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Brain Activity in College Students with the Broad Autism Phenotype

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Brain Activity in College Students with the Broad Autism Phenotype

By

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Brain Activity in College Students with the Broad Autism Phenotype

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Abstract

This study examined brain activity in college students with the broad autism phenotype (BAP) while viewing facial expressions. Quantitative Electroencephalogram assessments were conducted in the temporal lobe area in the brains of 38 college students declared as Science, Technology, Engineering, and Math (STEM) majors. Participants were divided into BAP+ versus BAP- groups based on their scores on the Broad Autism Phenotype Questionnaire (BAPQ). Findings revealed that individuals categorized as BAP+ demonstrated a higher alpha relative power score and a higher T4 relative to T3 coherence Z score when looking at expressive faces than when looking at neutral faces when compared to the BAP- individuals. Also, participants classified as BAP+ had significantly lower social adjustment than those classified as BAP-. Findings discuss the possibility of using QEEG BAP+ brain markers as an objective measure of social impairments in at-risk college students.

Keywords: Broad Autism Phenotype (BAP), Autism Spectrum Disorder (ASD), Electroencephalography (EEG), alpha activity, face processing

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CHAPTER I

INTRODUCTION

Brain Activity in College Students with the Broad Autism Phenotype

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder diagnosed in one out of every 59 children in the United States (Baio et al., 2018). ASD is characterized by impairments in communication, social interactions, and restricted or repetitive interests and behaviors (American Psychiatric Association, APA, 2013). BAP is a collection of mild or subclinical deficits in social skills, pragmatic language, restricted interests and behaviors that are common in relatives of individuals with ASD (Hurley, Losh, Parlier, Reznick, & Piven, 2007). Previous investigations have found a link between individuals with ASD and activity in the temporal lobes (Critchley et al., 2000; Pierce et al., 2001; Schultz et al., 2001; Hubl et al., 2003; Wang, Dapretto, Hariri, Sigman, & Bookheimer, 2004). Activity in the temporal lobe area of the brain has been linked to impairments in the processing of facial expressions (Pierce, Müller, Ambrose, Allen, & Courchesne, 2001). The general purpose of this study was to observe the brain activity of subjects with high BAP scores while processing faces exhibiting common emotions compared to individuals with low BAP scores. In specific, the current study compared EEG activity in the temporal lobe areas while processing faces between students with high scores on a BAP questionnaire and those with low scores on the same questionnaire. This study recruited individuals in majors related to Science, Technology,

Engineering and Math (STEM) as studies have indicated an elevated prevalence of individuals with BAP in these careers (Baron-Cohen, Wheelwright, Stott, Bolton, & Goodyer, 1997; Jarrold & Routh, 1998; Wheelwright & Baron-Cohen, 2001).

CHAPTER II
LITERATURE REVIEW

Autism

Autism Spectrum Disorder (ASD) is a neurodevelopmental disorder defined by pervasive and sustained deficits in reciprocal social interaction and social communication, repetitive behavior, and restricted interests that impair daily functioning (APA, 2013). Kanner (1943) first identified social impairment as the defining characteristic of ASD. Kanner described ASD as difficulties with non-verbal communication, such as correctly interpreting facial expressions and gestures, and lack of acknowledgment of others. These core behavioral characteristics are present in early childhood and vary from individual to individual based on age, developmental level and severity of autism. ASD individuals range from low functioning with severe impairments in multiple cognitive domains to high functioning with mild impairments predominantly in the areas of social functioning (Adolphs, Sears, & Piven, 2001).

The prevalence of ASD around the world in both children and adults is close to 1% of the population (APA, 2013). Today, there is now plenty of evidence that genetic variation contributes more than 50% of the likelihood of having ASD (De Rubeis & Buxbaum, 2015; Hallmayer et al., 2011). Concordance rates of ASD in monozygous twins range from 60-95%, siblings' rate 5-30%, with a sibling recurrence rate of 18% and as high as 33% for infants born into families with two or more children with autism (Bailey et al., 1995; Ozonoff et al., 2011). Similarly, 10 to 20% of siblings of individuals

with autism have symptoms of communication and social impairments related to autism (Bolton et al., 1994). Given the above-mentioned links of the genetic liability to autism, there is a possibility of inherited familial characteristics similar to autism (Bailey, Palferman, Heavey, & Le Couteur, 1998).

The Broad Autism Phenotype

Relatives of individuals with ASD appear to show genetic liability for deficits associated with ASD (Bailey et al., 1998). As early as 1943, Kanner described unusual social behaviors in the parents of children with ASD, such as having a preoccupation with “abstractions of a scientific, literacy, or artistic nature, and limited genuine interest in people” (Kanner, 1943, p. 250). Unlike ASD, the BAP does not require impairments to be pervasive across all three domains (social skills, pragmatic language, and restricted interests and behaviors) and is a collection of milder subclinical deficits than those present in ASD (Pickles et al., 2000). Recently, a large-scale study found BAP features in 5-9% of a community-based group and significantly higher amounts of BAP features (14-23%) in parents of a child with autism (Sasson, Lam, Childress, Parlier, Daniels, & Piven, 2013).

Initially, evidence of a familial phenotype to autism began to emerge through studies conducting interviews with relatives of individuals with ASD. Wolff, Narayan, and Moyes (1988) interviewed parents of children with autism and parents of children with intellectual disabilities (blind to diagnoses) and found that compared to the parents of the children with intellectual disabilities, the parents to the children with autism had more difficulty establishing rapport, an unusual way of communicating, and a lack of

emotional responsiveness and empathy. Furthermore, the parents of the children with autism reported special interest patterns, a preference to being alone, and over-sensitivity to experience.

Landa, Piven, Wzorek, Gayle, Chase, and Folstein (1992) noted significant differences in spontaneous narrative-discourse and social language use between parents of children with autism and the control group made up of parents of children with Down syndrome and adults without children with autism. Forty-two percent of the parents of children with autism had deficits in pragmatic language skills compared to only 2% of the control group. Parents of children with autism exhibited odd humor, atypical greeting behavior, expressed ideas awkwardly, were overly talkative and changed topics abruptly. In a seminal study on BAP, Bolton et al. (1994) found that approximately 20% of siblings of individuals with ASD evidenced symptoms of autism, including social impairments, atypical communication, or restricted behaviors compared to the control group of siblings of children with Down syndrome (3.1%). Furthermore, BAP was more prevalent in male relatives of individuals with ASD. Results of ASD parents paralleled but to a lesser degree those of their non-ASD children; yet, ASD parent symptoms remained higher than those exhibited by the control group of parents and siblings of children with Down syndrome.

Piven, Palmer, Jacobi, Childress, and Arndt (1997) provided a more etiologically homogenous sample by extending this line of research with parents of children with multiple-incidences of autism. Multiplex autism families are more likely than single incidence autism families to have children with autism due to genetic causes. The genetic

liability for autism is also more likely to be higher in multiple-incidence autism probands than single-incidence probands. Using a semi-structured family history interview, Piven and colleagues (1997) compared stereotyped interests and behaviors and deficits in social communication between 25 multiple-incidence autism families and 30 Down syndrome families with the objective of better defining the BAP. Multiple incident autism families had higher rates of stereotyped behaviors and social and communication deficits than Down syndrome probands. Data replicated previous findings (Folstein & Rutter, 1977; Bailey et al., 1995; Piven et al., 1994; Bolton et al., 1994) providing further evidence of a BAP; however, multiplex autism probands have a greater genetic liability to autism than simplex autism probands and the direct comparison of the two studies is difficult (Bailey et al., 1998).

Since Bailey and colleagues' comprehensive review of BAP research (1998), a number of tools have been developed to measure the autism phenotype as a set of continuous and quantitative traits. Among these are the Modified Personality Assessment Schedule (M-PAS), adapted from the Personality Assessment Schedule (PAS); (Tyrer & Alexander, 1988, Piven et al., 1994): the PAS (Tyrer & Alexander, 1979; Tyrer et al., 1979; Tyrer & Alexander, 1988) which was constructed to formally assess a personality disorder and yielded adequate inter-rater and temporal reliability (Tyrer et al., 1979, 1983); the Autism-Spectrum Quotient, developed by Baron-Cohen, Wheelwright, Skinner, Martin, and Clubley (2001) to measure traits associated with autism in adults with normal intelligence; and the Social Responsiveness Scale (SRS; formerly referred to

as the Social Reciprocity Scale), which is a parent/teacher report questionnaire developed to quantifiably measure specific and observable symptoms of autism (Constantino, 2002).

The Broad Autism Phenotype Questionnaire (BAPQ)

The BAPQ is now the most commonly used self-report questionnaire used with adults to measure three subscales of ASD characteristics present in the BAP: aloof subscale, pragmatic language subscale, and rigidity subscale (Hurley et al., 2007). A large-scale study on 626 undergraduate college students compared the BAPQ, AQ, and SRS-A regarding their internal consistency, factor structure, distribution of scores, and criterion-related validity (Ingersoll, Hopwood, Wainer, & Donnellan, 2011). Results showed a continuous distribution and criterion validity in all three measures. Findings further revealed that the factor structure corresponding to the BAPQ is better at assessing BAP traits in the general population than the AQ or the SRS and that the BAPQ and SRS-A have better internal consistency than the AQ (Ingersoll et al., 2011).

Sasson, Lam, Parlier, Daniels, and Piven (2013) confirmed the high heritability of autism when they investigated the likelihood of both parents having BAP in groups of parental pairs of children with autism compared to parental pairs of typically developing children. Findings revealed that only a small percentage of both members of both groups of parental pairs had positive BAP composites with significantly more parental pairs with positive BAP composites in the parental pairs of children with autism (4.3%) compared to the parental pairs of typically developing children (1.6%). Significantly more pairs of parents of children with autism both had at least one BAP feature (15.1%) compared to only 5.3 % of each member of the typically developing children's parental pairs (Sasson

et al., 2013). Findings of higher rates of BAP among parents of children with autism compared to parents of typically developing children were also found in a large study conducted in China (Shi et al., 2015). Similarly, Shi and colleagues (2015) administered the BAPQ to 299 families with children with autism and 274 families with typically developing children. Total BAPQ scores were higher in both parents of children with autism and these parents also had higher scores on the Aloof personality and Pragmatic language subscales than the parents of children without autism. Unlike previous studies finding higher rates of BAPQ in fathers (Sasson et al., 2013; Seidman, Yirmiya, Milshtein, Ebstein, & Levi, 2012; Wheelwright, Auyeung, Allison, & Baron-Cohen, 2010), Bishop et al., 2004; Murphy et al., 2000), both groups had higher rates of BAP than fathers (Shi et al., 2015).

