthermore, in light of the amygdala theory of autism, we also conducted planned comparisons of *scary* trials.

Exclusions

Two of the youngest 8-year-old control participants had outlying low scores on accuracy of their emotion identification. Both of these responded with many false positives by choosing *happy* after *scary* and *sad* trials. These two participants were excluded from analysis of

the behavioral data. One participant with ASD had an outlying SCR response to *scary* trials and was not included in analysis of the psychophysiological data.

Results

Baseline Physiology

Inspection of the baseline physiological data indicated that skin conductance level (SCL) did not differ between the age-combined ASD and CON groups, $t(86) = .88$, $p = .38$. However, correlation analysis of age and baseline arousal levels demonstrated a significant, negative coefficient $r = -.42$, $p < .001$. We therefore conducted a 2 (age group) x 2 (diagnostic group) ANOVA that indicated a reliable effect for age group, $F(1, 90) = 22.45$, $p < .001$, $\eta^2 = .19$. Follow-up analyses show that the *child* group had significantly higher SCL than the *adolescent* group for both diagnostic categories (ASD $t(37) = 2.35$, $p < .05$; CON $t(47) = .4.43$, $p < .001$ groups). There were no significant differences for diagnostic group, $F(1, 90) = 1.26$, $p = .26$, $\eta^2 = .01$ or a diagnostic group x age group interaction, $F(1, 90) = 0.73$, $p = .40$, $\eta^2 = .00$.

Skin Conductance Response

The 2 x 2 x 3 repeated measures ANOVA for SCR revealed significant main effects for diagnosis $F(1, 82) = 6.53$, $p = .01$, $\eta^2 = .05$; age, $F(1, 82) = 14.22$, $p < .001$, $\eta^2 = .11$, and emotion condition $F(2, 164) = 3.45$, $p = .03$, $\eta^2 = .01$. Tukey's HSD post-hoc tests revealed that the ASD group showed reduced arousal compared to the CON group. In line with the baseline skin conductance levels, Tukey's HSD also indicated that the *child* group showed increased arousal compared to the *adolescent* group. A comparison across emotion condition indicated that participants showed increased arousal in response to *scary* excerpts compared to *happy*. There were no significant interactions between any of the three factors.

Accuracy of Emotion Identification

A 2 x 2 x 3 analysis of accuracy revealed a main effect for emotion condition $F(2, 170) = 26.47$, $p < .001$, $\eta^2 = .15$. Tukey's HSD revealed significant differences in accuracy across emotion conditions (*happy* > *scared* > *sad*).

There was a significant age x diagnosis x emotion condition interaction, $F(2, 170) = 5.28$, $p = .006$, $\eta^2 = .03$. In order to better understand this effect, we conducted post-hoc comparisons by analyzing the age groups separately using 2 (diagnostic group) x 3 (emotion condition) repeated measures ANOVAs. Neither age group showed a main effect for diagnosis.

There was significant interaction of emotion condition x diagnosis within the *child* group $F(2, 92) = 4.48$, $p = .01$, $\eta^2 = .05$ driven by a between-groups difference specifically to *scary* stimuli, which was identified in the ASD group more accurately than *sad* music while the opposite pattern was observed for the CON group (see Figure 2). For the *adolescent* group, the overall interaction for all emotion conditions was not significant $F(2, 78) = 1.41$, $p = .25$, $\eta^2 = .02$; however visual inspection of the analysis plots showed that groups again differed specifically for *scary* stimuli but in the opposite direction: the CON group identified *scary* stimuli significantly more accurately than *sad* stimuli while the ASD group was (non-significantly) more accurate for *sad* than *scary*.

To better understand the developmental differences in ASD compared with typically developing controls and following our planned comparison to test the amygdala theory of autism, we conducted a 2 (diagnostic group) x 2 (age group) ANOVA for the *scary* music response. The significant interaction effect is depicted in Figure 4, $F(1,85) = 4.25$, $p = .04$, $\eta^2 = .048$. In other words, for the participants with ASD, the *child* group recognized *scary* music more accurately

than the *adolescent* group while the opposite pattern was observed for the CON participants, i.e., the *adolescent* group recognized *scary* music more accurately than the *child* group.

Emotion Intensity

Following the pattern of the accuracy results, emotion intensity results indicated a main effect for emotion condition, $F(2, 169) = 29.38$, $p < .001$, $\eta^2 = .10$. Interestingly, using the SAM rating scale, both ASD and CON groups described the *sad* music stimuli as significantly more intense than either *happy* or *scary* items. In the case of emotion intensity, the age x diagnosis x emotion condition interaction was only marginally significant, $F(2, 169) = 2.41$, $p = .09$, $\eta^2 = .01$. However, we again looked specifically at the *scared* stimuli and found the same pattern of result, namely a significant age x diagnosis interaction, $F(1, 85) = 4.59$, $p = .04$, $\eta^2 = .05$. Again, this was driven by the participants with ASD, i.e., the *child* group rated *scary* music as more intense than the *adolescent* group (Figure 4).

