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Young Adults' Autistic Behaviors Predict P1 and N170 Responses to Emotion Stimuli

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Abstract

Autism Spectrum Disorder (ASD) is a developmental disorder characterized by core deficits in social, communication, and motor skills (CDC, 2013). Deficits in emotional processing have also been identified, especially with negative emotions and surprise. These behavioral deficits are reflected in differences in neural responses, specifically with the P1 and N170 event-related potential components. The current study explored how these neural differences in emotion processing are modified by autistic behaviors in a subclinical population using a task that varied both by facial features available and instructions intended to modify the type of processing occurring. The results supported previous findings that those with low levels of autistic behaviors have increased neural attention, as measured by P1 and N170 amplitude, to fearful stimuli, while those with high levels did not show higher amplitudes. Exploratory analyses using autistic behaviors as a continuous variable showed this same response pattern with surprise for P1 yet showed an increase in N170 amplitude in those with high levels of autistic behaviors. These findings maintained their significance when controlling for social anxiety-related behaviors. Additionally, the results demonstrated that, in those with high levels of autistic behaviors, less neural attention occurred in response to faces in which only the eye region was shown, contrasting the increase in neural attention in those with low levels of autistic behaviors when presented the eye region instead of a face. Together the findings indicate in a subclinical population that the impact of autistic behaviors on the processing of emotions varies by emotion as well as by the facial features available.

Key Words: autism, emotion, ERPs

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In a Center for Disease Control study conducted in 2012 at over 11 different sampling sites, it was estimated that 1 in 68 children in the United States have autism (CDC, 2016). Autism Spectrum Disorder (ASD) is a developmental disorder characterized by social and communication deficits as well as by repetitive behaviors (American Psychiatric Association, 2013). A deficit in emotion recognition has also been demonstrated among individuals with ASD (Gross, 2004; Harms, Martin, & Wallace, 2010). A review focusing on emotion recognition in ASD individuals reported behavioral differences compared to neurotypical individuals in facial scanning during the recognition process; specifically, ASD individuals spent less time looking at the eyes and more time looking at the lower half of the face (Harms et al., 2010). Emotion recognition is an important social process as it helps to predict the behavior of others (Adams, Ambady, Macrae, & Kleck, 2006). Deficits and differences in emotional recognition are, therefore, likely to impact social knowledge and behaviors.

Individuals with ASD have been shown to particularly struggle with processing emotions of a negative valence. Adults with ASD are less accurate in identifying negative emotions (i.e., fear, disgust, and anger) than neurotypical individuals, while no differences existed between the groups in identifying positive and neutral expressions (Ashwin, Chapman, Colle, & Baron-Cohen, 2006; Humphreys, Minshew, Leonard, & Behrmann, 2007; Kuusikko et al., 2009). Beyond valence, certain emotions have been shown to be particularly difficult for individuals with ASD to identify, namely surprise (Baron-Cohen, Spitz, & Cross, 1993; Lacroix, Guidetti, Rogé, & Reilly, 2009). One study compared neurotypical children and children with ASD on a number of emotional processing tasks and demonstrated a deficit in identifying surprise among those with ASD (Lacroix et al., 2009). Thus the emotional processing deficits of individuals with ASD have been demonstrated more specifically with emotions of a negative valence as well as with surprise.

There is also a body of literature examining emotion processing among the broader autism phenotype, which refers to the presence of autistic behaviors among a non-diagnosed, neurotypical population. Examining the broader autism phenotype allows researchers to isolate particular aspects of autism and connect them to their corresponding deficits and strengths. The current study examines the broader autism phenotype in order to provide a more detailed characterization of emotional processing deficits than studying only clinical populations which point to negative and complex emotions as being particularly difficult for individuals diagnosed with autism. In a study focusing on the broader autism phenotype, parents of children with autism were less accurate in identifying happy, neutral, and surprised expressions compared with parents of neurotypical children (Kadak, Dimrel, Yavuz, & Demir, 2014). The two groups also differed significantly in the social skills subscale of the Autism Quotient (AQ), a self-report survey that consists of five subscales that is used to measure autistic behaviors; the parents of autistic children demonstrated a higher level of autistic behaviors related to social skills (Kadak et al., 2014; Baron-Cohen et al., 2001). These findings together suggest that the facial recognition deficits observed in the broader autism phenotype are connected to behaviors related to social skills. In contrast, Poljac and colleagues (2013) found that among neurotypical adults, those with low levels of autistic behaviors as measured by the AQ were significantly more accurate than those with high levels for faces expressing fear, disgust, and sadness in an emotion recognition task, in accordance with the results of clinical studies. Another study among an adult neurotypical population found those high in autistic behaviors as measured by the AQ were slower in recognizing emotions in a task in the participant is asked to identify the emotion being expressed in the eyes presented than those with a low level of autistic behaviors (Miu, Pana, & Avram, 2012). Taken together, this research on the broader autism phenotype has found conflicting patterns in emotion processing deficits, implicating difficulty both with positive emotions and with negative emotions in separate studies.