In sum, the development of various measures of the BAP has helped narrow the construct to a set of continuous, measurable traits with lesser degrees of the three defining features of ASD (pragmatic language difficulties, aloof personality, and rigid personality) that can be observed in the general population as well as in relatives of individuals with ASD (Sucksmith, Roth, & Hoekstra, 2011). These milder measurable traits of the BAP are thought to represent the genetic liability for ASD (Piven et al., 1997). Research supports the heritability of these traits (Constantino & Todd, 2003, 2005; Sasson et al., 2013) and the value of studying these traits in the general population (Constantino & Todd, 2003). Unlike other measures, the BAPQ was specifically designed to identify the BAP and therefore, has convergent validity with the BAP personality traits (Hurley et al., 2007) and has also demonstrated acceptable (>.85) internal consistency for

total score and individual subscales (Constantino et al., 2003; Hurley et al., 2007) making it to date, the best measure of the BAP.

The Impact of Social Skills Deficits on College Students with ASD

The transition to college brings much change and uncertainty that can evoke anxiety and feelings of being overwhelmed especially in students lacking in social skills. Social skills and recognition of emotions are critical during this period of adaptation to college life. Students with deficits in these skills have a harder time adjusting to college and are at greater risk of difficulties with relationships, emotional difficulties, and interpersonal difficulties. Social adjustment and emotional adjustment are as important as academic performance in making a successful adjustment to college (Gerdes & Mallinckrodt, 1994).

Taylor and Seltzer (2011) found that approximately 50% of students in high school with high-functioning ASD plan to pursue a post-secondary educational degree. In fact, now, over the past decade the number of students with ASD attending college has continued to increase and is estimated to be between 0.7% to 1.9% (White, Ollendick, & Bray, 2011). In a longitudinal study conducted by the U.S. Department of Education, 47% of young adults with autism had enrolled in a postsecondary institution within 6 years of graduating from high school but only 35% of them earned a degree compared to the 51% postsecondary degree completion rate for the general population (Sanford et al., 2011). Unfortunately, the attrition rate for college students with ASD is high, and individuals with ASD currently have an 80% failure rate (Vanbergeijk, Klin, & Volkmar, 2008). This may be because the majority of students with ASD that are admitted to

college do have the cognitive abilities to achieve academic success but are often not successful due to social and communication deficits, lack of self-advocacy skills and deficits in independent daily living skills (Adreon & Durocher, 2007). Profound social impairments in individuals with ASD interfere with college-specific social behaviors, communication, and appropriately responding to nonverbal cues (American Psychiatric Association, 2013).

The College Social Experience for Individuals with ASD

The majority of high school students leaving home to attend college will experience a disruption in their social support networks (Kenny, 1987). Oswald and Clark (2003) found that during the transition from high school to college, the number and quality of high school friendships dissipated significantly and 41% of high school best friends became more distant within the first semester of college. Developing new friendships during this time is extremely important and, in fact, can provide the crucial social support needed to counteract the stressors and challenges associated with this major life transition (Tokuno, 1986). For the student with ASD, developing friendships poses a significant obstacle. Seventy to 80% of individuals diagnosed with ASD as children will continue to experience significant impairments socially as adults (Billstedt, Gillberg, & Gillberg, 2005). Sperry and Mesibov (2005) identified forming and maintaining interpersonal relationships and developing relationships with the opposite sex as an important developmental challenge affecting the young adults with ASD. Orsmond, Krauss, and Seltzer (2004) interviewed 235 adolescents and adults with ASD

and found that almost half (46.4%) did not have a same-aged friend to mutually interact with outside an organized setting.

Mazurek (2014) was the first to investigate the impact loneliness and friendships have on adults with ASD. Adults with ASD with greater quantity and quality of friendships were less likely to be lonely. Significant positive correlations were found between loneliness and depression and anxiety. Loneliness was also associated with lowered self-esteem and life satisfaction. College students with ASD reported increases in mental health issues (Van Hees, Moyson, & Roeyersl, 2015). College students interviewed by Van Hees et al. described increases in stress, anxiety, depression, fatigue, feeling overwhelmed, and loneliness that resulted from inseparable stressors experienced in college such as: social relationships, specifically exhausting but necessary social contacts, unexpected changes, new situations, problems with time management, processing large amounts of information, and not knowing when to disclose.

By the time most individuals with ASD reach adolescence, they are painfully aware of their difficulties interacting with peers and rather than taking the risk of a possible rejection, choose to be alone (Tse, Strulovitch, Tagalakis, Meng, & Fombonne, 2007). This increased awareness of social ineptness often results in depression and anxiety (Mazurek & Kanne, 2010). There is a much greater risk of developing mood and anxiety disorders in adults with ASD compared to the general public (Moseley et al., 2011). Rates of co-morbid depression and/or anxiety in individuals with ASD are as high as 65% (Green, Gilchrist, Burton, & Cox, 2000). In fact, an inverse relationship was found between lower impairment in intelligence and social functioning and depression

(Sterling, Dawson, Estes, & Greenson, 2008). Sterling and colleagues (2008) found that of the 46 adults with ASD sampled, almost half had depressive symptoms but significantly better social skills and cognitive functioning than the other adults with ASD.

Difficulty initiating social interactions was reported by the majority of ASD adults as their most significant challenge (Müller, Schuler, & Yates, 2008). Müller and colleagues (2008) asked 18 adults with ASD to describe their social experiences. “Six major themes emerged in response to questions regarding ASD adults navigating their social worlds: (1) intense isolation, (2) difficulty initiating social interactions, (3) challenges related to communication, (4) longing for intimacy and social connectedness, (5) desire to contribute to one’s community, and (6) effort to develop greater social/self-awareness” (Müller et al., 2008, p. 177). Intense isolation was the defining feature of living with ASD that was reported by 17 of the 18 participants. Sadly, as they became more aware of their differences with age, the feelings of isolation increased. Reflections of feeling ‘out of place’ and ‘at the bottom of a remote abyss...’ were shared. Communication challenges were described such as making small-talk, understanding implicit/explicit meaning, social and emotional inferencing, and interpreting gestures and tone of voice. Longing for intimacy was desired by 15 of the 18 participants, but ambivalence toward it was also mentioned. Many of the adults with ASD shared an inability to find and sustain romantic relationships. The desire to contribute to making the world better and effort to develop social awareness was shared by the majority of adults with ASD (Müller et al., 2008).

The College Social Experience for Individuals with BAP

College students with high scores on the BAP will also experience similar social deficits as those with ASD (Ingersoll, 2010). High scores on the BAPQ were found to predict real-world social skills deficits (Sasson, Nowlin, & Pinkham, 2012). College students who reported higher amounts of BAP traits had significantly more difficulties with depression/anxiety, interpersonal relationships, and personal adjustment (Kanne, Christ, & Reiersen, 2009). Jobe and White (2007) investigated the relationship between the BAP and social functioning in a non-clinical sample of 97 college students and found that students with more characteristics of BAP had fewer friends than students without BAP, and the friendships they had were of shorter duration. A positive relationship between loneliness and non-clinical traits of BAP was observed.

Students with higher levels of BAP have a poorer adjustment to college (Trevisan & Birmingham, 2016). Typically developing college students with high scores on the BAPQ had significantly lower scores on the Student Adaptation to College Questionnaire (SACQ) in the areas of academic and social adjustment and slightly lower on personal-emotional adjustment compared to those without BAP characteristics. Pragmatic language difficulties led to the lowest adjustment scores in all areas assessed on the SACQ; whereas, aloof personality was associated with variance in social adjustment and rigid personality was associated with variance in personal-emotional adjustment (Trevisan & Birmingham, 2016).

The ASD/BAP STEM Connection

A disproportionately higher representation of engineers has been found in first and second-degree relatives of children with ASD (Baron-Cohen et al., 1997). Baron-Cohen et al. (1997), for instance, sampled 919 ASD families and found that 28.4% of the fathers or grandfathers were engineers compared to only 15% of engineers found in the control families. Moreover, the number of biological relatives with ASD was found to be significantly higher in a group of university students studying mathematics, engineering, and physics compared to a control group of students studying literature (Baron-Cohen et al., 1998). More recently, a study conducted by the Stanford Research Institute found that 36% of college students with ASD chose majors relating to STEM while only 22% of the total student body chose majors in STEM fields (Wei, Yu, Shattuck, McCracken, & Blackorby, 2013).

In 2001, Baron-Cohen et al., (2001) revealed through a large-scale study in England that university students with majors in mathematics and natural science had higher levels of autistic traits than students in social sciences and humanities. Consistent with the findings of Baron-Cohen et al., STEM students had significantly more BAP traits than other majors. Therefore, the STEM students also provide a unique population of adults known to have higher levels of BAP.

Face Processing In ASD

Difficulties processing faces most likely contribute significantly to the impairments in social interactions and communication found in individuals with ASD (Hadjikhani et al., 2004). Face processing provides nonverbal information critical to

conveying meaning and emotions in social situations. Face processing is one of the earliest forms of visual processing to develop and part of the complex social brain circuitry most likely implicated in the social interaction abnormalities and language impairments seen in autism spectrum disorder (Dawson, Webb, & McPartland, 2005).

Healthy newborns only nine minutes old showed a preference for face-like stimuli over equally complex stimuli of scrambled facial features (Goren, Sarty, & Wu, 1975). Disinterest in faces is one of the earliest observable symptoms of autism. Osterling and Dawson (1994) viewed home videos of first birthdays and noted significant differences in the amount of time one-year-olds with autism looked at the faces of others compared to typically developing one-year-olds and one-year-olds with mental retardation (Osterling & Dawson, 2002). In a large-scale study comparing three and four-year-olds with ASD to typically developing children, 111 children were shown photographs of their own mother's face, an unfamiliar face, their favorite toy, and a novel toy while electroencephalographic recordings were made of their brains (Dawson et al., 2002). Typically developing children showed brain amplitude differences to a familiar face versus a novel face and a familiar object versus a novel object. Children with ASD only showed brain amplitude differences to the familiar object versus the novel object. No significant differences were found in brain amplitudes to the familiar face versus the novel face in the children with autism, suggesting individuals with autism three and four-years of age already have impairments in face processing (Dawson et al., 2002). According to Pierce, Conant, Hazin, Stoner, and Desmond (2011), 40% of toddlers with ASD fixated longer than 50% of the viewing time on the geometric patterns instead of

social images compared to typically developing toddlers who spent 1.9 % of the children with language or global delays who spent 9% and instead both preferred to look at social images of faces over objects. Some of the ASD toddlers spent as much as 90% of their time viewing the geometric patterns. Contrary to the findings of Pierce and colleagues, Parish-Morris, Chevallier, Tonge, Letzen, and Schultz (2013) found that the amount of time children with ASD focused their attention on faces over objects was not significantly different from typically developing controls yet the ASD group scored much lower on the face processing skills. In fact, many of the social deficits found in children with ASD such as joint attention, eye contact, or reciprocating emotions involve face processing (Dawson et al., 2005). Children with autism matched on verbal and non-verbal abilities to controls demonstrated impairments in recognizing unfamiliar faces; yet, showed no impairments in attention or discrimination to buildings compared to verbal-ability matched controls (Boucher & Lewis, 1992).