Discussion

This study has two main findings: 1) overall, our ASD samples demonstrated reduced skin conductance response to music-evoked emotions; and 2) behavioral responses to *scary* music showed a change across the two age groups that were opposite to the change seen in controls. Young children with ASD tended to be *more* accurate than their older peers in identifying the *scary* music whereas the young children in the CON tended to be *less* accurate at identifying the *scary* music than their older peers. Our findings extend those of Quintin et al. (2011) by showing a developmental effect for recognition, intensity rating, and arousal response to scary music. This effect was most prominent with *scary* music for participants with ASD; the younger group had increased arousal response and subjective intensity rating with an associated increased accuracy compared to the adolescent group.

One ongoing puzzle for emotion regulation research in ASD is how to reconcile atypical connections between psychophysiological and cognitive manifestations of emotion. For example, in non-autism samples, increased anxiety is most often associated with increased autonomic arousal (Lang, Bradley & Cuthbert, 1998). As in many areas of ASD research, findings in this area are quite heterogeneous (see recent reviews by Mazefsky et al., 2013; White et al., 2014). However, on the whole it appears that the relationship between physiological response and behavioral manifestations of anxiety is less straightforward in ASD and may depend much more than usual on context such as degree of uncertainty (Chamberlain et al., 2013), social cues (Riby et al., 2012) or specific physiological measure (Kuski et al., 2013).

How is anxiety maintained or even heightened in the relative absence of physiological response in older adolescents and adults diagnosed with ASD? Rodgers and colleagues (Boulter et al., 2014; Rodgers et al., 2012; Wigham et al., 2014) have highlighted the role of intolerance of uncertainty including dynamic influences of uncertainty, sensory processing and repetitive behavior in understanding anxiety in ASD. Imbalance in relationship between physiological and cognitive interpretations of emotion may contribute to uncertainty about how to interpret emotional cues which could lead to considerable confusion about how to respond in emotional situations, leading to feelings of anxiety and difficulty making decisions (Luke et al., 2012).

In typical development there are age-related increases in the integration of physiological and cognitive emotional cues in association with increased white matter connectivity (see Monk, 2008). In our study, baseline SCR arousal was significantly less for the older than younger age groups, indicating that reliance on physiological cues for emotion recognition in music potentially decreases with age. In particular, the relative physiological sensitivity to and subjective intensity rating of *scary* music stimuli appear to decrease with age for individuals with

ASD, but so does the relative accuracy. These performance differences suggest that adolescents with ASD are not able to compensate as well as their typically developing peers without the physiological cues; it may be that awareness and sensitivity to physiological responsiveness decreases as individuals with ASD develop. Alternatively, hyperactive activity in amygdala and related structures in childhood may lead to decreased function later in life (see Schumann et al., 2004). The enactive mind theory of autism (Klin et al., 2003) suggests that cognitive development in autism does not integrate information from bodily experiences with the environment; this likely becomes more apparent over time.

In the context of atypical connectivity in ASD (McFadden and Minshew, 2013), it is likely that the *balance* of physiological and cognitive response to emotion—including both the experience of emotion as well as strategies for regulating or coping with aversive emotional cues—develops differently with age in ASD (White et al., 2014). The groups used in this study intentionally cross the age threshold (around 12½) used by Schumann et al. (2004), where younger children diagnosed with ASD had larger amygdala volume than controls while older adolescent ASD children did not show the same trajectory for continued amygdala growth as did healthy controls. The increased accuracy for identifying *scary* music stimuli in our younger ASD group may reflect a general bias towards threat interpretation associated with amygdala overgrowth. However, a later plateau in the development of the amygdala and associated connections may leave some individuals with ASD with reduced emotion capacity. That is, early-developing emotion deficits become exacerbated with age as typical children grow more adept ASD children continue to develop these skills less efficiently. Thus, studies of adolescents have shown differences in the neural response to making mistakes (Larson et al., 2010) and understanding emotional cues (Bernhardt et al., 2014; Bird et al., 2010; Cook et al., 2013).

