NEUROBIOLOGICAL FOUNDATIONS OF SELF-CONSCIOUS EMOTION UNDERSTANDING IN ADOLESCENTS WITH AUTISM SPECTRUM DISORDERS

by

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DISSERTATION ABSTRACT

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This dissertation explored the subjective experience and neural correlates of self-conscious emotion (SCE) understanding in adolescent males with high-functioning Autism Spectrum Disorder (ASD) and age-matched neurotypical (NT) males (ages 11-17). Study I investigated group differences in SCE attributions (the ability to recognize SCEs conveyed by others) and empathic SCEs (the ability/tendency to feel empathic SCEs for others) in 56 adolescents (ASD = 30; NT = 26). It also explored associations between SCE processing and a triad of social cognitive abilities (self-awareness/introspection, perspective-taking/cognitive empathy, affective empathy) and autistic symptoms/traits. Study II investigated the neural correlates of SCE processing in 52 adolescents (ASD = 27; NT = 25).

During an MRI scan, participants completed the Self-Conscious Emotions Task-Child, which included 24 salient, ecologically-valid videos of adolescents participating in a singing competition. Videos represented two factors: emotion (embarrassment, pride) and perspective-taking (PT) demands (low, high). In low PT clips, singers' emotions matched their performance (sing poorly, act embarrassed); in high PT clips, they did not (sing well, act embarrassed). Participants used a 4-point Likert scale to rate how intensely embarrassed and proud singers felt. They made congruent ratings, which matched the conveyed emotions (rating how embarrassed an embarrassed singer felt), and incongruent ratings, which did not match the conveyed emotions (rating how proud an embarrassed singer felt). Outside the scanner, participants rated how empathically embarrassed and proud they felt for the singers.

The ASD and NT groups made similarly intense inferred congruent and empathic congruent SCE ratings, suggesting that emotion attribution and affective empathy are intact in ASD. However, the ASD group made more intense inferred incongruent SCE ratings, suggesting that emotion attribution in ASD may be more strongly impacted by the situational context. An over-reliance on contextual cues may reflect a strict adherence to rule-following and serve as a compensatory strategy for attenuated mentalizing. Neuroimaging results support this interpretation. The ASD group recruited atypical neural patterns within social cognition regions, visual perception regions, salience regions, and sensorimotor regions. These findings similarly suggest an over-reliance on abstract social conceptual knowledge when processing discrepant affective and contextual cues. Implications for intervention are discussed.

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TABLE OF CONTENTS

Chapter Page

Chapter Page

Chapter Page

Chapter Page

Chapter Page

Chapter Page

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

BACKGROUND

Overview

A recent two-hit model of autism proposes that adolescents with autism spectrum disorders (ASD) experience a critical secondary (post-infancy/early childhood) wave of impairments in social cognition and peer interactions, which are enhanced by accelerated neural maturation and socioaffective changes associated with puberty (Picci & Scherf, 2015). Neurotypical (NT) adolescence is accompanied by heightened self-consciousness (Rankin, Lane, Gibbons, & Gerrard, 2004) and enhanced perspective-taking (PT) abilities (Dumontheil, Apperly, & Blakemore, 2010), yet these attributes reportedly develop atypically in ASD. In particular, self-conscious emotion (SCE) understanding may be altered in ASD. Given that adolescence is considered to be a period of significant social reorientation (Nelson, Jarcho, & Guyer, 2016; Nelson, Leibenluft, McClure, & Pine, 2005), acquiring advanced social cognitive abilities and applying them appropriately in affective and interpersonal contexts is paramount for developing strong peer relationships and positive mental health outcomes. Relatively little work has explored advanced social cognition, such as SCE processing, in adolescents with ASD. To close this gap, the overarching goal of this dissertation is to characterize the subjective experience and neurobiological substrates of SCE understanding in adolescents with ASD and NT adolescents.

Self-Conscious Emotions

Overview. Emotions can be broadly categorized into basic, nonsocial emotions (including happiness, sadness, anger, and fear) and complex, social emotions (such SCEs; including shame, guilt, embarrassment, and pride). Nonsocial emotions are frequently considered biologically-innate (Izard, 1971) and typically emerge within the first six to nine months of life (Lewis, 2007; Lewis, Sullivan, Stanger, & Weiss, 1989). In comparison, social emotions are the product of personal appraisal and inferred evaluation (Tracy & Robins, 2007e). SCEs are elicited by directly experiencing, inferring, or anticipating others' evaluations of the self, which are informed by internalized social rules and expectations (Leary, 2007; Lewis, 1995, 1997). Consequently, SCEs can be described as being supported by three social cognitive processes: (i) self-awareness, underlying self-consciousness and self-reflection; (ii) other-awareness, underlying mental state attribution; and (iii) social norm-awareness, underlying the identification and adoption of societal standards (Beer, 2007; Jankowski & Takahashi, 2014; Lagattuta & Thompson, 2007). Reflecting their greater cognitive complexity, SCEs have a protracted developmental trajectory. SCEs typically emerge at 36 months, coinciding with the maturation of self-reflective and self-evaluative abilities, as well as the acquisition and internalization of social standards, rules, and goals (Lewis, 1995, 2007). In support of the critical role of PT abilities in SCE development, children ages 4-7 are more likely to make SCE attributions in response to social norm violations if they can pass second-order Theory of Mind (ToM) tasks (e.g., "X thinks that Y thinks"), compared to those who cannot (Bennett & Matthews, 2000).

Unlike basic emotions, which are theorized to promote biological goals, SCEs are proposed to promote social goals. SCEs inform social decision-making and both guide and regulate interpersonal behaviors by serving as an "emotional moral barometer" and providing feedback on the social appropriateness of one's thoughts and actions (Beer, 2007; Tangney & Tracy, 2012; Tracy & Robins, 2004a, 2007e). This includes adhering to social standards, encouraging socially-valued actions, discouraging socially-unacceptable actions, and promoting reparations for social transgressions (Leary, 2007; Tangney, Stuewig, & Mashek, 2007b; Tracy

& Robins, 2004a). Consequently, SCEs play an integral role in supporting and maintaining interpersonal relationships (Leary, 2007; Tracy & Robins, 2007e).

Embarrassment. Embarrassment is a SCE that represents inferred negative self-evaluations in response to social norm violations (Miller, 1996). While early manifestations of embarrassment are evoked by feelings of exposure and self-consciousness (e.g., excessive attention or praise), more mature manifestations include an evaluative component (e.g., mental state attribution) (Lewis et al., 1989). Early forms of embarrassment typically develop by 5 or 6 years old. According to parent report, only 25% of 3-4 year olds show signs of embarrassment, compared to over 50% of 5 year olds, and approximately 75% of 6 year olds (Buss, Iscoe, & Buss, 1979). Evaluative embarrassment develops in two stages: (i) primitive evaluative embarrassment, evoked by directly perceiving the reactions/judgments of others; and (ii) mature evaluative embarrassment, evoked by merely inferring the reactions/judgments of others (Bennett, 1989). While children (ages 5-8) require the presence of an active audience to experience embarrassment, adolescents (ages 11-13) experience embarrassment in the absence of a physical audience or explicit feedback (Bennett, 1989; Bennett & Gillingham, 1991; Bennett & Matthews, 2000). Thus, embarrassment understanding continues to mature throughout childhood and into adolescence, reflecting the developmental trajectory of PT abilities. By adolescence, youths have developed, and commonly reference, an implicit audience, which they to use to evaluate their own actions via mental state attribution and inferred social judgments.

Broadly, embarrassment is characterized as an emotional response to “normative public deficiencies” (Tangney, Stuewig, & Mashek, 2007a). These include physical pratfalls or inept performances (e.g., tripping on one’s shoelaces), cognitive shortcomings (e.g., forgetting someone’s name), failures to maintain privacy (e.g., being observed in one’s underwear), losses of control (e.g., passing gas/burping); awkward social interactions; teasing; increased public attention; and empathically observing others experiencing embarrassment (Keltner, 1996; Keltner & Buswell, 1997). Embarrassment is strongly tied with impression management and represents a concern for evoking negative social evaluations or conveying an undesirable or negative self-image (Miller, 1996; Miller & Tangney, 1994; Parrott & Smith, 1991). In support of a social evaluation model, embarrassment is more commonly experienced in public, in the presence of individuals with high social status, and in response of perceived ridicule (Miller, 1996; Parrott & Smith, 1991). Emotional reactions include feeling awkward, uncomfortable, nervous, incompetent, or inferior (Parrott & Smith, 1991).

Embarrassment is considered a discrete emotion, which can be reliably distinguished from other negatively-valenced SCEs, such as shame and guilt, based on its unique antecedents, nonverbal displays, and social functions (Keltner, 1995; Keltner & Buswell, 1997; Miller & Tangney, 1994; Tangney, Miller, Flicker, & Barlow, 1996). Unlike shame or guilt, which are more closely tied to moral violations, embarrassment is typically elicited by social transgressions (Miller & Tangney, 1994). Shame and guilt evoke intense, enduring feelings of disgust, regret, and anger; while embarrassment evokes more mild, short-lived feelings of awkwardness, conspicuousness, and "temporary error" (Keltner & Buswell, 1997; Miller, 1996; Miller & Tangney, 1994; Tangney et al., 1996). Shame and guilt are more closely tied to personal evaluations, while embarrassment is more strongly linked to social evaluations, thus relying on the presence of a real or imaginary audience (Miller, 1996; Tangney et al., 1996). In fact, embarrassment is typically experienced when others are present or aware of the embarrassing situation (Miller & Tangney, 1994). Thus, embarrassment uniquely represents a concern for one's social image, following social norm violations, which may negatively impact one's social status.

Embarrassment is associated with distinct nonverbal displays, which are reliably recognized in photographs (Keltner, 1996) and videos (Keltner, 1995). Unlike basic emotions, which are recognizable by facial expressions alone, embarrassment is conveyed through a combination of facial expressions and body postures, and can be further identified by hand gestures, body motions, and vocal cues (Edelmann & Hampson, 1981a, 1981b; Miller, 1996). Embarrassed individuals avert their gaze, lower and turn their head away (usually to the left), make frequent gaze shifts, display a controlled smile, and touch their face (i.e., covering their eyes or mouth) (Keltner, 1995). Embarrassed individuals also display nervous body movements, by shifting their posture, moving their legs and feet, and using hand gestures, as well as making speech errors (e.g., stuttering) (Edelmann & Hampson, 1981a, 1981b). Physiologically, embarrassed individuals often report blushing (Keltner & Buswell, 1997).

Like most SCEs, embarrassment draws attention to the inferred evaluations of others and serves a self-regulatory function (Leary, 2007; Tangney & Tracy, 2012). Embarrassment maintains social status by interrupting social transgressions (Miller, 2007), promoting avoidance and reconciliatory behaviors (Keltner & Buswell, 1997; Tracy & Robins, 2007e), and deterring future norm violations (Tangney et al., 1996). Embarrassment may be best depicted as serving an appeasement function (Keltner, 1995; Keltner & Buswell, 1997), by signaling one’s desire to monitor, hide, or change one’s behavior (Tangney et al., 2007a). By conveying acknowledgment and regret of one's transgressions, embarrassment serves as a “nonverbal apology” and prevents social rejection (Miller, 2007). Thus, embarrassment promotes social reparations, social acceptance, and prosociality in others (Keltner & Buswell, 1997; Tangney, 1999).

Pride. Pride is a SCE that represents inferred positive self-evaluations in response to achieving socially-valued goals or exceeding societal standards (Lewis, 1997). Similar to "achievement motivation" (Lewis, 1997; Lewis & Sullivan, 2005), pride reflects accepting personal responsibility for a specific, successful, socially-valued action, which elicits feelings of efficacy, mastery, or joy (Leary, 2007; Lewis & Sullivan, 2005). Pride follows a similar developmental trajectory as embarrassment (Stipek, Recchia, McClintic, & Lewis, 1992). Initially, young children experience and display mastery (a precursor to pride) following personal achievement, in the absence of explicit self-reflection or social attributions (Stipek et al., 1992). However, older children (ages 2.5-3) seek out others' attention, anticipate others' reactions, and experience enhanced feelings of pride following praise, thus reflecting the growing salience of social evaluations (Stipek, 1995; Stipek et al., 1992). By approximately 4 years old, children learn to recognize nonverbal displays of pride, and this ability improves throughout childhood (Tracy, Robins, & Lagattuta, 2005). As children enter adolescence, their understanding becomes more refined, and they learn to identify pride according to specific causal attributions (Kornilaki & Chlouverakis, 2004; Rosenberg, 1979).

Pride is characterized by its unique nonverbal displays and social functions. Pride is distinguishable from basic emotions, such as happiness and surprise (Tracy & Robins, 2004b), and pride displays are reliably and universally recognized, generalizing across western and nonwestern cultures (Tracy & Robins, 2008). These displays generalize across target gender and ethnicity, and have been replicated in both sighted and congenitally blind individuals (Tracy & Robins, 2008), which further supports their universal recognition. Pride is conveyed through a combination of facial expressions and body postures (Tracy & Robins, 2003, 2004b, 2007c). Proud individuals display a small non-Duchenne smile, tilt their head slightly backwards, expand their chest, push their torso outward, and either raise their arms above their head with their hands in fists or place their hands on their hips with their arms akimbo (Tracy & Matsumoto, 2008; Tracy & Robins, 2003, 2004b).

Pride displays are posited to reflect status, competence, and achievement (Tracy & Robins, 2004b), which are closely related to their proposed functions, namely, to obtain, maintain, and convey social status (Leary, 2007; Tracy & Matsumoto, 2008; Tracy & Robins, 2004b; Tracy, Shariff, & Cheng, 2010). Tracy, Shariff, and Cheng (2010) proposed three pathways through which pride promotes social status. First, pride evokes positive, rewarding emotions, which reinforce and motivate socially-valued actions (Leary, 2007; Tracy & Robins, 2007a, 2007b, 2007e; Tracy et al., 2010). Second, pride informs individuals that their actions warrant enhanced status and social acceptance (Tracy & Robins, 2007b; Tracy et al., 2010), and increases self-confidence and self-esteem (Tangney et al., 2007a; Tangney & Tracy, 2012; Tracy & Robins, 2007a; Tracy, Weidman, Cheng, & Martens, 2014), thus serving as an affective cue for maintaining social status (Tracy et al., 2010). Third, pride communicates one's achievements to others through boasting and dominant (yet approachable) nonverbal displays, as well as draws attention to these achievements (Leary, 2007; Tracy & Robins, 2004b, 2007b). Thus, pride signals one's deservedness of social acceptance and draws others' attention to one's increased social status (Tracy & Robins, 2004a, 2007a, 2007b; Tracy et al., 2010; Tracy et al., 2014).

It is important to note that pride can be parsed into two facets: authentic and hubristic pride (Tracy & Robins, 2007d). Authentic pride is achievement-oriented and represents accomplishment, confidence, and prosociality; while hubristic pride is self-aggrandizing and represents arrogance, conceitedness, and narcissism (Tracy & Robins, 2007a, 2007d). Authentic pride reflects unstable, controllable, specific attributions (i.e., feelings of achievement due to effort), while hubristic pride reflects stable, uncontrollable, global attributions (i.e., feelings of achievement due to innate ability) (Tracy & Robins, 2004a, 2007d). Authentic and hubristic pride are conveyed via indistinguishable nonverbal displays (Tracy & Robins, 2007b); however, they are associated with distinct psychological correlates and social functions. Authentic pride is associated with genuine self-esteem, adaptive personality traits, and interpersonal success, while hubristic pride is associated with narcissism and antisocial behaviors (Tracy, Cheng, Robins, & Trzesniewski, 2009; Tracy & Robins, 2007d). Furthermore, only authentic pride supports the attainment and maintenance of interpersonal relationships, promotes prosociality in others, and fosters long-term social status (Tracy & Prehn, 2012; Tracy & Robins, 2007b; Tracy et al., 2014; Wubben, De Cremer, & van Dijk, 2012).

Autism and Adolescence

ASD represents a set of neurodevelopmental disorders characterized by impairments in social communication and social interactions, as well as restricted, repetitive patterns of behaviors, interests, and activities (American Psychiatric Association, 2013). Currently, ASD represents one of the fastest growing developmental disorders; prevalence rates have increased almost 120% over the past ten years, representing an estimated 1 in 68 births (Wingate et al., 2014). Despite the growing number of children with ASD entering adolescence, relatively little research has explored autism during this key developmental period. Longitudinal studies suggest that individuals with ASD experience broad improvements in symptom severity with increasing age, but social challenges persist into adolescence (Anderson, Maye, & Lord, 2011). In particular, many individuals with ASD experience increased social withdrawal and decreased social participation during adolescence (Anderson et al., 2011; Shattuck, Orsmond, Wagner, & Cooper, 2011). A recent study exploring peer relationships and social interactions found that close to 50% of adolescents with ASD never see friends, are never called by friends, and are never invited to social activities (Shattuck et al., 2011). Such interpersonal challenges are proposed to reflect poor social skills, including difficulties initiating and maintain conversations, joining groups, and making friends (Shattuck et al., 2011). These findings converge with research underscoring a link between impaired social skills and interpersonal success (Orsmond, Krauss, & Seltzer, 2004). Given that adolescence is widely considered to represent a significant period of social reorientation (Nelson et al., 2016; Nelson et al., 2005), where peer relationships become more salient and meaningful (O'Brien & Bierman, 1988), it is imperative to explore advanced social cognitive abilities in adolescents with ASD, in order to shed light onto underlying causes of interpersonal challenges, as well as illuminate potential avenues for intervention.

Autism and Atypical Social Cognition

Theory of Mind. Individuals with ASD reportedly demonstrate atypicalities across a triad of social cognitive abilities, which overlap with those underlying SCE processing. These abilities include self-reflection/introspection (self-awareness), ToM/PT (other-awareness), and empathy. One of the most commonly reported symptoms of ASD is impaired or atypical PT abilities, including difficulties inferring the thoughts, feelings, and intentions of others (Baron-Cohen, 1990; Baron-Cohen, Leslie, & Frith, 1985; Frith, 2001). In fact, impaired mental state attribution serves as the foundation for the popularized “mindblindness” theory of ASD (Baron-Cohen, 1990; Baron-Cohen et al., 1985; Frith, 2001). Individuals with ASD demonstrate impaired performance on first- and second-order ToM tasks (Baron-Cohen et al., 1985; Buitelaar, Van der Wees, Swaab–Barneveld, & Van der Gaag, 1999), poor performance on mental state attribution tasks (Abell, Happe, & Frith, 2000; Baron- Cohen, Jolliffe, Mortimore,

& Robertson, 1997; Castelli, Frith, Happé, & Frith, 2002; F. G. Happé, 1994; T. Jolliffe & Baron-Cohen, 1999; Mazza et al., 2014), and difficulties inferring others' intentions, such as evaluating moral behavior (Moran et al., 2011) and non-literal speech (Wang, Lee, Sigman, & Dapretto, 2006). Interestingly, ToM deficits may not be as ubiquitous as once believed, particularly in older individuals with greater verbal intelligence (Bowler, 1992; F. G. Happé, 1995). For example, young adults with ASD can pass second-order ToM tasks, although they may use fewer mental state terms when justifying their responses (Bowler, 1992). Although adults with ASD show impaired performance on spontaneous PT tasks, they demonstrate comparable performance when they are given explicit cues/prompting (Senju, Southgate, White, & Frith, 2009). Relatedly, children and adults with ASD may demonstrate difficulties inferring the emotional states of others, although these impairments are subtler in older, higher-functioning individuals. For example, young adults with ASD demonstrated intact first- and second-order cognitive and affective ToM abilities (e.g., recognizing targets' thoughts and preferences, respectively), but greater difficulties recognizing more complex "fortune of other" emotions (e.g., envy, gloating) (Shamay-Tsoory, 2008). While large-scale reviews suggest that approximately 40-70% of individuals with ASD experience poor emotion recognition, these impairments are most commonly observed when evaluating complex/blended emotions or low-intensity emotions (Bons et al., 2013; Doi et al., 2013; Golan, Baron-Cohen, Hill, & Golan, 2006; Harms, Martin, & Wallace, 2010). Thus, ASD may be associated with atypical cognitive and affective ToM, although group differences may be more nuanced than previously believed.

Self-Awareness. In addition to demonstrating difficulties understanding *others'* minds, individuals with ASD also demonstrate difficulties understanding their *own* minds (Lombardo & Baron- Cohen, 2010; Williams, 2010). Originally, ASD was characterized by an extreme self-focus and egocentrism (Kanner, 1943), which may reflect atypical social cognition (e.g., PT abilities and joint-attention). Recently, ASD has been characterized by poor self-awareness, as reflected in the "absent self" theory of ASD (Frith, 1989). Empirical research broadly lends support for atypical self-processing in autism. Individuals with ASD demonstrate reduced personal pronoun use (Lee, Hobson, & Chiat, 1994), fewer self-oriented gestures (Hobson & Meyer, 2005), reduced self-monitoring (Baez et al., 2012), attenuated/absent self-referential memory (Grisdale, Lind, Eacott, & Williams, 2014; Henderson et al., 2009; Lombardo, Barnes, Wheelwright, & Baron-Cohen, 2007; Toichi et al., 2002), and reduced/atypical self-other distinction (Lombardo et al., 2009; P. Mitchell & O'Keefe, 2008; Pfeifer et al., 2013).

Relatedly, ASD has been associated with poor introspection and heightened levels of alexithymia (Griffin, Lombardo, & Auyeung, 2016; Hill, Berthoz, & Frith, 2004; Lombardo et al., 2007; Patil, Melsbach, Hennig-Fast, & Silani, 2016; Silani et al., 2008), which represent difficulties identifying and describing one's own emotions, and a tendency to engage in externally-oriented thinking (Bagby, Parker, & Taylor, 2004). In fact, approximately 50% of individuals with ASD experience severe alexithymia (Bird & Viding, 2014). A recent theory, which is growing in popularity, is that comorbid alexithymia may underlie affective impairments in ASD, particularly atypical emotion recognition and empathy (Bird & Cook, 2013; Bird et al., 2010; Cook, Brewer, Shah, & Bird, 2013; Heaton et al., 2012). This theory serves as a link between atypical self-awareness, other-awareness, and empathy in ASD.

Empathy. ASD has also been broadly categorized as an "empathy disorder" (Gillberg, 1992). Atypical empathy has been commonly reported in children and adults with ASD, extending across cognitive and affective domains (Lombardo et al., 2007). While cognitive empathy represents emotional PT abilities (e.g., "I understand what you feel"), affective empathy represents emotional resonance/affective contagion (e.g., “I feel what you feel”) (Shamay-Tsoory, Aharon-Peretz, & Perry, 2009). Despite claims of a global empathy deficit, when cognitive and affective empathy are examined separately, a distinct pattern often emerges: children and adults with ASD demonstrate impaired *cognitive* empathy, yet intact *affective* empathy, which converges with the “Empathy Imbalance Hypothesis of Autism” (Smith, 2009). Individuals with ASD reveal attenuated *cognitive* empathy, including atypical performance on mentalizing and emotion recognition tasks (Dziobek et al., 2008; Jones, Happé, Gilbert, Burnett, & Viding, 2010; Lombardo et al., 2007; Mazza et al., 2014; Rogers, Dziobek, Hassenstab, Wolf, & Convit, 2007; Rueda, Fernández-Berrocal, & Baron-Cohen, 2015; Schwenck et al., 2012; Yirmiya, Sigman, Kasari, & Mundy, 1992), as well as lower PT scores on empathy questionnaires, including the Interpersonal Reactivity Index (IRI) and Basic Empathy Scale (BES) (Adler, Dvash, & Shamay- Tsoory, 2015; Dziobek et al., 2008; Mazza et al., 2014; Rogers et al., 2007; Rueda et al., 2015). In comparison, individuals with ASD frequently reveal intact *affective* empathy, including similarly intense ratings of empathic concern for targets in empathy tasks (Dziobek et al., 2008; Jones et al., 2010; Mazza et al., 2014; Schwenck et al., 2012), as well as comparable empathic concern scores on the IRI and BES (Dziobek et al., 2008; Mazza et al., 2014; Patil et al., 2016; Rogers et al., 2007; Rueda et al., 2015); yet a few studies have reported reduced empathic concern (Adler et al., 2015; Lombardo et al., 2007; Patil et al., 2016). However, individuals with ASD often report a heightened tendency for feeling personal distress on the IRI (Adler et al., 2015; Dziobek et al., 2008; Lombardo et al., 2007; Patil et al., 2016; Rogers et al., 2007), suggesting empathic hyperarousal. Overall, this cognitive-affective dissociation suggests that children and adults with ASD may experience difficulties inferring and understanding how others feel, may experience similar levels of empathic concern for others, and may experience more intense emotional arousal/distress. This pattern may reflect underlying group differences in PT abilities, alexithymic tendencies, and/or anxiety/emotion regulation.