The difficulties seen in children and adolescents with autism not only involve recognition of faces but also the perception of emotions (Gepner, de Schonen, & Buttib, 1994). The ability to interpret facial emotions is critical for successful social interaction. Kanner (1943) originally described ASD as a ‘disorder of affective contact,’ and the ‘persistent impairment in reciprocal social communication and social interaction’ is the essential feature of the DSM-5 diagnostic criteria for ASD (APA, 2013). Numerous behavioral studies found impairments of facial emotional processing in individuals with autism (Tantam, Monaghan, Nicholson, & Stirling, 1989; Boucher & Lewis, 1992; Gepner, de Schonen, & Buttib, 1994; Gepner, de gelder, & de Schonen, 1996; Osterling

& Dawson, 1994, 2002; Klin et al., 1999; Pierce, 2011; Parish-Morris et al., 2013). Over the last few decades, functional neuroimaging studies have shed light on the neural structures involved in the social deficits present in individuals with autism, implicating several key brain structures: the fusiform gyrus, the superior temporal sulcus, and the amygdala (Pelphrey, Adolphs, & Morris, 2004).

Processing of Facial Emotions and BAP

Behavioral findings of deficits in face processing in individuals with ASD are complemented by neuroimaging studies that also show evidence that individuals with ASD process faces differently than typically developing individuals. The converging research suggests that these differences may underlie deficits in face processing in ASD. Relatives of individuals with ASD appear to show genetic liability for milder subclinical manifestations of autism and frequently present with mild deficits in social skills and communication (Constantino et al., 2006; Rutter, 2000). These milder forms of impairments in social cognition and social skills seen in the BAP may also manifest in impaired interpretations of facial expressions (Ingersoll, 2010).

To test the genetic hypothesis that relatives of individuals with autism have more genetic liability for mild traits of autism, Baron-Cohen and Hammer (1997) compared 30 parents of children with autism with 30 parents of children without autism matched for age and IQ. Subjects were tested on their ability to analyze visual designs as quickly as possible and infer mental states from pictures of the eye region. Compared to the control group, parents of children with autism analyzed the visual designs faster but showed significant deficits accurately attributing mental states to pictures of the eye region;

fathers of children with autism did significantly worse than mothers of children with autism (Baron-Cohen & Hammer, 1997). Extending this genetic hypothesis, Dorris, Espie, Knott, and Salt (2004) found similar results in the typically developing siblings of children with autism. Two studies furthered the genetic link to the social characteristics of the BAP (Losh & Piven, 2007; Losh et al., 2009). The 'Eyes Test,' which measures the ability to infer emotional states from the eyes-only region of the face, was administered to 48 parents of individuals with autism (13 identified in the 'aloof' subgroup) and 22 control parents. Overall, the performance of the parents of individuals with autism was unimpaired on the 'Eyes Test'; however, significant deficits were observed in the performance on the 'Eyes Test' in the 13 parents in the 'aloof' subgroup. The 'aloof' subgroup of parents had social-cognitive impairments similar to the ones seen in autism, with difficulties in pragmatic language use and low quality of friendships. Similar to the deficits seen in individuals with autism (Adolphs et al., 2001; Baron-Cohen et al., 2001), parents with high levels of BAP also showed impairments in facial affect processing (Losh et al., 2009). Parents of children with autism were administered the MPAS and divided into groups of BAP+ and BAP- and then compared to a control group of parents of typically developing children on their ability to infer the emotional states represented in pictures of the eye region of a face. The BAP+ group perceived positive faces as more negative than the BAP- and control groups (Losh et al., 2009). Other studies found that parents of children with autism discriminated the facial expressions just as well as parents of typically developing children (Adolphs, Spezio, Parlier, & Piven, 2008; Bölte & Poustka, 2003).

Parents of children with autism were assessed for BAP and those with high levels of “aloof personality” were placed in the BAP+ group, and those with no evidence of “aloof personality” were placed in the BAP – group. Both groups, along with a control group of parents of typically developing children, were presented with decomposed pictures of an entire face and asked to determine as quickly as possible if the expression was one of fear or happiness. Similar to strategies used by individuals with autism (Spezio, Adolphs, Hurley, & Piven, 2007), the BAP+ group spent more time processing the mouth region than the eye region when compared to the BAP- or control groups (Adolphs et al., 2008).

In a large study conducted in Germany, Bölte and Poustka (2003) investigated basic emotional recognition abilities in 102 probands of individuals with autism compared to 46 probands of individuals with schizophrenia and 22 control probands. Both multiplex and simplex probands were included in the study. Subjects viewed 50 photographs depicting seven neutral expressions, seven happy, eight sad, five fearful, eight of anger, six of surprise, six of disgust, one mixed happy/surprise, one mixed happy/neutral, and a mixed sad/neutral. No significant differences were found between these groups in their ability to judge facial affect. Differences were found in performance between the autistic and schizophrenic probands. Families with one individual with autism did significantly better on facial affect recognition than the families with multiple individuals with autism. This trend was not observed between the schizophrenic multiplex and simplex relatives suggesting that deficits in facial affect recognition may be genetically specific to autism (Bölte & Poustka, 2003).

Mothers and fathers of 20 children with severe autism along with 40 individuals acting as controls were asked to state the emotion expressed in a drawing of a face (Palermo, Pasqualetti, Barbati, Intelligente, and Rossini, 2006). Both parents of children with autism performed just as well as controls on facial recognition and visual organization tasks but showed difficulties labeling emotions. The fathers of a child with autism performed significantly worse than the mothers of a child with autism and worse than male and female controls. The mothers with a child with autism did better than the fathers of a child with autism but not as well as the male and female controls (Palermo et al., 2006).

Wallace, Sebastian, Pellicano, Parr, and Bailey (2010) comprehensively investigated face-processing difficulties in relatives of ASD individuals by comparing face discrimination, facial expression recognition and judging eye-gaze direction abilities in a group of parents and adult siblings of individuals with ASD, adults with ASD and typically developing adults. The relatives had more difficulty than the typically developing adults when it came to seeing subtle differences between the faces but were still better at discriminating differences than the individuals with ASD. Compared to the typically developing adults the relatives were far worse at identifying expressions of disgust and fear and also exhibited a similar pattern seen in adults with ASD of being more sensitive to direct eye gaze direction than averted eye gaze (Wallace et al., 2010).

Contrary to prior research conducted using the 'Eyes test,' Miu, Pana, and Avram (2012) found no differences in emotional face processing accuracy but longer response times in students with high autistic traits compared to students with low autistic traits.

Two groups of college students were selected based on their AQ scores: 34 students with high AQ scores of >21 and 47 students with low AQ scores of <13. Participants viewed a computer presentation of 36 photographs of the eye-region of the face with four words in each corner of the screen describing what the person was thinking or feeling. Participants were asked to choose the word that best described how the person photographed was thinking or feeling. No significant differences were found between the groups on the number of errors they made, but the group with the high AT scores took longer to respond correctly. Results were interpreted as reflective of reduced cognitive efficiency when inferring the emotions of another and as an extension of the research linking the BAP to a continuous distribution found in the general population (Miu et al., 2012).

Face Processing Biological Structures and Function

Face processing activates a network of neural structures in cortical regions in the inferior temporal lobe, along with the parietal and frontal cortex of the brain (Atkinson & Adolph, 2011). The face-processing network includes the fusiform-gyrus (fusiform-face area) (Kanwisher, McDermott, & Chun, 1997), the superior temporal sulcus, and the lateral occipital cortex (inferior LOC, face-selected regions are labeled the occipital face area, OFA). The face-processing network extends to include the amygdala, inferior frontal gyrus, middle frontal gyrus, and orbital frontal cortex (Sabatinelli et al., 2011). Neuroimaging studies on face processing have revealed abnormal brain activity in several regions of the brain in individuals with ASD, specifically the fusiform gyrus for processing faces, the superior temporal sulcus processes facial movement, and the amygdala for processing emotions (Aylward, Bernier, Field, Grimme, & Dawson, 2004).

Fusiform Gyrus

The fusiform gyrus is located in a region of the brain referred to as the occipitotemporal cortex and is specialized for facial processing (Puce, Allison, Asgari, Gore, & McCarthy, 1996; Kanwisher et al., 1997; McCarthy, Puce, Gore, & Allison, 1997). Puce and colleagues (1996) took functional magnetic resonance images (fMRI) of twelve normal subjects viewing a sequence of stimuli meant to evoke different regions of the brain. Results demonstrated bilateral activation of the fusiform gyrus when viewing the face stimuli, with additional activity in the right occipitotemporal and inferior occipital sulci and part of the lateral cortex in the middle of the temporal gyrus (Puce et al., 1996). The fusiform face area showed significantly more brain activity on fMRIs when healthy subjects viewed intact faces over scrambled faces, photographs of front-views of faces over photographs of front views of houses, and photographs of three-quarter-view faces over photographs of human hands (Kanwisher et al., 1997). McCarthy et al. (1997) also used fMRIs and found activation in bilateral regions of the posterior fusiform gyrus when faces were presented interspersed with pictures of objects and nonobjects. Differences were found in which region activated depending on whether faces were viewed among nonobjects (bilateral regions of the posterior fusiform gyrus) or objects (focal right fusiform region).

Research has well documented the activation of the fusiform gyrus during face processing (Puce et al., 1996; Kanwisher et al., 1997; McCarthy et al., 1997). Only in the past few decades has it become evident through the use of neuroimaging techniques that individuals with autism process faces in different areas of the brain than typically

developing individuals (Schultz et al., 2000). In the first study to investigate the involvement of the fusiform gyrus in individuals with autism while discriminating faces, Schultz and colleagues (2000) used functional magnetic resonance imaging (fMRI) on 14 individuals with high functioning autism and two matched normal control groups. Confirming previous studies, the control groups showed activation of the fusiform gyrus area while processing faces; whereas, the autism group did not. Instead, the autism group discriminated faces in the inferior temporal gyri, an area of the brain used by normal individuals to process objects. The study was unable to determine if these differences were biological or due to lack of experience with faces and a feature based processing style (Schultz et al., 2000). At around the same time, other researchers were questioning if there would be neurobiological differences between individuals with high functioning autism and normal controls in the processing of faces when emotions were involved (Critchley et al., 2000). Nine adult males with high-functioning autism were compared to nine intellectually matched controls on conscious (explicit) and unconscious (implicit) processing of emotional expressions. Functional magnetic resonance images showed that the individuals with high-functioning autism failed to activate the fusiform face area during the conscious (explicit) task and lacked activation of the left amygdala and left cerebellum during the unconscious (implicit) task. Even when matched for intelligence, individuals with high-functioning autism showed biological differences from controls when processing facial expressions (Critchley et al., 2000).