There are a number of limitations to this study. Although our sample sizes are larger than many previous studies they are still modest and larger samples are needed to establish the reliability especially for the age-related differences. While we explicitly chose a younger and an older group to exclude the midpoint of the Schumann et al. (2004) findings on amygdala development, inclusion of a continuous age span would allow for a smoother examination of age and emotion response. Our SAM rating system was made specifically for this study. Our intent was to use a nonverbal rating of emotion and intensity. However, by doing so we may have introduced another confound since past studies have shown abnormal face processing in ASD (Ewing, Pellicano, & Rhodes, 2013; Greimel et al., 2014; Nickl-Jockschat et al, 2015). We only recruited high-functioning individuals with ASD. Because of the broad range of symptoms and severity in ASD, we are not able to extend our finding across all individuals along the autism spectrum. Prospective longitudinal research would help to clarify age-related changes in emotion recognition in ASD. Functional imaging studies may help us better understand the potential underlying neural correlates of emotion processing of music. Based on our observed underarousal during music listening, future studies could investigate potential psychophysiological differences of active (i.e., participants are asked to identify target emotions) vs. passive (i.e., participants listen to music without any direction) listening for emotional musical stimuli in autism.

Conclusion

Understanding the mechanisms that underlie significant symptoms of anxiety and other emotion regulation difficulties in ASD may lead to improved understanding of the neurobiology of autism and to improved specificity of interventions. However, findings regarding the relationship of cognition, physiology, and behavior continue to be mixed. White et

al. (2014) note the importance of various kinds of context, reviewing a number of studies that show increases or decreases in psychophysiological arousal depending on the situation and/or the measurement method. The present study shows that age is an important context to consider when trying to elucidate the balance of physiological arousal and cognitive awareness of emotional cues in ASD. Music can be an effective non-social emotional stimulus and future studies of emotion in autism may benefit from manipulations involving musical cues.

References

Adolphs, R., Baron-Cohen, S., & Tranel, D. (2002). Impaired recognition of social emotions following amygdala damage. *Journal of Cognitive Neuroscience, 14*(8), 1264-1274. doi: 10.1162/089892902760807258

Amaral, D. G., Schumann, C. M., & Nordahl, C. W. (2008). Neuroanatomy of autism. *Trends in Neurosciences, 31*(3), 137-145. doi: 10.1016/j.tins.2007.12.005

American Psychiatric Association (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Baron-Cohen, S., Ring, H. A., Bullmore, E. T., Wheelwright, S., Ashwin, C., & Williams, S. C. R. (2000). The amygdala theory of autism. *Neuroscience and Biobehavioral Reviews, 24*(3), 355-364. doi: 10.1016/s0149-7634(00)00011-7

Bhatara, A. K., Quintin, E.-M., Heaton, P., Fombonne, E., & Levitin, D. J. (2009). The effect of music on social attribution in adolescents with autism spectrum disorders. *Child Neuropsychology, 15*(4), 375-396. doi: 10.1080/09297040802603653

Bradley, M. M., & Lang, P. J. (1994). Measuring emotion: The self-assessment manikin and the semantic differential. *Journal of Behavior Therapy and Experimental Psychiatry, 25*(1), 49-59. doi: 10.1016/0005-7916(94)90063-9

Centers for Disease Control and Prevention (2014). Prevalence of autism spectrum disorder among children aged 8 years – Autism and developmental disabilities monitoring network, 11 sites, United States, 2010. *Surveillance Summaries*, *63*(2), 1-21. Retrieved from http://www.cdc.gov/mmwr/pdf/ss/ss6302.pdf

Constantino, J. N., Davis, S. A., Todd, R. D., Schindler, M. K., Gross, M. M., Brophy, S. L., . . . Reich, W. (2003). Validation of a brief quantitative measure of autistic traits: Comparison

of the social responsiveness scale with the autism diagnostic interview-revised. *Journal of Autism and Developmental Disorders, 33*(4), 427-433. doi: 10.1023/A:1025014929212

Corbett, B. A., Schupp, C. W., Levine, S., & Mendoza, S. (2009). Comparing cortisol, stress, and sensory sensitivity in children with autism. *Autism Research, 2*(1), 39-49. doi: 10.1002/aur.64

Daly, E. M., Deeley, Q., Ecker, C., Craig, M., Hallahan, B., Murphy, C., . . . Murphy, D. G. M. (2012). Serotonin and the neural processing of facial emotions in adults with autism: An fmri study using acute tryptophan depletion. *JAMA Psychiatry, 69*(10), 1003-1013.