The above findings demonstrate that individuals with ASD display deficits or atypicalities in a triad of social cognitive abilities integral for SCE processing, which suggest that they may also experience difficulties in SCE processing.

Autism and Atypical Self-Conscious Emotion Processing

Basic Emotion Processing. ASD is commonly associated with affective processing deficits, as described in Baron-Cohen' Theory of Mind Hypothesis (Baron-Cohen et al., 1985) and Hobson's Emotion Recognition Hypothesis (Hobson, 1986). Support for these theories has largely come from studies exploring the ability to recognize basic, nonsocial emotions, such as happiness, sadness, and fear (Harms et al., 2010). While previous research investigating younger and/or lower-functioning children has often reported generalized impairments in nonsocial emotion recognition and understanding, studies investigating older and/or higher-functioning adolescents and adults have reported relatively intact abilities. This has included the ability to label nonsocial emotional facial expressions in photographs (Capps, Yirmiya, & Sigman, 1992; Heerey, Keltner, & Capps, 2003; Tracy, Robins, Schriber, & Solomon, 2011; Wright et al., 2008), describe autobiographical memories of nonsocial emotions (Capps et al., 1992; Losh & Capps, 2006), and demonstrate clear nonverbal displays of nonsocial emotions (Hobson et al., 2006). Thus, previously reported difficulties in nonsocial emotion processing may reflect developmental delays or lower verbal intelligence (Baron- Cohen, 1991; Buitelaar, van der Wees, Swaab-Barneveld, & van der Gaag, 1999). In contrast, youths with ASD broadly demonstrate impoverished (albeit intact) advanced social emotional processing (e.g., SCE processing), particularly within the context of heightened PT demands.

Personal Experience/Expression of Self-Conscious Emotions. Several studies have explored how individuals with ASD *personally experience and express* SCEs. Laboratory manipulations and parental reports reveal that both preschoolers and older children express pride following the successful completion of a task; however, they may demonstrate reduced social sharing, as well as attenuated social responsivity to praise (Hobson et al., 2006; Kasari, Sigman, Baumgartner, & Stipek, 1993). In addition, youths with ASD can describe personal accounts of SCEs (including embarrassment and pride), but they tend to reference the presence of an audience less frequently and less explicitly (Capps et al., 1992; Kasari, Chamberlain, & Bauminger, 2001; Losh & Capps, 2006). Furthermore, adults with ASD report greater embarrassment after observing videos of themselves being embarrassed, compared to experiencing embarrassment in real life, which may reflect reduced implicit self-monitoring that is only facilitated through explicit prompting (Adler et al., 2015). In two related studies, adults viewed flattering and unflattering photographs of themselves and others and rated them on photogenicity and evoked embarrassment (Morita et al., 2016; Morita et al., 2012). Adults with ASD and NT adults reported feeling similar levels of embarrassment when viewing self-photographs; however, adults with ASD revealed a weaker relationship between photogenicity ratings and embarrassment ratings for self-photographs, which the authors interpreted as a "decoupling between cognitive evaluation and emotional responses" (Morita et al., 2012, p. 236). Adults with ASD also demonstrated an attenuated observer effect; knowing that they were being observed did not modulate the relationship between photogenicity ratings and embarrassment ratings for self-photographs in the ASD group, although it did in the NT group (Morita et al., 2016). These findings suggest that SCE processing in ASD, while intact, may be less socially-oriented and/or less self-evaluative, possibly reflecting limited self-other differentiation, impaired mental state attribution, or reduced salience of social evaluations (Capps et al., 1992; Hobson et al., 2006; Kasari et al., 1993; Losh & Capps, 2006). Furthermore, research demonstrating that children and adolescents with ASD may require greater time and more frequent prompting to describe autobiographical memories of SCEs (Capps et al., 1992; Losh & Capps, 2006), as well as offer less specific, less causal, and more generalized/scripted examples (Capps et al., 1992; Kasari et al., 2001; Losh & Capps, 2006; Williams & Happé, 2010), suggest that youths with ASD may have a less in-depth understanding of SCEs, compared to NT youths.

Self-Conscious Emotion Recognition. Autism research exploring SCE *recognition* offers mixed findings. While some studies report that children and adults with ASD can accurately label SCEs across modalities (Adler et al., 2015; Hillier & Allinson, 2002a; Hobson et al., 2006; Tracy et al., 2011; Williams & Happé, 2010); others report impaired SCE recognition (Heerey et al., 2003; Kasari et al., 2001). In addition, some studies report intact but atypical abilities, such as requiring greater time and more frequent prompting to label SCEs (Capps et al., 1992) or offering impoverished justifications for their evaluations (Hillier & Allinson, 2002a). In addition, youths with ASD demonstrate an intact, albeit attenuated, understanding of the role of an audience in the elicitation of SCEs. Youths with ASD find situations more embarrassing when an audience is *explicitly* present (Hillier & Allinson, 2002b), yet they show greater difficulty understanding the impact of an *implicit* audience (Hillier & Allinson, 2002a), and they offer less rich justifications for their evaluations (Hillier & Allinson, 2002b). Thus, individuals with ASD may recognize the social rules that inform embarrassment, but may pay less attention to mental states when inferring others' emotions (Hillier & Allinson, 2002a). In support of this interpretation, research investigating children and adolescents with ASD has linked advanced

ToM abilities with greater SCE recognition (Heerey et al., 2003) and richer justifications for SCE attributions (Hillier & Allinson, 2002a).

Empathic Self-Conscious Emotions. Several studies have explored *empathic* SCE processing, or feeling SCEs *on behalf of others*. Adults with ASD report heightened empathic embarrassment when viewing drawings of tsagets in embarrassing situations (Krach et al., 2015) and watching videos of targets performing embarrassing tasks (Adler et al., 2015). However, adults with ASD and NT adults report similarly intense empathic embarrassment when viewing photographs of targets (Morita et al., 2016; Morita et al., 2012). Research suggests that empathic embarrassment may be modulated by the situational context: adults with ASD and NT adults report feeling similar levels of embarrassment for targets who engage in *accidental* social norm violations, but adults with ASD report feeling reduced empathic embarrassment for targets who engage in *intentional* transgressions (Paulus, Kamp-Becker, & Krach, 2013).

Research has not yet uncovered the social cognitive basis for atypical empathic SCE processing in ASD. One study linked elevated empathic embarrassment to increased personal distress (possibly reflecting emotional hyperresponsivity and impaired emotion regulation) (Adler et al., 2015), while another linked vicarious embarrassment to empathic tendencies (Paulus et al., 2013). To date, only one study has explored empathic SCEs in youths with ASD. Children with ASD and NT children reported similar levels of empathic embarrassment when they viewed drawings of targets in embarrassing situations, yet children with ASD offered less rich justifications for their ratings (Hillier & Allinson, 2002b). Overall, these findings suggest that children and adults with high-functioning ASD may have an intact conceptual understanding of empathic SCEs (at least of empathic embarrassment) when framed within the context of expected outcomes and internalized social rules, although empathic responses may be modulated by mentalizing abilities, empathic tendencies, or the situational context.

Neural Correlates of Self-Conscious Emotion Processing

Overview. A recent review (Jankowski & Takahashi, 2014) highlighted three potential neural networks underlying SCE processing. First, cortical midline structures (CMS), associated with self-processing and self-evaluation, may be involved in SCE processing, including medial prefrontal cortex (mPFC; dorsal, anterior rostral, and ventral regions [dmPFC, armPFC, vmPFC] and anterior cingulate cortex [ACC]) and medial posterior parietal cortex (mPPC; precuneus [PC], posterior cingulate cortex [PCC], retrosplenial cortex [RSC]) (Northoff & Bermpohl, 2004; Northoff et al., 2006; Qin & Northoff, 2011). In particular, the armPFC and vmPFC have been highlighted as key regions for supporting self-referential processing (Denny, Kober, Wager, & Ochsner, 2012) and self-consciousness (Somerville et al., 2013). A second set of potential regions include the anterior insula (AI), dorsal anterior cingulate cortex (dACC), and inferior frontal gyus (IFG), underlying interoception and empathic processing (i.e., emotional resonance and empathic concern) (Fan, Duncan, de Greck, & Northoff, 2011; Lamm, Decety, & Singer, 2011). Finally, regions of the putative “social brain” supporting mental state inference and intention attribution, including mPFC, PC/PCC, posterior superior temporal sulcus (pSTS), temporoparietal junction (TPJ), and anterior temporal lobe (ATL)/temporal pole (TP), are likely integral to SCE processing (Gallagher et al., 2000; Ruby & Decety, 2004; Young, Cushman, Hauser, & Saxe, 2007). Moral reasoning, which engages similar processes as SCE processing, including self-evaluation and social norm referencing, is associated with a frontal-temporal-limbic network, which reveals significant overlap with the proposed SCE regions, including mPFC, TPJ/pSTS, and ATL (Moll, de Oliveira-Souza, Bramati, & Grafman, 2002; Moll, Oliveira- Souza, & Zahn, 2008; Moll, Zahn, de Oliveira-Souza, Krueger, & Grafman, 2005). Moll, Zahn, and colleagues proposed that the ATL broadly encodes abstract social concepts, while frontal-limbic regions differentially encode social context and social function: the mPFC is associated with self-agency and promotes prosociality; the dorsolateral prefrontal cortex (dlPFC) and orbitofrontal cortex (OFC) are associated with criticism of others and promote social aversion; and mesolimbic regions are associated with pleasure/reward and promote social attachment and empathic concern (Fontenelle, de Oliveira-Souza, & Moll, 2015; Moll et al., 2008; Zahn et al., 2008).

Embarrassment. A growing body of research has begun to explore the neural correlates of embarrassment processing in NT adults. Embarrassment is commonly associated with activity within the "social brain" (mPFC, pSTS/TPJ), supporting mental state inference and social perception; the ATL/TP, representing conceptual social knowledge (i.e., social standards/rules); the hippocampus, supporting memory; and occipital regions, reflecting salience (Berthoz, Armony, Blair, & Dolan, 2002; Krach et al., 2011; Michl et al., 2012; Moll et al., 2007; Takahashi et al., 2004). These findings are supported by neuroimaging research as well as lesion studies (see Jankowski & Takahashi, 2014 for review).

Embarrassment was initially explored within the framework of moral reasoning. Participants read first- and third-person vignettes representing intentional or unintentional (embarrassing; e.g., spitting out food) social norm violations and imagined how embarrassed a target would feel in each scenario (Berthoz et al., 2002). Broadly, social norm violations (relative to normative social behavior) were associated with recruitment of bilateral prefrontal, temporal, and occipital activity supporting mental state attribution (mPFC, TPJ, ATL/TP) and negative emotion processing (OFC, lPFC)). Intentional norm violations, relative to unintentional ones, were associated with greater activity within social cognition regions, perhaps representing heightened emotional PT demands. Research exploring first-person social and moral transgressions also reported TPJ and prefrontal (dmPFC, vlPFC) activity, which suggests that these regions may respectively facilitate intention attribution and behavioral change in response to aversive social cues (Finger, Marsh, Kamel, Mitchell, & Blair, 2006).

Studies explicitly investigating first-person embarrassment offer converging evidence for the importance of a medial prefrontal-temporal-occipital network. In a seminal study by Takahashi and colleagues (2004), participants read sentences that elicited embarrassment (e.g., "I noticed that the zipper on my pants was open"), guilt (e.g., "I shoplifted a dress from the store"), or neutral emotion (e.g., "I changed into my pajamas at night"). Embarrassment, compared to neutral emotion, was associated with greater activity within bilateral prefrontal (mPFC, OFC), medial temporal (pSTS, hippocampus), and occipital regions associated with mental state attribution, memory, and emotional salience; and embarrassment ratings correlated positively with pSTS and occipital activity. Compared to guilt, embarrassment recruited greater anterior and medial temporal activity, possibly representing enhanced social conceptual knowledge processing. A replication study reported bilateral frontal, temporal, and occipital activity during embarrassment processing, although in more lateral regions (excluding mPFC) (Michl et al., 2012).

To date, no study has investigated the neural correlates of specific SCEs within developmental samples. Somerville and colleagues (2013) broadly explored the emergence of self-consciousness across development, which the authors linked with feeling of embarrassment. Participants (ages 8-22) were told that the researchers were testing out a new video camera. Participants passively watched a computer screen that indicated if the camera was on (evaluation stage), warming up (anticipation stage), or off (control stage). Participants were told that an age- and gender-matched peer would be watching the video feed, and thus, could observe the participant when the camera was on. Changes in self-consciousness during the anticipation and evaluation stages were modeled across development via behavioral, physiological, and neural indicators, with age as a linear, quadratic, or asymptotic predictor. Collapsed across age, only the mPFC was recruited during the anticipation and evaluation stages, and activity increased linearly (peaking at age 15). Embarrassment ratings also increased linearly (peaking at age 17), and skin conductance showed quadratic effects (peaking at age 14). These findings suggest that self-consciousness emerges and peaks during adolescence, and that CMS activity (particularly the mPFC) may play a key role in feelings of self-consciousness and social evaluation.

A cross-sectional study compared neural patterns recruited by adolescents and adults during nonsocial emotion (disgust, fear) and social emotion (embarrassment, guilt) processing (Burnett, Bird, Moll, Frith, & Blakemore, 2009). Participants read emotion-eliciting sentences and evaluated how intensely the target (either oneself or one's mother) would feel in each scenario. Example sentences included, "You tripped in front of a boy you liked" (embarrassment) and "You laughed when your friend told you she was feeling upset" (guilt). Both adolescents and adults recruited activity within the armPFC and pSTS/TPJ (although from different hemispheres); adolescents uniquely recruited PC activity, and they recruited greater armPFC activity compared to adults, while adults recruited greater ATL/TP activity. While this study did not investigate neural patterns uniquely associated with embarrassment, results broadly suggest that negative SCE processing in adolescents may be associated with anterior and posterior CMS activity, although developmental differences may exist.

Researchers have begun to investigate neural patterns associated with empathic embarrassment. Krach and colleagues (Krach et al., 2011; Paulus, Müller-Pinzler, Jansen, Gazzola, & Krach, 2014) showed participants drawings of targets in embarrassing situations and manipulated targets' awareness of the social context; this allowed researchers to investigate neural patterns uniquely associated with shared and nonshared empathic embarrassment. Empathic embarrassment (relative to neutral emotion) was broadly associated with activity within social cognition regions (i.e., mPFC, ATL/TP), as well as regions implicated in affective and empathic pain processing (i.e., AI and ACC). Empathic embarrassment ratings correlated positively with AI and ACC activity, as did trait empathy (Krach et al., 2011; Paulus et al., 2014). These findings suggest that the AI and ACC may play key roles in empathic embarrassment, possibly representing emotional resonance of others' pain. Shared empathic embarrassment was associated with greater pSTS activity compare to nonshared empathic embarrassment, which the authors interpreted as representing enhanced simulation of emotional states (emotional contagion). Melchers and colleagues (Melchers et al., 2015) studied empathic embarrassment using more ecologically-valid stimuli: video clips from reality TV shows. Empathic embarrassment was associated with activity within inferior frontal, inferior parietal, and medial temporal regions, which correlated positively with empathic embarrassment ratings. The authors proposed that these patterns might reflect mental state attribution and empathic concern associated with empathic embarrassment.

Broadly, these studies suggest that embarrassment processing may be supported by a medial prefrontal-temporal-occipital network underlying mental state inference, social norm referencing, and salience attribution; while empathic embarrassment may be supported by a limbic network supporting introspection, emotional resonance, and empathic concern.

Pride. Several studies have investigated the neural correlates of pride. In a seminal study by Takahashi and colleagues (Takahashi et al., 2007) participants read first-person sentences representing pride (e.g., "I graduated at the head of my class"), joy (e.g., "I won the lottery"), and neutral emotion (e.g., "I went to school yesterday"). Pride, compared to neutral emotion, was associated with right pSTS and left ATL/TP activity; and pride ratings correlated positively with pSTS activity. In contrast, joy was associated with ventral striatal activity, which correlated positively with joy ratings. These findings may reflect the more social cognitive nature of pride (requiring mental state attribution), compared to the more hedonic nature of joy. Interestingly, pride was not associated with mPFC activity, which the authors proposed may represent their task's less elaborate or explicit self-reflection demands. In a related study, participants viewed photographs that evoked feelings of pride (e.g., students graduating), compassion (e.g., needy children), and neutral emotion (Simon-Thomas et al., 2011). Pride was associated with PCC activity (but not mPFC activity); and pride, compared to compassion, was associated with greater activity within PCC, inferior temporal gyrus. and parahippocampus, which the authors suggested may reflect heightened episodic memory. Furthermore, pride-relevant ratings (pride and enjoyment) correlated negatively with activity within the AI, IFG, and vlPFC during pride processing, which the authors posited may reflect reduced other-focus and emotional sharing (Simon-Thomas et al., 2011). Research by Roth and colleagues (Roth, Kaffenberger, Herwig, & Brühl, 2014) investigated first-person pride processing via autobiographical memories and found that pride recollection was associated with activity within CMS (dmPFC, PCC, PC), dlPFC, AI/IFG, striatal regions (VS, thalamus, caudate), and amygdala. Interestingly, recalling memories that evoked feelings of pride, as well as those that evoked feelings of shame/guilt, were similarly associated with mPFC activity, which the authors attributed to their task's strong self-referential nature. In addition, pride and shame/guilt recruited comparable ventral striatal activity, which the authors suggested may reflect similar salience or affective motivation. However, research by Zahn and colleagues (Zahn et al., 2008) linked medial prefrontal and mesolimbic activity during pride processing to self-agency and prosociality/motivation, respectively. Overall, these findings suggest that pride may be associated with a temporal-parietal social cognition network (similar to embarrassment), and the recruitment of medial prefrontal, medial posterior parietal, limbic, and striatal activity may be task-specific, reflecting differences in self-agency/self-reference, memory retrieval, and affiliative motivation.

Neural Correlates of Self-Conscious Emotion Processing in ASD

To date, only a few neuroimaging studies have investigated SCE processing in ASD. Krach and colleagues (Krach et al., 2015) compared neural patterns recruited by adults with ASD and NT adults in response to viewing photographs of physically painful or socially painful (embarrassing) situations. Adults with ASD recruited similar activity as NT adults during empathic *physical* pain processing; however, they recruited attenuated AI activity (and marginally attenuated ACC activity) during empathic *social* pain processing, and reduced AI activity was associated with greater autism symptom severity. Interestingly, empathic social pain ratings correlated with greater AI and ACC activity for NT adults, but greater hippocampal activity for adults with ASD. The authors suggested that atypical empathy for social pain in ASD may reflect difficulties integrating social rules/expectations with complex contextual demands. Consequently, individuals with ASD may experience impaired emotional embodiment of others' social pain (as reflected in reduced AI/ACC activity), which they may compensate for by explicitly referencing and rigidly applying learned social rules (as reflected by increased hippocampal recruitment).

Pantelis and colleagues (Pantelis, Byrge, Tyszka, Adolphs, & Kennedy, 2015) used a more ecologically-valid task to measure responsivity to social awkwardness (a possible precursor for empathic embarrassment). Adults with ASD and NT adults viewed an episode of *The Office*, a TV show featuring socially-inappropriate scenarios, and rated levels of social awkwardness, which were regressed onto neural patterns. Both groups recruited activity from a prototypical social cognition network, including mPFC, TPJ, STS, and PC, as well as OFC and occipital regions. However, NT adults recruited greater activity than adults with ASD within the right TPJ/pSTS, which the authors suggested may play a distinct role in atypical social cognition in ASD. Overall, these studies offer preliminary evidence for a relatively intact mentalizing network during empathic SCE processing, but atypicalities within select regions supporting emotional awareness/affective embodiment (AI/ACC) and intention attribution (pSTS/TPJ), particularly during complex social situations.

CHAPTER II

CURRENT STUDIES

Motivation

"If God wanted to create a perfect recipe for embarrassment, the teen years might be it."

-Miller, 1996, p. 87

As described in previous sections, SCE processing plays a key role in interpersonal success, by promoting social acceptance and preventing social rejection (Tracy & Robins, 2007e). Adolescence is an ideal period to investigate the development of SCE understanding. SCEs (particularly embarrassment) are experienced more frequently and more intensely during adolescence (Buss et al., 1979; Miller, 1992), and empathic embarrassment emerges in late childhood (Bennett & Cormack, 1996) and continues to develop throughout adolescence. Advanced social cognitive abilities and their underlying neural correlates mature significantly during adolescence (Blakemore & Choudhury, 2006), which are reflected in the heightened social cognitive demands associated with adolescent interpersonal interactions. Furthermore, peer perceptions and peer relationships become increasingly valued and important (Csikszentmihalyi & Larson, 2014; Nelson et al., 2016). In fact, Miller suggests that adolescents' heightened subjective experience of embarrassment may be attributed to enhanced concerns of peer evaluations (Miller, 1992).

Despite age-related reductions in autistic symptoms and gains in verbal IQ, approximately 75% of children with ASD continue to experience significant social challenges in adolescence and adulthood (Anderson et al., 2011; VanBergeijk, Klin, & Volkmar, 2008)**.** Atypical social cognition, characteristic of ASD, can significantly impair social interactions and peer relationships; and emotion perception, in particular, is a noted moderator of socialization skills in youths with ASD (Hudepohl, Robins, King, & Henrich, 2015). Atypical SCE processing may be perceived as diminished social awareness or reduced empathic concern, which may put youths with ASD at increased risk for bullying or social exclusion. The current study aims to investigate the subjective experience of SCEs in adolescents with ASD; to elucidate the neurobiological correlates of existing atypicalities in adolescents with ASD; and to broadly explore the role of a triad of social cognitive processes in adolescents with and without ASD. One long-term goal is to shed light onto the real-world interpersonal challenges experienced by youths with ASD and to offer potential avenues for future intervention.

Innovation

This dissertation is innovative in its methodological design and developmental approach. Neuroimaging studies investigating SCEs have commonly implemented tasks where participants are instructed to read hypothetical sentences or short vignettes representing SCEs and imagine themselves as the target. These tasks, as well as paradigms featuring drawings of targets experiencing SCEs, often demonstrate an over-reliance on prototypical examples, such as ripping one's pants in public to demonstrate embarrassment. These scenarios tend to be uncommon or unrealistic and lack personal salience, thus limiting the generalizability of potential findings. In comparison, this dissertation implemented a novel task featuring dynamic video clips of peers participating in a singing competition and acting embarrassed or proud of their performance. Recent neuroimaging research has advocated for the use of more naturalistic and ecologically-valid paradigms to better reflect real-world abilities and responsivity, particularly when investigating individuals with ASD who may show intact abilities within a controlled laboratory environment, but report real-world difficulties within more complex, contextualized social interactions (Pantelis et al., 2015; Redcay, 2008; Redcay et al., 2010). Indeed, dynamic affective stimuli (compared to static affective stimuli) more closely resemble real-world SCE expressions, as well as facilitate greater accuracy on emotion recognition tasks (Krumhuber, Kappas, & Manstead, 2013; Wehrle, Kaiser, Schmidt, & Scherer, 2000); and dynamic affective stimuli elicit more robust neural activity within emotion-processing regions (Trautmann, Fehr, & Herrmann, 2009). Dynamic video stimuli are also effective in inducing empathy in others (Adler et al., 2015; Raz et al., 2013). Thus, this dissertation is well positioned to explore inferential SCE abilities and empathic SCE tendencies in individuals with and without ASD.