Time and again neuroimaging studies found similar results of hypoactivity in the fusiform gyrus when individuals with autism processed faces. Functional magnetic

resonance imaging was performed on seven adult males with autism and eight normal controls while viewing a nonrepeating series of 60 faces and 60 shapes (Pierce et al., 2001). All eight of the normal control subjects showed maximal activation of the fusiform face area; yet, adults with autism demonstrated abnormally weak or no activation of the fusiform gyrus area and also had increased activity in individual specific neural sites (e.g., frontal cortex, occipital cortex, and anterior fusiform gyrus) (Pierce et al., 2001). One study measured neural activity through blood oxygen level-dependent (BOLD) signal changes in different regions of the brain during processing of faces and complex patterns (Hubl et al., 2003). When processing faces the seven children with autism had lower BOLD signals (lower activity) in the fusiform gyrus and higher BOLD signals (more activity) in the medial occipital gyrus, an area used for object-related visual processing involved in visual search (Hubl et al., 2003). Compared to matched age controls individuals with ASD evidenced lower fusiform activity when judging their own emotional reactions to faces and when inferring emotion from others. Social deficits in the ASD individuals were inversely related to the activity levels in the fusiform gyrus with decreased frontal gyrus activity being observed in the ASD individuals whose reactions to facial emotions were the least congruent (Greimel, 2010).

Amygdala

The amygdala is part of the limbic system and is located in the anterior medial temporal lobe (Amunts et al., 2005). The amygdala is thought to have a neurobiological basis for social cognition and along with the orbito-frontal cortex and superior temporal gyrus has been referred to as the “social brain” (Brothers, 1990). Decreased activation in

the amygdala region was found when subjects with autism were asked to judge the mental states of others by looking at photographs of the eye region and choosing the best word choice out of two words to describe what the person might be thinking or feeling (Baron-Cohen et al., 1999). Functional magnetic resonance imaging results of six subjects with autism and 12 healthy subjects matched for age, handedness, socioeconomic status, education, and IQ showed increases in activation in the amygdala, the superior temporal gyrus and the prefrontal cortex in the subjects without autism. The subjects with autism instead showed hypoactivation of the amygdala and increased activation in the temporal lobe, possibly to use facial memory and language to compensate for the dysfunction of the amygdala (Baron-Cohen et al., 1999). Adult males with high-functioning autism also showed significant biological differences in the amygdala region when unconsciously processing facial emotions (Critchley et al., 2000). Brain scans were conducted on nine adult males with average intelligence compared to nine controls matched on sex, age, handedness, and IQ while viewing alternating male and female pictures depicting Happy/Angry vs. Neutral expressions and asked to indicate the sex of the picture by pressing one of two buttons: Male - Female. During this implicit task, the amygdala and the left cerebellum were activated in the controls but not in the individuals with autism (Critchley et al., 2000). In the majority of studies individuals with ASD showed hypo-activation in the amygdala area when processing faces when compared to controls (Critchley et al., 2000; Hadjikhani et al., 2004; Grelotti et al., 2005; Dapretto et al., 2005; Hadjikhani et al. 2007). However, a couple of studies found hyper-

activation of the amygdala area during face processing (Dalton et al., 2005; Monk et al., 2010).

Amygdala activation can differ depending on the task demands. Typically developing children and adolescents were found to modulate their level of amygdala activation depending on the task demand and showed more amygdala activation while labeling faces with emotions than when choosing a word to best describe the emotion (Wang et al., 2004). Children and adolescents with autism showed no difference in amygdala activation when matching faces with emotions compared to tasks involving the use of language (choosing a word to label the emotion) (Wang et al., 2004). Individuals with lesions to the amygdala have significantly more difficulty recognizing fear (Adolphs, Tranel, Damasio, & Damasio, 1994; Adolphs, Tranel, Damasio, & Damasio, 1995; Broks et al., 1998; Sprengelmeyer et al., 1999; Anderson & Phelps, 2000), anger and surprise (Adolphs et al., 1999), as well as disgust and sadness (Schmold & Squire, 2001). The deficits seen in individuals with autism are similar to the impairments present in individuals with lesions in the amygdala (Adolphs, Sears, & Piven, 2001). Whole brain scans of the amygdala using structural magnetic resonance imaging on 15 individuals with high-functioning autism found significant decreases in the grey matter in the individuals with high-functioning autism compared to the 15 controls matched for age and IQ (Abell et al., 1999). Decreased amygdala volume has been linked to nonverbal social impairment in adolescents and adults with autism (Nacewicz et al., 2006). Remaining blind to each subject's diagnosis, researchers measured amygdala volume in 54 males with ASD and 26 controls matched for age and sex using high-resolution

anatomical magnetic resonance imaging techniques. Individuals in the ASD group had smaller amygdalae than controls, and those in the ASD group with the smallest amygdala took the longest to identify happy, angry, or sad facial expressions, 40% longer than subjects with the larger amygdala. These same subjects were reported to have significant deficits in social reciprocity (Nacewicz et al., 2006).

BAP Brain Findings

Unaffected siblings of individuals with autism have differences in brain structure and function from typically developing individuals (Dalton, Nacewicz, Alexander, & Davidson, 2007). Functional magnetic resonance imaging of the brains of 12 subjects with autism, 10 of their unaffected siblings, and 12 healthy controls while performing face-processing tasks known to evoke atypical patterns of brain activity in individuals with autism resulted in hypoactivation of the fusiform gyrus in the individuals with autism and their siblings but not in the control group. Like their siblings with autism, the unaffected siblings not only had diminished fusiform activation while processing pictures of faces but also had a significant reduction in their amygdala volume (Dalton et al., 2007).

Adolescents with autism and their fathers showed differences in brain activation while engaged in tasks that involved emotional responses to the faces (Greimel et al., 2010). Groups were tasked to infer emotions from faces or judge their own emotions. The ASD group had trouble providing congruent responses to their own inferred emotions to faces; whereas their fathers showed no deficits in performance on either task; however, both the ASD group and their fathers showed less activity in the fusiform gyrus

area than the control group during all tasks. Yucel et al. (2014) extended the knowledge base of the brain neural circuitry implicated in the genetic link to ASD through fMRIs findings that parents of children with ASD showed more activation in the core face-processing regions of the brain, the amygdala, and the fusiform gyrus than control parents. The ASD parents with high aloof scores on the BAPQ had hyper-activation of the lateral occipital cortex (LOC) bilaterally, which was attributed to behavioral features of the BAP.

QEEG in ASD

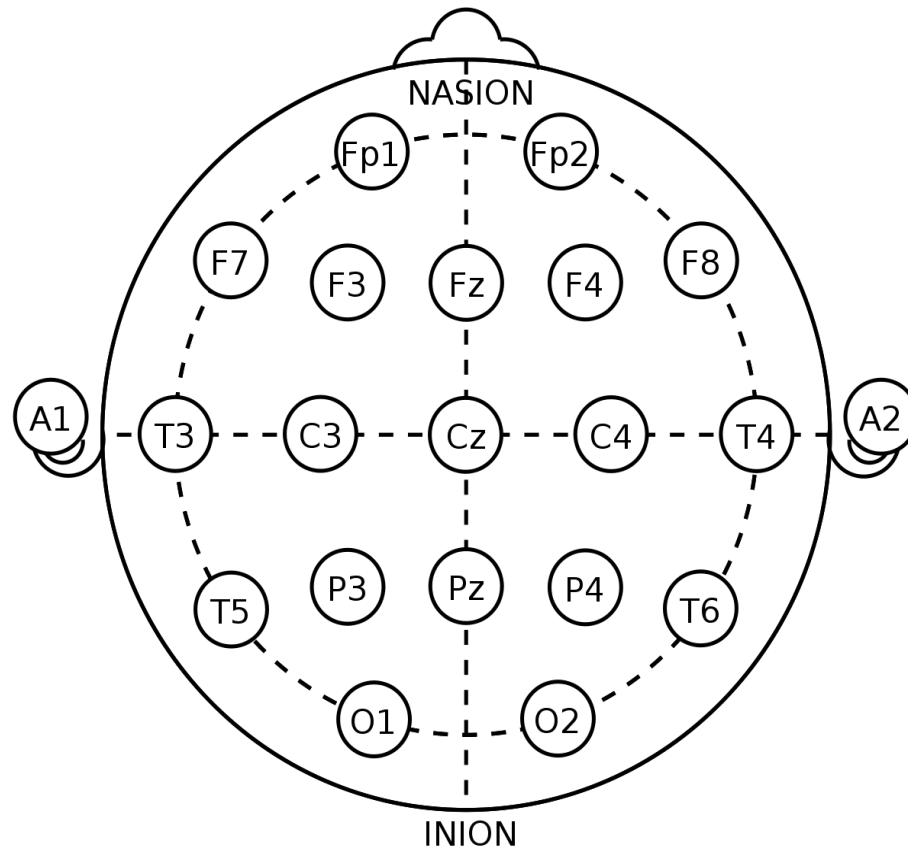
Electroencephalogram (EEG) is a non-invasive procedure used to measure the electrical activity of firing neurons in the brain through metal electrodes filled with conductive substance placed on the head to record and amplify the sound of synaptic excitation of neurons in the outer section of the cortex. A quantitative electroencephalogram (QEEG) as defined by the American Academy of Neurology is “the mathematical processing of digitally recorded EEG in order to highlight specific waveform components, transform the EEG into a format or domain that elucidates relevant information, or associate numerical results...” (Nuwer, 1997, p. 278). The QEEG applies computerized mathematical algorithms to change the raw EEG data into frequency bands. The raw EEG data falls on a continuum of states of consciousness ranging from deep dreamless sleep to active alertness. The standard classification of frequency bands includes: Delta (1.5 – 3.5 Hz), Theta (3.5 -7.5 Hz), Alpha (7.5 -12.5 Hz), Beta (12.5 – 30 Hz), and Gamma (30 – 70 Hz) (Steriade, Gloor, Llinás, Lopes da Silva, & Mesulam, 1990). The mu rhythm (8 - 13 Hz waveform found over the sensorimotor

cortex) is also studied in ASD research since mu suppression has been linked to mirror neuron system (MNS) functioning and MNS dysfunction has been thought to explain social deficits in ASD (Williams, Whiten, Suddendorf, & Perrett, 2001).