Eschamps, P.K., Cooppes, L., Kenemans, J.L., Schutter, D.J., Matthys, W. (2013). Electromyogrpahic responses to emotional facial expressions in 6-7 year olds with autism spectrum disorders. *Journal of Autism and Developmental Disorders,* doi:10.1007/s10803-013-1890-z

Ecker, C., Suckling, J., Deoni, S. C., Lombardo, M. V., Bullmore, E. T., Baron-Cohen, S., . . . Murphy, D. G. M. (2012). Brain anatomy and its relationship to behavior in adults with autism spectrum disorder: A multicenter magnetic resonance imaging study. *Archives of General Psychiatry, 69*(2), 195-209. doi: 10.1001/archgenpsychiatry.2011.1251

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

Gosselin, N., Peretz, I., Johnsen, E., & Adolphs, R. (2007). Amygdala damage impairs emotion recognition from music. *Neuropsychologia, 45*(2), 236-244. doi: 10.1016/j.neuropsychologia.2006.07.012

Greimel, E., Nehrkorn, B., Schulte-Rüther, M., Fink, G. R., Nickl-Jockschat, T., Herpertz-Dahlmann, B., . . . Eickhoff, S. B. (2013). Changes in grey matter development in autism spectrum disorder. *Brain Structure & Function, 218*(4), 929-942. doi: 10.1007/s00429-012-0439-9

Greimel, E., Schulte-Rüther, M., Kamp-Becker, I., Remschmidt, H., Herpertz-Dahlmann, B., & Konrad, K. (2014). Impairment in face processing in autism spectrum disorder: A developmental perspective. *Journal Of Neural Transmission*, *121*(9), 1171-1181. doi:10.1007/s00702-014-1206-2

Hallett, V., Ronald, A., Colvert, E., Ames, C., Woodhouse, E., Lietz, S., . . . Happé, F. (2013). Exploring anxiety symptoms in a large-scale twin study of children with autism spectrum disorders, their co-twins and controls. *Journal of Child Psychology and Psychiatry, 54*(11), 1176-1185.

Hochhauser, M., & Engel-Yeger, B. (2010). Sensory processing abilities and their relation to participation in leisure activities among children with high-functioning autism spectrum disorder (hfasd). *Research in Autism Spectrum Disorders, 4*(4), 746-754. doi: 10.1016/j.rasd.2010.01.015

Juslin, P. N., & Sloboda, J. A. (2001). Communicating emotion in music performance: A review and theoretical framework. In P. N. Juslin (Ed.), *Music and emotion: Theory and research* (pp. 307–331). New York: Oxford University Press.

Jou, R. J., Jackowski, A. P., Papademetris, X., Rajeevan, N., Staib, L. H., & Volkmar, F. R. (2011). Diffusion tensor imaging in autism spectrum disorders: Preliminary evidence of abnormal neural connectivity. *Australian and New Zealand Journal of Psychiatry, 45*(2), 153-162. doi: 10.3109/00048674.2010.534069

Juranek, J., Filipek, P. A., Berenji, G. R., Modahl, C., Osann, K., & Spence, M. A. (2006). Association between amygdala volume and anxiety level: Magnetic resonance imaging (mri) study in autistic children. *Journal of Child Neurology, 21*(12), 1051-1068. doi: 10.1177/7010.2006.00237

Kennedy, D. P., & Adolphs, R. (2012). Perception of emotions from facial expressions in high-functioning adults with autism. *Neuropsychologia, 50*(14), 3313-3319. doi: 10.1016/j.neuropsychologia.2012.09.038

Khalfa, S., Roy, M., Rainville, P., Dalla Bella, S., & Peretz, I. (2008). Role of tempo entrainment in psychophysiological differentiation of happy and sad music? *International Journal of Psychophysiology, 68*(1), 17-26. doi: 10.1016/j.ijpsycho.2007.12.001

Kim, Y. S., Leventhal, B. L., Koh, Y.-J., Fombonne, E., Laska, E., Lim, E.-C., . . . Grinker, R. R. (2011). Prevalence of autism spectrum disorders in a total population sample. *The American Journal of Psychiatry, 168*(9), 904-912. doi: 10.1176/appi.ajp.2011.10101532

Larsen, J. T., Berntson, G. G., Poehlmann, K. M., Ito, T. A., & Cacioppo, J. T. (2008). The psychophysiology of emotion. In M. Lewis, J. M. Haviland-Jones & L. F. Barrett (Eds.), *Handbook of emotions (3rd ed.).* (pp. 180-195). New York, NY US: Guilford Press.