Another strength of this dissertation is its use of age-matched targets. While commonly-used affective stimuli often feature adult actors (Tottenham et al., 2009), this dissertation featured adolescent actors. A recent meta-analysis of facial recognition studies found that using stimuli featuring age-matched targets enhanced task saliency and improved task performance in children and adults (Rhodes & Anastasi, 2012). Consequently, emotion recognition tasks that use age-matched targets may be more salient and facilitate greater task performance as well.

An additional strength of this dissertation is its use of multimodal stimuli. Most emotion recognition studies use static images of faces, or an isolated region of the face (e.g., the eye region), which may not closely resemble the real-world subjective experience of SCE processing, and may unintentionally handicap individuals with ASD who may rely more strongly on postural affective cues (Klin, Jones, Schultz, Volkmar, & Cohen, 2002). This dissertation used stimuli that provided a full complement of facial, postural, gestural, and prosodic affective cues, thus, more accurately reflecting real-world emotion expression, and offering the opportunity to more accurately investigate the emotion recognition abilities of individuals with ASD.

Finally, this dissertation is innovative in its developmental approach. Neuroimaging studies explicitly investigating SCE processing have been restricted to adult samples, and few neuroimaging studies have explored advanced social cognitive abilities in youths with ASD. However, as described above, adolescence represents a significant sensitive period for the development of advanced social cognitive processes and critical neural circuitry underlying SCEs. Thus, adolescence represents a key time stage for investigating the development of SCE understanding, as well as for implementing future interventions.

Aims of the Current Study

Aim 1. Youths with ASD recognize prototypical SCE facial expressions (Adler et al., 2015; Hillier & Allinson, 2002a; Hobson et al., 2006; Tracy et al., 2011; Williams & Happé, 2010) but offer less appropriate justifications for their evaluations (Hillier & Allinson, 2002a, 2002b). Adults with ASD experience empathic embarrassment on behalf of their peers, but the intensity of these emotions are diminished when intention attribution is required (Paulus et al., 2013). These findings suggest a more basic understanding of SCEs in ASD, which emphasize surface level processing over intention attribution. The first aim of this dissertation was to characterize group differences in the subjective experience of embarrassment and pride processing, and to investigate the modulatory role of PT demands on group differences. Adolescents with ASD and NT adolescents watched short video clips of peers participating in a singing competition and acting either embarrassed or proud of their singing. During clips with low PT demands, singers' emotional reactions matched the situational context (i.e., singers sang poorly and acted embarrassed, or singers sang well and acted proud). During clips with high PT demands, singers' emotional reactions did not match the situational context (i.e., singers sang poorly and acted proud, or singers sang well and acted embarrassed).

To investigate group differences in the ability to make SCE attributions, participants rated how embarrassed and how proud they believed each singer felt (inferred SCE ratings). To investigate group differences in the ability to experience empathic SCEs for others, participants rated how embarrassed and how proud they felt on behalf of each singer (empathic SCE ratings). To investigate the influence of the proposed triad of social cognitive abilities on SCE understanding, participants completed a battery of questionnaires and tasks assessing self-awareness/introspection, PT/cognitive empathy, and affective empathy; and their scores were compared across groups and correlated with inferred and empathic SCE ratings. Scores reflecting autism symptom severity and autistic traits were also compared across groups and correlated with inferred and empathic SCE ratings.

I predicted a main effect of group and a main effect of PT demands, qualified by an interaction effect between group and PT demands. Specifically, I predicted that adolescents with ASD would recognize and resonate with SCEs (as reflected in average inferred and empathic SCE ratings), but less intensely, compared to NT adolescents. Collapsed across groups, I predicted that both inferred and empathic SCE ratings would be reduced when PT demands were high, and PT demands would modulate group differences. Specifically, when PT demands were high, adolescents with ASD would demonstrate significantly reduced inferred and empathic SCE ratings, and group differences would be stronger. While I did not have any strong *a priori* hypotheses for the effect of emotion, if a three-way interaction existed, I predicted the least (or perhaps no) group differences for pride processing when PT demands were low, given that youths with ASD rely strongly on valence cues during SCE recognition (Losh & Capps, 2006), and pride can be more easily identified by positive surface-level features. Furthermore, I predicted that inferred and empathic SCE ratings would be positively correlated with the triad of social cognitive abilities, such that participants who scored higher on self-awareness/introspection, PT/cognitive empathy, and affective empathy would report more intense inferred and empathic SCE ratings. I also predicted that inferred and empathic SCE ratings would be negatively correlated with autism symptom severity/autistic traits, such that participants who scored higher on autism symptom severity or autistic traits would report less intense inferred and empathic SCE ratings.

Aim 2. Regardless of the extent of group differences in the subjective experience of SCEs, the neural basis of SCEs in ASD is unclear. While a few neuroimaging studies have begun to explore embarrassment processing in adults with ASD (Krach et al., 2015; Pantelis et al., 2015), no study has explored pride processing in individuals with ASD; and SCE processing has yet to be explored within developmental samples. The second aim of this dissertation was to characterize group differences in neural activation patterns recruited during embarrassment and pride processing in adolescents with and without ASD, and to investigate the modulatory role of PT demands on differential neural patterns. Embarrassment processing is associated with a medial prefrontal-temporal-occipital network, including regions associated with self-reflection and ToM (anterior CMS, pSTS/TPJ, ATL/TP), as well as regions associated with empathy/interoception (AI, IFG, ACC) (Krach et al., 2011; Melchers et al., 2015; Morita et al., 2008; Morita et al., 2013; Paulus et al., 2014; Takahashi et al., 2004). Pride is associated with a medial parietal-temporal network, which includes overlapping ToM regions (pSTS, as well as posterior CMS) (Roth et al., 2014; Simon-Thomas et al., 2011; Takahashi et al., 2007). Preliminary research exploring embarrassment processing in adults with ASD suggests atypical recruitment of AI/ACC and temporal regions (Krach et al., 2015; Morita et al., 2016; Morita et al., 2012; Pantelis et al., 2015), while neuroimaging research more broadly exploring social cognitive abilities in ASD suggests atypical recruitment of ToM regions (e.g., Gallagher et al., 2000; Castelli et al., 2002).

I predicted a main effect of group and a main effect of PT demands, qualified by an interaction effect between group and PT demands. Specifically, I predicted that NT adolescents would recruit CMS, pSTS/TPJ, ATL/TP, and limbic regions associated with interoception (AI, IFG, ACC) during embarrassment and pride processing, and adolescents with ASD would recruit similar, albeit attenuated, activity, particularly within the "social brain" network supporting ToM (CMS, pSTS/TPJ, ATL/TP). I predicted that participants would recruit greater activity within the "social brain" network during high, compared to low, PT demands, and group differences would be stronger during high PT demands.

CHAPTER III

METHODS

Participants

Adolescent males (ages 11-17) were recruited to participate in the current study. Participants represented two groups: adolescents with high functioning autism spectrum disorders (ASD; including Autism, Autism Spectrum Disorder, Asperger's Syndrome, High Functioning Autism, and Pervasive Developmental Disorder-Not Otherwise Specified) and age-matched (within one year) adolescents with neurotypical development (NT). Participants were recruited via flyers posted in multiple physical and online communities, as well as from the University of Oregon's Developmental Database and the University of Oregon's Developmental Social Neuroscience (DSN) Lab's Research Database. Participants were excluded from the study if they had a neurological disorder, including: seizure disorder, central nervous system infection (e.g., meningitis), brain tumor, muscular or myotonic dystrophy, significant visual impairment (e.g., strabismus, visual handicap), and color blindness. Participants were also excluded from the study if they had MRI contraindications, including metallic braces or ferromagnetic orthodontia, metallic implants/metal fragments in their body, required a pacemaker or electronic medical implants; tattoos on their face, head or neck; habitual involuntary movement or twitching of their face, arms, or legs; hyperactivity; and claustrophobia.

Participants in the NT group were excluded if they had a diagnosis of an ASD or a first-degree relative had a diagnosis of an ASD (or concern thereof). Participants in the NT group were also excluded if they had a diagnosis of schizophrenia, bipolar disorder, recurrent major depression, Tourette's syndrome, attention deficit disorder, attention deficit hyperactivity disorder, conduct disorder, serious emotional disturbance, obsessive compulsive disorder, dyslexia, delay in learning to speak, learning disorder, anxiety disorder, mood disorder, drug dependency, or mental retardation/intellectual disability. Participants in the ASD group were excluded if they had a diagnosis of schizophrenia, Tourette's syndrome, dyslexia, or mental retardation/intellectual disability. All participants had a FSIQ >= 75 (according to the two-subscale FSIQ score on the WASI-II). Participants in the ASD group were not excluded if they had a diagnosis of depression, anxiety, attention deficit disorder, or attention deficit hyperactivity disorder, given their high comorbidity and overlapping symptomatology.

Autism diagnosis was confirmed for participants in the ASD group using the Autism Diagnostic Observation Schedule (ADOS), which is considered gold-standard within the field. Autism diagnosis was additionally confirmed using the Social Responsiveness Scale (SRS) and Autism Spectrum Rating Scale (ASRS). The ASRS and SRS are more sensitive to milder forms of autism (which may be more reflective of high-functioning adolescents with ASD including in the current sample), and the ASRS specifically reflects new DSM-V criteria (such as sensory sensitivities), which are not accounted for in ADOS scores. Participants in the ASD group scored within the autism range on all three indices: ADOS social + communication score (raw scores = 7+), SRS total score (T scores = 55+), and ASRS total and DSM-V scores (T scores = 60+). The ADOS was only administered to participants in the ASD group; however, all participants completed the SRS and ASRS. Participants in the NT group were excluded if they fell within the autism range on either the SRS or ASRS. (See Appendix for more information.)

82 participants enrolled in this dissertation research project. 16 participants from the ASD group and 10 participants from the NT group were excluded from Study I and Study II (ASD: n = 6 diagnostic criteria; n = 2 IQ criteria; n = 3 MRI contraindications; n = 2 noncompliance; n = 1 deceased; NT: n = 4 diagnostic criteria; n = 3 MRI contraindications; n = 1 withdrawal; n = 2

old version of the task). In addition, two participants from the ASD group were not invited to the MRI appointment (Study II) because their IQ data were initially scored incorrectly. After their data was correctly rescored, they were deemed eligible to participate but data collection was already complete. In addition, one participant from the ASD group was not invited to the MRI appointment (Study II) due to oversampling (participants who clearly met diagnostic criteria were prioritized for the autism evaluation appointment). Thus, 56 participants (30 ASD, 26 NT) were included in the final analyses for Study I and 52 participants (27 ASD; 25 NT) for Study II.

Procedures

Participants in the ASD group completed up to three appointments: a behavioral appointment, an autism evaluation, and a magnetic resonance imaging (MRI) appointment. Participants in the NT group completed up to two appointments: a behavioral appointment and an MRI brain scan. Behavioral appointments took place at the University of Oregon's DSN Lab in Eugene, Oregon or at the University of Oregon's White Stag building in Portland, Oregon. During behavioral appointments, participants and their parents/guardians completed paper and pencil tasks and questionnaires and computer tasks. The behavioral appointment was approximately 2.5 hours long, with a short break and snack provided halfway through the appointment. MRI appointments took place at the University of Oregon's Lewis Center for Neuroimaging. During the MRI appointment, participants completed a mock scan in an MRI simulator, where they practiced laying in the scanner bed and completing a practice version of the Self-Conscious Emotions Task (SCET-C). They also had the opportunity to listen to sample scanner sounds. Following the mock scan, participants completed the real MRI scan. After the MRI scan, they completed the Self-Conscious Emotions Rating Task (SCERT) and semi-structured interviews on their personal evaluations and experiences of embarrassment and pride.

Participants were debriefed at the end of the appointment to explain the study goals and the purpose of deception. The MRI appointment was approximately 2.5 hours, with a short break and snack provided immediately following the MRI scan. Only participants in the ASD group completed an autism evaluation. This appointment was approximately 1 hour long and took place at University of Oregon in Eugene, Oregon or at the University of Oregon's White Stag building in Portland, Oregon. During the autism evaluation, participants completed the ADOS, which was conducted by a research-certified ADOS administrator. Participants received monetary compensation for their time and effort ($25 for the behavioral appointment, $40 for the MRI appointment, and $15 for the autism evaluation, if eligible), and participants traveling from out of town were offered additional compensation.

Originally, participants were encouraged, when possible, to withhold anti-stimulant medication 24-hours prior to the MRI scan. (Other medications, such as anti-depressants, were not withheld.) However, this led to unusable scans, due to excessive motion. As of October 2016, participants were not required to withhold any medication prior to participating in the MRI scan.

Overview of Social Cognition, Autism, Social Competence, and Demographic Measures

Participants and their parents/guardians completed a battery of tasks and questionnaires assessing social cognitive abilities, autism symptoms/autistic traits, real-world social outcomes, and demographic information. Key social cognitive abilities included self-awareness/alexithymia, PT/cognitive empathy, and affective empathy, as measured by the Revised Self-Consciousness Scale-Child, Toronto Alexithymia Scale, Reading the Mind in the Eyes Task, Strange Stories Task, Interpersonal Reactivity Index, and Basic Empathy Scale. Autism symptoms/autistic traits were measured by the Social Responsiveness Scale, Autism Spectrum Rating Scale, and Autism Quotient. Social outcomes was assessed using child and parent versions of the Social Competence with Peers Questionnaire, as well as the Autism Spectrum Rating Scale. Information on general intelligence, pubertal status, age, ethnicity, and socioeconomic status was also collected. (See Appendix for more information on specific measures.)

Self-Conscious Emotion Measures

Self-Conscious Emotions Task- Child. Participants completed a child-friendly version of the Self-Conscious Emotion Task-Child (SCET-C; unpublished), designed specifically for this dissertation, to investigate the neural correlates of SCE processing in ASD and NT adolescents. During the MRI scan, participants watched short video clips of actors competing in a singing competition and rated the intensity of the singers' emotions. This task was modeled off an adult version of the task (SCET; unpublished), which was used to study the neural correlates of SCEs in Japanese adults (manuscript in-prep). Actors in the SCET-C included male and female American adolescents representing participants' age range.

The SCET-C included 30 short (~10s) video clips: 24 emotion clips and 6 neutral control clips. Emotion clips portrayed singers singing familiar pop songs either poorly or well in front of two judges and acting either embarrassed or proud of their performance. Neutral control clips portrayed singers waiting for the competition to start. These clips were designed to control for low-level visual, auditory, and semantic processes without presenting emotion, and are described further below. Emotion clips represented two SCE conditions (embarrassment, pride) and two PT conditions (low, high), such that clips varied according to the PT demands required to infer the singers' emotional states. In clips with low PT demands, singers expressed emotions that matched the situational context (singing quality; e.g., singers sang poorly and expressed embarrassment). Thus, participants could infer singers' emotions in clips with low PT demands by either paying attention to singers' affective facial and postural cues or the situational context (singing quality). In clips with high PT demands, singers expressed emotions that did not match the situation context (singing quality; e.g. singers sang well and expressed embarrassment). Thus, participants could only infer singers' emotions in clips with high PT demands by paying attention to singers' affective facial and postural cues, but not the situational context (singing quality). In summary, the task included five conditions: embarrassment with low PT demands (EmbLo), embarrassment with high PT demands (EmbHi), pride with low PT demands (PrideLo), pride with high PT demands (PrideHi), and neutral emotion (Neutral).

Feelings of embarrassment and pride in the emotion clips were conveyed via facial expressions, hand gestures, and body postures, as informed by affective research (Keltner & Buswell, 1997; Tracy & Prehn, 2012; Tracy & Robins, 2004b; Tracy, Robins, & Schriber, 2009). Specifically, actors expressed embarrassment by tilting their head downwards and sideways, directing their gaze downward, hunching and slumping their shoulders, narrowing their chest, and displaying a frown or a small silly smile. Actors expressed pride by tilting their head backwards and upwards, arching their back, pushing back their shoulders, expanding their chest, displaying a smile, and resting their hands on their hips with their arms akimbo. During the emotion clips, actors sang in front of two judges, to prime feelings of social evaluation.

During neutral emotion control clips, actors displayed neural facial expressions and body posture waiting for the competition to start. Singers stood still and looked forward while an announcer introduced the singer and instrumental versions of popular songs played in the background. For example, in one clip the announcer said, "This is contestant number twenty. The contestant will sing the song 'Take me to church' by the artist Hozier" while an instrumental version of the song "Take me to church" played in the background. A Gaussian filter was applied to neutral emotion control clips to distort and blur visual information. These clips were designed to control for surface level visual, auditory, and semantic processing. In addition, these clips did not provide information on performance quality, emotional content, or social evaluation, and judges were not present (to priming feelings of social evaluation). (See Figure 1 and Appendix for more information about the task design.)

A.

B.

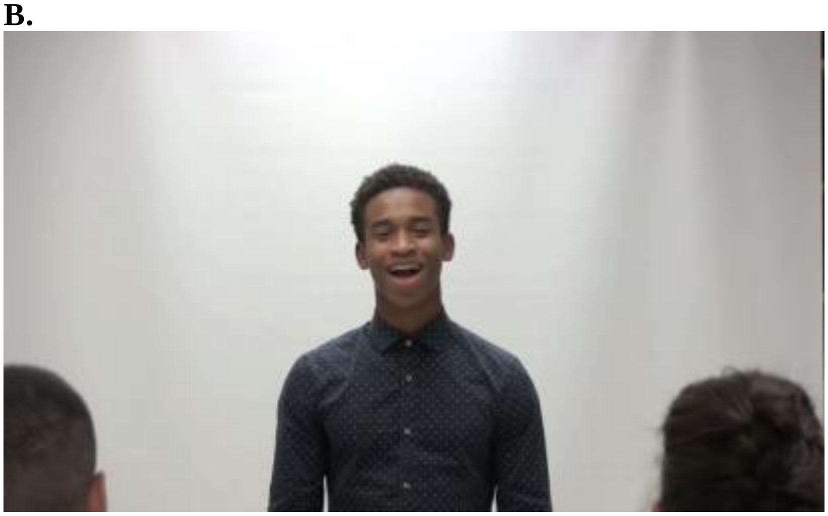

Figure 1. Still images of Self-Conscious Emotions-Child Task stimuli

Panel A) Still image of embarrassment video clip. **Panel B)** Still image of pride video clip.

The block-design MRI-compatible SCET-C consisted of two runs, with 15 video clips per run and 3 video clips per condition (i.e., EmbLo, EmbHi, PrideLo, PrideHi, and Neutral). Emotion and neutral control clips (8-12s) were presented in a pseudo-random order, based on a Latin square design, and all participants viewed the video clips in the same order. (See Appendix Table S4 for presentation order.) At the start of the task, participants were told that they would watch short video clips of peers singing in a singing competition. They were informed that the singers would have different singing abilities and would feel differently about their performance. Specifically, some singers would sing poorly and others would sing well, and some singers would feel bad about their singing and others would feel good about their singing. Participants were instructed to watch each clip and pay attention to both how the singers were singing and how they were feeling. After viewing each clip, participants used an MRI-compatible button box to rate how embarrassed the singer felt and how proud the singer felt on a 4-point Likert scale. (The order of emotion ratings was counterbalanced, such that half of participants made embarrassment ratings first and half made pride ratings first.) Participants pressed “1” with their index finger to select “none”, “2” with their middle finger to select “low”, “3” with their ring finger to select “medium”, and “4” with their pinky to select “high”. If the video clip was a neutral control clip, participants were instructed to press “0” with their thumb to select “blur”. (See Figure 2 for an example of the rating scale). Participants were given 4s to make each rating. Upon pressing a button, a blue triangle appeared above the number the participants pressed, indicating their response. Participants could change their answers by pressing a different button. (If a participant pressed multiple buttons in response to a video clip or responded in a way that was uncharacteristic of previous responses, the lead researcher made a note of these clips. After completing the MRI scan, outside the MRI, participants were asked to watch any video clips in question and confirm their responses. In most cases, participants confirmed that their last response was indeed the response they wished to select.) A 4s rest period followed the emotion ratings. During this time, participants passively viewed a white fixation cross on a black background. Jitter was interspersed between the video clips, rating periods, and rest periods. (See Figure 3 for task schematic.)

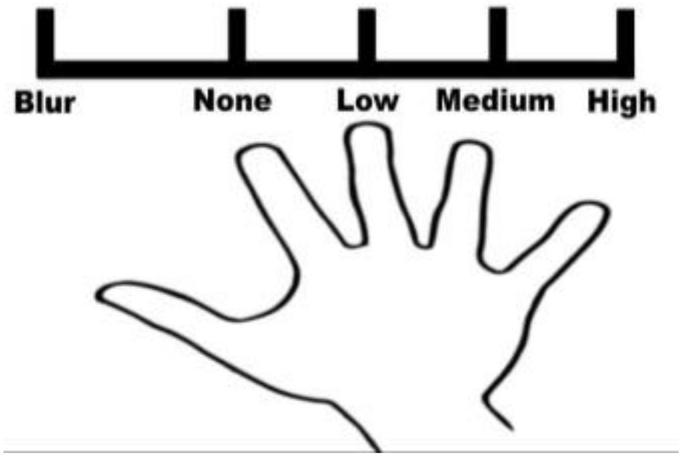

Figure 2. Self-Conscious Emotions Task-Child rating scale

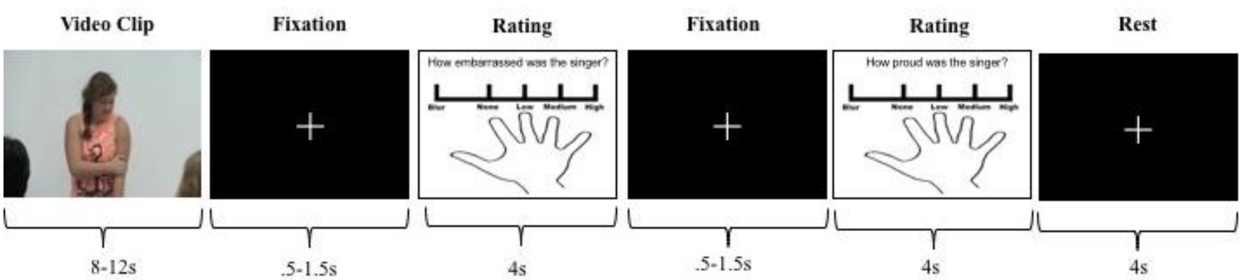

Figure 3. Self-Conscious Emotions Task-Child task schematic

Self-Conscious Emotions Rating Task. Following the MRI brain scan, participants completed the Self-Conscious Emotions Rating Task (SCERT; unpublished), designed specifically for this dissertation. During the SCERT, participants watched the same emotion video clips from the SCET-C, in the same order that they were presented during the MRI scan. After each video clip, participants were instructed to rate: how well the singer sang (singing quality), how bad they felt for the singer (empathy for negative emotion), how embarrassed they felt for the singer (empathic embarrassment), how good they felt for the singer (empathy for positive emotion), how proud they felt for the singer (empathic pride), and how funny the clip was (humor). Participants who rated embarrassment first during the SCET-C rated empathy for negative emotion and empathic embarrassment first during the SCERT; participants who rated pride first during the SCET-C rated empathy for positive emotion and empathic pride first; 1 participant who rated pride first during the SCET-C rated empathy for negative emotion and empathic embarrassment first for the SCERT, due to a technical error. Participants made their rating using the 1-5 numerical keys on a standard computer keyboard. Participants used a 5-point Likert scale to rate singing quality, where “1” represented “very bad” and “5” represented “very good”. Participants used a 4-point Likert scale (similar to the SCET-C) to rate empathy for negative emotion, empathic embarrassment, empathy for positive emotion, empathic pride, and humor, where “1” represented “none”, “2” represented “low”, “3” represented “medium”, and “4” represented “high”. Participants could take as long as they needed to complete the task and could change their answers as necessary.