Beyond behavioral measures of emotion processing, electroencephalogram (EEG) measures can also be used to measure electrical activity of the brain during the task. EEG recordings have the advantage of being time-sensitive and being able to connect electrical activity to precise events during particular cognitive processes. The emotion processing that occurs when viewing a face happens on the order of milliseconds, and the time-sensitive nature of EEG makes it a valuable method for capturing brain activity throughout the process. There are also multiple stages of emotion processing that happen within distinct time windows. Using EEG and, specifically, event-related potentials (ERPs) allow for the investigation of specific aspects of emotion processing that may otherwise be impossible to isolate from the process as a whole.

Both P1 and N170 are ERPs that have been identified as neural correlates for early face processing. P1 has a timecourse typically beginning around 110 ms post-stimulus and peaking around 146 ms and is thought to reflect activity of occipital regions V3 and V3a, of the middle-occipital gyrus, and of the fusiform gyrus (Di Russo, Martinez, Sereno, Pitzalis, & Hillyard, 2001). The P1 has been established as related to facial processing, with both scrambled and intact faces eliciting more neural activity than scrambled and intact cars in the right hemisphere (Roisson & Caharel, 2011). It also has shown some limited sensitivity to emotion, with neutral and surprised faces eliciting smaller responses than that of angry, fearful, disgusted, and happy faces in one study and fearful faces leading to larger amplitudes than happy or neutral faces in another study (Batty & Taylor, 2003; Luo, Feng, He, Wang, & Luo, 2010). The N170 has also been established as particularly sensitive to faces over other objects and is connected to holistic facial processing, with particular sensitivity for the eyes over other parts of the face (Itier & Batty, 2009). N170 typically peaks around 170 ms and is thought to reflect activity of the posterior fusiform gyri (Deffke et al., 2007). The N170 has been suggested to be a relatively early artifact of facial processing prior to face identification, in part evidenced by familiar and unfamiliar faces eliciting the same N170 (Bentin & Deouell, 2000). It is, however, impacted by particular emotional expressions, demonstrating more negative amplitudes for happy faces than fearful faces, longer latencies for negative than positive emotions, and larger amplitudes for fearful faces than the other emotions tested (Batty & Taylor, 2003; Righart & de Gelder, 2008). Luo and colleagues (2010) also demonstrated an emotional sensitivity, as happy and fearful faces led to significantly larger N170 amplitudes than neutral faces. Thus, both the P1 and N170 are important ERPs for characterizing early aspects of emotion processing and have been shown to have particular sensitivity to faces and even specific emotions.

There has been research connecting both the P1 and N170 with emotion processing in studies on the broader autism phenotype as well as in clinical studies. It has been demonstrated in studies of both adults and children that neurotypical participants display larger P1 amplitudes in response to inverted faces than upright faces, indicative of holistic facial processing, while no difference has been shown among individuals with ASD (Hileman, Henderson, Mundy, Newell, & Jaime, 2011; Webb et al., 2012). Hileman and colleagues (2011) also found among neurotypical children, social behaviors and cognition were related to P1 amplitude in that more typical social behaviors and higher social cognition scores were associated with larger P1 amplitudes. These studies demonstrated neural differences in facial processing that are then associated with differences in social cognition and behaviors. Wagner and colleagues (2013) reported that P1 amplitudes were significantly higher among participants with ASD in response to houses than among neurotypical participants, indicative of an attentional preference for objects among those with ASD. They also found among neurotypical participants more negative N170 responses to fearful faces as compared to angry faces, yet no such difference among participants with ASD, suggesting an attentional bias towards faces exhibiting fear exists among neurotypicals and not individuals with ASD (Wagner, Hirsch, Vogel-Farley, Redcay, & Nelson, 2013).

The expression of autistic behaviors is often made more complicated due to the high rates of comorbidity with psychiatric disorders. Adults with ASD are more likely to also experience a clinical level of a variety of anxiety disorders, including agoraphobia, social phobia, and obsessive-compulsive disorder, in addition to being significantly more likely to experience multiple anxiety disorders than the neurotypical population (Joshi et al., 2013). A study in children with ASD found likewise that they experienced more social phobia-related symptoms than their neurotypical cohort (Kuusikko et al., 2008). As both social phobia and ASD are partially characterized by social deficits, it is important to understand the interaction between the two disorders on social-related behaviors such as emotion processing. A review of emotion processing related to social anxiety found an overall lower level of emotional knowledge, including lessened ability to identify complex emotions and a difference in attention to negative emotions as compared to neurotypical individuals (O'Toole, Hougaard, & Mennin, 2013). A study comparing individuals with social phobia and neurotypical individuals found that faces expressing unpleasant emotions (i.e. anger, fear, and disgust) led to an increase in brain activation, specifically in the amygdala, in those with social phobia and not in neurotypical individuals (Phan, Fitzgerald, Nathan, & Tancer, 2006). Greater P1 amplitudes are observed in phobic participants when viewing faces, regardless of emotion portrayed, compared to neurotypical controls and suggest that social phobia leads to irregular attention during the holistic processing of faces (Kolassa et al., 2008).

The current study differs from most previous work by examining an adult neurotypical population, as opposed to the traditional comparison of children with ASD and those without ASD. By studying the broader autism phenotype, we will be able to have a more detailed characterization of emotion processing deficits, as it is easier to isolate from other autism-related deficits and strengths than in clinical studies. Using self-report surveys to measure the level of autistic behaviors in a non-clinical population also allows for the investigation of how particular categories of autistic behaviors are related to the behavioral findings measured by the task. Additionally, as there is much less research on adults with ASD than on children with ASD, less is known about how autistic behaviors, deficits, and strengths are manifested in adulthood after development.