Liu, T. (2013). Sensory processing and motor skill performance in elementary school children with autism spectrum disorder. *Perceptual and Motor Skills, 116*(1), 197-209. doi: 10.2466/10.25.PMS.116.1.197-209

Lord, C., Risi, S., Lambrecht, L., Cook, E. H., Jr., Leventhal, B. L., DiLavore, P. C., . . . Rutter, M. (2000). The autism diagnostic observation schedule—generic: A standard measure of social and communication deficits associated with the spectrum of autism. *Journal of Autism and Developmental Disorders, 30*(3), 205-223. doi: 10.1023/A:1005592401947

Lord, C., Rutter, M., & Le Couteur, A. (1994). Autism diagnostic interview—revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 24*(5), 659-685. doi: 10.1007/BF02172145

Lundqvist, L.-O., Carlsson, F., Hilmersson, P., & Juslin, P. N. (2009). Emotional responses to music: Experience, expression, and physiology. *Psychology of Music, 37*(1), 61-90. doi: 10.1177/0305735607086048

McIntosh, D. N., Miller, L. J., & Shyu, V. (1999). Development and validation of the short sensory profile. In W. Dunn (Ed.), *Sensory profile manual* (pp. 59-73). San Antonio, TX: Psychological Corporation.

Munson, J., Dawson, G., Abbott, R., Faja, S., Webb, S. J., Friedman, S. D., . . . Dager, S. R. (2006). Amygdalar volume and behavioral development in autism. *Archives of General Psychiatry, 63*(6), 686-693. doi: 10.1001/archpsyc.63.6.686

Nickl-Jockschat, T., Rottschy, C., Thommes, J., Schneider, F., Laird, A. R., Fox, P. T., & Eickhoff, S. B. (2015). Neural networks related to dysfunctional face processing in autism spectrum disorder. *Brain Structure & Function*. *220*(4), 2355-2371. doi:10.1007/s00429-014-0791-z

Quintin, E.-M., Bhatara, A., Poissant, H., Fombonne, E., & Levitin, D. J. (2011). Emotion perception in music in high-functioning adolescents with autism spectrum disorders. *Journal of Autism and Developmental Disorders, 41*(9), 1240-1255. doi: 10.1007/s10803-010-1146-0

Roy, M., Mailhot, J.-P., Gosselin, N., Paquette, S., & Peretz, I. (2009). Modulation of the startle reflex by pleasant and unpleasant music. *International Journal of Psychophysiology, 71*(1), 37-42. doi: 10.1016/j.ijpsycho.2008.07.010

Song, Y., & Hakoda, Y. (2012). Selective attention to facial emotion and identity in children with autism: Evidence for global identity and local emotion. *Autism Research, 5*(4), 282-285. doi: 10.1002/aur.1242

South, M., Ozonoff, S., Suchy, Y., Kesner, R. P., McMahon, W. M., & Lainhart, J. E. (2008). Intact emotion facilitation for nonsocial stimuli in autism: Is amygdala impairment in autism specific for social information? *Journal of the International Neuropsychological Society, 14*(1), 42-54. doi: 10.1017/S1355617708080107

Spielberger, C. (1973). *Manual for the State-Trait Anxiety Inventory for Children*. Palo Alto, CA:Consulting Psychologists Press.

Tanaka, J. W., Wolf, J. M., Klaiman, C., Koenig, K., Cockburn, J., Herlihy, L., . . . Schultz, R. T. (2012). The perception and identification of facial emotions in individuals with autism spectrum disorders using the let's face it! Emotion skills battery. *Journal of Child Psychology and Psychiatry, 53*(12), 1259-1267. doi: 10.1111/j.1469-7610.2012.02571.x

Tomchek, S. D., & Dunn, W. (2007). Sensory processing in children with and without autism: A comparative study using the short sensory profile. *American Journal of Occupational Therapy, 61*(2), 190-200. doi: 10.5014/ajot.61.2.190

Uljarevic, M., & Hamilton, A. (2013). Recognition of emotions in autism: A formal meta-analysis. *Journal of Autism and Developmental Disorders, 43*(7), 1517-1526. doi: 10.1007/s10803-012-1695-5

van Steensel, F. J. A., Bögels, S. M., & Perrin, S. (2011). Anxiety disorders in children and adolescents with autistic spectrum disorders: A meta-analysis. *Clinical Child and Family Psychology Review, 14*(3), 302-317. doi: 10.1007/s10567-011-0097-0

Vasa, R. A., Kalb, L., Mazurek, M., Kanne, S., Freedman, B., Keefer, A., . . . Murray, D. (2013). Age-related differences in the prevalence and correlates of anxiety in youth with autism spectrum disorders. *Research in Autism Spectrum Disorders, 7*(11), 1358-1369. doi: 10.1016/j.rasd.2013.07.005

von dem Hagen, E. A. H., Stoyanova, R. S., Baron-Cohen, S., & Calder, A. J. (2013). Reduced functional connectivity within and between 'social' resting state networks in autism spectrum conditions. *Social Cognitive and Affective Neuroscience, 8*(6), 694-701. doi: 10.1093/scan/nss053

Wong, N., Beidel, D. C., Sarver, D. E., & Sims, V. (2012). Facial emotion recognition in children with high functioning autism and children with social phobia. *Child Psychiatry and Human Development, 43*(5), 775-794. doi: 10.1007/s10578-012-0296-z

Appendix

Table 1. Participant Characteristics.