There is an International 10/20 system (See Figure 1) of placement of the electrodes to measure the range of synaptic excitation of neurons that can be anywhere from 5 to 100uV with a frequency of 1 to 40Hz (Dubey & Pathak, 2010). The International 10/20 system was developed by Jasper (1958) and was the first system to consistently provide absolute measurements that could generalize to varying head sizes. Computerized algorithms (i.e., Fourier Transform, Welch Model) transform the collected brain electrical activity from time domain into frequency domain to obtain the absolute and relative spectral power, which provides information on how the electrical activity is distributed throughout the brain and a scalp map of varying frequency bands is obtained (Dumermuth & Molinari, 1987). Coherence and symmetry are analyzed to measure communication pathways (connectivity) of brain activity.

Figure 1

International 10/20 System



Coherence is found when the windows of communication for input and output of the neuronal assemblies are open at the same time allowing the electrical activity of the neural groups to communicate effectively (Fries, 2005). Symmetry is determined by measuring the differences in brain activity between the two brain hemispheres. This scalp map data is entered to an age-matched normative database and cortical areas with abnormal activation can be identified. Poorly regulated cortical activity in specific frequency bands may indicate significant brain dysfunction or cognitive impairment (high delta); attentional difficulties or internal focus (slow theta); learning difficulties or

emotional instability (high alpha); increased levels of anxiety and irritability (excessive beta); or difficulties with problem solving and consolidating memories (high gamma) (Thompson & Thompson, 2003). Electrodes are placed in different areas over the brain and labeled with letters to specify each brain area (F for Frontal, C for central, T for temporal, P for parietal, and O for occipital). Electrodes on the left hemisphere are labeled with odd numbers, the right hemisphere even numbers, and midline the letter “Z” for zero (Libenson, 2012).

QEEG in Children with ASD

Research on individuals with ASD has been limited, the majority conducted on children with ASD with small sample sizes and the results have been inconsistent. Despite the inconsistencies, numerous studies have found a 10 to 83% rate of EEG abnormalities in individuals with ASD (Coben, Linden, & Myers, 2010). EEG abnormalities are linked to intellectual deficits, language impairments, and poor academic achievement (Hughes & John, 1999). The EEGs of low-functioning children with autism were found to be similar to those seen in toddlers, specifically with levels of alpha decreased and significant increases in slow wave activity and less inter- and intra-hemispheric asymmetry than healthy controls and the children with intellectual disabilities (Cantor, Thatcher, Hrybyk, & Kaye, 1986). Infants diagnosed with autism showed impairments in the left cerebral hemisphere (Dawson, Warrenburg, & Fuller, 1982). Seven out of the ten infants with autism showed differences on EEGs used to measure hemispheric activity, demonstrating a lack of left-hemispheric specialization in the region of the brain used for linguistic functions (Dawson, Warrenburg, & Fuller,

1982). Dawson, Klinger, Panagiotides, Lewy, and Castelloe (1995) compared activity in the frontal, temporal, and parietal regions of the brain on 28 children with autism with two groups of typically developing children (one matched for receptive language level and the other for age). EEGs were conducted during an alert baseline condition, and the children with autism demonstrated lower EEG power in the frontal and temporal regions of the brain compared to the typically developing children. The children with autism had significantly lower levels of activity in the left hemisphere than the right. Lower levels of alpha EEG power were found in the frontal region of the brains of the children classified as more “passive” when compared to the children with autism classified as more “active but odd” (Dawson et al., 1995).

Initially, individuals with autism were treated with Neurotherapy for symptoms associated with Attention Deficit Disorder. In the first study of QEEG findings in children with Asperger’s Syndrome, Ross and Caunt (2004) compared QEEG characteristics of seven children with Asperger’s Syndrome to seven children with Attention Deficit Disorder using a Lexicor 19-channel system during eyes-closed, eyes-open, and while reading and performing math problems. The individuals with Asperger’s Syndrome showed elevations of 4-7 Hz activity in the posterior regions, dissociation produced loss of regulatory control between anterior and posterior regions of the cortex, and slowing at the vertex; whereas, the children with Attention Deficit Disorder also had elevation of 4-7 Hz activity but in different regions of the brain (anterior and central regions), also had slowing at the vertex, but did not show regulatory dissociations between anterior and posterior regions of the brain (Ross & Caunt, 2004). Findings

revealed that although the presenting symptoms seen in Asperger's Syndrome and Attention Deficit Disorder are similar, significant differences are found in QEEG characteristics revealing the involvement of different regions of the brain (Ross & Caunt, 2004). Using 19 channel EEG recordings of raw EEG, relative power, absolute power and multivariate connectivity, Linden (2004, 2006) was able to identify four QEEG subtypes of autism:

- (1) Over-focused/over aroused pattern (high beta)
- (2) Abnormal EEG/seizure pattern
- (3) High delta/theta
- (4) Low voltage/metabolic

Linden also identified two QEEG subtypes of Asperger's:

- (1) High theta/alpha slowing in the right temporal/parietal areas and
- (2) Low coherence between right temporal/parietal brain regions and other regions

Most students with Autism showed coherence abnormalities; 50-60% had the high beta subtype evidenced by anxiety, obsessing, and over focusing; whereas, the delta/theta subtype associated with inattention, cortical slowing, hyperactivity, and impulsivity was seen in 30-40%; the abnormal subtype associated with EEG/seizure activity was found in 33%; and the metabolic subtype with low brain activity was found in 10% of the students with Autism (Linden, 2004). The profile that emerged for the students with Asperger's presented in the areas of the brain used for social/emotional recognition known as the right temporal and parietal regions (Linden, 2004). Linden (2004) observed that the

students with Asperger's often had more than one subtype. One QEEG profile was found to be 17 times more likely in children with ASD (Chan, Sze, & Chung, 2007).

Chan and colleagues (2007) compared QEEG profiles of 66 children with ASD and 90 normal controls and found that children with ASD had significantly lower relative alpha and higher relative delta than normal controls of the same age and the findings were widespread across the cortex and not specific to one area of the brain. The profiles had 91% sensitivity and 73% specificity differentiating 91% of the children with ASD and 73% of the normal children. Coben, Clarke, Hudspeth, and Barry (2008) compared QEEGs of 20 children with autism to 20 matched controls during eyes-closed resting conditions and found neural underconnectivity, differences in intra and interhemispheric coherence, and group differences in power. A pattern of underconnectivity on the long and short to medium inter-electrode distances was seen in the children with autism causing decreases in the interhemispheric delta and theta coherence. Children with autism had excessive theta in the right posterior regions of the brain, decreases of delta in the frontal cortex, and too much midline beta. The right temporal cortex may have reduced the ability to generate EEG rhythms in children with ASD (Stroganova et al., 2007).

Stroganova and colleagues (2007) found evidence of abnormal functional brain lateralization in boys with ASD. EEGs were recorded in 45 three- to eight-year-old boys while remaining still and maintaining visual attention to moving stimuli. Spectral power and asymmetry were analyzed within delta, theta, and alpha bands and compared to 45 typically developing boys. Theta and alpha bands were not homogenous in the ASD group. Upon elimination of 4 outliers, the ASD group displayed a between-group

difference in spectral power of a higher amount of prefrontal delta. EEG recordings further yielded a maximum effect over midtemporal regions of the brain of atypical leftward broadband EEG asymmetry in the boys with ASD. Also, the boys with ASD showed an absence of the normal leftward asymmetry of mu rhythm, suggesting that the lateralization abnormalities in ASD may be regionally/functionally specific (Stroganova et al., 2007). Coben et al. (2008) conducted the largest comprehensive study on EEG power and coherence in children with ASD with the purpose of investigating topographical differences in cerebral functioning using an eyes-closed resting condition to record EEGs on 20 children with ASD matched by age, gender, and IQ to 20 typically developing children. Findings revealed that the children with ASD had excessive beta over the midline, deficits in delta over the frontal cortex, and excessive theta, especially in the right posterior regions.

Compared to the typically developing children, within hemispheres the children with ASD demonstrated patterns of under-connectivity with decreases in delta and theta across short to medium and long inter-electrode distances; between the hemispheres, low delta and theta coherence was observed across the frontal region. Hypo-coherence in delta, theta, and alpha was also present across the temporal regions. Posterior regions showed low delta, theta, and beta coherence measurements. Consistent with previous studies, results indicate patterns of under-connectivity and dysfunctional integration of posterior and frontal regions of the brain in children with ASD (Coben et al., 2008). QEEGs of nine children with autism were compared with a normative database of QEEGs from healthy children, and brain rate was calculated (Pop-Jordanova, Zorcec,

Demerdzieva, & Gucev, 2010). The children with autism had slower brain activity and significantly lower calculated brain rate indicating lower mental arousal, and increased frontal lobe delta-theta activity compared to the normative database (Pop-Jordanova et al., 2010).

QEEG in Adults with ASD

Murias, Webb, Greenson, and Dawson (2007) found that adults with ASD have a different pattern of resting EEG and functional connectivity than adults without ASD. EEG coherence was analyzed between pairs of electrodes using a high-density electrode array on narrow frequency bands in 18 adults with ASD compared to 18 control adults during an eye closed resting state. For the ASD group elevated coherence in the left hemisphere frontal and temporal regions was revealed in the theta range (3-6 Hz); whereas, reduced coherence was evident in the lower alpha range (8-10 Hz) for the entire frontal region and between the frontal and scalp regions. These findings support the hypothesis of connectivity deficits between frontal regions and other regions of the brain (Murias, Webb, Greenson, & Dawson, 2007). Coben, Hirshberg, and Chabot (cited in Coben et al., 2010) analyzed QEEG profiles of 91 individuals with Autism and 310 healthy controls and found five relative power subtypes and connectivity anomalies in 83% of the individuals with Autism. Most individuals with Autism had an overlap of subtypes, but 26.5% showed only high levels of beta, 25.3% of alpha, and 4.1% of theta. Dysfunction specific to the frontal lobe with too much theta and alpha was seen in 10.9% (cited in Coben et al., 2010).

Similarly, Mathewson and colleagues (2012) presented the first link of brain activity to specific behavior to ASD. EEG alpha power and coherence was examined in all five frequency bands in 15 adults with ASD matched to 16 unimpaired adults while at rest in eyes-closed and eyes-open situations such as social functioning and attention to detail and compared to the unimpaired adults, the group with ASD reported more difficulty with the social functioning tasks (social skills, communication, attention switching and imagination), yet no differences in alpha activity was observed between the groups. When required to pay more attention to detail the ASD group showed reduced coherence and decreased alpha power compared to the control group. The ASD group also scored higher than the controls in all areas of the AQ, even attention to detail. It appears that adults with ASD are automatic in their ability to process details and require less synchronized neuronal units compared to unimpaired adults (Mathewson et al., 2012).