In the current study, we used a task that allowed for the examination of differences in scanning during facial processing; specifically, the task presented participants with displays of full faces as well as the same faces showing only the eyes. As previous studies have typically only included either the full faces or the eyes, this study will contribute to the literature in that it will explore the importance of the eye region in emotion recognition. It has been found that neurotypical individuals scan faces in a regimented, organized pattern between the eyes and mouth, while individuals with autism have less regular scanning behaviors, with more time spent looking at non-central facial features (Harms et al., 2010; Wiekowski & White, 2017). At a neural level, it has been demonstrated that the N170 is affected by time spent looking at the eye region of the face (Itier & Batty, 2009; Eimer, Kiss, & Nicholas, 2010). In the current study, we decided to use both full-face and eye region stimuli in this study to control for the behavioral scanning differences and to isolate the resulting impact on neural activity. Previous studies have compared face and non-face stimuli and lack the current study's direct comparison of face and eye region stimuli. Investigating P1 and N170 will allow us to determine if ASD-related differences in facial processing occur during early holistic processing and the degree to which emotion valence and complexity impact them. The results of previous studies suggest that those high in autistic behaviors would be less accurate in identifying negative emotions, though there is also evidence counter to this prediction. We expected to see differences in P1 and N170 based on specific emotions, especially fear, for those with low levels of autistic behaviors, but not high levels. In addition, lower P1 amplitudes regardless of emotion portrayed were expected among those with high levels of autistic behaviors compared to those with low levels of autistic behaviors. Behavioral and neural results impacted by social phobia behaviors should follow different patterns from those impacted by autistic behaviors. A final goal of this study was to explore if the relationship between autistic behaviors and neural activity is still significant when controlling for social anxiety, which is often co-morbid with autism.

Methods

Participants

Participants (N = 48, 26 female and 22 male) aged 18 to 25 (M_{age} = 19.17, SD = 1.31) were recruited from a medium-size public liberal arts university in Virginia and participated either for monetary payment or partial fulfillment of a course requirement. All participants were neurotypical (not diagnosed with a neurological disorder). All procedures were approved by The

College of William and Mary Protection of Human Subjects Committee, and written informed consent was obtained from each participant.

Experimental Paradigm

Emotional processing was measured using a computer task in which a series of faces exhibiting different emotions (happy, angry, fear, surprise, and neutral) were presented. Color images of White male faces from the NimStim Set of Facial Expressions were used as stimuli (Tottenham et al., 2009). For each trial, each stimulus was presented for 1000 ms, preceded by a fixation that varied randomly between 500, 750, and 1000 ms. An inter-stimulus interval of 500 ms was used between trials. In one of two conditions, participants were instructed to respond one way if the emotion of the face matched that of the face presented before it and another if it did not. In a second condition, participants were instructed to respond one way if the emotion of the face was the target valence (i.e. positive or negative) and another if it was not (i.e. the opposite valence or neutral). All participants completed both conditions, in counterbalanced order. Participants were instructed to respond by pressing 'x' or 'm' to indicate whether the stimulus met the target criteria or not, and the target response key was counterbalanced between blocks. Because previous research has demonstrated behavioral differences in facial scanning between individuals with ASD and neurotypical individuals, four blocks were composed of stimuli displaying the full face and four were composed of stimuli displaying only the eye region. There were eight blocks in total, each comprised of 75 trials and presented in a random order.

Questionnaires

Broad Autism Phenotype Questionnaire. A self-report measure of autistic behaviors is the Broad Autism Phenotype Questionnaire, a 36-question survey with three subscales: aloof personality (e.g., "I would rather talk to people to get information than to socialize."), rigid personality (e.g., "I have to warm myself up to the idea of visiting a new place."), and pragmatic language problems (e.g., "People ask me to repeat things I've said because they don't understand.") (Hurley, Losh, Parlier, Reznick, & Piven, 2007). Participants respond according to how often their experiences match the statements on a six-part scale of "very rarely", "rarely", "occasionally", "somewhat often", "often", and "very often" (Hurley et al., 2007). Scores are calculated by converting the responses to point values (with "very rarely" scoring 1 point and "very often" scoring 6 points), reverse coding the appropriate questions, and averaging the numerical values within each subscale for three subscale scores and across the subscales all for a total score (Hurley et al., 2007). The cutoff scores for belonging to the broad autism phenotype were determined to be 3.25 for the aloof personality subscale, 3.50 for the rigid personality subscale, 2.75 for the pragmatic language subscale, and 3.15 for the total score (Hurley et al., 2007). Acceptable internal consistency for each of the subscales of the BAPQ ($\alpha > .70$) was confirmed in a sample of undergraduate students (Ingersoll, Hopwood, Wainer, & Donnellan, 2011).