Self-Conscious Emotions Task Post-Scan Interview. The Self-Conscious Emotions Task Post-Scan Interview (unpublished) is a semi-structured interview that assesses the types of affective cues and strategies participants employed to infer embarrassment and pride during the SCET-C. Participants first answered an open-ended question asking how they made embarrassment and pride ratings. Next, they described the specific cues/strategies they used to make these ratings. For example, participants were explicitly asked if they paid attention to the actors' facial expressions or part of his/her face or if they paid attention to the actors' body or posture. If participants answered "yes", they were asked to describe which parts of the face or body they paid attention to. At the end of the interview, participants answered an open-ended question asking if they had felt certain emotions *for* the actors, and finally were asked if they had felt specific emotions (e.g., sadness, anger, fear, embarrassment, shame, happiness, pride, or a different emotion) *for* the actors. The order of the interview questions was fixed. (All participants answered questions about embarrassment first and pride second.)

Data Analysis

Behavioral Data Analysis. Behavioral measures were analyzed in SPSS using independent-samples *t*-tests to investigate group differences in the proposed triad of social cognitive abilities (self-awareness/alexithymia, PT/cognitive empathy, and affective empathy) and autism symptomatology/traits. These measures were also used in correlational analyses to investigate relationships with inferred and empathic SCE ratings. To investigate group differences in the ability to make SCE attributions and to feel empathic SCEs on behalf of others, 2 (group: NT, ASD) x 2 (emotion: embarrassment, pride) x 2 (PT demands: low, high) repeated measures ANOVAs were conducted for inferred and empathic SCE ratings separately. While the SCET-C and SCERT were designed to investigate congruent SCE ratings, incongruent SCE ratings were also recorded and analyzed (see below). Congruent SCE ratings represented inferred or empathic SCEs that match the singer's expressed emotions (e.g., rating how embarrassed an embarrassed singer felt, or how empathically embarrassed one felt for an embarrassed singer). Incongruent SCE ratings represent inferred or empathic SCEs that did not match the singer's expressed emotions (e.g., rating how proud an embarrassed singer felt, or how empathically proud one felt for an embarrassed singer). Thus, to address the aims of Study I, group differences in the intensity of inferred congruent SCEs and empathic congruent SCEs were investigated. In addition, exploratory analyses were conducted to characterize group differences in the intensity of inferred incongruent SCEs and empathic incongruent SCEs. To address the additional aims of Study I, correlational analyses were conducted to investigate the role of the triad of social cognitive abilities, as well as autism symptoms/traits, in SCE understanding. Group differences in interview responses were explored using chi-square analyses.

Imaging Data Acquisition. Imaging data were acquired using a Siemens Skyra 3.0 Tesla head-only MRI scanner at the University of Oregon's Lewis Center for Neuroimaging. At the start of the scan, a circle localizer was acquired to allow the prescription of slices in the following scans. (During this time, participants also watched a practice video clip to adjust the volume of auditory stimuli.) A high-resolution T2-weighted structural scan (MP-RAGE; magnetization-prepared rapid-gradient echo sequence) was acquired coplanar to the functional sequence (TR = 2500 ms, TE = 34 ms, flip angle = 7°, matrix size = 256 x 256, in-plane resolution = 1 x 1 mm, 1 slice, slice thickness = 1 mm), and a standard double-echo sequence field map was acquired while participants watched child-friendly animated movies. Afterwards, participants completed the functional task while blood oxygen-level dependent, echo-planar images (BOLD-EPI; 200 and 203 volumes for the first and second run, respectively) were acquired across the whole brain with a T2*-weighted gradient echo sequence (TR = 2000 ms, TE = 25 ms, flip angle = 90°, matrix size = 64 x 64, in-plane resolution = 2 x 2 mm, 72 slices, slice thickness = 2 mm, interleaved acquisition) along the anterior commissure-posterior commissure (AC-PC) transverse oblique plane, as determined by the midsagittal section, using GRAPPA acceleration parallel image acquisition (R=2). Javascript was used to present stimuli (via back-projection) and to collect participants' responses and reaction times (RTs). Participants used an

MRI-compatible button-box to make task-relevant ratings. All participants used a right-handed button box. Three participants were left-handed/ambidextrous; they confirmed they felt comfortable and practiced using a right-handed button-box prior to the MRI scan. Foam padding was used to prevent head movement, and MRI-compatible earbuds were worn to protect hearing and deliver auditory stimuli.

Imaging Data Analysis. Imaging data were preprocessed using Statistical Parametric Mapping 12.0 (SPM12; Wellcome Department of Imaging Neuroscience, London, UK) software implemented in MATLAB. Images were converted from DICOM to NIfTI format using MRIconvert (https://lcni.uoregon.edu/~jolinda/MRIConvert). Each participant's MP-RAGE was coregistered to SPM's canonical structural template (MNI-152). In cases where coregistration was unsuccessful, modifications were made by manually orienting the coregistered MP-RAGE to the MNI-152 structural template. Voxel displacement maps were calculated for each participant using a double-echo field map (see https://lcni.uoregon.edu/kb-articles/kb-0003) and functional images were realigned and unwarped using participant-specific voxel displacement maps. (One participant was missing a field map. To address this discrepancy, an average of all participants' phase maps was calculated using FSL (FMRIB Software Library). Functional images were unwarped using the average of all participants' phase maps and the specific participant's structural image as inputs for the phase and magnitude maps, respectively.) The realigned and unwarped mean image and functional images were then coregistered to the coregistered MP-RAGE. Each participant's coregistered MP-RAGE was segmented into six tissue types (corresponding to gray matter, white matter, cerebral spinal fluid, bone, skin, and air/background) and combined to create a DARTEL template, representing all 56 participants.

Data were normalized to the DARTEL template and smoothed using a 6 mm full-width, half-maximum (FWHM) isotropic Gaussian kernel.

Participants were excluded from the final MRI analyses if >30% of the volumes of each run (or >30% of the total volumes) had motion artifact. In cases where >30% of the volumes of only one run had motion artefact, these individual runs were excluded from the analyses but the participant was not excluded. Motion artefact was characterized using both automated and manual artefact detection methods. First, using scripts developed in the DSN Lab (http://github.com/dsnlab/auto-motion), motion parameters were transformed into Euclidian distance for translations (x, y, z) and rotations (pitch, roll, yaw). These distances, along with the mean and standard deviation of voxel intensity for each volume, were used to detect volumes affected by motion. Volumes that exceeded .3 mm movement in Euclidian distance; volumes that were greater than 3 standard deviations above or 1.5 standard deviations below the mean voxel intensity across subjects; and volumes that were greater than 3 standard deviations above or below the mean standard deviation of voxel intensity across subjects were marked. Volumes that were immediately preceded by and followed by volumes marked as described above were also marked (i.e., "sandwich volumes"). Finally, motion artefact was assessed by visually inspecting 4d movies of each volume per participant (created and viewed in FSL).

Subject-level models were calculated in SPM12. For each participant, condition effects were estimated according to the general linear model, using a canonical hemodynamic response function. An optimal threshold mask representing the average of all participants' combined, binarized, and smoothed gray matter and white matter maps was applied to the data. A 128 s high pass filter was used to remove low-frequency noise and an autoregressive model, AR(1), was used to estimate temporal autocorrelation. First-level, single-subject models included five regressors of interest (each emotion condition: EmbLo, EmbHi, PrideLo, PrideHi, and Neutral) and seven regressors of no interest (a trash variable representing instructions, two trash variables representing rating blocks for embarrassment and pride, five motion parameters representing i) and ii) Euclidean distance for translations and rotations, respectively; iii) and iv) their first derivatives; and v) a binary-coded variable marking individual volumes with motion artefacts detected automatically or manually. Planned linear contrasts were created to identify neural regions where activity was greater for each SCE condition compared to the neutral control condition (EmbLo > Neutral, EmbHi > Neutral, PrideLo > Neutral, PrideHi > Neutral).

To estimate population effects, whole-brain, group-level models were calculated in AFNI (version 17.1.07) implemented in R (version 3.3.3). The decision to switch analysis programs for group-level modeling was informed by learning that SPM's full factorial design does not properly account for subject-level variance and SPM's flexible factorial design does not appropriately model the main effect of group. In comparison, AFNI's 3dMVM properly accounts for subject-level variance, appropriately models main effects and interaction effects for mixed-design models (including between-subject and within-subject variables), and appropriately analyzes main and interaction effects of group when groups have an unequal number of participants (as is the case for this dissertation).

Subject-level contrasts were entered into a 2 (group: NT, ASD) x 2 (emotion: embarrassment, pride) x 2 (PT demands: low, high) repeated measures ANOVA using 3dMVM. Post-hoc *t*-tests and ANOVAs were also specified in this model. I was particularly interested in exploring the main effect of group and interaction effects between group and emotion, and between group and PT demands. I was also interested in a three-way interaction effect between group, emotion, and PT demands, if it existed. Results were masked using the same average optimal threshold mask applied at the subject-level. A combined voxel-height and cluster-extent threshold was calculated to control for Type 1 error using Monte Carlo simulations via AFNI's 3dClustSim (version 17.1.07); an $\alpha = 0.05$ was achieved via $p < 0.001$, $k > 30$. Smoothness estimates entered into 3dClustSim represented an average of subject-level spatial autocorrelation function (acf) parameters based on individual subjects' residuals from the group-level model, as calculated by 3dFWHMx using the -acf flag and the average optimal threshold mask.

To investigate significant interaction effects, masks of significant clusters of activity for each group-level contrast of interest (main effect of group, group x emotion interaction effect, group x PT interaction effect, and group x emotion x PT interaction effect) were created using 3dClust. These cluster-specific masks were then used to extract average parameter estimates from subject-level contrast maps (representing EmbLo > Neutral, EmbHi > Neutral, PrideLo > Neutral, PrideHi > Neutral) for each participant using 3dmaskave. These parameter estimates were entered into post-hoc *t*-tests in SPSS to explore simple effects. For three-way interactions, I conducted paired *t*-tests for each group to explore the effect of PT demands for each emotion (EmbLo vs EmbHi; PrideLo vs PrideHi), and to explore the effect of emotion for each level of PT demands (EmbLo vs PrideLo; EmbHi vs PrideHi). I also conducted independent samples *t*-tests to explore group differences during each condition (NT vs ASD EmbLo, EmbHi, PrideLo, PrideHi). Results were considered significant at $p \leq 0.05$ (uncorrected), and marginally significant at $p \leq 0.06$ (uncorrected). In addition, significant clusters from the intercept that represented *a priori* regions of interest were used as ROIs. Parameter estimates were similarly extracted from masks representing these clusters and entered into 2 (group: NT, ASD) x 2 (emotion: embarrassment, pride) x 2 (PT demands: low, high) repeated measures ANOVAs and analyzed in SPSS. Results were considered significant at $p \leq 0.05$ (uncorrected), and marginally significant at $p \leq 0.06$ (uncorrected). Post-hoc analyses were conducted to explore main effects and interaction effects using the same analysis plan as mentioned above. I also conducted independent samples *t*-test to explore group differences in activity within each ROI during each condition (NT vs ASD EmbLo, EmbHi, PrideLo, PrideHi), regardless if a significant main or interaction effect was observed. Anatomical labels were determined via visual inspection and confirmed with AFNI's automated labeling program.

In addition, two 2 (emotion: embarrassment, pride) x 2 PT demands (low, high) repeated measures ANOVAs were calculated for the NT and ASD groups, separately. Combined voxel-height and cluster-extent thresholds were calculated to control for Type 1 error using Monte Carlo simulations via AFNI's 3dClustSim (version 17.1.07); an $\alpha = 0.05$ was achieved via $p < 0.001$, $k = 45$ and $k = 46$, for NT and ASD groups, respectively. Parameter estimates were extracted from masks representing significant clusters and analyzed in SPSS. Results were considered significant at $p \leq 0.05$ (uncorrected), and marginally significant at $p \leq 0.06$ (uncorrected).

CHAPTER IV

STUDY I RESULTS: THE SUBJECTIVE EXPERIENCE OF SCES

Demographics Information

30 participants in the ASD group and 26 participants in the NT group participated in Study I. The ASD group ranged from ages 137.90 to 203.80 months (11 years 6 months to 16 years 11 months), with a mean age of 173.97 months (14 years 5 months). The NT group ranged from ages 132.00 to 211.10 months (11 years 0 months to 17 years 7 months), with a mean age of 179.94 months (14 years 8 months). With respect to pubertal development, the ASD group endorsed scores ranging from 1-4 (pubertal stage: pre-puberty = 2, early puberty = 1, mid puberty = 13, late puberty = 13, post-puberty = 1), and the NT group endorsed scores ranging from 1.2-3.6 (pubertal stage: pre-puberty = 1, early puberty = 3, middle puberty =12, late puberty = 10, post-puberty = 0). Groups did not significantly differ on age, $t(54) = 0.51$, $p = 0.611$; pubertal development, $t(54) = -0.17$, $p = 0.869$; or pubertal category, $X^2(4) = 2.49$, $p = 0.646$. All participants had a FSIQ of at least 75 (ASD: 77-141, $M = 109.43$; NT: 93-140, $M = 116.15$), and groups did not significantly differ in FSIQ, $t(54) = 1.68$, $p = 0.098$. Both groups were predominantly Caucasian, reflecting local demographics (ASD: Caucasian = 27, Hispanic = 1, Multi-ethnic = 2; NT: Caucasian = 18, Hispanic = 4, Multi-Ethnic =2; 2 NT participants had missing data), and groups did not significantly differ in ethnic representation, $X^2(2) = 2.97$, $p = 0.227$. Groups did not differ on maternal education (ASD: Public school = 0, High school = 3, Trade school = 2, Associate degree = 7, Undergraduate degree = 11, Post-graduate degree = 6; NT: Public school = 1, High school = 2, Trade school = 2, Associate degree = 2, Undergraduate degree = 6, Post-graduate degree = 11; 1 ASD participant declined to answer; 2 NT participants had missing data), $X^2(5) = 6.52$, $p = 0.260$). In addition, groups did not differ on paternal/spousal

education (ASD: Public school = 0, High school = 8, Trade school = 0, Associate degree = 3, Undergraduate degree = 6, Post-graduate degree = 10; NT: Public school = 2, High school = 3, Trade school = 0, Associate degree = 3, Undergraduate degree = 5, Post-graduate degree = 7; 1 ASD participant and 1 NT participant declined to answer; 2 ASD participants and 3 NT participants had missing data; 2 NT participants noted that data was not available), $X^2(4) = 3.94$, $p = 0.414$, respectively). Groups also did not differ on annual household income (ASD: $0-$25,000 = 4, $25,000-$40,000 = 1, $40,000-$75,000 = 8, $75,000-$100,000 = 6, $100,000+ = 8; NT: $0-$25,000 = 0, $25,000-$40,000 = 7, $40,000-$75,000 = 5, $75,000-$100,000 = 6, $100,000+ = 6; 3 ASD participants declined to answer; 2 NT participants had missing data), $X^2(4) = 9.33$, $p = 0.053$.

Autism Symptomatology/Traits

The ASD group endorsed significantly greater and more severe autistic symptoms than the NT group. The ASD group had higher total SRS scores, total ASRS scores, and total ASRS DSM-V scores. These results reflect greater autistic mannerisms/symptomatology, as well as greater difficulties in social awareness, social cognition, social communication, and social motivation. These group differences were expected, given that the ASRS and SRS are commonly used to assess autism symptomatology and designed to distinguish ASD from related psychological disorders. The ASD group also scored significantly higher on the AQ, a non-diagnostic measure that assesses autistic traits within the general population.

Social Cognition

As expected, there were significant group differences on key social cognitive variables (see Table 1). Broadly, the ASD group reported attenuated self-awareness/introspection and cognitive empathy, but similar affective empathy, compared to the NT group.

Table 1. Group Comparisons of Social Cognitive and Autism-Relevant Variables

Measure	Group	N	M (SD)	*T* Statistic
Public Self-Consciousness (RSCS-C)	NT ASD	26 30	30.58 (7.08) 25.08 (9.14)	$t(54) = 2.49$, $p = 0.016$*
Private Self-Consciousness (RSCS-C)	NT ASD	26 30	42.31 (5.52) 38.66 (6.43)	$t(54) = 2.26$, $p = 0.028$*
Difficulty Describing Feelings (TAS-20)	NT ASD	26 29	13.81 (3.41) 16.10 (4.35)	$t(53) = -2.16$, $p = 0.035$*
Difficulty Identifying Feelings (TAS-20)	NT ASD	26 29	16.42 (3.73) 18.74 (5.95)	$t(53) = -1.71$, $p = 0.094$
Externally Oriented Feelings (TAS-20)	NT ASD	26 29	20.50 (3.82) 23.60 (4.97)	$t(53) = -2.57$, $p = 0.013$*
Total Alexithymia (TAS-20)	NT ASD	26 29	50.82 (7.71) 58.45 (12.58)	$t(53) = -2.67$, $p = 0.010$*
Reading the Mind in the Eyes	NT ASD	26 30	20.54 (2.69) 19.33 (3.08)	$t(54) = 1.55$, $p = 0.127$
Strange Stories ToM	NT ASD	26 30	13.42 (2.23) 12.33 (2.97)	$t(54) = 1.53$, $p = 0.132$
Perspective-Taking (IRI)	NT ASD	26 30	15.46 (2.66) 13.93 (3.18)	$t(54) = 1.93$, $p = 0.059^{\dagger}$
Fantasy (IRI)	NT ASD	26 30	14.77 (3.52) 14.83 (3.62)	$t(54) = -0.067$, $p = 0.947$
Empathic Concern (IRI)	NT ASD	26 30	13.49 (2.30) 13.32 (3.22)	$t(54) = 0.23$, $p = 0.817$
Personal Distress (IRI)	NT ASD	26 30	14.19 (2.73) 14.43 (3.64)	$t(54) = -0.27$, $p = 0.783$
Cognitive Empathy (BES)	NT ASD	26 29	36.73 (3.19) 31.69 (4.74)	$t(53) = 4.57$, $p < 0.001$**
Affective Empathy (BES)	NT ASD	25 29	36.96 (5.72) 34.86 (8.25)	$t(52) = 1.07$, $p = 0.290$
Autism Social Impairment (SRS)	NT ASD	26 30	44.88 (4.69) 81.53 (9.21)	$t(54) = -18.32$, $p < 0.001$**
Autism Symptomatology (ASRS)	NT ASD	26 29	44.58 (6.20) 67.45 (4.94)	$t(53) = -15.20$, $p < 0.001$**
DSM-V Autism Symptomatology (ASRS)	NT ASD	26 29	45.12 (6.96) 70.62 (6.57)	$t(53) = -14.00$, $p < 0.001$**
Autistic Traits (AQ)	NT ASD	25 30	11.05 (4.92) 34.46 (6.69)	$t(53) = -14.53$, $p < 0.001$**

Social Competence (SCQ-Pu)	NT ASD	26 30	15.23 (3.69) 8.80 (3.37)	$t(54) = 6.82$, $p < 0.001$**
Social Competence (SCQ-Pa)	NT ASD	26 30	15.38 (4.23) 4.83 (3.92)	$t(54) = 9.68$, $p < 0.001$**
Peer Socialization (ASRS)	NT ASD	26 29	45.35 (7.05) 71.62 (6.75)	$t(53) = -14.11$, $p < 0.001$**
Social/Emotional Reciprocity (ASRS)	NT ASD	26 29	44.69 (7.66) 66.28 (6.07)	$t(53) = -11.64$, $p < 0.001$**

AQ = Autism Quotient; ASD = Autism Spectrum Disorder; ASRS = Autism Spectrum Rating Scale; BES = Basic Empathy Scale; DSM-V = Diagnostic Statistical Manual- 5th Edition; IRI = Interpersonal Reactivity Index; NT = Neurotypical; RSCS-C = Revised Self-Consciousness Scale- Child; SCQ-Pu = Social Competence with Peers Questionnaire- Pupil; SCQ-Pa = Social Competence with Peers Questionnaire- Parent; SRS = Social Responsiveness Scale; TAS-20 = Toronto Alexithymia Scale; ToM = Theory of Mind.

Note: † $p < .06$; * $p < 0.05$; ** $p < 0.001$

Self-Awareness. Self-awareness were measured using the Revised Self-Consciousness Scale-Child (RSCS-C) and Toronto Alexithymia Scale (TAS-20). The ASD group reported both lower Public Self-Consciousness and lower Private Self-Consciousness scores on the RSCS-C. The ASD group also reported higher Alexithymia scores on the TAS-20; specifically, the ASD group reported higher scores on the Difficulty Describing One's Own Feelings and Externally-Oriented Thinking subscales. The ASD group also reported higher scores on the Difficulty Identifying One's Own Feelings subscale, although group differences were nonsignificant.

Perspective-Taking/Cognitive Empathy. Task-based measures of PT and cognitive empathy included the Reading the Mind in the Eyes Task and the ToM subscale of the Strange Stories Task. There were no significant group differences on either of these task-based measures.

The Basic Empathy Scale (BES) is traditionally categorized as a self-report assessment of empathic tendencies and includes both cognitive and affective dimensions. The Cognitive Empathy subscale is associated with the ability and tendency to understand other people's mental states and is associated with PT and ToM. The ASD group reported lower Cognitive Empathy scores, representing attenuated mental state understanding. The Interpersonal Reactivity Index (IRI) is often described as an assessment of empathic tendencies. However, the Perspective-Taking subscale of the IRI represents the ability and tendency to adopt other people's point of view, and thus best represents cognitive empathy. The ASD group reported marginally lower PT tendencies. Thus, task-based measures of ToM abilities failed to reveal group differences, yet scores from child-report questionnaires suggest possibly attenuated mentalizing abilities and reduced real-world PT tendencies.

Affective Empathy. Empathic abilities and tendencies were measured using the BES and IRI. Groups did not differ on the Affective Empathy subscale of the BES (which closely represents emotional resonance). Similarly, groups did not differ on the Empathic Concern or Personal Distress subscales of the IRI (which closely resemble "other-oriented" sympathy and "self-oriented" personal anxiety, respectively).

Social Competence

Social competence was assessed using child and parent versions of the Social Competence with Peers Questionnaire, and the Peer Socialization and Social/Emotional Reciprocity treatment subscales of the ASRS. The ASD group was associated with lower social competence (according to both child-report and parent-report), greater difficulties appropriately socializing with peers, and greater difficulties demonstrating appropriate social/emotional reciprocity. Thus, the ASD group revealed greater real-world interpersonal challenges, particularly when socially relating to and interacting with peers.

Self-Conscious Emotion Understanding

Self-conscious emotion understanding was assessed in two ways: the ability to infer SCEs experienced by others, and the ability/tendency to feel empathic SCEs on behalf of others. Inferred SCEs were assessed during the MRI scan using the SCET-C. Empathic SCEs were assessed immediately following the MRI scan using the SCERT. During the SCET-C and SCERT, participants made both embarrassment and pride ratings, regardless of the emotion being conveyed by the singers. Thus, participants made *congruent* SCE ratings, which matched the emotions the singers expressed, and *incongruent* SCE ratings, which did not match the emotions the singers expressed. When describing the results, the emotion included in the label represents the emotion the singer conveyed. For example, if a participant observed a singer singing poorly and acting embarrassed, inferred *congruent* embarrassment ratings represented evaluations of how *embarrassed* (congruent emotion) the *embarrassed* (conveyed emotion) singer felt; inferred *incongruent* embarrassment ratings represented evaluations of how *proud* (incongruent emotion) the *embarrassed* (conveyed emotion) singer felt; empathic *congruent* embarrassment ratings represented evaluations of how empathically *embarrassed* (congruent emotion) the participant felt for the *embarrassed* (conveyed emotion) singer; and empathic *incongruent* embarrassment ratings represented evaluations of how empathically *proud* (incongruent emotion) the participant felt for the *embarrassed* (conveyed emotion) singer. Clips were also associated with either low or high PT demands. In clips with low PT demands, singers expressed emotions that matched the situational context (i.e., singing quality; e.g., singers sang poorly and acted embarrassed, like the example above). In clips with high PT demands, singers expressed emotions that did not match the situational context (e.g., singers sang well and acted embarrassed). Thus, inferred *congruent* embarrassment ratings during *low PT* demands represented evaluations of how *embarrassed* (congruent emotion) the *embarrassed* (conveyed emotion) singer felt when he/she sang *poorly* (low PT); while inferred *congruent* embarrassment ratings during *high PT* demands represented evaluations of how *embarrassed* (congruent emotion) the *embarrassed* (conveyed emotion) singer felt when he/she sang *well* (high PT), and inferred *incongruent* embarrassment ratings during *high PT* demands represented evaluations of how *proud* (incongruent emotion) the *embarrassed* (conveyed emotion) singer felt when he/she sang *well* (high PT). (See Table 2 for inferred and empathic SCE ratings for each group; means and standard deviations are provided.)