Child group (ASD *n* = 24; CON *n* = 26)

	M		SD		Range		t
Measure	A	CON	ASD	CO	ASD	CON	
Age (years)	10	9.76	1.22	1.11	8-12	8-11	0.83
FSIQ	11	111.85	12.58	11.5	94-	86-	0.39
VIQ	10	108.73	12.68	13.1	81-	85-	1.08
PIQ	11	112.88	15.02	12.0	93-	89-	0.29
SRS Total	11	26.25	20.91	14.2	80-	4-50	16.69***
ADOS	13	--	4.39	--	7-21	--	--
SCAS-P	30	13.80	18.21	11.3	2-76	2-37	3.42***
SCAS-C	27	29.12	12.85	14.1	0-52	10-68	0.28
IUS-P	39	23.65	9.87	10.1	19-58	12-45	4.79***
SSP-A	22	11.26	3.39	4.10	16-29	6-22	7.95***

Adolescent group (ASD *n* = 18; CON *n* = 23)

	M		SD		Range		t
Measure	A	CON	ASD	CON	ASD	CON	
Age (years)	16	16.81	0.91	1.10	15-18	14-18	0.72
FSIQ	10	109.68	12.22	9.36	85-	92-	0.45
VIQ	10	110.09	13.71	10.12	86-	93-	0.48
PIQ	10	107.14	11.22	10.31	88-	86-	0.02
SRS Total	10	24.37	21.42	16.97	68-	2-68	12.15***
ADOS	13	--	4.22	--	7-20	--	--
SCAS-P	22	10.38	12.14	8.79	3-45	3-39	3.17**
SCAS-C	23	19.50	8.16	8.07	2-36	6-40	1.42
IUS-P	37	22.18	10.50	7.91	19-56	12-40	4.59***
SSP-A	98	12.73	29.87	7.70	65-	6-29	2.75**

Note. ASD = Autism Spectrum Disorder; CON = typical control. IQ from the Wechsler Abbreviated Scales of Intelligence (FSIQ = Full Scale IQ, VIQ = Verbal IQ, PIQ = Performance IQ). SRS = Social Responsiveness Scale. ADOS = Autism Diagnostic Observation Schedule (Module 3 or 4); SCAS = Spence Children's Anxiety Scales (P = Parent report, C = Child report); IUS = Intolerance of Uncertainty Scale (P = Parent report, C = Child report); SSP = Short Sensory Profile (A = Auditory).

Figure 1. Skin conductance response averaged across emotion conditions and age group for both ASD and controls.

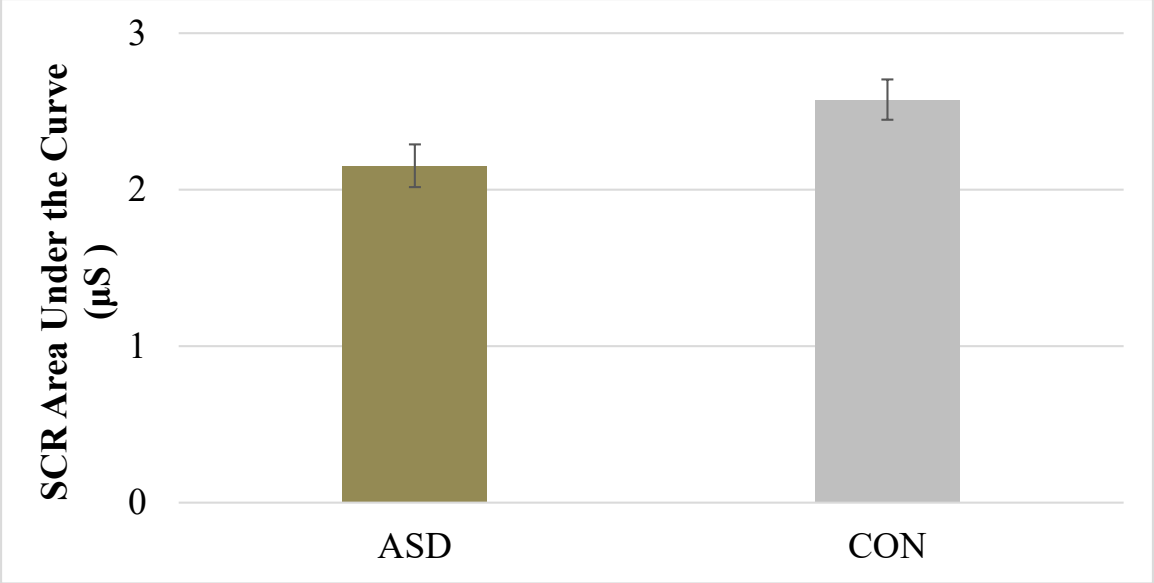


Figure 2. Accuracy of music-evoked emotion recognition for the child group.