Autism Quotient. The Autism-Spectrum Quotient (AQ) is a self-report measure of autistic behaviors composed of 50 questions from five subscales: social skills (e.g., "I prefer to do things with others rather than on my own."), communication (e.g., "I find it easy to "read between the lines" when someone is talking to me."), attention to detail (e.g., "I often notice car number plates or similar strings of information."), attention switching (e.g., "I frequently get so absorbed in one thing that I lose sight of other things."), and imagination (e.g., "When I am reading a story, I can easily imagine what the characters might look like.") (Baron-Cohen, Wheelwright, Skinner, Martin, & Clubley, 2001). Participants respond with the degree to which they agree with each of statements on a four-part scale of "definitely agree", "slightly agree", "slightly disagree", and "definitely disagree," yet the responses are scored dichotomously as either agreement or disagreement (Baron Cohen et al., 2001). The cut-off score is 32 for clinical and is 26 for subclinical high-functioning Autism symptoms (Smith, Robinson, Wheelwright, & Baron-Cohen, 2005). Good internal consistency for the AQ has been confirmed in a large sample of Dutch students (r = .81) and among members of the general community (r = .71), in addition to a strong test-retest reliability in a twin sample (r = .71; Hoekstra, Bartels, Cath, & Boomsma, 2008).

Social Anxiety. In order to measure social anxiety, the participants were given an abbreviated version of the Social Phobia and Anxiety Inventory (SPAI-23), which asks participants to respond on a 5-point scale how often they feel anxiety, indicating "never", "very infrequent", "sometimes", "very frequent", or "always", in various social situations and has social phobia (16 questions) and agoraphobia subcategories (7 questions) (Roberson-Nay, Strong, Nay, Beidel, & Turner, 2007). A sample social phobia question is "I feel anxious when in a small gathering of people," while a sample agoraphobia question is "Being in large open spaces makes me nervous." (Roberson-Nay, Strong, Nay, Beidel, & Turner, 2007). The SPAI-23 has demonstrated excellent psychometric properties, often demonstrating strengths relative to peer measures in diagnostic sensitivity, specificity, and discriminability (Peters, 2000; Turner, Beidel, Dancu, & Stanley, 1989). Internal consistency was confirmed for both the social phobia (α = .96) and agoraphobia (α = .85) subscales of the SPAI in a sample of undergraduate students (Turner et al., 1989).

Procedure

Participants first completed an informed consent form. The participant was then given verbal instructions, seated in a Faraday chamber, and began the computer task, which took approximately 20-25 minutes, while EEG was recorded throughout. EEG data were recorded using an standard 32Ch actiCAP electrode cap with thirty-two electrodes and a BrainAmp DC amplifier (BrainVision LLC, Morrisville, NC), with a 10 Hz low-pass filter and a 250 Hz high-pass filter. After completion of the task, the experimenter removed the cap and electrodes from the participant, and the participants completed an online survey comprised of demographic information, ASD scales, and the social anxiety scale. The participants were then debriefed on the nature of the study.

Electrophysiological Analysis

Following data collection, the EEG data was analyzed using BrainVision Analyzer software (BrainVision LLC, Morrisville, NC). Eye movement artifacts in the data were corrected, using either ocular correction or ocular ICA correction based on how noisy the continuous data were (Gratton, Coles, & Donchin, 1983). All EEG data were filtered at low pass .01 Hz and at high pass 30 Hz. Segmentation 200 ms prior to stimulus onset and 1000 ms post-stimulus onset was performed. After baseline correction over the pre-stimulus interval, segmented data were averaged for each participant in each of the conditions.

Each ERP was quantified through visual inspection of the grand average waveforms. Following quantification, a repeated measures ANOVA was conducted including all of the electrodes and conditions. The typical electrodes used for each ERP as well as the electrodes with the highest amplitudes were examined. The P1 component was identified as the largest positive voltage between 75 and 175 ms, and the P7, P8, and Pz electrodes were chosen for analysis. The N170 component was identified as the largest negative voltage between 110 and 210 ms, and the O1, O2, P8, and TP10 electrodes were chosen for analysis. The P2 component was identified as the largest positive voltage between 175 and 250ms. The N3 component was quantified as the largest negative component between 210 and 310 ms. The P3 component was identified as the largest positive voltage between 250 and 650 ms. The N4 component was identified as the largest negative voltage between 320 and 430 ms. The ERPs that were most defined and of most theoretical interest were P1 and N170, so we chose to conduct analyses on these two below.

Results

Participants' data were eliminated from the analyses if the participants did not complete a block (n = 1) or if they expressed a misunderstanding on the task instructions during or after the task (n = 1). Additionally, participants for whom there were errors in collecting EEG data (n = 6) and whose EEG data had too high of impedances following application of filters (n = 5) were eliminated from analysis. Analyses were performed for 34 participants (15 males; $M_{age} = 19.15$; 67.6% White). Correlations between the self-report measures, as reported in Table 1, demonstrate the BAPQ Aloof ($M = 3.02$, $SD = 0.83$), BAPQ Rigid Behavior ($M = 3.32$, $SD = 0.91$), and BAPQ Pragmatic Language ($M = 2.88$, $SD = 0.67$) subscale scores were highly correlated with each other. Additionally, each of the BAPQ subscales was significantly correlated with the SPAI Difference Score ($M = 31.03$, $SD = 11.29$).