Table 2. Group Comparisons of Self-Conscious Emotion Ratings

Rating Type	Group	N	EmbLo	EmbHi	PrideLo	PrideHi
Inferred Congruent Emotion	NT	26	2.58 (0.34)	2.31 (0.34)	2.61 (0.25)	2.20 (0.40)
	ASD	30	2.62 (0.30)	2.22 (0.48)	2.69 (0.35)	2.15 (0.54)
Inferred Incongruent Emotion	NT	26	0.60 (0.36)	1.03 (0.51)	0.34 (0.27)	0.61 (0.27)
	ASD	30	0.58 (0.39)	1.09 (0.57)	0.51 (0.38)	1.04 (0.62)
Empathic Congruent Emotion	NT	26	1.56 (1.01)	1.01 (0.76)	1.83 (0.79)	0.76 (0.62)
	ASD	29	1.76 (0.88)	1.16 (0.87)	2.00 (0.79)	1.08 (0.72)
Empathic Congruent Emotion	NT	26	0.63 (0.63)	1.44 (0.70)	0.35 (0.55)	1.46 (0.84)
	ASD	29	0.74 (0.74)	1.29 (0.76)	0.34 (0.48)	1.16 (0.88)

ASD = Autism Spectrum Disorder; EmbLo = embarrassment with low PT demands; EmbHi = embarrassment with high PT demands; NT = Neurotypical; PrideLo = pride with low PT demands; PrideHi = pride with high PT demands; PT = perspective-taking.

Note: One ASD participant was missing SCERT data (empathic emotion ratings).

Inferred Congruent Self-Conscious Emotions. Results from the repeated measures ANOVA for inferred congruent SCE ratings revealed a significant main effect of PT demands, $F(1,54) = 107.97$, $p < 0.001$; and a significant interaction effect between emotion and PT demands, $F(1,54) = 4.16$, $p = 0.046$. Post-hoc *t*-tests revealed that participants inferred more intense congruent SCEs when PT demands were low compared to high (e.g., participants inferred greater embarrassment when singers sang poorly and acted embarrassed than when singers sang well and acted embarrassed), $t(55) = 10.37$, $p < 0.001$. This pattern held for both embarrassment, $t(55) = 7.01$, $p < 0.001$; and pride, $t(55) = 8.65$, $p < 0.001$. When PT demands were low, participants inferred more intense congruent pride than congruent embarrassment, $t(55) = -0.82$, $p = 0.415$; but when PT demands were high, participants inferred more intense congruent embarrassment than congruent pride, $t(55) = 1.05$, $p = 0.299$, although these differences were nonsignificant. There was no significant main effect of group, $F(1,54) = 0.01$, $p = 0.929$; nor main effect of emotion, $F(1,54) = 0.13$, $p = 0.724$. In addition, there was no significant interaction effect between group and emotion, $F(1,54) = 0.10$, $p = 0.755$; between group and PT demands, $F(1,54) = 2.77$, $p = 0.102$; nor between group and emotion and PT demands, $F(1,54) = 0.00$, $p = 0.988$. (See Figure 4.)

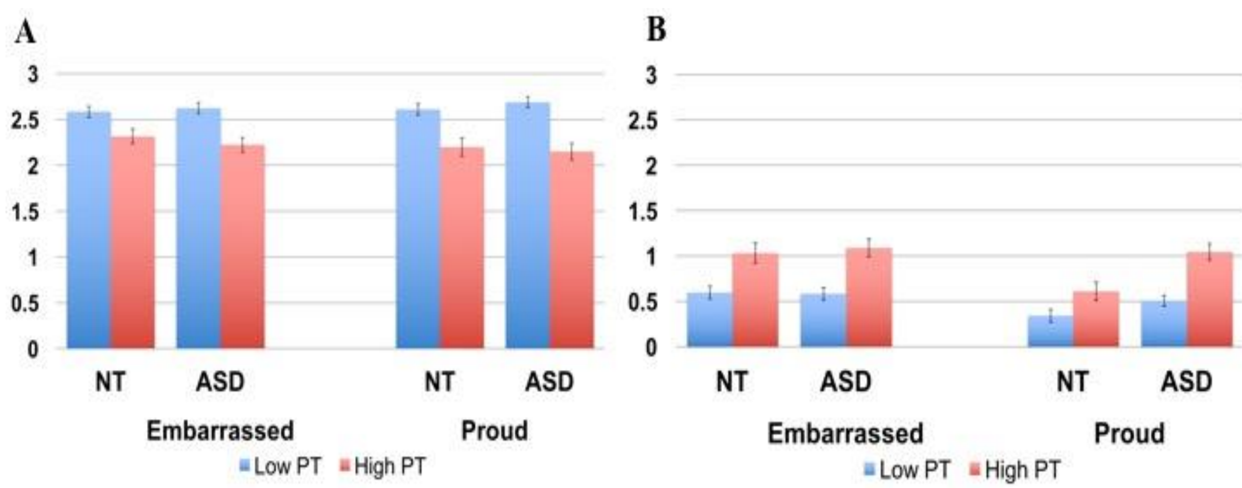

Figure 4. Group comparisons of inferred congruent and incongruent self-conscious emotion ratings

Panel A) Inferred congruent self-conscious emotion ratings. **Panel B)** Inferred incongruent self-conscious emotion ratings.

ASD = Autism Spectrum Disorder; NT = Neurotypical; PT = perspective-taking demands.

Note: Standard error bars represent standard error values from 2 x 2 x 2 repeated measures ANOVA.

Inferred Incongruent Self-Conscious Emotions. Results from the repeated measures ANOVA for inferred incongruent SCE ratings revealed a significant main effect of group, $F(1,54) = 4.49$, $p = 0.039$; a significant main effect of emotion, $F(1,54) = 7.10$, $p = 0.010$; and a significant main effect of PT demands, $F(1,54) = 114.09$, $p < 0.001$. There was also a significant interaction effect between group and PT demands, $F(1,54) = 4.29$, $p = 0.043$. Post-hoc *t*-tests exploring the main effect of group revealed that broadly, the ASD group reported more intense incongruent SCE ratings than the NT group, $t(54) = -2.12$, $p = 0.039$. The main effect of emotion revealed that participants broadly inferred more intense incongruent embarrassment than incongruent pride (e.g., participants inferred more intense pride when singers acted embarrassed than they inferred embarrassment when singers acted proud), $t(55) = 2.49$, $p = 0.016$. The main effect of PT demands revealed that participants inferred more intense incongruent SCEs during clips with high compared to low PT demands (e.g., participants inferred more intense pride when singers sang well and acted embarrassed than when singers sang poorly and acted embarrassed), $t(55) = -10.55$, $p < 0.001$. Post-hoc *t*-tests exploring the interaction effect between group and PT demands revealed that both the NT group and ASD group reported more intense inferred incongruent SCE ratings during high compared to low PT demands (e.g., both groups inferred more intense pride when singers sang well and acted embarrassed compared to when singers sang poorly and acted embarrassed), $t(25) = -7.45$, $p < 0.001$ for the NT group; and $t(28) = -6.91$, $p < 0.001$ for the ASD group. When PT demands were low, the NT and ASD groups reported similarly intense inferred incongruent SCE ratings, $t(54) = -1.20$, $p = 0.234$; however, when PT demands were high, the ASD group reported more intense inferred incongruent SCE ratings than the NT group, $t(54) = -2.36$, $p = 0.022$, (e.g., both groups inferred similarly intense pride for singers who sang poorly and acted embarrassed, but the ASD group inferred more intense pride than the NT group for singers who sang well and acted embarrassed). There was no significant interaction effect between group and emotion, $F(1,54) = 3.43$, $p = 0.069$; between emotion and PT demands, $F(1,54) = 1.10$, $p = 0.300$; nor between group and emotion and PT demands, $F(1,54) = 2.47$, $p = 0.122$. (See Figure 4.)

Comparison of Inferred Congruent and Inferred Incongruent Self-Conscious Emotions. Significant group differences in the endorsement of inferred incongruent SCE ratings prompted an exploratory analysis investigating potential group differences in the intensity of inferred congruent SCE ratings relative to inferred incongruent SCE ratings. Difference scores between inferred congruent SCE ratings and inferred incongruent SCE ratings were calculated for each clip and averaged across emotion conditions (e.g., EmbLo, EmbHi, PrideLo, PrideHi) for each participant. Low difference scores represented more similar intensity ratings for congruent and incongruent SCEs, while high difference scores represented less similar intensity ratings. These average difference scores were entered into a 2 (group) x 2 (emotion) x 2 (PT demands) repeated measures ANOVA. Results revealed a significant main effect of PT demands, $F(1,54) = 157.00$, $p < 0.001$; qualified by a significant interaction effect between group and PT demands, $F(1,54) = 4.96$, $p = 0.030$. Post-hoc *t*-tests revealed greater difference scores when PT demands were low compared to high, $t(55) = 12.29$, $p < 0.001$. This pattern held for the NT group, $t(25) = 7.22$, $p < 0.001$; and the ASD group, $t(29) = 10.49$, $p < 0.001$. When PT demands were low, the NT and ASD groups endorsed similarly intense difference scores, $t(54) = 0.18$, $p = 0.859$; however, when PT demands were high, the NT group endorsed more intense difference scores than the ASD group, $t(54) = 2.08$, $p = 0.042$. In other words, when PT demands were high, the ASD group provided more similar intensity ratings for congruent and incongruent SCEs than the NT group. There was no significant main effect of group, $F(1,54) = 2.39$, $p = 0.128$; nor of emotion, $F(1,54) = 1.70$, $p = 0.198$. In addition, there was no significant interaction effect between group and emotion, $F(1,54) = 0.76$, $p = 0.386$; between emotion and PT demands, $F(1,54) = 0.46$, $p = 0.501$; nor between group and emotion and PT demands, $F(1,54) = 0.83$, $p = 0.365$.

Empathic Congruent Self-Conscious Emotions. Results from the repeated measure ANOVA for empathic congruent SCE ratings revealed a significant main effect of PT demands, $F(1,53) = 109.71$, $p < 0.001$; which was qualified by a significant interaction effect between emotion and PT demands, $F(1,53) = 2.39$, $p < 0.001$. Post-hoc *t*-tests revealed that participants reported significantly more intense empathic congruent SCEs when PT demands were low relative to high, $t(54) = 10.62$, $p < 0.001$; this pattern was observed for both empathic congruent embarrassment, $t(54) = 8.34$, $p < 0.001$; and empathic congruent pride, $t(54) = 9.51$, $p < 0.001$. When PT demands were low, participants reported significantly more intense empathic congruent pride than embarrassment (e.g., participants reported feeling more intense pride for singers who sang well and acted proud than they felt embarrassment for singers who sang poorly and acted embarrassed), $t(54) = -2.62$, $p = 0.011$. However, when PT demands were high, participants reported similarly intense empathic congruent embarrassment and empathic congruent pride (e.g., participants reported feeling similarly intense embarrassment for singers who sang well and acted embarrassed as they felt pride for singers who sang poorly and acted proud), $t(54) = 1.27$, $p = 0.209$. There was no significant main effect of group, $F(1,53) = 1.51$, $p = 0.225$; nor of emotion, $F(1,53) = 0.21$, $p = 0.649$. In addition, there was no significant interaction effect between group and emotion, $F(1,53) = 0.14$, $p = 0.713$; between group and PT demands, $F(1,53) = 0.13$, $p = 0.720$; nor between group and emotion and PT demands, $F(1,53) = 0.98$, $p = 0.326$. (See Figure 5.)

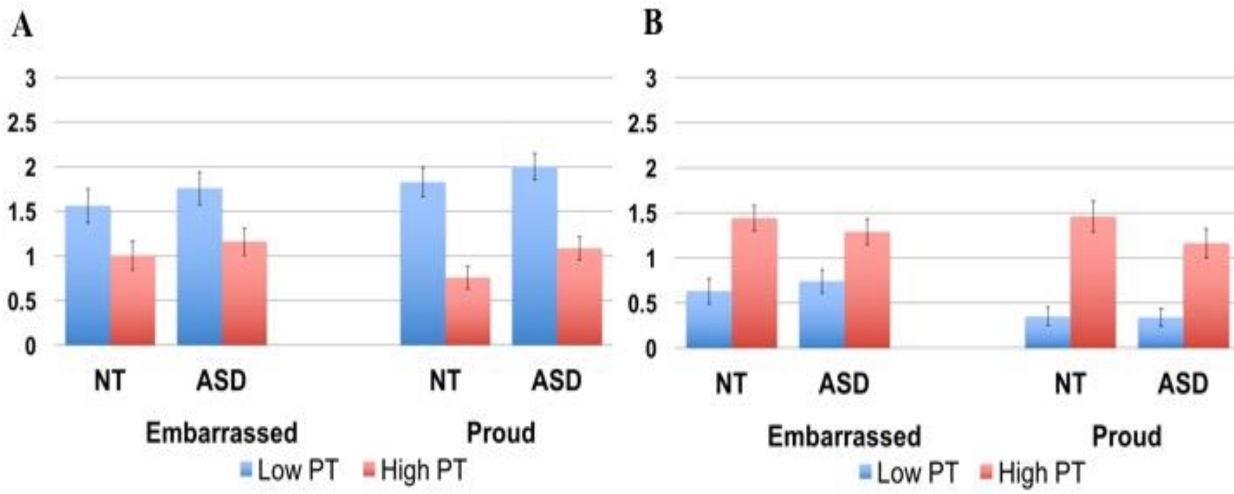

Figure 5. Group comparisons of empathic congruent and incongruent self-conscious emotion ratings

Panel A) Empathic congruent self-conscious emotion ratings. **Panel B)** Empathic incongruent self-conscious emotion ratings.

ASD = Autism Spectrum Disorder; NT = Neurotypical; PT = perspective-taking demands.

Note: Standard error bars represent standard error values from 2 x 2 x 2 repeated measures ANOVA.

Empathic Incongruent Self-Conscious Emotions. Results from the repeated measure ANOVA for empathic incongruent SCE ratings revealed a significant main effect of PT demands, $F(1,53) = 110.58$, $p < 0.001$; which was qualified by a significant interaction effect between emotion and PT demands, $F(1,53) = 9.10$, $p = 0.004$. Post-hoc *t*-tests revealed that participants reported more intense empathic incongruent emotions when PT demands were high relative to low, $t(54) = -10.23$, $p < 0.001$; this pattern was observed for both empathic incongruent embarrassment (e.g., participants reported feeling more intense pride for singers who sang well and acted embarrassed compared to singers who sang poorly and acted embarrassed), $t(54) = -8.20$, $p < 0.001$; and empathic incongruent pride (e.g., participants reported feeling more intense embarrassment for singers who sang poorly and acted proud compared to singers who sang well and acted proud), $t(54) = -9.44$, $p < 0.001$. When PT demands were low, participants reported feeling more intense empathic incongruent embarrassment than empathic incongruent pride (e.g., participants reported feeling more intense pride for singers who sang poorly and acted embarrassed than they felt embarrassment for singers who sang well and acted proud), $t(54) = 3.18$, $p = 0.002$. When PT demands were high, participants reported feeling similarly intense empathic incongruent embarrassment and empathic incongruent pride (e.g., participants reported feeling similarly intense pride for singers who sang well and acted embarrassed as they felt embarrassment for singers who sang poorly and acted proud), $t(54) = 0.49$, $p = 0.625$. There was no significant main effect of group, $F(1,53) = 0.45$, $p = 0.504$; nor of emotion, $F(1,53) = 3.44$, $p = 0.069$. In addition, there was no significant interaction effect between group and emotion, $F(1,53) = 0.39$, $p = 0.535$; between group and PT demands, $F(1,53) = 3.16$, $p = 0.081$; nor between group and emotion and PT demands, $F(1,53) = 0.00$, $p = 0.952$. (See Figure 5.)

Table 3. Correlations between Self-Conscious Emotion Ratings and Social Cognitive Variables

Measure	Inferred Congruent	Inferred Incongruent	Empathic Congruent	Empathic Incongruent
Public Self-Consciousness (RSCS-C)	-0.08	0.04	-0.03	0.19
Private Self-Consciousness (RSCS-C)	-0.07	0.10	0.13	0.21
Difficulty Describing Feelings (TAS-20)	0.11	-0.08	-0.07	-0.20
Difficulty Identifying Feelings (TAS-20)	0.08	-0.04	0.02	-0.06
Externally Oriented Feeling (TAS-20)	0.02	0.18	0.14	0.01
Total Alexithymia (TAS-20)	0.09	0.02	0.04	-0.09
Reading the Mind in the Eyes	-0.18	-0.07	-0.06	-0.12
Strange Stories ToM	0.07	-0.27*	-0.13	-0.01
Perspective-Taking (IRI)	0.06	-0.15	-0.12	0.08
Fantasy (IRI)	-0.06	-0.14	0.29*	0.19
Empathic Concern (IRI)	0.10	-0.12	-0.15	-0.01
Personal Distress (IRI)	-0.08	0.12	0.19	0.12
Cognitive Empathy (BES)	0.05	-0.22	-0.04	0.20
Affective Empathy (BES)	-0.06	-0.20	0.34*	0.41**

BES = Basic Empathy Scale; IRI = Interpersonal Reactivity Index; RSCS-C = Revised Self-Consciousness Scale- Child; TAS-20 = Toronto Alexithymia Scale; ToM = Theory of Mind.

Note: df range: 51-54; * $p < 0.05$; ** $p < 0.005$

Correlations with Social Cognition

Inferred Congruent Self-Conscious Emotions. Mean inferred congruent SCE ratings were not correlated with self-processing variables associated with self-awareness. They were also not correlated with PT variables associated with mental state attribution nor cognitive empathy. Furthermore, they were not correlated with empathy variables associated with affective empathy nor emotional resonance. (See Table 3 for correlation statistics.) Exploratory analyses separately investigated correlations with mean inferred congruent SCE ratings for clips with low and high PT demands but revealed no significant correlations.

Inferred Incongruent Self-Conscious Emotions. As exploratory analyses, correlations with mean inferred incongruent SCE ratings were conducted. Mean inferred incongruent SCE ratings were not significantly correlated with self-processing variables associated with self-awareness nor self-reflection. However, they were associated with PT variables associated with cognitive empathy, specifically, ToM scores on the Strange Stories Task. Mean inferred incongruent SCE ratings were not correlated with variables associated with affective empathy nor emotional resonance. (See Table 3 for correlation statistics.) Exploratory analyses separately investigated correlations with mean inferred incongruent SCE ratings for clips with low and high PT demands. ToM scores on the Strange Stories Task were significantly correlated with mean inferred incongruent SCE ratings when PT demands were high, $r(54) = -0.34$, $p = 0.011$; but not when PT demands were low, $r(54) = -0.10$, $p = 0.487$. All other correlations were nonsignificant.

Empathic Congruent Self-Conscious Emotions. Mean empathic congruent SCE ratings were not correlated with self-processing variables associated with self-awareness nor self-reflection. They were also not correlated with PT variables associated with mental state attribution nor cognitive empathy. (Interestingly, mean empathic congruent SCE ratings were correlated with Fantasy scores on the IRI.) In addition, mean empathic congruent SCE ratings were significantly correlated with Affective Empathy scores on the BES. (See Table 3 for correlation statistics.) Exploratory analyses revealed that Affective Empathy scores on the BES were significantly correlated with empathic congruent SCE ratings for clips with both low PT demands, $r(51) = 0.32$, $p = 0.021$; and high PT demands, $r(51) = 0.32$, $p = 0.018$, respectively. All other correlations were nonsignificant.

Empathic Incongruent Self-Conscious Emotions. As exploratory analyses, correlations with mean empathic incongruent SCE ratings were conducted. Mean empathic incongruent SCE ratings were not significantly correlated with self-processing variables associated with self-awareness nor self-reflection. They were also not correlated with PT nor cognitive empathy variables. However, mean empathic incongruent SCE ratings were significantly correlated with Affective Empathy scores on the BES. (See Table 3 for correlation statistics.) Exploratory analyses separately investigated correlations with mean inferred incongruent SCE ratings for clips with low and high PT demands. Affective Empathy scores on the BES were significantly correlated with empathic incongruent SCE ratings during clips with both low PT demands, $r(51) = 0.28$, $p = 0.042$; and high PT demands, $r(51) = 0.40$, $p = 0.003$. All other correlations were nonsignificant.

Correlations with Autism Symptomatology/Traits

Table 4. Correlations between Self-Conscious Emotion Ratings and Autism Symptoms/Traits

Measure	Inferred Congruent	Inferred Incongruent	Empathic Congruent	Empathic Incongruent
Autism Social Impairment (SRS)	-.06	.32*	.11	-.10
Autism Symptomatology (ASRS)	-.11	.24	.13	-.15
DSM-V Autism Symptomatology (ASRS)	-.11	.23	.11	-.17
Autistic Traits (AQ)	-.00	.20	.11	-.14

AQ = Autism Quotient; ASRS = Autism Spectrum Rating Scale; DSM-V = Diagnostic Statistical Manual- 5th Edition; SRS = Social Responsiveness Scale.

Note: df range: 52-54; * $p < 0.05$; ** $p < 0.001$

Mean inferred congruent SCE ratings were not correlated with variables associated with autism symptom severity nor autistic traits. In contrast, mean inferred incongruent SCE ratings were significantly correlated with total SRS scores. Neither mean empathic congruent SCE ratings nor mean empathic incongruent SCE ratings were correlated with variables associated with autism symptoms severity or autistic traits. (See Table 4 for correlation statistics.)

Exploratory analyses separately investigating inferred congruent SCE ratings for clips with low and high PT demands, as well as empathic congruent SCE ratings for clips with low and high PT demands, similarly revealed no significant correlations. Total SRS scores were significantly correlated with inferred incongruent SCE ratings during clips with high PT demands, $r(54) = 0.35$, $p = 0.009$; but not low PT demands, $r(54) = 0.19$, $p = 0.157$. In addition, ASRS total scores were significantly correlated with inferred incongruent SCE ratings for clips with high PT demands, $r(54) = 0.27$, $p = 0.047$; but not low PT demands, $r(54) = 0.15$, $p = 0.285$. All other correlations were nonsignificant.

Correlations with Social Competence

Table 5. Correlations between Self-Conscious Emotion Ratings and Social Competence Variables

Measure	Inferred Congruent	Inferred Incongruent	Empathic Congruent	Empathic Incongruent
Social Competence (SCQ-Pu)	0.05	-0.22	0.03	0.32*
Social Competence (SCQ-Pa)	0.07	-0.24	-0.14	0.13
Peer Socialization (ASRS)	-0.09	0.23	0.16	-0.14
Social/Emotional Reciprocity (ASRS)	-0.12	0.23	0.11	-0.12

ASRS = Autism Spectrum Rating Scale; SCQ-Pu = Social Competence with Peers Questionnaire- Pupil; SCQ-Pa = Social Competence with Peers Questionnaire- Parent

Note: df range: 52-54; * $p < 0.05$; ** $p < 0.001$

Mean inferred congruent SCE ratings were not correlated with any variables associated with social competence nor interpersonal success. Similarly, mean inferred incongruent SCE ratings did not reveal any significant correlations. Mean empathic congruent SCE ratings were not correlated with any variables associated with social competence nor interpersonal success. However, mean empathic incongruent SCE ratings were significantly correlated with SCQ-Pu scores, $r(53) = 0.32$, $p = 0.019$, reflecting participants' personal evaluations of their own social competence. (See Table 5 for correlation statistics.)