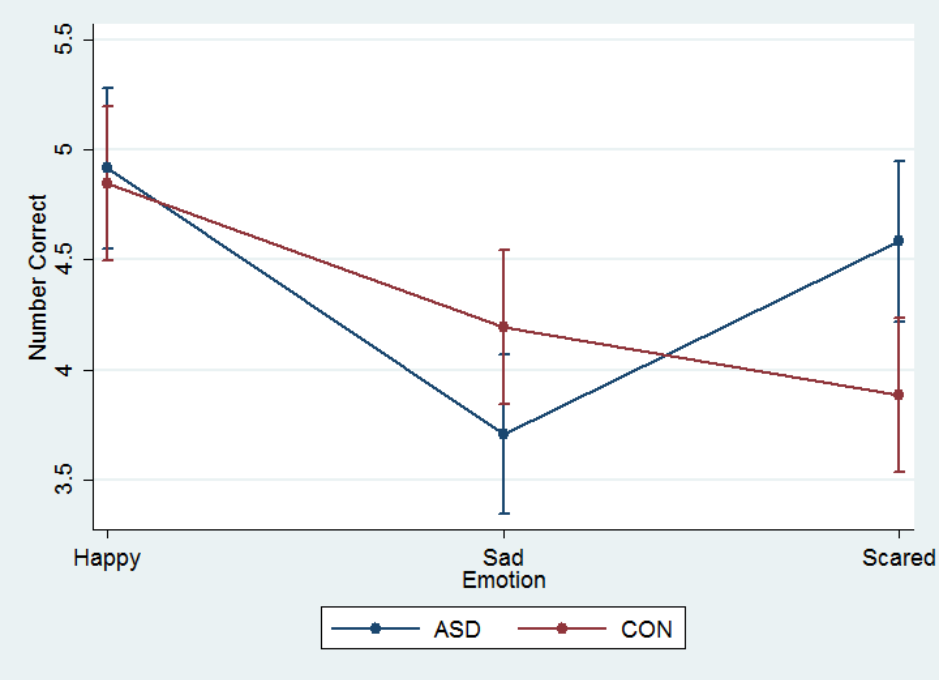


Figure 3. Mean SCR for scary music across age groups.

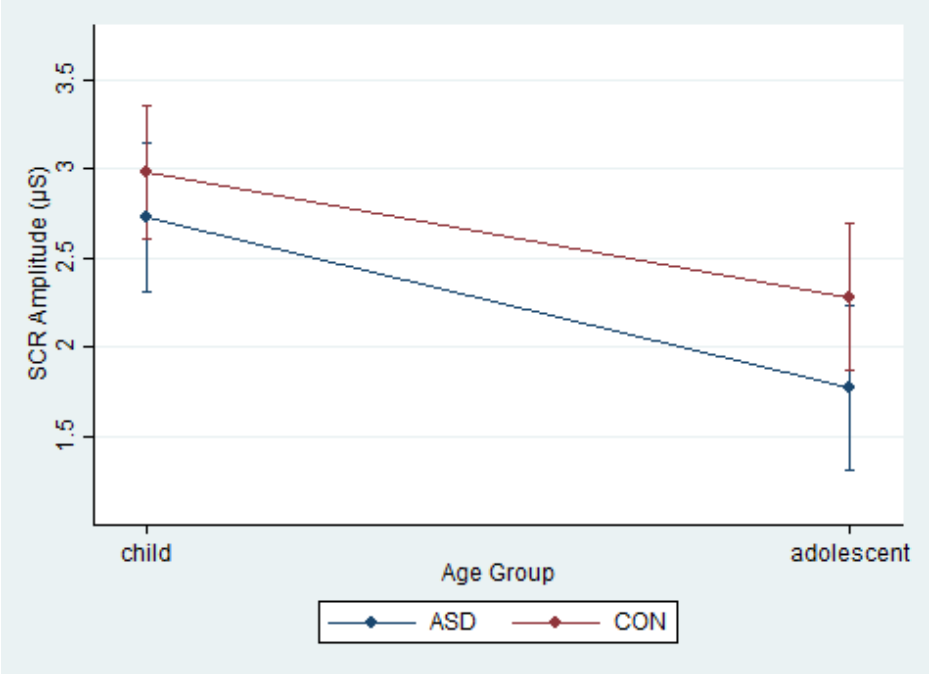


Figure 4. Mean accuracy for identification of scary music across age groups.