Analysis Strategy

In order to examine effect of specific emotions, task instructions, and available feature conditions on ERP amplitude, a 5 (Emotion: Angry, Fear, Happy, Neutral, Surprise) x 2 (Instructions: Valence, Matching) x 2 (Features: Face, Eye) x 2 (BAPQ: Low, High) mixed model Analyses of Variance (ANOVA) with the last variable as the between-subjects factor was conducted separately for P1 and N170. For BAPQ, the pragmatic language subscale was used as it is most directly connected to the task paradigm. The pragmatic language subscale measures autistic behaviors related to social skills specific to interpersonal conversation, in contrast to the aloof and rigid subscales, which measure social interest and ability to adapt, respectively. Emotion processing, as measured by the task in this study, is likely to contribute to the communication and social skills measured by the pragmatic language subscale. In order to examine the interaction between the BAPQ pragmatic language and the task, the participants were split into three groups, as has been done in previous work examining emotional processing in subclinical groups (Dickter, Burk, Fleckenstein, & Kozokowski, 2017), and the top third (M = 3.50, SD = 0.32) and bottom third (M = 2.17, SD = 0.48) were compared. These groups were shown to be significantly different from each other, t = -7.96, p < .001.

P1

For P1 at the P8 electrode, there was a marginally significant Emotion x Instructions x Features x BAPQ interaction, F (4,88) = 2.46, p = .084, η^2 = .096. Although this effect did not reach traditional levels of significance, we had a small sample size and a medium effect size, so we decided to break down this interaction about which we had an *a priori* hypothesis. In order to examine this interaction, we conducted separate ANOVAs for face trials and for eyes trials. For the face trials, there were no significant effects. For the eye trials, there was a marginal three-way interaction of Emotion x Instruction x BAPQ, F (4,88) = 2.61, p = .057, η^2 = .106. Separate ANOVAs were then conducted for the task instructions. For the trials with matching instructions, there were no significant effects. For the valence instructions trials, there was a marginal two-way interaction of Emotion x BAPQ pragmatic language, F (4,88) = 2.27, p = .100, η^2 = .094. Simple main effects were conducted to examine this interaction by comparing high and low BAPQ participants for each emotion, with no significant effects found.

In order to further examine the effects of behaviors related to autism on P1 amplitude responses to emotional faces, exploratory correlational analyses were performed at the P8 electrode across all BAPQ subscales. The BAPQ pragmatic language subscale was significantly correlated with P1 amplitude in response to fearful faces under matching instructions, $r = -.40$, $p = .021$, and to surprised eyes under valence instructions, $r = -.49$, $p = .003$. Both the BAPQ rigid behavior subscale, $r = -.37$, $p = .036$, and the BAPQ total scores, $r = -.35$, $p = .048$, were significantly correlated with P1 amplitude in response to surprised faces under the match condition.

In order to isolate the impact of particular types of autistic behaviors on the P1 component for the fearful emotion, which was significantly correlated with P1 amplitude, multiple linear regression analyses were conducted. The first regression was conducted with BAPQ Aloof, Rigid Behavior, and BAPQ Pragmatic Language as independent variables and P1 amplitude for fearful faces with matching instructions as the dependent variable. Results revealed that the correlation with BAPQ Pragmatic Language was still significant when controlling for BAPQ Aloof and Rigid Behavior scores, $\beta = -.46$, $t = -2.22$, $p = .034$. Additionally, since SPAI scores were significantly correlated with the BAPQ pragmatic language subscale scores, as reported in Table 1, regressions were conducted in order to isolate the impact of the BAPQ pragmatic language related behaviors. The BAPQ pragmatic language subscale was still a significant predictor of P1 amplitude for fearful faces with matching instructions when controlling for SPAI, $\beta = -.51$, $t = 2.95$, $p = .006$. The regression demonstrated that the SPAI was a predictor that almost reached a marginal level of significance when controlling for the BAPQ pragmatic language subscale, $\beta = .29$, $t = 1.67$, $p = .105$.

N170

For N170 at the TP10 electrode, there was an effect that was almost marginally significant Emotion x Instructions x Feature x BAPQ interaction, $F(4,88) = 1.99$, $p = .130$, $\eta^2 = .083$. Although this effect did not reach marginal levels of significance, we had a small sample size and a medium effect size, so we decided to break down this interaction about which we had an *a priori* hypothesis. In order to examine this interaction, we conducted separate ANOVAs for face trials and for eyes trials. For the face trials, there were no significant effects. For the eye trials, there was a marginal three-way Emotion x Instruction x BAPQ interaction, $F(4,88) = 2.46$, $p = .062$, $\eta^2 = .100$. Separate ANOVAs were then conducted for the task instructions. For the trials with matching instructions, as shown in Figure 1b, there were no significant effects. For the valence instructions trials, as shown in Figure 1a, there was a significant two-way interaction of Emotion x BAPQ pragmatic language, $F(4,88) = 3.83$, $p = .025$, $\eta^2 = .148$. Simple main effects were conducted to examine this interaction by comparing high and low BAPQ participants for each emotion. A significant effect was found with the fear trials comparing high ($M = 3.50$, $SD = 0.32$) and low BAPQ ($M = 2.17$, $SD = 0.48$), $t = -2.68$, $p = .014$. No other significant effects were found.