Exploratory analyses separately investigating mean inferred congruent SCE ratings for clips with low and high PT demands did not reveal any significant correlations. However, SCQ-Pu scores were significantly correlated with mean empathic incongruent SCE ratings for clips with high PT demands, $r(54) = 0.30$, $p = 0.028$; but not low PT demands, $r(54) = 0.24$, $p = 0.079$. Interestingly, SCQ-Pa scores (reflecting parents' evaluations of their son's social competence) were also significantly correlated with mean inferred incongruent SCE ratings for clips with high PT demands, $r(54) = -0.31$, $p = 0.021$; but not low PT demands, $r(54) = -0.07$, $p = 0.603$. All other correlations were nonsignificant.

Supplementary Analyses

Self-Conscious Emotions Post-Scan Interview Responses. Following the MRI scan, participants completed a semi-structured interview. In a free response format, participants were asked to describe which emotion(s) they felt when they observed clips of singers singing poorly and well. Responses such as "bad" and "good" were coded as "basic emotions", and responses such as "embarrassed" and "proud" were coded as "self-conscious emotions". Each participant was assigned a score of "0" or "1", which indicated if they endorsed "basic emotions" and/or "self-conscious emotions", and Pearson Chi-Square analyses were conducted. There were no group differences in the likelihood for participants to report a basic emotion, $X^2(1) = 0.42$, $p = 0.349$; nor a SCE, $X^2(1) = 0.29$, $p = 0.269$, when describing how they felt when observing clips of singers who sang poorly. In addition, there were no group differences in the likelihood for participants to report a basic emotion, $X^2(1) = 0.42$ $p = 0.389$; nor a SCE, $X^2(1) = 0.28$, $p =$

0.218, when describing how they felt when observing clips of singers who sang well. These findings converge with results from the empathic SCE ratings analyses.

Humor as a Potential Confound. To investigate confounds that might impact inferred and empathic SCE ratings, a 2 (group) x 2 (emotion) x 2 (PT demands) repeated measures ANOVA was conducted for humor ratings (participants' perceptions of how humorous each clip was). There were no significant main effect of group, $F(1,53) = 2.76$, $p = 0.102$; nor main effect of emotion, $F(1,53) = 0.18$, $p = 0.670$; but there was a significant main effect of PT demands, $F(1,53) = 7.25$, $p = 0.009$, such that participants perceived clips with high PT demands as more humorous than clips with low PT demands, $t(54) = -2.43$, $p = 0.018$. In addition, there was a significant interaction effect between emotion and PT demands, $F(1,53) = 57.35$, $p < 0.001$; and between group and PT demands, $F(1,53) = 5.11$, $p = 0.028$; although there was no significant interaction effect between group and emotion, $F(1,53) = 0.42$, $p = 0.520$; nor between group and emotion and PT demands, $F(1,53) = 3.14$, $p = 0.082$. Post-hoc *t*-tests revealed that during low PT demands, participants perceived embarrassment clips as more humorous than pride clips (when singers sang poorly and acted embarrassed compared to when they sang well and acted proud), $t(54) = 6.29$, $p < 0.001$. Yet during high PT demands, participants perceived pride clips as more humorous than embarrassment clips (when singers sang poorly and acted proud compared to when they sang well and acted embarrassed), $t(54) = -6.16$, $p < 0.001$. Embarrassment clips were perceived as more humorous when PT demands were low, compared to high, (when singers sang poorly and acted embarrassed compared to when they sang well and acted embarrassed), $t(54) = 6.41$, $p < 0.001$; but pride clips were perceived as more humorous when PT demands were high, compared to low, (when singers sang poorly and acted proud compared to when they sang well and acted proud), $t(54) = -6.60$, $p < 0.001$. Another way of framing these results is that perceived humor was strongly impacted by the situational context: participants found clips more humorous when singers sang poorly compared to when they sang well.

Group differences also existed. When PT demands were low, the NT and ASD groups perceived clips as similarly humorous, $t(53) = 1.16$, $p = 0.252$; but when PT demands were high, the NT group perceived clips as more humorous than the ASD group, $t(53) = 2.01$, $p = 0.050$. The NT group perceived clips with high, compared to low, PT demands as more, $t(25) = -3.34$, $p = 0.003$; yet the ASD group perceived clips with low and high PT demands as similarly humorous, $t(28) = -0.31$, $p = 0.756$.

Age as a Potential Confound. Although participants from each group were age-matched within 12 months, the relationship between age (in months) and SCE understanding was further investigated in a set of exploratory analyses. Collapsed across groups, age was not significantly correlated with mean inferred congruent SCE ratings, $r(53) = -0.08$, $p = 0.538$; nor mean empathic congruent SCE ratings, $r(53) = -0.08$, $p = 0.540$. This pattern held for both the NT group, $r(22) = -0.11$, $p = 0.617$; and the ASD group, $r(27) = 0.05$, $p = 0.807$. When separately investigating mean inferred congruent and mean empathic congruent SCE ratings during low and high PT demands, all correlations were nonsignificant.

The relationship between age and incongruent SCEs was also explored. Collapsed across groups, age was not significantly correlated with mean inferred incongruent SCE ratings, $r(54) = -0.11$, $p = 0.441$; nor mean empathic incongruent SCE ratings, $r(53) = -0.01$, $p = 0.972$. When separately investigating mean inferred incongruent and mean empathic incongruent SCE ratings during low and high PT demands, all correlations were nonsignificant.

CHAPTER V

STUDY I DISCUSSION: THE SUBJECTIVE EXPERIENCE OF SCES

The goal of the first study of this dissertation was to investigate the subjective experience of SCE processing in adolescent males with high functioning ASD relative to neurotypical adolescent males matched on age and level of intellectual functioning. I was particularly interested in exploring group differences in the intensity of inferred and empathic SCE ratings, as well as the differential impact of heightened PT demands on these abilities across groups. Broadly, results suggest that adolescent males with ASD have intact, yet atypical, SCE recognition, while their ability/tendency to feel empathic SCEs on behalf of others is unimpaired. Furthermore, results suggest that atypical social cognitive abilities may underlie group differences in SCE understanding, which may, in turn, impact real world social interactions and interpersonal success.

Self-Conscious Emotion Attribution

Congruent Self-Conscious Emotions. Results from the current study revealed that adolescent males with high-functioning ASD were indeed able to recognize SCEs conveyed in dynamic social stimuli, and this ability extended to both negatively-valenced (embarrassment) and positively-valenced (pride) emotions. Furthermore, adolescents with ASD made similarly intense emotional inferences as neurotypical adolescents. These findings not only demonstrate that adolescents with high-functioning ASD can *identify* complex social emotions, but that they can also *recognize the intensity* of these emotions to a similar degree as neurotypical peers. Given that participants were required to make intensity ratings, and not simply give binary responses (yes/no or positive/negative), the absence of group differences in congruent SCE ratings cannot be attributed to adolescents with ASD performing at chance or simply relying on low-level valence attributions. Broadly, these results converge with previous findings of intact emotion recognition abilities in older children with high-functioning (e.g., Capps et al., 1992; Heerey et al., 2003). While autism has historically been associated with impaired emotion recognition (Hobson, 1989), the current findings support recent theories that these deficits may be driven by lower verbal intelligence or developmental delays in younger children (Buitelaar, van der Wees, Swaab-Barneveld, et al., 1999; Golan et al., 2006; Rump, Giovannelli, Minshew, & Strauss, 2009; Teunisse & de Gelder, 2001) and may not accurately represent the capabilities of older, higher-functioning adolescents and adults.

While the current study lends support for intact emotion recognition abilities in adolescent males with high-functioning ASD, the broader literature offers mixed findings. Contrasting paradigm designs implemented in the current study and past research may enhance our understanding of emotion recognition abilities in ASD, as well as potentially clarify inconsistent findings. Previous studies have predominantly used static visual stimuli, particularly photographs of the eye region of the face, to explore emotion recognition in individuals with ASD. While this approach allows researchers to pinpoint which types of facial cues are critical for performing distinct tasks, it may inadvertently introduce a group-specific handicap that is not experienced outside of the laboratory setting. Although neurotypical individuals commonly reference the eye region of the face to make emotion attributions (Klin et al., 2002), individuals with ASD often demonstrate an aversion to (or reduced sensitivity to) direct eye contact (Kliemann, Dziobek, Hatri, Steimke, & Heekeren, 2010; Moriuchi, Klin, & Jones, 2016), as represented by more frequent gaze shifts away from, and shorter gaze fixations on, the eye region of the face (Jones, Carr, & Klin, 2008; Kliemann et al., 2010; Klin et al., 2002; Speer, Cook, McMahon, & Clark, 2007). In contrast, body/postural cues may be more salient in ASD.

Individuals with ASD demonstrate longer gaze fixations on body regions compared to eye regions (Klin et al., 2002; Speer et al., 2007), and they demonstrate similar nonsocial emotion recognition abilities as neurotypical peers when referencing photographs of bodies as opposed to of eyes (Peterson, Slaughter, & Brownell, 2015). Thus, commonly used unimodal tasks (particularly those that capitalize on static images of the eye region of the face) may fail to accurately represent real-world social interactions and may unintentionally “stack the cards” against individuals with ASD (Kliemann et al., 2010). In contrast, the SCET-C used in this dissertation provides substantial multimodal affective information, including facial, gestural, body/postural, and speech/prosodic cues. Thus, this dissertation may be better positioned to investigate the real-world emotion recognition abilities and challenges of high-functioning adolescent males with ASD.

Findings from the current study shed light onto the broader emotion processing capabilities of male youths with high-functioning ASD. The reported absence of group differences in congruent SCE attributions suggests that high-functioning adolescents with ASD can appropriately select salient affective cues from facial expressions, body postures/gestures, reports that individuals with high-functioning ASD, as well as low-functioning ASD, use affective information from multiple sources to aid in emotion recognition (Loveland et al., 1997). These findings suggest that when viewing targets conveying high-intensity emotions, adolescents with ASD may not require explicit instructions (or additional prompting) to direct their attention to salient cues. Furthermore, these findings suggest that adolescents with ASD can identify salient affective cues even when they are embedded within more complex, dynamic scenes; thus, their success cannot be attributed to salient cues being presented in isolation (such as images of only a specific region of the face). By requiring participants to identify and process multiple, dynamic affective cues, this dissertation offers a more ecologically-valid design that more accurately simulates real-world social interactions.

Of particular significance, the current findings suggest that intact emotion recognition abilities in ASD extend beyond basic nonsocial emotions to include more advanced social emotions. While a small number of studies have explored (and generally report intact) SCE recognition abilities in ASD, conclusions are often based on the recognition of one stimulus (Heerey et al., 2003; Hobson et al., 2006; Williams & Happé, 2010), which limits the generalizability of these findings. Two previous studies have explored SCE processing using more diverse stimuli sets. Tracy and colleagues (2011) reported that adolescents with ASD successfully recognized pride expressions in a set of briefly presented photographs, however, participants were only required to report the presence or absence of an emotion, not its intensity. Adler and colleagues (2015) reported that individuals with ASD successfully recognized embarrassment in short video clips, and that they made similarly intense emotional inferences as neurotypical peers; however, the study only included adult participants. The current findings suggest that successful SCE recognition is not limited to adults with ASD, but extends to adolescents as well, and includes both the ability to label and to recognize the intensity of both positive and negative SCEs.

A key aim of this dissertation was to explore potential group differences in SCE attributions when PT demands were low and high. Surprisingly, adolescent males with high-functioning ASD were not differentially impacted by changes in PT demands when making congruent SCE attributions, despite reports of pervasive ToM impairments in ASD across development (Baron-Cohen, 1990; Baron-Cohen et al., 1985; Frith, 2001). Regardless of group membership, adolescents' congruent SCE attributions were attenuated when PT demands were high. For example, adolescents with and without ASD inferred less intense embarrassment when they observed targets singing well and acting embarrassed (during high PT demands), compared to when they observed targets singing poorly and acting embarrassed (during low PT demands). This pattern suggests that adolescents with ASD and neurotypical adolescents are equally impacted by changes in PT demands when making congruent SCE attributions, perhaps because high-intensity affective cues (such as those provided in the SCET-C) are equally salient to adolescents with and without ASD.

Incongruent Self-Conscious Emotions. As a means of addressing potential MRI confounds, participants rated how intensely embarrassed and how intensely proud each target felt, regardless of the emotion the target conveyed (i.e., regardless if participants viewed embarrassment clips or pride clips). Thus, participants made both *congruent* SCE attributions (e.g., participants rated how intensely embarrassed an embarrassed target felt) and *incongruent* SCE attributions (e.g., participants rated how intensely proud an embarrassed target felt). This design is strikingly different from most emotion recognition tasks, where participants only rate the intensity of expressed emotions (i.e., congruent SCE attributions). Thus, this dissertation's design serendipitously afforded a more nuanced investigation of SCE understanding via the exploration of incongruent SCE attributions. Regardless of group membership, adolescents' incongruent SCE attributions were elevated when PT demands were high. For example, adolescents inferred more intense pride when they observed targets singing well and acting embarrassed (during high PT demands), compared to when they observed targets singing poorly and acting embarrassed (during low PT demands). Interestingly, during incongruent SCE attributions, adolescents with ASD were more strongly impacted by changes in PT demands than neurotypical adolescents. Adolescents with ASD reported similarly intense incongruent SCE attributions as neurotypical adolescents when PT demands were low; however, adolescents with ASD reported significantly more intense incongruent SCE attributions when PT demands were high.

Broadly speaking, these findings suggest that adolescent males with high-functioning ASD are differentially impacted by changes in PT demands during emotion processing, although perhaps not in the way one might have initially expected. While adolescents with ASD and neurotypical adolescents inferred similarly intense *congruent* SCEs during both low and high PT demands, adolescents with ASD inferred more intense *incongruent* SCEs during high PT demands. Taken together, these results suggest that adolescents with ASD are as capable as neurotypical adolescents at identifying high-intensity congruent SCEs; however, when PT demands are elevated, adolescents with ASD may additionally infer more intense incongruent SCEs which targets may not actually experience/express. Thus, during high PT demands, the emotional inferences of adolescents with ASD may be more complex and multifaceted. This unique pattern of results may shed light onto how individuals with ASD can pass explicit emotion recognition tasks within a laboratory setting (when they are only required to make congruent SCE attributions), yet commonly report emotion recognition difficulties and interpersonal challenges outside the laboratory (when they may make inappropriate incongruent SCE attributions).

Although this dissertation was initially designed to explore the impact of differential PT demands on SCE understanding, an alternative way of framing this study may be that it explores the impact of the situational context on SCE understanding. Under this framework, clips with low PT demands may be characterized as instances when a target's emotional reaction matches the situational context (i.e., a target acts embarrassed when he/she sings poorly), while clips with high PT demands may be characterized as instances when a target's emotional reaction does not match the situational context (i.e., a target acts embarrassed when he/she sings well). Thus, an alternative interpretation of the current findings is that adolescents with ASD and neurotypical adolescents may be similarly impacted by the situational context when they make *congruent* SCE attributions; however, adolescents with ASD may be more strongly impacted by the situational context when they make *incongruent* SCE attributions. Specifically, adolescents with ASD may be more likely to infer that targets feel emotions that reflect the situational context (or how adolescent expect or believe targets *should* feel), even if targets do not convey these emotions. Thus, the emotion attributions of individuals with ASD may be the product of intact emotion recognition abilities, in addition to personal expectations of situationally-appropriate reactions, according to learned social scripts.

Potential Difficulties Prioritizing/Integrating Affective Information

The current findings suggest that adolescent males with high-functioning ASD can appropriately recognize affective facial, body/postural, and/or prosodic cues. This is evidenced by similarly intense congruent SCE ratings made by adolescents with ASD and NT adolescents, as well as successful performance on a popular emotion recognition task (the Reading the Mind in the Eyes Task). However, significant group differences in incongruent SCE ratings and social competence measures, as well as correlations between more intense incongruent SCE ratings and reduced social competence, suggest that adolescents with ASD may experience difficulties integrating and interpreting diverse, conflicting cues when making emotional inference. These difficulties may, in turn, contribute to real-world interpersonal challenges. Specifically, when making emotion attributions, adolescents with ASD may prioritize using general contextual cues and rely less strongly on more salient/relevant affective information expressed by targets.

The ability to identify affective information from multimodal sources and prioritize using certain types of cues over others is characterized by distinct developmental profiles. Young neurotypical children (ages 5-7) commonly demonstrate a “contextual bias” when inferring others’ intentions, such that they prioritize information obtained from the situational context over information obtained from prosody; this pattern is observed despite their ability to use prosodic information when it is the only type of cue available (Aguert, Laval, Le Bigot, & Bernicot, 2010). However, as children mature, they begin to use more cognitively advanced strategies, particularly when they are presented with discrepant information. By approximately nine years old, neurotypical children switch from relying primarily on explicit lexical or contextual information, to referencing both contextual and prosodic information; and adults demonstrate a bias for using prosodic information over contextual information (Aguert et al., 2010; Friend & Bryant, 2000; Morton & Trehub, 2001).

Interestingly, linguistic research lends support for a “contextual bias” in ASD, but only when affective cues conflict with each other. Children and adolescents with ASD (ages 9-17; mean age 12) identified basic emotions as accurately as neurotypical youths during a speech comprehension task, but demonstrated a “contextual bias” when presented with incongruent prosodic and contextual cues (Le Sourn-Bissaoui, Aguert, Girard, Chevreuil, & Laval, 2013). The authors of this research proposed that group differences may represent atypical inferential processing strategies, particularly when integrating information from multiple cues. Results from this dissertation support and extend this interpretation, suggesting that a “contextual bias” in ASD extends beyond basic nonsocial emotion processing to include complex social emotion processing in older, high-functioning adolescents. Together, these findings suggest that youths with ASD may rely on a developmentally less mature strategy for weighing and integrating discrepant information, which may be the source of interpersonal challenges. I propose that neurotypical adolescents may prioritize making mental state attributions using affective cues (e.g., from prosody or facial expressions/body postures) to infer emotional states, while adolescents with ASD may prioritize making contextual inferences, based on learned social rules and generalized social scripts.

Research investigating moral reasoning lends additional support that individuals with ASD demonstrate atypical inferential abilities, particularly when they are required to integrate multiple, conflicting cues. Moran and colleagues (2011) presented participants with vignettes that required them to reflect on the targets' intentions and the stories' outcomes in order to make moral judgments. Adults with ASD and neurotypical adults responded similarly to vignettes portraying neutral actions, attempted harms, and intentional harms; however, they differed on their judgments of accidental harms. Adults with ASD judged accidental harms as less socially permissible than neurotypical adults, which suggests that when presented with conflicting information, adults with ASD may rely more strongly on situational outcomes, while neurotypical adults may rely more strongly on targets' intentions. The authors suggested that when presented with discrepant cues, adults with ASD may demonstrate an over-reliance on contextual information and an under-reliance on mental state information, which may broadly reflect difficulties integrating mental state information. Research by Zalla and colleagues (Zalla, Barlassina, Buon, & Leboyer, 2011) lends further support that adults with ASD may demonstrate an over-reliance on referencing learned rules when making moral judgments, and an under-reliance on referencing targets' intentions or affective responses, which the authors suggested may be associated with impaired cognitive empathy skills in ASD. Supporting my interpretation, Zalla and colleagues (2011) similarly proposed that adults with ASD may adopt a rule-based strategy for making moral judgments, which may serve as a means of compensating for poor ToM abilities. Baez and colleagues (2012) similarly argued that social cognitive impairments in adults with Asperger Syndrome may represent underlying difficulties integrating contextual and mental state (intention) information. Taken together, it appears that a contextual bias is pervasive in ASD across development and may broadly underlie group differences in language comprehension, moral reasoning, and emotional inference.

Interestingly, Baron-Cohen (1991) argued that atypical emotion recognition in ASD is most clearly observed when emotions are the consequence of beliefs (not situations or desires), which underscores the potential modulatory role of mental state attribution in atypical emotion processing in ASD. Indeed, in this dissertation, adolescents with ASD displayed intact SCE attributions when targets expressed emotions that matched the situational context (situationally-based emotions). However, they displayed atypical SCE attributions when targets expressed emotions that did not match the situational context and instead reflected singers' perceptions of their singing quality (belief-based emotions). These findings further underscore the potential combined impact of PT difficulties and rigid rule adherence in atypical SCE processing in ASD.

Empathic Self-Conscious Emotions

In addition to investigating potential group differences in SCE recognition abilities, this dissertation also investigated the ability/tendency to feel empathic SCEs for others. Adolescent males with high-functioning ASD reported feeling both negatively-valenced (embarrassment) and positively-valenced (pride) empathic SCEs, and there were no significant group differences in the intensity of empathic SCE ratings. Specifically, adolescents with ASD reported feeling similarly intense empathic *congruent* SCEs, as well as similarly intense empathic *incongruent* SCEs. Regardless of group membership, adolescents broadly reported attenuated empathic congruent SCE ratings when PT demands were high, such that they reported feeling more intense embarrassment for singers who sang poorly and acted embarrassed (during low PT demands) than for singers who sang well and acted embarrassed (during high PT demands). In addition, regardless of group membership, adolescents broadly reported attenuated empathic incongruent SCE ratings when PT demands were low, such that they reported feeling more intense pride for singers who sang well and acted embarrassed (during high PT demands) than for singers who sang poorly and acted embarrassed (during low PT demands). Interestingly, adolescents with ASD were not differentially impacted by changes in PT demands, compared to neurotypical adolescents. These findings suggest that adolescents with high-functioning ASD have an intact ability to feel empathic SCEs, which converge with previous reports of intact affective empathy (particularly empathic concern) in ASD (Dziobek et al., 2008; Rogers et al., 2007; Rueda et al., 2015).

Only two studies have explicitly investigated empathic SCE processing in individuals with ASD. In research by Paulus and colleagues (2013), participants viewed drawings of embarrassing scenarios and rated how intensely embarrassed they felt for the targets. Adults with ASD reported similarly intense empathic embarrassment ratings for targets who made accidental social norm violations and were aware of their transgressions (similar to embarrassment clips with low PT demands in the current study), as well as for targets who made accidental social norm violations and were unaware of their transgressions (similar to embarrassment clips with high PT demands in the current study), thus converging with results from this dissertation. However, a recent study by Alder and colleagues (2015) reported that adults with ASD felt more intense empathic embarrassment than neurotypical adults when viewing video clips of targets performing embarrassing tasks. One possible explanation for these discrepant findings is that empathic embarrassment ratings in these studies may reflect distinct affective processes. Alder and colleagues (2015) reported that empathic embarrassment ratings were correlated with personal distress scores in adults with ASD, suggesting that these ratings may more accurately reflect participants' physiological arousal, while empathic SCE ratings in the current study may more accurately reflect emotional simulation/resonance. Differences between the premises of these two tasks further support this interpretation. Participants in Adler and colleagues' (2015) study were aware that the targets in the videos were required to perform embarrassing actions as part of the study (and participants had recently performed the same embarrassing actions themselves). Thus, viewing these targets likely evoked feelings of personal distress. In contrast, participants in this dissertation were led to believe that targets were performing in a singing competition, which may have prompted them to engage in affective simulation. An alternative explanation for a lack of group differences in empathic SCE ratings in this dissertation may represent a developmental trend, such that adults with ASD may feel more intense empathic SCEs compared to neurotypical adults, while adolescents with ASD and neurotypical adolescents experience similar levels of empathy. However, research by Paulus and colleagues (2013) suggest that adults and adolescents with ASD may feel similarly intense empathic SCEs. Cross-sectional research comparing task performance between adolescents and adults, as well as longitudinal research tracking developmental changes from pre-adolescence extending into adulthood, will be key for exploring this theory.