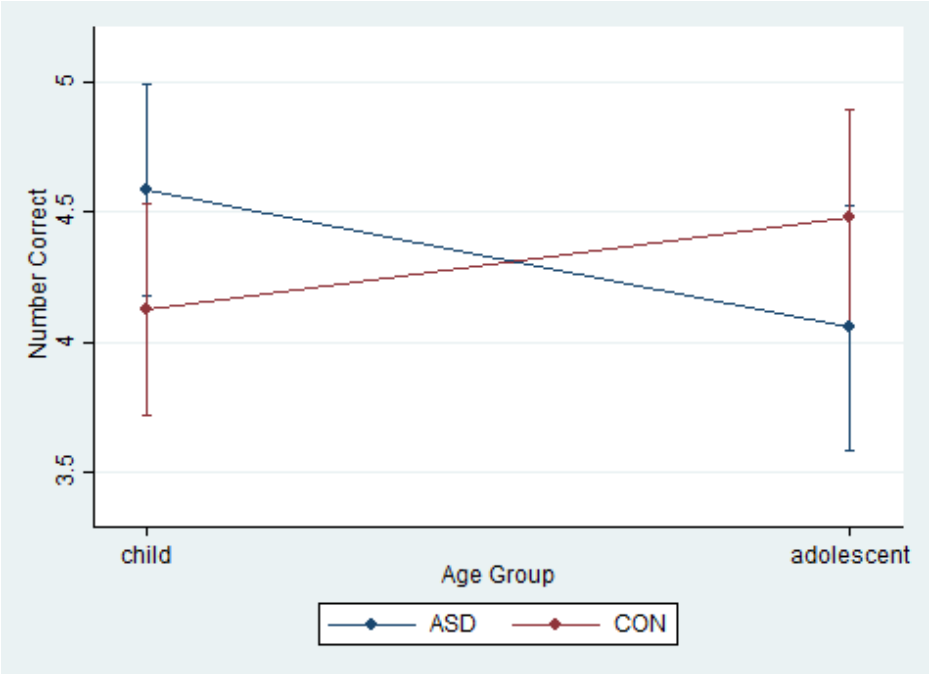
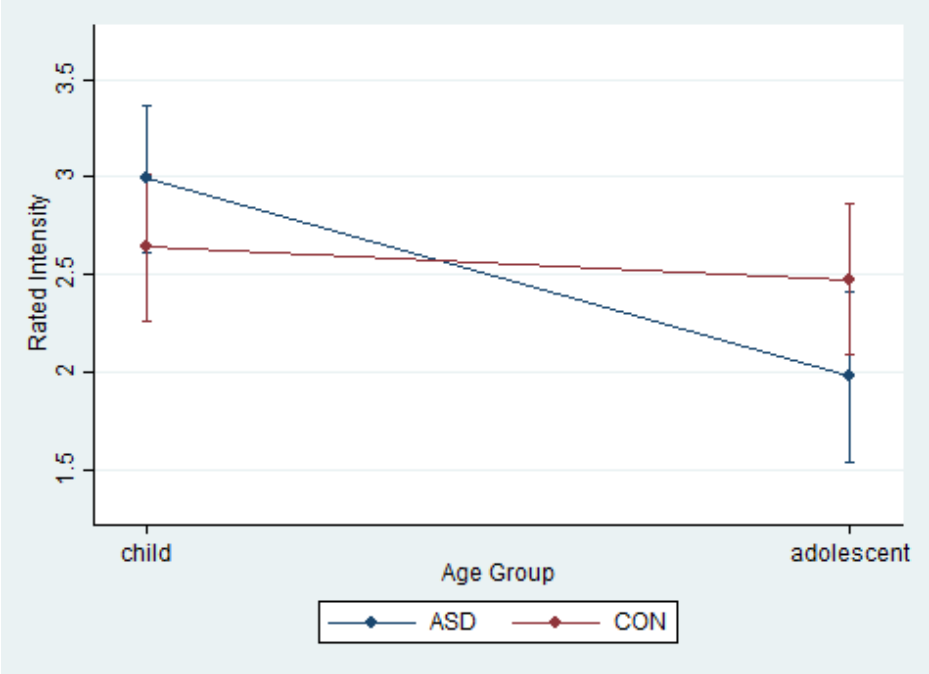


Figure 5. Mean intensity for scary music across age groups.



Supplemental Materials

Supplemental Figure 1. Self-assessment manikins used for identifying accuracy and arousal.