Conclusion

There is an abundance of behavioral and physiological research documenting the differences in brain interconnectivity between individuals with ASD and healthy controls when recognizing emotional information from faces and social interactions. Individuals with the BAP have subclinical levels of the three defining features of ASD (pragmatic language difficulties, aloof personality, and rigid personality) and most likely have interconnectivity differences, albeit to a lesser degree. At this time there is limited research on brain activity in adults with the BAP. Considering the importance of emotional recognition and social skills to adjustment to college, investigating the

differences in brain activity of college students with high BAP scores while processing faces compared to those with low BAP scores may bring possible interventions closer to the forefront. The aim of this study was to determine if there are differences in physiological characteristics of subjects with BAP symptoms while processing facial expressions compared to subjects without BAP.

Purpose of the Study

The general purpose of this study was to determine the electrophysiological characteristics of college students attending classes in STEM with high levels of BAP symptoms compared to control college students attending the same classes with low levels of BAP symptoms. In specific, the current study compared levels of brain activity while processing facial expressions between students with high BAP and those with low BAP scores.

Problem

Use a QEEG assessment to measure alpha, theta, and high beta relative power and coherence scores to determine physiological differences while processing facial expressions between those with high BAP and those with low BAP.

Hypotheses

Consistent with the literature (Linden, 2004, 2006), it was hypothesized that:

- I. Those with higher BAP symptoms would demonstrate a high relative power z score alpha activity at locations T3, T4.
- II. Those with higher BAP symptoms would demonstrate a high relative power z score theta activity at locations T3, T4.

- III. Those with higher BAP symptoms would demonstrate a high relative power z score high beta activity at locations T3, T4.
- IV. Those with higher BAP symptoms would demonstrate a low coherence z scores between locations T3, T4 on alpha, theta, and high beta frequency bands.
- V. Finally, those with high BAP would demonstrate low adaptation to college and more difficulty maintaining meaningful friendships.

CHAPTER III

METHOD

Participants

Data was collected from 38 undergraduate and graduate students attending a regional university in East Texas who are declared Science, Technology, Engineering, and Math (STEM) majors. Participants were recruited via fliers posted in the hallways in buildings where STEM classes were offered. The fliers included a link to the Human Neuroscience Laboratory website for participants to sign up online. Participants were instructed that the purpose of the study was to compare brain activity in STEM students with certain personality traits to the brain activity of STEM students with other personality traits.

The solicited participants were screened for the following inclusion criteria: (1) reported age ≥ 18 years; (2) no history of seizures or neurological condition; (3) no metal plates or implants in their skulls; (4) not currently wearing earrings; (5) have hairstyles that permit access to scalp (e.g. no dreadlocks); and (6) have hair free of products (e.g. hairspray, gel, mousse). Participants were instructed that they would be administered a QEEG assessment and then asked to complete questionnaires. The QEEG assessment and possible side effects were described to the students and informed consent in writing was obtained by the participants prior to participation. Participants were explained that upon signing informed consent they would each be assigned a number and that all information obtained would remain confidential. Participants were informed that a QEEG assessment to map their brains would be reviewed with them by the examiner and that results would

be provided to them. However, there would be no clinical interpretation of such results. This protocol was approved by the Institutional Review Board (IRB) at the regional university in East Texas.

Equipment and Measures

Quantitative Electroencephalography (QEEG) Assessment. A QEEG assessment was conducted while the participant viewed images on the computer of faces with expressions. BrainMaster Discovery 24E hardware was used to amplify the EEG signal. EEG data was recorded from 19 electrodes placed on the skull (10/20 system), with ground and reference electrodes placed on Cz (somatosensory cortex central location). EEG analysis was completed using the commercially available NeuroGuide software (Applied Neuroscience, Inc.) on locations T3 and T4 for the frequency bands: Theta, Alpha, and High Beta. Relative power and coherence raw scores were transformed to age standardized scores (z-scores) by comparing them to the BrainDx EEG data base (Neuroguide database, Thatcher, Walker, Biver, North, & Curtin, 2003). For the purpose of this study, we recorded 5 minutes of EEG with eyes open for each condition. For analysis, approximately 120 seconds of artifact-free EEG segments were selected.

Face Stimuli. One hundred black and white pictures of neutral faces and 100 black and white pictures of faces depicting basic emotions found across cultures (happy, sad, angry, disgusted, fearful, surprised) based on the findings of Ekman, Friesen, and Ellsworth (1972) were used as the stimuli. The order of presentation of the 100 randomized neutral faces and the 100 randomized expressive faces alternated by each participant and each face was presented for 3 seconds.

The Broad Autism Phenotype Questionnaire (BAPQ). The BAPQ is a self-report questionnaire used with adults to measure three subscales of ASD characteristics present in the BAP: aloof subscale, pragmatic language subscale, and rigidity subscale (Hurley et al., 2007). The BAPQ contains 36 items on a 6-point scale, with responses ranging from very rarely, to very often. The BAPQ provides a total score and scores for the three subdomains. The BAPQ demonstrated excellent internal consistency with Cronbach's scores ranging from 0.80 to 0.95 (Sasson et al., 2013). Recently, the BAPQ performed better than the Social Responsiveness Scale (Constantino, 2002) and the Autism Quotient (Baron-Cohen et al., 2001) in measuring internal consistency, criterion validity, and incremental validity of the BAP in non-clinical adults (Ingersoll et al., 2011). Although Hurley and colleagues (2007) originally set the BAP cutoff at 3.15, a recent empirical study suggested that higher cutoffs of 3.17 for females and 3.55 for males would lead to fewer false positives (Sasson et. al, 2013).

The Student Adaptation to College Questionnaire (SACQ). The Student Adaptation to College Questionnaire (SACQ) was originally created by Baker and Siryk, (1984) consisted of 52 items that measured a participants' adjustment to college. The SACQ will be used to explain how possible relationships between BAPQ and QEEG scores impact student's college adaptation. The SACQ used for this study has been modified and copyrighted by Western Psychological Services (1989) and now contains 67 items and four subscales: Academic Adjustment (24 items), Social Adjustment (20 items), Personal-Emotional Adjustment (15 items), and Goal Commitment-Institutional Attachment (15 items). The SACQ takes approximately 20 minutes to complete. The

SACQ has good internal consistency reliability (.89 to .95) with significant correlations found between freshman-year GPA and academic adjustment and over-all college satisfaction and institutional attachment (Baker & Siryk, 1989).

McGill Friendship Questionnaire-Friend's Functions (MFQ-FF). The MFQ-FF, short form (Mendelson & Aboud, 1999) will be used to explain how possible relationships between BAPQ and QEEG scores impact the ability of the student to maintain peer-relationships. The questionnaire was designed to assess the functions of friendship in late adolescence and adulthood. The measure includes six subscales (5 items each): Stimulating Companionship, Help, Intimacy, Reliable Alliance, Self-Validation, and Emotional Security. The Stimulating Companionship subscale measures time spent together in engaging activities that provide enjoyment and stimulate amusement. The Help subscale quantifies the amount of guidance, assistance, material aid, and information the friend provides. The Intimacy subscale addresses self-disclosure, acceptance and sensitivity to needs. The Reliable Alliance subscale measures the loyalty of the friendship. How much the friend helps maintain the individual's self-image through reassurance, listening, encouragement and agreeing is measured in the Self-validation subscale. The comfort provided during threatening and difficult times is measured by the Emotional Security subscale. The MFQ-FF has excellent reliability with overall Cronbach's alpha of .97 and subscales ranging from .84 to .90 and (Mendelson & Aboud, 1999). The MFQ-FF was found to be valid with the degree the friend fulfilled the functions of friendship related to friend satisfaction and positive feelings towards a best friend (Mendelson & Aboud, 1999).

Procedure

Participants were recruited from Science, Technology, Engineering, and Math (STEM) classes at a regional university in East Texas. Participants were recruited via fliers posted in the STEM buildings. The fliers included a link to the regional university's laboratory website for participants to sign up online. Once participants arrived at the regional university laboratory for their scheduled appointment, the examiner ensured that they met the requirements (declared STEM student) and reviewed inclusion criteria: (1) reported age ≥ 18 years; (2) no history of seizures or neurological condition; (3) no metal plates or implants in their skulls; (4) not currently wearing earrings; (5) have hairstyles that permit access to scalp (no dreadlocks); and (6) have hair free of products (hairspray, gel, mousse). The examiner reviewed procedures, discussed possible side effects of the QEEG, and obtained informed consent. Participants were then assigned a number to be used as an anonymous identifier on all data. Cell phones and any other electronic devices were removed from the chamber. Participants were fitted with the electrode scalp cap and signed into the computer. The examiner entered the anonymous identifier into the computer and the QEEG assessment and its accuracy was confirmed by each participant. Participants were instructed that they would be watching a series of faces and they needed to remember these faces. The participants were administered two QEEG assessments while viewing the 100 black and white pictures of faces with various expressions. The examiner reviewed data obtained from the QEEG assessments with each participant. Next, participants completed the measures described above, first entering their anonymous identifier on the top of each protocol, then completing the BAPQ

(Hurley et al., 2007), next the SACQ (Baker & Siryk, 1984), and finally the MFQ-FF, short form (Mendelson & Aboud, 1999). All questionnaires were completed in the same order for each participant during a single meeting. All data collected took place in the regional university's laboratory and took on average 60 minutes to complete.

CHAPTER IV

Results

Final Sample

The final sample was composed of 38 participants (BAP+ frequency = 10). The current sample ranged in age from 18 to 34 years old ($m = 22.34$, $sd = 3.496$), mostly male (65.8%), mostly seniors (34.2%), majoring in biology/biochemistry (29%), computer science (24%), physics engineering (18%), geology (16%), math (5%), chemistry (5%), and double majors (3%). One person (10%) in BAP+ reported to be on ADHD medication. Two individuals (7%) in BAP- reported to be on ADHD medication and one participant (3%) in BAP- reported to be on anxiety medication. On the SACFS, participant scores were in the average range ($m=46.61$, $sd = 10.19$). On the four indices within the SACFS, participants' average score on Academic Adjustment was 49.16 ($sd = 11.33$), on Social Adjustment the participants' average score was 44.68 ($sd = 7.226$), on Personal Emotional Adjustment the participants' average score was 44.61 ($sd = 12.45$), and on the Attachment to College the participants' average score was 47.55 ($sd = 7.127$). Regarding Friendships, the current sample score on the MFQ-FF was 195.39 ($sd = 25.60$).