Role of Underlying Social Cognitive Abilities

This dissertation investigated the role of a proposed triad of social cognitive abilities in adolescents' ability to infer SCEs and their ability/tendency to feel empathic SCEs. I hypothesized that adolescent males with high-functioning ASD would demonstrate atypical social cognition, and that these atypicalities would underlie group differences in SCE understanding. As expected, adolescents with ASD reported attenuated self-awareness/introspection, as represented by reduced self-consciousness and greater alexithymic tendencies, including difficulties describing their own feelings, converging with past research (Griffin et al., 2016; Patil et al., 2016; Silani et al., 2008). In addition, adolescents with ASD reported reduced PT abilities and attenuated cognitive empathy within the real world, converging with previous findings (Castelli et al., 2002; Dziobek et al., 2008; Happé, 1994). However, there were no group differences in PT task performance. This pattern of results resembles findings from the executive functioning literature, where children with ASD demonstrate successful performance on laboratory tasks but report impairments within the real world (Geurts, Corbett, & Solomon, 2009; Kenworthy, Yerys, Anthony, & Wallace, 2008).

Surprisingly, there were no group differences in affective empathy. While previous studies have generally reported similar levels of empathic concern in individuals with and without ASD, individuals with ASD commonly demonstrate elevated levels of personal distress (Dziobek et al., 2008; Patil et al., 2016; Rogers et al., 2007). The gender composition of the current study may possibly explain a lack of group differences in empathy abilities. Longitudinal research has found that neurotypical males typically experience a decrease in empathy during early and middle adolescence, while neurotypical females experience stable levels across adolescence (Van der Graaff et al., 2014). Consequently, previously reported group differences may have been driven by the relatively greater empathic abilities of female neurotypical participants within the comparison group. An alternative explanation is that adolescents with high-functioning ASD may actually demonstrate similar levels of empathic concern and personal distress as neurotypical adolescents, perhaps representing developmental differences between adolescents and adults with ASD. Indeed, previous reports of heightened personal distress are based solely on research studying adults with ASD (Adler et al., 2015; Dziobek et al., 2008; Lombardo et al., 2007; Patil et al., 2016; Rogers et al., 2007). Additional research is necessary to test these theories.

Contrary to my expectations, inferred congruent SCE ratings were not correlated with social cognitive abilities, such that ToM impairments/PT difficulties were not associated with less intense congruent SCE attributions. One possible explanation for a nonsignificant relationship between inferred congruent SCE ratings and ToM abilities may be due to ceiling effects on the SCET-C. The SCET-C uses high-intensity stimuli to enhance the capability to observe group differences in neural activation patterns; both adolescents with ASD and neurotypical adolescents reported, on average, medium to high intensity ratings for congruent SCE clips. Thus, the current task may not have been sufficiently sensitive to explore more nuanced group differences in SCE processing, and thus, may have been unable to detect associations between emotion recognition abilities and social cognitive skills, if a relationship does exist. Future studies should adopt more subtle/ambiguous stimuli sets to test this theory. An alternative explanation is that the ability to recognize emotional expressions (e.g., from photographs or videos) may function independent of PT skills, while the ability to cognitively infer emotional states (e.g., from short vignettes) may more strongly rely on cognitive empathy skills. Indeed, research exploring embarrassment understanding using short vignettes found that children with ASD offered less appropriate justifications for their emotion attributions compared to neurotypical children, and impoverished justifications were associated with worst performance on a ToM task (Hillier & Allinson, 2002a).

Interestingly, there was a significant relationship between social cognitive abilities and inferred *incongruent* SCE ratings, such that more intense inferred incongruent SCE ratings were associated with worse PT abilities. This finding is novel, as previous studies have only explored congruent SCE ratings. This finding suggests that reduced cognitive empathy may underlie atypical SCE attributions in adolescents with ASD. Specifically, ToM difficulties did not appear to be associated with a tendency to infer less intense *congruent* SCEs, but instead, a tendency to infer more intense *incongruent* SCEs. A possible explanation for this pattern is that adolescents with ASD may compensate for atypical ToM abilities when PT demands are high by relying more strongly on learned rules/social scripts. Indeed, previous research has suggested that adults with ASD adopt rule-based strategies when participating in emotional facial recognition tasks (Rutherford & McIntosh, 2007) and may reference social knowledge to compensate for social cognitive difficulties (Baez et al., 2012).

Both empathic congruent SCEs and empathic incongruent SCEs were related to social cognitive abilities. Participants who reported feeling more intense empathic SCEs for targets also reported experiencing higher levels of affective empathy within the real world. This pattern held for both empathic congruent and incongruent SCE ratings, which suggests that adolescents who reported experiencing greater empathy in everyday life not only resonated more strongly with the emotions that they observed targets expressing (*congruent* empathic SCEs), but also felt more intense vicarious emotions on behalf of others, even if targets did not express these emotions themselves (*incongruent* empathic SCEs). Specifically, empathic congruent and empathic incongruent SCE ratings correlated positively with Affective Empathy scores on the BES, but not with Empathic Concern or Personal Distress scores on the IRI. Previous research has similarly reported an association between the intensity of empathic SCE ratings and real world affective empathy, although this relationship was driven by elevated levels of personal distress (Adler et al., 2015). Overall, these findings suggest that empathic SCE attributions may be a function of general empathic processing in both adolescents with ASD and neurotypical adolescents. The intensity of empathic congruent SCE ratings were also associated with Fantasy scores on the IRI, such that adolescents who reported a greater tendency to adopt the perspectives of fictional characters reported feeling more intense empathic SCEs. An interesting avenue for future research will be to investigate if these patterns extend to familiar targets. Interestingly, empathic SCE ratings were not related to PT abilities/cognitive empathy, suggesting that the tendency to feel SCEs on behalf of others may not be associated with the ability or tendency to adopt others' perspectives. Given reports of intact affective empathy but reduced cognitive empathy in ASD, it perhaps should not be surprising that these two processes appear independent in the current study. Future research should explore the relationship between empathic SCE ratings and PT abilities using less intense/more complex affective stimuli, to rule out the possibility that the current findings were the result of reduced task demands.

Recently, several researchers have proposed an "alexithymia hypothesis", which posits that atypical emotion recognition and empathy processing in ASD may be driven by heightened levels of alexithymia, above and beyond the impact of elevated autistic symptoms/traits (Bird & Cook, 2013). Adults with ASD and neurotypical adults matched on alexithymia demonstrated similar sensitivity in their ability to recognize morphed facial expressions of nonsocial emotions; and alexithymic tendencies, but not autistic traits, predicted worst sensitivity (Cook et al., 2013). Relatedly, adults with high-functioning ASD demonstrated worst recognition of nonsocial emotional vocalizations compared to neurotypical adults, and task performance correlated with alexithymia scores for both groups of adults (Heaton et al., 2012). The current study revealed significant group differences in autistic symptom severity, autistic traits, and alexithymia, which suggest that group differences in SCE processing (as reflected in heightened inferred incongruent SCE ratings) may be associated with either autism-specific social challenges or more general impairments in introspection. Interestingly, adolescents who reported more intense inferred incongruent SCE ratings also reported more severe autism-related social impairments, but not elevated levels of alexithymia, suggesting that atypical SCE processing in ASD may not be driven by greater alexithymia. These findings converge with reports linking alexithymic traits with impaired emotional resonance, but autistic traits with impaired cognitive PT (Lockwood, Bird, Bridge, & Viding, 2013). Thus, atypical SCE recognition in the current study appears to be autism-specific, driven by underlying cognitive empathy impairments, which does not support the “alexithymia hypothesis”.

Although purely speculative, a significant relationship between inferred incongruent SCE ratings and SRS scores, but not ASRS scores nor AQ scores, in the current study may shed further light onto the underlying causes of atypical SCE recognition in ASD. While the SRS is designed to measures autism-relevant social impairments (including poor social awareness, social cognition, social communication, and social motivation), the ASRS and AQ measure autistic symptoms and autistic traits more broadly, without emphasizing social difficulties. The ASRS is designed to broadly measure autistic behaviors and mannerisms (including unusual behaviors, poor self-regulation, and sensory sensitivities, as well as social/communication symptoms), and the AQ is designed to broadly measure autistic traits (including atypical cognition, atypical perception, and repetitive behaviors, as well as social difficulties). Thus, the current findings suggest that atypical SCE processing in ASD may be driven by real-world social impairments, and more intense incongruent SCE attributions may be the product of compensatory strategies aimed at addressing these social challenges.

Strengths, Limitations, and Future Directions

As mentioned earlier, this dissertation is associated with several strengths, relative to previous emotion processing studies. First, this study used dynamic emotional stimuli, which provided facial, postural/gestural, and prosodic affective cues. Thus, the SCET-C provided participants with multiple types of affective information from which to make emotion attributions. Dynamic stimuli are more ecologically valid, more closely resemble real world emotion expressions (particularly SCEs), and promote greater emotion recognition, relative to static stimuli (Krumhuber et al., 2013; Wehrle et al., 2000). Second, this study used more developmentally-appropriate stimuli featuring adolescent targets. Peer relevance increases substantially during adolescence (Nelson et al., 2016), which suggests that stimuli featuring age-matched targets, relative to stimuli featuring adults, may be more motivationally salient to adolescent participants. Furthermore, adolescents may more easily recognize emotional facial expressions conveyed by adolescents. Adolescents are presumably in greater contact with a wide range of peers, which affords more frequent opportunities to observe and practice identifying adolescent emotional expressions, compared to those of adults. Indeed, research suggests that increased contact with members of specific age groups is associated with enhanced facial recognition (Proietti, Pisacane, & Cassia, 2013). In addition, children and adults demonstrate greater accuracy and discriminability for recognizing faces of age-matched peers, which represents an “own-age” bias (Rhodes & Anastasi, 2012). Consequently, adolescents may demonstrate greater accuracy on emotion recognition tasks which include adolescent targets. Third, the social context of the SCET-C may be more engaging and motivationally salient than previously-used emotion recognition paradigms. While participants in previous studies often viewed decontextualized static images of isolated faces, participants in the current study viewed peers participating in an entertaining singing competition.

This dissertation is associated with several limitations, which may inform avenues for future research. As described previously, the SCET-C includes high-intensity, strongly recognizable affective stimuli. While these stimuli were selected to elicit high recognition rates and robust neural activity, reduced task demands may have resulted in ceiling effects and limited the ability to detect more nuanced group differences. Previous research exploring emotion recognition in ASD suggests that group differences are often more apparent when task demands are high; therefore, future research should explore SCE processing using less prototypical, more subtle/complex stimuli, or by significantly limiting response times (Rump et al., 2009). With the addition of more diverse stimuli, future research could also include a wider rating scale, to increase the ability to detect subtle group differences in intensity ratings. Future studies could also require participants to identify SCEs, either by selecting from multiple labels (similar to the Reading the Mind in the Eyes Task) or by generating their own labels, in addition to rating the intensity of these emotions. Participants could also be required to justify their ratings. In two previous studies, children with ASD demonstrated similar emotion recognition rates as neurotypical children, but offered less appropriate justifications for their emotion attributions (Hillier & Allinson, 2002a, 2002b). Thus, exploring *how* youths with ASD make emotion attributions may prove informative.

Another significant limitation is that this dissertation only explored SCE processing in adolescent males. Autism research is generally limited to studying males; thus, relatively little is known about the female profile in ASD. Future research should prioritize enhancing our understanding of the social cognitive abilities of females with ASD by including both male and female participants. In addition, research exploring neurotypical youths has reported important gender differences in social cognitive abilities. Neurotypical females are generally better at recognizing facial expressions (McClure, 2000), and females generally demonstrate greater PT abilities and empathy compared to males (Hoffman, 1977). Consequently, the findings from the current may not generalize to female samples, and research exploring SCE processing in mixed-gender samples may observe more robust group differences, given that a more skilled comparison group is used. The development of PT abilities and empathy is also characterized by gender-specific trajectories. Females experience greater gains in PT during adolescence compared to males (Van der Graaff et al., 2014). Given that the intensity of inferred incongruent SCE ratings was related to PT abilities, these findings suggest that neurotypical adolescent females may infer less intense incongruent SCEs, and that group differences may be more robust than the current study has indicated. Furthermore, male youths experience decreases in empathic concern from early adolescence to middle adolescence, followed by increases in late adolescence that resemble early adolescent levels; in comparison, female youths experience stable levels throughout adolescence (Van der Graaff et al., 2014). Future research should explore group differences in inferred and empathic SCE attributions in both males and females throughout adolescence, as well as investigate possible interaction effects between group, gender, and pubertal status.

Implications for Intervention

Results from the current study demonstrated that adolescent males with high-functioning ASD can appropriately recognize high-intensity affective facial, postural, and/or prosodic cues to make SCE attributions; nevertheless, they frequently experience interpersonal challenges within the real world. One possible explanation for these seemingly inconsistent findings is that youths with ASD may have difficulty applying aaffective knowledge to novel social contexts. This interpretation is supported by the Weak Central Coherence Theory (Frith, 1989), which proposes that individuals with ASD have a local processing bias which hinders them from seeing the "big picture" or "gestalt". Consequently, individuals with ASD may experience difficulties processing similarities within the environment, and thus, may demonstrate an impaired ability to generalize across contexts (Plaisted, 2001; Vermeulen, 2015). The Weak Central Coherence Theory (Frith, 1989) and the related Reduced Generalization Theory (Plaisted, 2001) can tentatively explain significant group differences in inferred incongruent SCE ratings. Individuals with ASD often demonstrate a strict adherence to rules, even when they are contextually inappropriate (Klinger & Dawson, 2001). Thus, in the current study, youths with ASD may have rigidly followed learned rules/social scripts (e.g., if you do well on a task, such as sing well in a competition, you feel proud of yourself), and thus made contextually inappropriate emotional inferences. Assuming that adolescents with high-functioning ASD do indeed have intact emotion recognition abilities, then the current findings suggest that more intensive emotion recognition training may not be beneficial, as these youths have successfully learned how to identify and process salient affective cues. Instead, youths with ASD may more strongly benefit from practicing applying this knowledge to novel social situations, such as through role-playing. Another avenue for intervention could be to teach adolescents with ASD the necessity of differentially weighting affective and contextual cues, particularly when they are incongruent. Finally, intervention programs should aim to use a diverse range of stimuli (not simply high-intensity, prototypical exemplars) as testing criteria, to promote broader generalization of emotion recognition skills within the real world.

CHAPTER VI

STUDY II RESULTS: THE NEURAL CORRELATES OF SCES

Demographics Information

27 participants in the ASD group and 25 participants in the NT group participated in Study II. (Participants in Study II represented a subsample of participants from Study I.) The ASD group ranged from ages 137.90 to 203.80 months (11 years 5 months to 16 years 11 months), with a mean age of 176.42 months (14 years 8 months). The NT group ranged from ages 133.30 to 211.10 months (11 years 1 month to 17 years 7 months), with a mean age of 178.74 months (14 years 10 months). With respect to pubertal development, the ASD group endorsed scores ranging from 1.0-4.0, with a mean of 2.67 (pubertal stage: pre-puberty = 1, early puberty = 1, mid puberty = 11, late puberty = 13, post-puberty = 1), and the NT group endorsed scores ranging from 1.20-3.60, with a mean of 2.62 (pubertal stage: pre-puberty = 0, early puberty = 3, middle puberty = 12, late puberty = 10, post-puberty = 0). Groups did not significantly differ on age, $t(50) = 0.40$, $p = 0.689$; pubertal development, $t(50) = -0.28$, $p = 0.782$; or pubertal category, $X^2(4) = 3.36$, $p = 0.499$. All participants had a FSIQ of at least 75 (ASD: 77-141, $M = 109.33$; NT: 93-140, $M = 116.56$), and groups did not significantly differ in FSIQ, $t(50) = 1.69$, $p = 0.097$. Both groups were predominantly Caucasian, reflecting local demographics (ASD: Caucasian = 24, Hispanic = 1, Multi-ethnic = 2; NT: Caucasian = 18, Hispanic = 4, Multi-Ethnic = 2; 1 NT participant had missing data), and groups did not significantly differ in ethnic representation, $X^2(2) = 2.49$, $p = 0.288$. Groups did not differ on maternal education (ASD: Public school = 0, High school = 3, Trade school = 1, Associate degree = 7, Undergraduate degree = 10, Post-graduate degree = 5; NT: Public school = 1, High school = 2, Trade school = 2, Associate degree = 2, Undergraduate degree = 6, Post-graduate

degree = 11; 1 ASD participant declined to answer; 1 NT participant had missing data), $X^2(5)$ = 7.49, p = 0.186. In addition, groups did not significantly differ on paternal/spousal education (ASD: Public school = 0, High school = 8, Associate degree = 3, Undergraduate degree = 5, Post-graduate degree = 8; NT: Public school = 2, High school = 3, Associate degree = 3, Undergraduate degree = 5, Post-graduate degree = 7; 1 ASD participant and 1 NT participant declined to answer; 2 ASD participants and 2 NT participants had missing data), $X^2(6)$ = 4.05, p = 0.671 Groups did not significantly differ on annual household income (ASD: $0-$25,000 = 4, $25,000-$40,000 = 1, $40,000-$75,000 = 7, $75,000-$100,000 = 6, $100,000+ = 6; NT: $0-$25,000 = 0, $25,000-$40,000 = 7, $40,000-$75,000 = 5, $75,000-$100,000 = 6, $100,000+ = 6; 1 NT participant had missing data), $X^2(4)$ = 8.83, p = 0.065.

Whole Brain Analyses for NT Group

Results from the 2 x 2 repeated measures ANOVA for the NT group revealed a main effect of emotion, a main effect of PT demands, and an interaction effect between emotion and PT demands. (See Figure 6 and Table 6.)

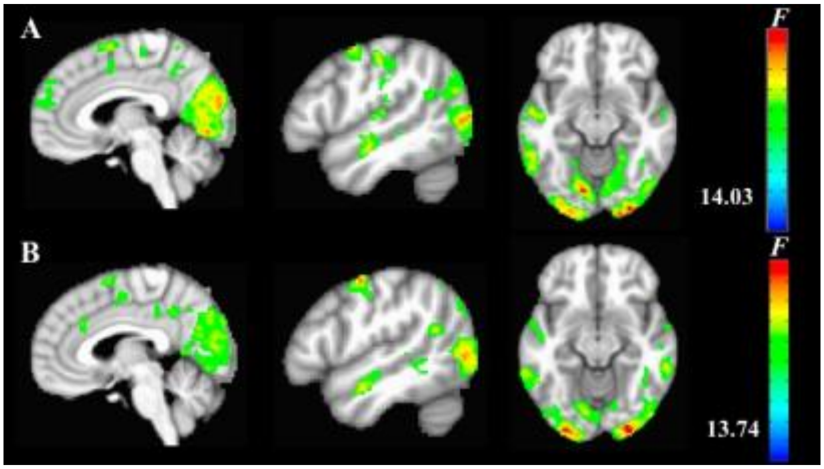

Figure 6. Intercept for NT and ASD groups, separately

Panel A) Intercept for NT group. **Panel B)** Intercept for ASD group. ASD = Autism Spectrum Disorder; NT = Neurotypical.

Note: Voxel-height and cluster-extent thresholds of $p < 0.001$ and $k = 45$ and $k = 46$ for NT and ASD groups

Table 6. Neural Activity during Self-Conscious Emotion Processing for NT Group

Contrast	Hemisphere	Region	k	x	y	z	F
Intercept							
	Bilateral	Lingual gyrus (ext. cuneus, calcarine gyrus; left middle occipital gyrus, middle temporal gyrus, angular gyrus)	8476	-12	-78	-12	100
	Right	Middle temporal gyrus (BA 37; ext. middle occipital gyrus, superior occipital gyrus, inferior occipital gyrus, lingual gyrus, inferior temporal gyrus, fusiform gyrus)	3007	48	-66	4	100
	Left	Inferior occipital gyrus (ext. lingual gyrus, calcarine gyrus, middle occipital gyrus)	2195	-24	-102	-8	100
	Left	Supramarginal gyrus (BA 40; ext. inferior parietal lobe, postcentral gyrus, Rolandic operculum)	688	-62	-24	40	53.33
	Bilateral	Posterior cingulate cortex (BA 31/7; ext. precuneus)	527	-8	-34	34	66.23
	Left	Middle temporal gyrus (BA 37/21; ext. inferior temporal gyrus)	517	-60	-46	-12	57.16
	Left	Middle temporal gyrus (BA 21/22; ext. superior temporal gyrus/Heschl's gyrus)	411	-58	-8	-10	93.60
	Right	Angular gyrus (BA 7/39)	324	48	-64	26	33.05
	Right	Precentral gyrus (BA 6)	254	52	4	48	87.52
	Right	Supplementary motor area (BA 6)	221	6	10	66	79.77
	Left	Superior frontal gyrus/precentral (BA 6)	169	-20	-10	70	75.76
	Right	Supramarginal gyrus (BA 40)	167	60	-34	20	60.55
	Left	Postcentral gyrus (BA 5; ext superior parietal lobe)	158	-22	-42	66	59.75
	Left	Supplementary motor area/middle cingulate cortex (BA 24)	150	8	2	52	40.36
	Left	Fusiform gyrus (BA 37)	148	-42	-50	-18	56.18
	Right	Heschl's gyrus (BA 41)	139	52	-18	8	42.14
	Left	Precentral gyrus (BA 6)	118	-50	-2	54	45.93
	Right	Inferior temporal gyrus (BA 20)	114	42	-2	-46	25.85

		Medial prefrontal cortex (BA 9/10)	110	4	60	18	23.62
	Right	Middle temporal gyrus (BA 21)	92	50	-10	-18	55.12
	Left	Cerebellum	78	30	-62	-54	46.14
	Right	Supplementary motor area (BA 6)	70	8	-20	62	38.59
	Left	Precentral gyrus (BA 4)	53	-34	-20	46	38.94
	Left	Middle frontal gyrus (BA 9/6)	52	-40	12	50	27.76
	Left	Cerebellum	48	-32	-62	-24	28.74
Main Effect of Emotion							
	Right	Lingual gyrus (ext. calcarine gyrus, middle occipital, middle temporal gyrus)	1559	16	-86	-8	60.5
	Left	Middle occipital gyrus	938	-50	-76	10	59.38
	Left	Superior temporal gyrus/supramarginal gyrus (BA 41)	81	-44	-38	16	33.71
	Right	Superior temporal gyrus (BA 22)	80	50	-12	2	38.68
	Left	Superior temporal gyrus (BA 22)	76	-46	-16	0	35.95
	Right	Superior temporal gyrus/inferior parietal lobe (BA 13/40)	46	56	-38	24	24.91
Main effect of PT							
	Right	Middle temporal gyrus (BA 19)	292	42	-66	2	51.43
	Right	Lingual gyrus (ext. calcarine gyrus)	198	18	-88	-8	56.29
	Left	Middle occipital gyrus	89	-50	-78	6	46.1
Emotion x PT							
	Left	Precentral gyrus (BA 4/6; ext. postcentral gyrus)	148	-22	-22	60	33.1
	Left	Calcarine gyrus (ext. cuneus)	85	-2	-96	10	26.9
	Right	Precentral gyrus (BA 6)	72	40	-10	38	33.83
	Right	Postcentral gyrus (BA 4/6; ext. precentral gyrus)	51	62	0	24	28.52
	Left	Postcentral gyrus (BA 4/6)	46	-44	-12	42	24.07
	Right	Inferior parietal lobe (BA 40)	45	26	-54	50	20.14

BA = Brodmann Area; NT = Neurotypical; PT = perspective-taking demands.

Note: Voxel-height and cluster-extent thresholds of $p < 0.001$ and $k = 45$.