In order to further examine the effects of behaviors related to autism on N170 amplitude responses to emotional faces, exploratory correlational analyses were performed at the TP10 electrode across all BAPQ subscales. The BAPQ Pragmatic Language subscale, $r = .39$, $p = .022$, and the BAPQ total scores, $r = .37$, $p = .033$, were significantly correlated with N170 amplitude in response to angry eyes under the valence condition. The BAPQ Pragmatic Language subscale, $r = .51$, $p = .002$, and the BAPQ total scores, $r = .35$, $p = .047$, were significantly correlated with N170 amplitude in response to fearful eyes under the valence condition. The BAPQ Aloof subscale, $r = -.44$, $p = .009$, BAPQ Pragmatic Language subscale, $r = -.42$, $p = .015$, and the BAPQ Total, $r = -.40$, $p = .022$, were significantly correlated with N170 amplitude in response to surprised eyes under the valence condition.

In order to isolate the impact of particular types of autistic behaviors on the N170 component, regression analyses were conducted. The first regression was conducted with BAPQ Aloof, BAPQ Rigid Behavior, and BAPQ Pragmatic Language as independent variables and N170 amplitude for fearful eyes with valence instructions as the dependent variable. Results revealed that the correlation with BAPQ Pragmatic Language was still significant when controlling for BAPQ Aloof and Rigid Behavior scores, $\beta = .54$, $t = 2.75$, $p = .010$. In order to isolate the impact of autistic behaviors from those of social anxiety, an additional regression analysis was conducted. The BAPQ pragmatic language subscale was still a significant predictor of N170 amplitude for fearful eyes with valence instructions when controlling for SPAI, $\beta = .67$, $t = 4.46$, $p = .000$. The regression demonstrated that the SPAI was a significant predictor when controlling for the BAPQ pragmatic language subscale, $\beta = -.42$, $t = -2.83$, $p = .008$.

Discussion

This study explored how autistic behaviors in neurotypical young adults varying in autistic behaviors affect neural correlates of emotion processing. It also examined how these differences were characterized based on the specific emotions being portrayed, the facial features available, and the task instructions presented. In accordance with previous literature (Luo et al., 2010; Wagner et al., 2013), our study demonstrated that those with low levels of autistic behaviors showed an increase in neural attention to negative emotions, particularly fear, compared to other emotions while this increase was lacking among those with high levels of autistic behaviors. Additionally, for P1 in particular, increased amplitudes were demonstrated across multiple emotions among those with low levels of autistic behaviors and not among those with high levels, as suggested by previous literature (Hileman et al., 2011; Webb et al., 2012). Our study also supported the sensitivity of N170 for eyes (Itier & Batty, 2009) as well as the specificity of P1 and N170 for specific emotions (Batty & Taylor, 2003; Righart & de Gelder, 2008; Luo et al., 2010). In extension to this previous research, this study compared neural attention to full faces to solely the eye region and found, when only the eye region was presented, the increased N170 in response to the eyes present in those with low levels of autistic behaviors did not exist among those with high levels of autistic behaviors. Our study also demonstrated that the neural responses to viewing faces were modulated by task instructions, suggesting that variability in task design among previous emotion processing studies may in fact be testing different aspects of emotion processing and cannot be directly compared.

Both the P1 and the N170 components showed differential responses to negative emotions, fear in particular, based on autistic behaviors. Higher levels of autistic behaviors related to pragmatic language correspond with lower P1 amplitudes in response to fearful eyes in the matching condition in comparison to those with lower levels of these behaviors, as evidenced by the correlational analyses. This finding is in accordance with previous findings demonstrating that P1 increases in response to negative emotions among those with low levels of autistic behaviors (Luo et al., 2010). Higher levels of autistic behaviors related to pragmatic language correspond with lower N170 amplitudes in response to angry or fearful eyes in the valence condition in comparison to those with lower levels of these behaviors, as evidenced by the ANOVA and correlational analyses. These findings related to negative emotions supports previous clinical research, which demonstrates that N170 amplitude increases in response to fearful faces in neurotypical participants and not in those with ASD (Wagner et al., 2013). This, in combination with the current study findings, suggest that those with higher levels of autistic behaviors devote less neural attention fearful faces than those with lower levels of autistic behaviors.

When presented with only the eye region, the differences in the N170 ERP demonstrate that those with high autistic behaviors devote less neural attention to the eyes during emotion processing than do those with less autistic behaviors. Based on differences in processing, neurotypical spend more time looking at eyes when viewing a whole face than autistic individuals (Harms et al., 2010). These correlative differences in the N170 ERP demonstrate continued avoidance of the eye region in those with higher autistic behaviors, whereas those with low autistic behaviors show increased attention to the eyes when presented with only the eye region. Additionally, the increased N170 in those with low autistic behaviors fits with previous research demonstrating that in neurotypical participants, there is a larger N170 in response to the eye region than to the rest of the face (Itier & Batty, 2009). This finding extends previous research by exploring the impact of autistic behaviors in comparing neural attention to the eye region when presented alone and when a full-face is presented. Additionally, we demonstrated these effects in a subclinical population, extending previous facial scanning work comparing clinical and non-clinical groups.