Demographics and Social Emotional Outcome Scales by BAP groups

Demographics and social emotional outcome scales were compared among the BAP+ and BAP- participants. Participants classified as BAP- were significantly older than BAP+. Please note that age corrected QEEG Z-scores were used in the next sections

(Thatcher et. al, 2003). Also, participants classified as BAP+ had significantly lower social adjustment than those classified as BAP-. Although not statistically significant, students with high BAP showed a tendency to have less adaptation to college and more difficulty maintaining friendships. There were no observable differences in personal emotional adjustment and attachment to college. See Table 1.

QEEG variables by Condition and by BAP classification

Relative Power

A number of 2 (BAP classification) by 2 (condition) mixed ANOVAs were conducted in order to determine QEEG relative power Z scores differences facial expression processing between BAP+ and BAP-. QEEG relative power Z scores on alpha, theta, and hi-beta were compared at locations T3 and T4 of the brain. Table 2 shows the mean and standard deviations for each group by condition. Results indicated Alpha relative power at location T4 showed a significant main effect for condition and a significant interaction between group designation and conditions. In specific, individuals categorized as BAP+ demonstrated a higher alpha relative power score at location T4 when looking at expressive faces than when looking at neutral faces, when compared to the BAP- individuals. Hi-Beta relative power at location T4 was significantly lower in BAP+ individuals regardless of condition. There were no other significant findings for Z score relative power comparisons. See Table 2; see also Figure 2.

Table 1

Results of t-test and Descriptive Statistics by BAP Group

	BAP-			BAP+			95% CI for Mean Difference		
	M	SD	n	M	SD	n	t	p	
Age	22.94	3.85	28	20.67	1.24	10	0.59, 3.95	2.74*	.009
Academic Adjustment	49.96	11.48	28	46.90	11.16	10	-5.45, 11.58	0.73	.470
Social Adjustment	46.90	11.16	28	40.40	5.72	10	0.71, 10.92	2.31*	.027
Personal- Emotional Adjustment	46.14	7.17	28	40.30	5.72	10	-3.38, 15.06	1.29	.460
Attachment	48.07	6.64	28	46.10	8.56	10	-3.39, 7.33	0.75	.520
SACQ Full Scale	47.86	10.34	28	43.10	9.34	10	-2.79, 12.21	1.28	.196
MF-FF Quotient	199.79	20.40	28	183.10	34.90	10	-1.87, 35.24	1.82	.181

* p < .05.

Table 2

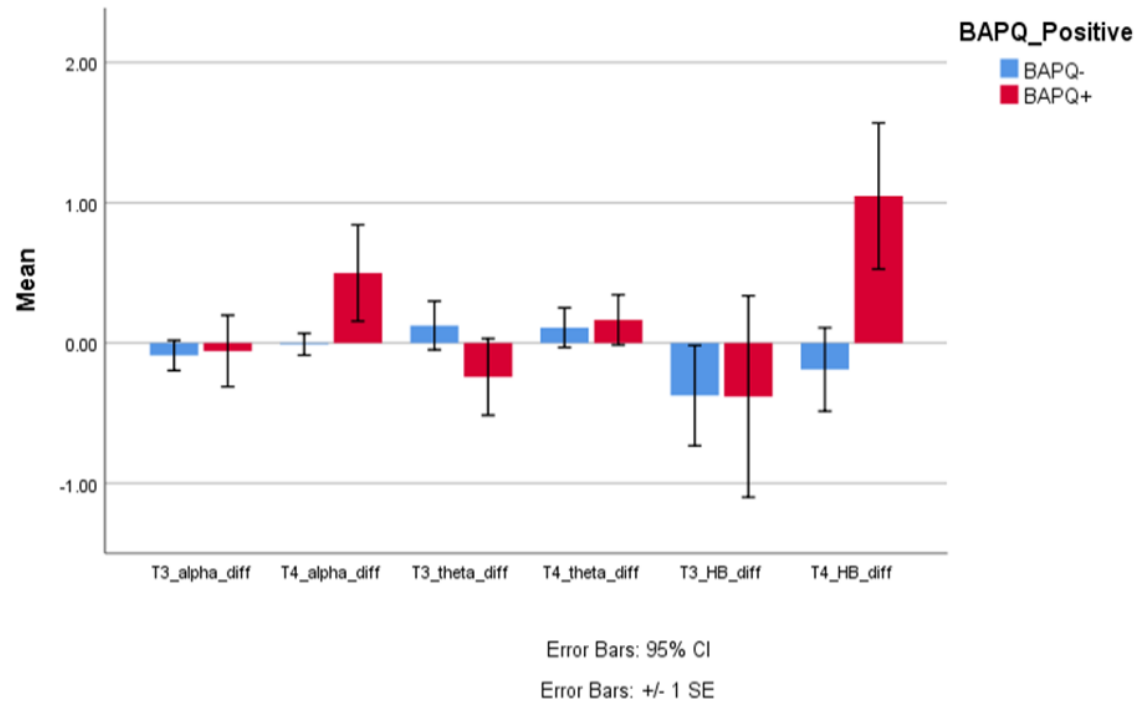
Results of a mixed ANOVA of EEG Relative Power by BAP Group for Neutral and Expressive Conditions

	Neutral		Expressive				
	BAP-	BAP+	BAP-	BAP+			
	28	10	28	10			
	M(sd)	M(sd)	M(sd)	M(sd)	F (ME Condition)	F (ME- Group)	F (Inter)
Alpha T3	-0.34(0.77)	-0.34(0.77)	-0.43(0.84)	-0.20(0.93)	0.39	0.58	0.02
Alpha T4	-0.52(0.56)	-0.73(1.29)	-0.53(0.68)	-0.24(0.97)	4.18**	0.02	4.50**
Theta T3	-0.08(-0.08)	-0.08(1.48)	0.05(1.56)	-0.32(1.47)	0.12	0.13	1.21
Theta T4	-0.15(-0.15)	0.34(0.91)	-0.04(1.26)	0.51(0.64)	1.12	1.56	0.05
Hi-Beta T3	0.42(0.42)	0.06(0.90)	0.38(0.70)	0.26(0.97)	0.60	0.97	1.35
Hi-Beta T4	0.15(0.15)	-0.54(1.37)	0.28(0.63)	-0.37(1.04)	1.29	5.83*	0.02

ME = Main Effect; * $p < .10$; ** $p < .05$.

Figure 2

Difference between Expressive and Neutral Conditions on EEG Relative Power by BAP Group



Coherence

A number of 2 (BAP classification) by 2 (condition) mixed ANOVAs were conducted to determine T4-T3 Coherence Z scores differences in facial expression processing between BAP+ and BAP-. Coherence Z scores were collected for alpha, theta, and hi-beta. Table 3 shows the mean and standard deviations for each group by condition. Results indicated a significant interaction between group designation and conditions for T4-T3 alpha coherence. In specific, individuals categorized as BAP+ demonstrated a higher T4 relative to T3 alpha coherence Z score when looking at expressive faces than when looking at neutral faces, when compared to the BAP- individuals. There were no other significant findings for T4-T3 coherence. See Table 3; see also Figure 3.

Table 3

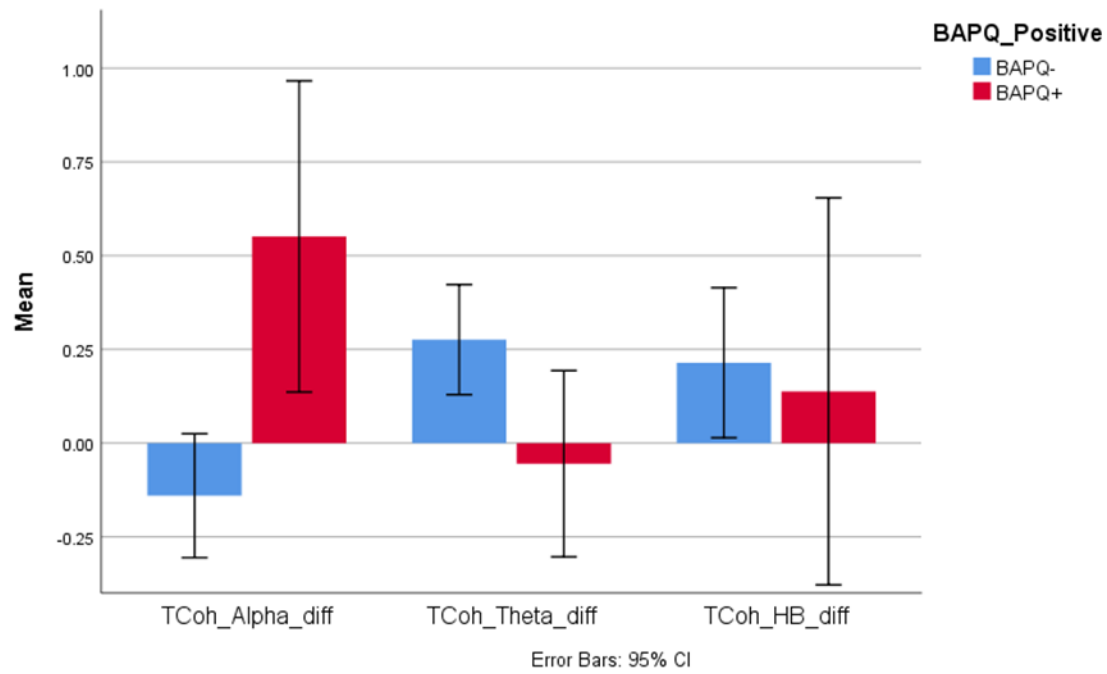
Results of a mixed ANOVA of EEG Coherence by BAP group for Neutral and Expressive Conditions

	Neutral		Expressive				
	BAP-	BAP+	BAP-	BAP+			
	28	10	28	10			
	M(sd)	M(sd)	M(sd)	M(sd)	F (ME- Condition)	F (ME- Group)	F (Inter)
Alpha T4-T3	-0.17(1.25)	0.10(0.93)	-0.31(1.15)	0.65(0.92)	1.24	2.63	3.51*
Theta T4-T3	-0.24(0.80)	0.09(0.72)	0.04(0.88)	0.03(0.90)	0.60	0.35	1.33
Hi-Beta T4-T3	-0.40(1.09)	-0.23(1.20)	-0.19(1.09)	-0.09(1.45)	0.61	0.14	0.03

ME = Main Effect; * $p < .10$; ** $p < .05$.

Figure 3

Difference between Expressive and Neutral Conditions on EEG Coherence by BAP Group



Relationship between QEEG variables and BAPQ, SACQ, and MF-FF

Correlations

A two-tailed Pearson Correlation was conducted to determine relationships between brain frequencies and the BAPQ, SACQ, and MF-FF. Results indicated significant correlations between alpha relative power at T4 with T4-T3 alpha coherence and with BAP+. Hi-Beta relative power was significantly linked to BAP+. The QEEG variables did not correlate with self-reports on the SACQ and MF-QQ. See Table 4.