While surprise has been demonstrated in behavioral studies as being difficult for autistic individuals to identify (Lacroix et al., 2009), it has not emerged in previous emotion processing studies examining the P1 or N170 ERPs in clinical or broader autism phenotype studies. Our exploratory correlational analyses demonstrated that in P1, lower amplitudes were observed in those with higher levels of autistic behaviors in response to surprise. This matches the differences in neural attention between high and low autistic behaviors found in response to fear targets. These findings support the behavioral findings that surprise and fear are processed differently compared to other emotions in individuals with ASD (Lacroix et al., 2009, Poljac et al., 2013). They also support the finding that the P1 amplitude is higher in neurotypical participants compared to those with ASD (Hileman et al., 2011). All correlation results in this study should be interpreted as, due to the exploratory nature of our analyses, we conducted many correlations, which could inflate the chance of a Type I error.

In N170, however, eyes exhibiting negative emotions produce an opposite pattern of neural attention than eyes exhibiting surprise. Higher levels of autistic behaviors related to pragmatic language correspond with higher amplitudes in response to surprised eyes in the valence condition in comparison to those with lower levels of these behaviors. More neural attention specific to N170 is paid to surprised eyes in those with higher levels of autistic behaviors than in those with lower levels. This finding contrasts with the effect of surprise on P1 amplitude and does not fit in with the current understanding of neural attention and emotion processing related to autistic behaviors. However, it does reflect the differential processing of surprise found in the behavioral literature (Lacroix et al., 2009). Previous ERP research has also focused on fewer emotions than the current study, perhaps explaining the lack of findings related to differential neural attention to surprise (Blau, Maurer, Tottenham, & McClandliss, 2007; Krobholz, Schaefer, & Boucsein, 2007).

All of the above interactions were modulated by task instructions. For example, for the electrodes chosen for P1 and N170 there were no correlations with the rigid behavior subscale found with the valence instructions. However, P1 amplitude in response to surprised faces in the match condition was significantly related to the BAPQ rigid subscale. As this subscale measures the ability to or interest in adapting behaviors in response to changes, it makes sense that the matching condition, which requires the use of working memory and a constant adjusting of the target, would be modulated by autistic rigidity. The valence condition, in which participants were required to categorize the emotions displayed by valence, was required to reveal the emotion specificity and the eye sensitivity of the N170 component as well as the differences in these caused by autistic behaviors.

Limitations to this study include that the 5-way interactions identified in the ANOVA tests did not reach traditional levels of statistical significance. However, for an interaction with this many independent variables and with a sample size this small, it is not unusual to have higher p-values, and when broken down, the smaller interactions and simple main effects were significant. Additionally, with a larger sample size and thus more power in the upper and lower thirds BAPQ subscale groups, the interactions may become more significant. It is also important to note that when the BAPQ subscales were treated as continuous variables, the effects in the correlations were much stronger, many achieving the *a priori* alpha level set for this experiment. We also did not observe effects of social anxiety on emotion processing of negative emotions that have been previously demonstrated (Phan et al., 2006; Kolassa et al., 2008). The regressions for both the P1 and N170 demonstrated that when controlling for autistic behaviors, there is a significant effect of social anxiety behaviors. These findings suggest that the effects of social anxiety on emotion processing were overpowered by that of autistic behaviors, providing a possible explanation for why we did not observe significant interactions between social anxiety measures and emotion processing in this study. Additionally, using a subclinical population may be seen as a limitation when studying behaviors related to a clinical group, however examining a subclinical population eliminates some of the difficulties with comorbidities present in clinical populations. The effects of specific types of autistic behaviors on emotion processing are easier through the self-report subscales in subclinical populations. Our reliance on college students for participants may also be seen as a limitation, however, as much of the research on autism is done comparing children with and without autism, our study addresses a population about which not much is known. College is a time at which much of the structure and support previously available to individuals with autism falls away as well as a time filled with many new social situations. Understanding the impact of autistic behaviors on social interactions for college-aged individuals in particular is important, both because of the vulnerability of this population and the lack of research currently available. It is also of note that the BAPQ was chosen for the analyses in this study due to the demonstrated weaknesses of the AQ and strengths of the BAPQ (Ingersoll et al., 2011).

Further analyses will be conducted to examine possible regional differences in P1 and N170. Additional exploratory analyses will be performed on some of the later ERP components related to emotion processing. Based on the current findings as well as previous research demonstrating larger N4 amplitudes in response to fearful faces (Leppänen, Moulson, Vogel-Farley, & Nelson), we expect to find this trend in those with low levels of autistic behaviors and not in those with high levels of autistic behaviors. In addition to these electrophysiological analyses, analyses will be conducted on the behavioral data collected during this study. Based on previous findings (Ashwin et al., 2006; Lacroix et al., 2009; Poljak et al., 2014), we expect to find those with high levels of autistic behaviors to be less accurate in identifying negative emotions and surprise, though there is some literature suggesting those with high levels may be less accurate on positive emotions beyond surprise (Kadak et al., 2014). Future studies should investigate the differential responses to surprise in P1 and N170 based on autistic behaviors, relating it to findings in behavioral literature. The differences in neural attention when the eye region is presented on its own warrant future study. Research should also explore how the type of categorization, beyond the categorization by valence used in this study, affects the type emotion processing and its neural correlates. Future studies should also explore how to relate this early emotion processing to more complex social skills and behaviors.

In this study we demonstrated, in a subclinical population, that differential neural attention is paid to fear in particular by those with low levels of autistic behaviors and not in those with high levels. Our findings also suggest that the neural response to surprise varies both by autistic behavior and by ERP component. Our participants with high levels of autistic behaviors demonstrated decreased neural attention to the eyes, even when no other facial features were presented. All of these results were modulated by the task instructions, suggesting we successfully manipulated the type of processing occurring when viewing the stimuli. By looking at these early neural components during emotion processing, we can better understand some of the basic differences in perception that drive social autistic behaviors. This understanding can then help us design interventions to address social difficulties faced by individuals with autism.

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	1	2	3	4	5	6
1. BAPQ Aloof						
2. BAPQ Pragmatic Language	.58***					
3. BAPQ Rigid	.60***	.43*				
4. BAPQ Total	.87***	.76***	.85***			
5. AQ Social Skills	.86***	.49**	.52**	.76***		
6. AQ Total	.80***	.61***	.68***	.85***	.87***	
7. SPAI Difference Score	.56**	.39*	.38*	.54**	.57***	.56**

*p<.05
**p<.01
***p<.001

Table 1. Bivariate Correlations between the Self-Report Measures and Relevant Subscales (*N*=33)

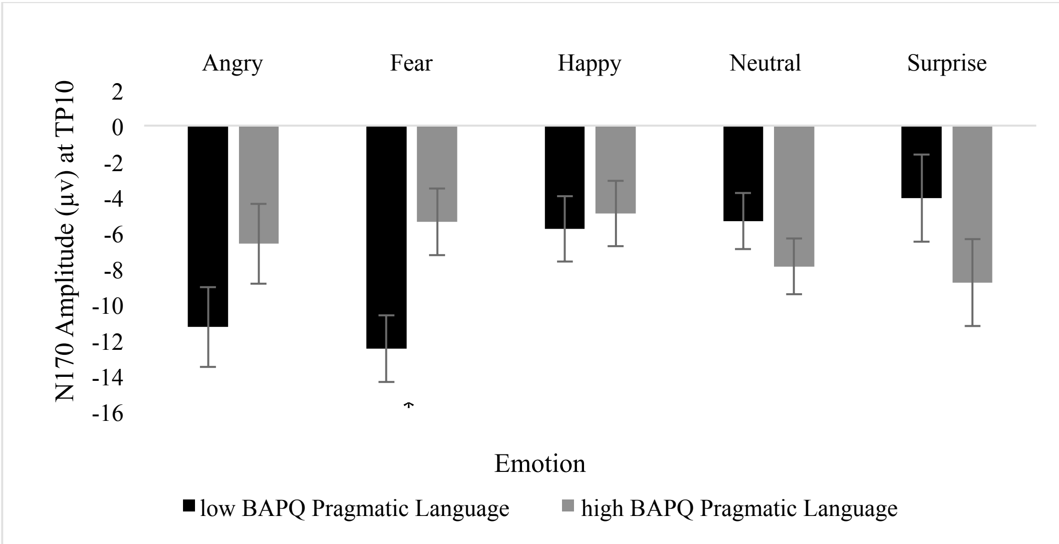

Figure 1a. N170 amplitude as a function of emotion at electrode TP10 during the eyes block with valence instructions

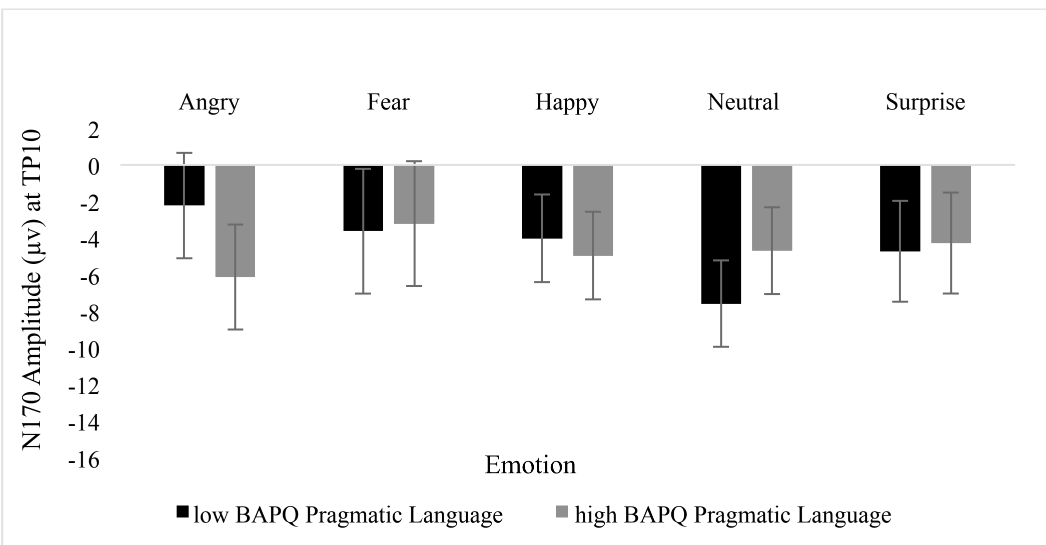

Figure 1b. N170 amplitude as a function of emotion at electrode TP10 during the eyes block with matching instructions