Table 4

Correlations between Brain Frequency, BAPQ, SACQ, and MF-FF
(N = 38)

Variables	1	2	3	4	5	6	7	8	9	10
1. T4_alpha_diff	-									
2. T4_HB_diff	.148	-								
3. TCoh_Alpha_diff	.336*	.187	-							
4. BAPQ Positive	.333*	.331*	.298	-						
5. AcadAdj	.272	.072	.113	-.121	-					
6. SocAdj	.089	-.055	-.138	-.359*	-.515**	-				
7. PrsEmAdj	.196	-.060	-.071	-.209	.723**	.550**	-			
8. Attchmt	.161	-.049	.037	-.123	.638**	.732**	.606**	-		
9. SACQFS	.243	.000	.018	-.208	.907**	.737**	.891**	.769**	-	
10. MFQ_FF	.090	-.096	-.030	-.291	.044	.282	.220	.144	.178	-

Note: T4_alpha_diff = difference in alpha relative power between expressive – neutral faces at location T4; T4_HB_diff = difference in hi-beta relative power at location T4; TCoh_Alpha_diff = difference in alpha coherence between locations T4-T3; BAPQ Positive = Broad Autism Phenotype positive score; AcadAdj = Academic Adjustment subscale on SACQ; SocAdj = Social Adjustment subscale score on SACQ; PrsEmAdj = Personal Emotional Adjustment subscale score on SACQ; Attchmt = Attachment subscale score on SACQ; SACQFS = Student Adjustment to College Questionnaire Full Scale; MFQ_FF = McGill Friendship Questionnaire-Friend's Functions.

* p < .10; ** p < .05

CHAPTER V

Discussion

This study investigated differences in brain activity in adults with BAP+ compared to BAP- while viewing neutral and expressive faces and provides insight into the social implications for college students. The BAP+ cutoff used was a total score on the BAPQ of 3.17 for females and 3.55 for males (Sasson et. al, 2013). Findings revealed that individuals with BAP+ demonstrated a higher alpha relative power score when looking at expressive faces than when looking at neutral faces when compared to BAP- individuals. This study also showed a higher T4 relative to T3 coherence Z score when looking at expressive faces than when looking at neutral faces, when compared to individuals without BAP. Positive links were found between alpha and hi-beta relative power and BAP+, as well as between alpha relative power at T4 and T4-T3 alpha coherence. Despite these differences, the study found no links between EEG measured brain activity and adjustment to college. These results suggest that while brain activity predicts BAP status, it does not fully predict academic or social adjustment to college.

The current study is the first one to demonstrate QEEG differentiation between BAP+ and BAP- while processing faces. Results also indicated a negative correlation between BAP+ and the social adjustment SACQ subscale score, with BAP+ demonstrating significantly lower social adjustment to college. Low social adjustment scores are linked to loneliness and social anxiety (Caro, 1986), being less involved in extracurricular activities (Wick & Shilkret, 1986b cited in Baker & Siryk, 1989), and

fewer romantic relationships and social support networks (Harris, 1988). Furthermore, although not reaching significance results suggest that BAP+ showed less adaptation to college and more difficulty maintaining friendships. The results of this study support the idea that social impairments associated with BAP+ could be measured using QEEG indicators.

A review of the literature revealed limited research using task-specific EEGs to measure brain activity in adults with BAP. Similar to the current study, Moore and Franz (2017) investigated patterns of EEG brain activity and BAP and found links to behavior (aloofness) associated with ASD. Using a much smaller sample size (20 participants) than the current study, Moore and Franz (2017) investigated resting-state alpha brain activity in individuals with BAP from the college community and included both eyes-open and eyes-closed conditions. Findings revealed a significant correlation between the total BAPQ score and the difference between the eyes-open and eyes-closed alpha distribution. Moore and Franz (2017) also found a significant correlation between brain activity and social impairment. However, Moore and Franz (2017) investigated resting state activity as opposed to the task-specific activity of viewing expressive faces and found a significant behavioral link (aloofness) between alpha activity in different regions of the brain (central and parietal).

More recently, Leno, Tomlinson, Chang, Naples, and McPartland (2018) investigated links between resting-state brain activity and subscale scores (aloof, pragmatic language, and rigidity) on the BAPQ to link subclinical expressions of traits of autism to the general population. A spectral decomposition method extracted absolute

alpha power from eyes-closed epochs in thirty-seven typically developing adults and revealed a positive correlation in the parietal region of the brain with the BAPQ rigidity subscale. This method was used on delta, theta, beta, and gamma frequency bands as well and specifically correlated with rigidity on only the alpha frequency range. Furthermore, there was no link between alpha power and other subscales on the BAPQ (aloofness or pragmatic language subscales). There are several similarities between the current study and the study conducted by Leno and colleagues (2018). Both studies used EEGs to measure alpha brain activity in healthy adults; both studies used samples similar in size and age; both studies used the BAPQ and found significant positive correlations between alpha power and areas of the brain, and both studies linked the BAPQ to impairments associated with autism.

However, the current study investigated an active-state EEG condition of viewing faces, linked alpha power to the temporal lobes of the brain, and used the BAPQ total score to link individuals with BAP+. Leno et al. (2018), on the other hand, focused only on an eyes-closed resting-state EEG condition, linked alpha power to the parietal region of the brain, and instead of looking for BAP+ status, looked for links between individual traits of BAP through the BAPQ subscales and brain activity. Therefore, the current study used a novel approach (task-specific EEG recording) to investigate brain activity in BAP+ adults. In comparison to previous studies, the results of the current study allow for a better understanding of the links between brain activity and behavior, as opposed to a resting state.

A limitation of this study is the lack of similar research for which to provide context and draw conclusions, for example, there are no studies to date that have looked into active state brain activity in BAP. A further limitation is that the study did not inquire about hand dominance which is often used to determine cerebral dominance. The majority of individuals (95% in right-handed and 70% in left-handed) are left brain dominant for language function; whereas, language lateralization is bilateral or right sided for individuals with right brain dominance. This study focused on brain activity in the temporal lobes. The left temporal lobe is the dominant lobe in most adults and involved in language processing and remembering verbal information (Hammond, 2005). The non-dominant right temporal lobe is associated with auditory processing, music perception, sound, remembering and recognizing spatial patterns, processing facial and nonverbal information (Joseph, 1986). Even if some participants have atypical language lateralization, it is unlikely that it would impact the brain activity involved in processing faces. Future studies should include the participants' hand dominance to assist with interpretation of results.

Several methodological limitations need also to be considered. First, the data was limited to STEM students from one university. The participants were recruited via fliers posted in the STEM building and required them to email the examiner to schedule an appointment. The defining features associated with BAP include pragmatic language difficulties, aloofness, and rigidity. It is possible that the BAP sample in this study did not entirely represent the BAP population of the STEM students at the university as students with BAP might be less likely to volunteer. It is unknown as to whether or not the results

of this study will generalize to other populations. Second, the study used self-report questionnaires to obtain data regarding personality traits, adjustment, and functions of friendships. Participants sometimes provide socially desirable responses on questionnaires which might threaten the validity of some of the data. Items on the personality questionnaires might have been interpreted as reflecting neuroticism and viewed as maladaptive and undesirable to endorse (Chan, 2009). Steps were taken to improve accurate responding on the self-reported questionnaires, including maintaining anonymity through the use of a code not linked to the participants' name, and explaining the importance of answering truthfully. Third, the study did not use ASD screening measures to rule-out the existence of participants with ASD. The study relied solely on self-reported psychiatric, neurological or psychological history. None of the participants reported a history of developmental disorders or ASD. Future studies should use additional objective measures to replicate the present findings and also consider including a group with ASD. Investigating individuals with ASD to show similar patterns most likely of a greater magnitude compared to those of BAP+ and BAP- could lead to further evidence of brain differences along the spectrum and assist with the diagnosis of ASD.

There is an abundance of physiological research documenting differences in brain activity between individuals with ASD and healthy controls while processing information from faces (Harms, Martin, & Wallace, 2010). The current findings support the hypothesis that those with higher BAP symptoms demonstrate different brain activity than BAP- individuals when processing faces and provides a possible biological marker of these differences. The BAP is present in relatives of individuals with ASD as well as

in the general population (Sucksmith, Roth, & Hoekstra, 2011), is known to be heritable (Sasson et al., 2013), and represents a genetic liability for ASD (Piven et al., 1997). Sugiura and colleagues (2000) linked the personality traits of novelty seeking, harm avoidance, and reward dependence to neural activity in the cerebral cortex by measuring regional cerebral blood flow. In a fMRI study, different levels of brain activity in the lateral orbital and medial prefrontal cortex and the ventral striatum were represented by individual differences in the personality trait of persistence (Gusnard et al., 2003). Most brain marker research involves primarily the use of functional neuroimaging techniques to link abnormal activity to structure. Advances in EEG technology now allow for improved spatial and temporal resolution, ease of administration, and a less expensive, less time consuming noninvasive means of acquiring diagnostic biomarkers of phenotypes and psychopathology (McLoughlin, Makeig, & Tsuang, 2014). Now there is possible evidence of BAP+ brain markers, and implications emerge from the results to support the idea that social impairments associated with BAP+ could be measured using QEEG indicators. College students with low social adjustment are at higher risk of feelings of homesickness and loneliness (Rich & Scovel, 1987), difficulties with relationships, struggling to become integrated into the university environment, and failing to develop support networks (Harris, 1988). Social adjustment is as necessary as academic success in graduating from college (Mallinckrodt, 1988).

Summary

Faces provide nonverbal information necessary for social interaction and communication. Face processing impairments are one of the earliest symptoms of

abnormal brain development in ASD (Dawson et al., 2002). Numerous neuroimaging studies of face processing in individuals with ASD have demonstrated abnormal patterns of brain activity. Even adolescents and adults with high functioning ASD showed slower neural speed at processing faces than IQ-matched adolescents and adults (McPartland et al., 2004). Individuals with BAP have subclinical levels of the three defining features of ASD (pragmatic language difficulties, aloof personality, and rigid personality). The current study is the first one to demonstrate differences in brain activity between BAP+ and BAP- while processing faces. Although the brain activity seen in BAP+ did not directly link to social impairment, the indirect relationship between social impairments and BAP+ could be brain mapped with a QEEG. Taken together the above evidence of the possibility of BAP+ brain markers and their implications holds much promise for providing objective screening measures for students at-risk socially and neurofeedback protocols to intervene.

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