Intercept. The intercept revealed frontal activity within the medial prefrontal cortex, left middle frontal gyrus, left superior frontal gyrus, bilateral precentral gyrus, left postcentral gyrus, and bilateral supplementary motor area; limbic activity within the right inferior frontal gyrus; parietal activity within bilateral posterior cingulate cortex, bilateral precuneus, and bilateral inferior parietal lobe (including bilateral angular gyrus and supramarginal gyrus); temporal activity within bilateral inferior temporal gyrus, bilateral fusiform gyrus, bilateral middle temporal gyrus, and bilateral superior temporal gyrus/Heschl's gyrus; occipital activity within bilateral lingual gyrus, bilateral calcarine gyrus, bilateral cuneus, bilateral inferior occipital gyrus, bilateral middle occipital gyrus, and right superior occipital gyrus; as well as activity within the middle cingulate cortex and the left cerebellum.

Main Effect of Emotion. The main effect of emotion revealed activity within bilateral superior temporal/inferior parietal and occipital regions. The NT group recruited relatively greater activity within the right superior temporal gyrus/inferior parietal lobe, right lingual gyrus, and left middle occipital gyrus during embarrassment clips. Meanwhile, the NT group recruited relatively greater activity within the left superior temporal gyrus/supramarginal gyrus and bilateral superior temporal gyrus during pride clips.

Main Effect of Perspective-Taking Demands. The main effect of PT demands revealed activity within the right middle temporal gyrus and bilateral occipital regions. The NT group recruited greater activity within the left lingual gyrus when PT demands were low, and recruited greater activity within bilateral middle temporal gyrus when PT demands were high.

Interaction Effect between Emotion and Perspective-Taking Demands. The interaction between emotion and PT demands revealed activity within bilateral somatosensory regions, right inferior parietal lobe, and left occipital regions.

Left precentral gyrus. There was a significant interaction effect between emotion and PT demands within the left precentral gyrus extending into the postcentral gyrus, $F(1,24) = 37.56$, p

< 0.001. There was no main effect of group, $F(1,24) = 1.19$, $p = 0.286$; nor main effect of PT demands, $F(1,24) = 0.06$, $p = 0.803$. Post-hoc *t*-tests exploring the interaction effect revealed that the NT group recruited greater activity during embarrassment clips with high, relative to low, PT demands, $t(24) = -3.48$, $p = 0.002$; but greater activity during pride clips with low, relative to high, PT demands, $t(24) = 3.32$, $p = 0.003$. During low PT demands, the NT group recruited greater activity for pride clips, $t(24) = -4.52$, $p < 0.001$; but during high PT demands, participants recruited greater activity for embarrassment clips, $t(24) = 2.16$, $p = 0.041$.

Right precentral gyrus. There was a significant interaction effect between emotion and PT demands within the right precentral gyrus, $F(1,24) = 32.07$, $p < 0.001$. There was also a main effect of emotion, $F(1,24) = 5.01$, $p = 0.035$, such that the NT group recruited greater activity during pride clips. There was no main effect of PT demands, $F(1,24) = 2.92$, $p = 0.101$. Post-hoc *t*-tests exploring the interaction effect revealed that the NT group recruited greater activity during embarrassment clips with high, relative to low, PT demands, $t(24) = -2.77$, $p = 0.011$; but greater activity during pride clips with low, relative to high, PT demands, $t(24) = 6.07$, $p < 0.001$. During low PT demands, the NT group recruited greater activity for pride clips, $t(24) = -5.65$, $p < 0.001$; but during high PT demands, the NT group recruited greater activity for embarrassment clips, $t(24) = 2.22$, $p = 0.036$.

Left postcentral gyrus. There was a significant interaction effect between emotion and PT demands within the left postcentral gyrus, $F(1,24) = 30.65$, $p < 0.001$. There was also a main effect of emotion, $F(1,24) = 10.34$, $p = 0.004$, such that the NT group recruited greater activity during pride clips. There was no main effect of PT demands, $F(1,24) = 3.82$, $p = 0.062$. Post-hoc *t*-tests exploring the interaction effect revealed that the NT group recruited similar activity during embarrassment clips with low and high PT demands, $t(24) = -1.76$, $p = 0.092$; but greater activity during pride clips with low, relative to high, PT demands, $t(24) = 5.20$, $p < 0.001$. During low PT demands, the NT group recruited greater activity for pride clips, $t(24) = -6.30$, $p < 0.001$; but during high PT demands, the NT group recruited similar activity for embarrassment and pride clips, $t(24) = 1.11$, $p = 0.280$.

Right postcentral gyrus There was a significant interaction effect between emotion and PT demands within the right postcentral gyrus extending into the precentral gyrus, $F(1,24) = 30.85$, $p < 0.001$. There was no main effect of emotion, $F(1,24) = 0.35$, $p = 0.561$; nor main effect of PT demands, $F(1,24) = 2.92$, $p = 0.101$ Post-hoc *t*-tests exploring the interaction effect revealed that the NT group recruited greater activity during embarrassment clips with high, relative to low, PT demands, $t(24) = -3.49$, $p = 0.002$; but greater activity during pride clips with low, relative to high, PT demands, $t(24) = 4.29$, $p < 0.001$. During low PT demands, the NT group recruited greater activity for pride clips, $t(24) = -3.84$, $p = 0.001$; but during high PT demands, the NT group recruited greater activity for embarrassment clips, $t(24) = 4.22$, $p < 0.001$.

Right inferior parietal lobe. There was a significant interaction effect between emotion and PT demands within the right inferior parietal lobe, $F(1,24) = 21.45$, $p < 0.001$. There was also a main effect of emotion, $F(1,24) = 5.99$, $p = 0.022$, such that the NT group recruited greater activity during embarrassment clips. There was a marginally significant main effect of PT demands, $F(1,24) = 3.98$, $p = 0.058$, such that the NT group recruited marginally greater activity during clips with high, relative to low, PT demands. Post-hoc *t*-tests exploring the interaction effect revealed that the NT group recruited greater activity during embarrassment clips with high, relative to low, PT demands, $t(24) = -5.43$, $p < 0.001$; but similar activity during pride clips with low and high PT demands, $t(24) = 1.40$, $p = 0.174$. During low PT demands, the NT group recruited similar activity for embarrassment and pride clips, $t(24) = -1.21$, $p = 0.238$; but during high PT demands, the NT group recruited greater activity for embarrassment clips relative to pride clips, $t(24) = 4.59$, $p < 0.001$.

Left calcarine gyrus. There was a significant interaction effect between emotion and PT demands within the left calcarine gyrus extending into the cuneus, $F(1,24) = 46.37$, $p < 0.001$. While there was no main effect of emotion, $F(1,24) = 2.87$, $p = 0.103$, there was a marginally significant main effect of PT demands, $F(1,24) = 4.05$, $p = 0.056$, such that the NT group recruited marginally greater activity during clips with high PT demands. Post-hoc *t*-tests exploring the interaction revealed that the NT group recruited greater activity during embarrassment clips with high, relative to low, PT demands, $t(24) = -5.69$, $p < 0.001$; but greater activity during pride clips with low, relative to high, PT demands, $t(24) = 2.64$, $p = 0.014$. During low PT demands, the NT group recruited greater activity for pride clips, $t(24) = -2.10$, $p = 0.046$; but during high PT demands, the NT group recruited greater activity for embarrassment clips, $t(24) = 4.91$, $p < 0.001$.

Whole Brain Analyses for ASD Group

Results from the 2 x 2 repeated measures ANOVA for the ASD group revealed a main effect of emotion and a main effect of PT demands. There was no significant interaction effect between emotion and PT demands. (See Table 7 and Figure 6.)

Table 7. Neural Activity during Self-Conscious Emotion Processing for ASD Group

Contrast	Hemisphere	Region	k	x	y	z	F
Intercept							
	Bilateral	Lingual gyrus (ext. calcarine gyrus, cuneus; left precuneus)	3740	-10	-74	-8	86.00
	Right	Middle temporal gyrus (BA 37; ext. inferior temporal gyrus, fusiform gyrus, lingual gyrus, cerebellum)	2973	54	-66	2	100
	Left	Inferior occipital gyrus (ext. lingual gyrus, middle occipital gyrus)	2407	-28	94	-12	100
	Left	Middle temporal gyrus (BA 37; ext. inferior temporal gyrus)	843	-60	-46	-8	80.66
	Right	Angular gyrus (BA 7)	831	44	-62	28	60.48
	Right	Middle temporal gyrus/inferior temporal gyrus (BA 21/20)	611	62	-34	-16	60.51
	Left	Angular gyrus (BA 7/40)	503	-38	-80	44	49.30
	Bilateral	Posterior cingulate cortex/precuneus (BA 31)	386	-2	-46	38	51.54
	Right	Supramarginal gyrus (BA 40)	264	60	-28	22	47.35
	Left	Middle temporal gyrus (BA 21)	254	-52	-4	-18	55.59
	Left	Middle frontal gyrus/precentral gyrus (BA 6/4)	236	50	0	52	52.70
		Dorsal anterior cingulate cortex (BA 32)	198	-6	28	30	65.11
	Bilateral	Middle cingulate cortex (BA 24)	175	-6	2	46	26.24
	Left	Precentral gyrus (BA 6)	130	-50	-4	54	78.27
	Right	Supplementary motor area (BA 6)	126	8	4	74	40.23
	Left	Precentral gyrus (BA 6)	121	-22	-18	68	25.63
	Right	Superior frontal gyrus (BA 8)	111	26	26	50	29.91
	Right	Middle frontal gyrus (BA 46)	104	36	42	8	28.76
	Right	Caudate	86	12	22	4	42.73
	Right	Heschl's gyrus (BA 41/42)	84	52	-18	10	30.30
	Left	Cerebellum	78	-26	-64	-26	40.79
	Left	Cerebellum	74	-18	-66	-50	33.59
	Right	Rolandic operculum/inferior frontal gyrus (BA 22/47)	63	54	10	0	27.38
	Right	Inferior frontal gyrus (BA 9)	60	44	10	24	32.77
	Right	Inferior frontal gyrus (BA 9)	56	40	16	36	26.13
	Left	Precentral gyrus (BA 4)	56	-38	-14	56	28.72
	Right	Anterior insula (BA 13/45/47)	49	36	24	4	27.17
	Right	Middle temporal gyrus (BA 21)	46	54	-8	-18	25.00
Main Effect of Emotion							
	Right	Lingual gyrus (ext. calcarine gyrus,	3141	18	-86	-8	99.02

		superior occipital gyrus, cuneus, middle temporal gyrus, inferior temporal gyrus, fusiform gyrus)					
	Left	Middle occipital gyrus (ext. inferior occipital gyrus, middle temporal gyrus)	1358	-26	94	10	83.08
	Right	Inferior parietal lobe/superior parietal lobe (BA 7/40)	354	26	-54	52	40.59
	Left	Superior parietal lobe (BA 7; ext. inferior parietal lobe)	213	-24	-60	54	34.85
	Left	Middle occipital gyrus (ext. superior occipital gyrus)	183	-26	-72	28	50.44
	Left	Superior temporal gyrus (BA 41/42)	103	-58	-16	6	34.02
	Right	Cuneus	58	20	-82	46	26.65
	Left	Middle occipital gyrus	56	-10	-104	4	26.77
Main effect of PT							
	Right	Middle temporal gyrus (BA 37/39; ext. middle occipital gyrus, inferior occipital gyrus)	854	48	-64	4	76.48
	Left	Calcarine gyrus (ext. middle occipital gyrus, superior occipital gyrus)	309	6	-94	8	40.70
	Left	Middle frontal gyrus (BA 9)	149	-42	30	36	32.38
	Left	Middle occipital gyrus/middle temporal gyrus (BA 19/37)	128	-48	-74	4	32.84
	Left	Inferior parietal lobe/angular gyrus (BA 40/7)	114	-40	-52	48	31.60
	Left	Cerebellum	100	-16	-84	-32	29.29
	Right	Lingual gyrus	67	28	-92	-16	31.72
	Left	Calcarine gyrus	62	-6	-98	4	35.98
	Left	Inferior occipital gyrus	48	-40	-74	-6	43.90
		Dorsal medial prefrontal cortex (BA 8)	46	4	36	54	27.97
Emotion x PT							
	-	-	-	-	-	-	-

ASD = Autism Spectrum Disorder; BA = Brodmann Area; PT = perspective-taking demands

Note: Voxel-height and cluster-extent thresholds of $p < 0.001$ and $k = 46$.

Intercept. The intercept revealed frontal activity within bilateral middle frontal gyrus, right superior frontal gyrus, bilateral precentral gyrus, and right supplementary motor area;

limbic activity within the right anterior insula, right inferior frontal gyrus, dorsal anterior cingulate cortex, and middle cingulate cortex; striatal activity within the right caudate; parietal activity within bilateral posterior cingulate cortex, bilateral precuneus, right supramarginal gyrus, and bilateral angular gyrus; temporal activity within bilateral inferior temporal gyrus, right fusiform gyrus, bilateral middle temporal gyrus, right Heschl's gyrus; occipital activity within bilateral lingual gyrus, bilateral calcarine gyrus, bilateral cuneus, bilateral inferior occipital gyrus, left middle occipital; as well as bilateral cerebellar activity.

Main Effect of Emotion. The main effect of emotion revealed activity within the left superior temporal gyrus, left superior parietal lobe/inferior parietal lobe, and bilateral occipital regions. The ASD group recruited greater activity during embarrassment clips within the left superior parietal lobe extending into inferior parietal lobe, right inferior parietal lobe/superior temporal gyrus, right cuneus, right lingual gyrus, left middle occipital gyrus, left middle occipital gyrus extending into inferior occipital gyrus and middle temporal gyrus, and left middle occipital gyrus extending into superior occipital gyrus. The ASD group recruited greater activity during pride clips within the left superior temporal gyrus.

Main Effect of Perspective-Taking Demands. The main effect of PT demands revealed activity within the right dorsal medial prefrontal cortex, left middle frontal gyrus, left inferior parietal lobe/angular gyrus, bilateral middle temporal gyrus, and bilateral occipital regions. For all regions, the ASD group recruited relatively greater activity during clips with high PT demands, including in the dorsal medial prefrontal cortex, left middle frontal gyrus, left inferior parietal lobe/angular gyrus, right middle temporal gyrus extending into middle and inferior occipital gyri, right lingual gyrus, left calcarine gyrus, left calcarine gyrus extending into middle occipital gyrus and superior occipital gyrus, left inferior occipital gyrus, left middle occipital gyrus, and left cerebellum.

Interaction Effect between Emotion and Perspective-Taking Demands. There was no significant interaction effect between emotion and PT demands.

Whole Brain Analyses for All Participants

Results from the 2 x 2 x 2 repeated measures ANOVA revealed a main effect of emotion and a main effect of PT demands, as well as two-way and three-way interaction effects. (See Figures 7 and 8 and Tables 8 and 9.)

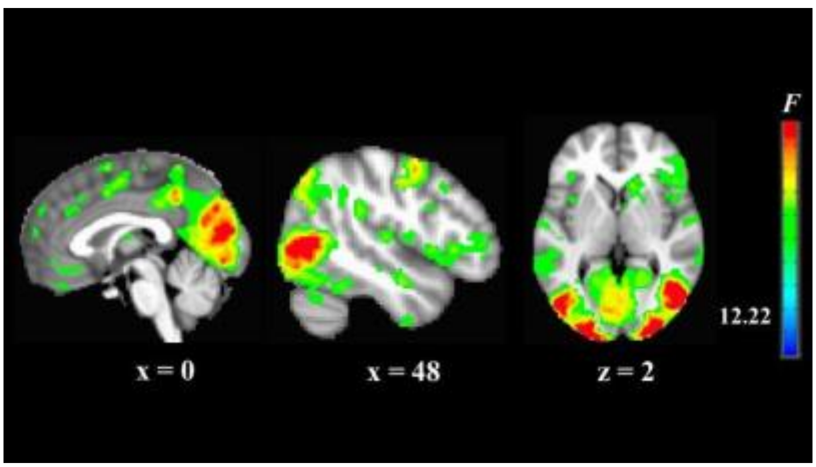

Figure 7. Intercept during self-conscious emotion processing

Note: Voxel-height and cluster-extent thresholds of $p < 0.001$ and $k = 30$.

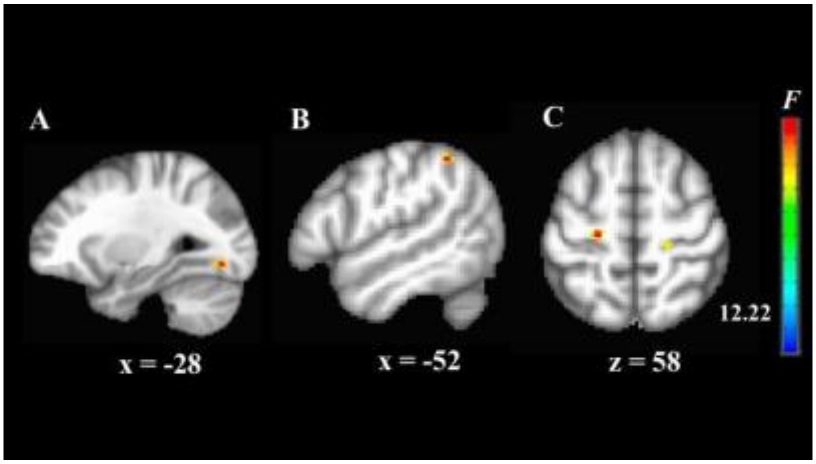

Figure 8. Interaction effects between group, emotion, and PT demands during self-conscious emotion processing

Panel A) Group x PT interaction effect within the left fusiform gyrus (not shown: left cerebellum, right lingual gyrus, and right inferior occipital gyrus). **Panel B)** Group x Emotion interaction effect within the left inferior parietal lobe. **Panel C)** Group x Emotion x PT interaction effect within the left and right precentral gyrus (not shown: left middle cingulate cortex/paracentral lobe, left cerebellum). PT = Perspective-taking demands.

Note: Voxel-height and cluster-extent thresholds of $p < 0.001$ and $k = 30$.

Table 8. Intercept during Self-Conscious Emotion Processing

Hemisphere	Region	k	x	y	z	F
Bilateral	Lingual gyrus (ext. bilateral cuneus, calcarine gyrus, precuneus; left middle occipital gyrus, angular gyrus, posterior cingulate cortex)	12231	-10	-80	-12	100
Right	Middle occipital gyrus (ext. inferior occipital gyrus, inferior temporal gyrus, middle temporal gyrus, fusiform gyrus, cerebellum)	4601	44	-76	-4	100
Left	Inferior occipital gyrus (ext. middle occipital gyrus, fusiform gyrus, cerebellum)	3922	-30	-90	-12	100
Left	Middle temporal gyrus (ext. superior temporal gyrus/Heschl's gyrus, inferior parietal lobe, precentral gyrus, postcentral gyrus, inferior parietal lobe, supramarginal gyrus)	3443	-60	-46	-10	100
Right	Transverse temporal gyrus/Heschl's gyrus (ext. inferior temporal gyrus and superior temporal gyrus)	1603	54	-18	10	62.63
Right	Angular gyrus	1519	40	-70	44	60.18
Left	Precentral gyrus (BA 6; ext. supplementary motor area and middle cingulate cortex)	1037	-18	-12	68	49.70
Right	**Inferior frontal gyrus (BA 47/45/13 ext. anterior insula)**	**869**	**48**	**24**	**0**	**33.02**
Left	Middle frontal gyrus (BA 6; ext. precentral gyrus)	488	-40	10	48	41.91
Right	Superior temporal gyrus/supramarginal gyrus (BA 40)	466	60	-32	20	78.87
Right	Precentral gyrus (BA 6; ext. middle frontal gyrus)	425	54	0	48	100
Right	Supplementary motor area (BA 6)	368	6	10	66	92.97
Left	Precentral gyrus (BA 6)	316	-50	-2	54	92.96
Left	Postcentral gyrus (BA 5; ext. superior parietal lobe, precuneus)	299	-20	-42	66	45.65
Right	Inferior temporal gyrus (BA 20; ext. fusiform gyrus)	272	42	-4	-46	50.76
Right	**Medial prefrontal cortex (BA 9/10; ext. dorsal medial prefrontal cortex)**	**262**	**4**	**58**	**14**	**28.93**
Right	Superior frontal gyrus (BA 8; ext. middle frontal gyrus)	252	28	24	50	26.79
Left	**Dorsal anterior cingulate cortex (BA 32; ext. dorsal medial prefrontal cortex)**	**226**	**-8**	**28**	**30**	**49.75**
Left	Cerebellum	191	-30	-62	-54	60.48
Right	Caudate	182	12	22	4	43.32
Right	Inferior parietal lobe (BA 7/40; ext. superior parietal lobe)	172	30	-48	54	36.09
Left	**Orbitofrontal cortex/ventral medial prefrontal cortex (BA 11/25)**	**135**	**-4**	**30**	**-14**	**28.24**
Left	Postcentral gyrus (BA 4; ext. precentral gyrus)	114	-58	-2	20	40.10
Left	Supramarginal gyrus/superior temporal gyrus (BA	112	-46	-38	24	41.96

	13)					
Right	Superior frontal gyrus (BA 6)	97	20	-16	64	32.18
Right	Supplementary motor cortex (BA 6)	93	8	-20	62	30.19
Right	Postcentral gyrus (BA 6; ext. precentral gyrus)	91	62	2	20	35.63
Right	Postcentral gyrus (BA 4)	89	58	-12	36	26/92
Left	**Inferior frontal gyrus (BA 47)**	**77**	**-34**	**20**	**-16**	**31.64**
Left	**Anterior insula (BA 13/47)**	**73**	**-42**	**12**	**-6**	**34.95**
Left	Cerebellum	67	-12	-92	-36	26.12
Right	Middle frontal gyrus (BA 9)	57	40	18	36	24.82
Left	**Inferior frontal gyrus (BA 11/47)**	**51**	**-36**	**34**	**-14**	**36.77**
Right	Thalamus	48	4	-10	12	39.27
Left	**Orbitofrontal cortex (rectal gyrus; BA 11)**	**47**	**-2**	**40**	**-26**	**20.05**
Left	Posterior insula (BA 13)	34	-34	-18	6	24.33
Left	**Temporal pole (BA 38)**	**33**	**-44**	**14**	**-20**	**38.06**
Left	**Inferior frontal gyrus (BA 47)**	**32**	**-38**	**28**	**2**	**22.90**
Left	Caudate	32	-16	4	22	27.08
Left	Hippocampus	31	16	-4	-16	34.43
Right	Inferior frontal gyrus (BA 9)	30	44	8	26	18.32

BA = Brodmann Area.

Note: Voxel-height and cluster-extent thresholds of $p < 0.001$ and $k = 30$. Bolded clusters represent *a priori* regions of interest that were selected as ROIs for further analysis.

Table 9. Neural Activity during Self-Conscious Emotion Processing as Modulated by Group, Emotion, and Perspective-Taking Demands

Contrast	Hemisphere	Region	k	x	y	z	F
Main Effect of Group							
	-	-	-	-	-	-	-
Main Effect of Emotion							
	Bilateral	Lingual gyrus (ext. bilateral calcarine gyrus, inferior occipital gyrus, middle occipital gyrus, middle temporal gyrus, fusiform gyrus; right superior occipital gyrus)	7855	18	-86	-8	100
	Right	Inferior parietal lobe/precuneus (BA 7; ext. superior parietal lobe, postcentral gyrus)	765	26	-54	52	35.85
	Left	Superior temporal gyrus (BA 41)	498	-56	-16	6	50.29
	Right	Superior temporal gyrus (BA 22/42; ext. Heschl's gyrus)	213	58	-14	8	31.7
	Left	Inferior parietal lobe/precuneus (BA 7; ext. superior parietal lobe)	184	-26	-52	52	29.89
	Right	Supramarginal gyrus (BA 40; ext. superior temporal gyrus)	90	58	-40	28	32.84
	Right	Superior frontal gyrus (BA 9/8)	85	24	40	38	24.87
	Right	Cerebellum	41	48	-74	-34	20.48
	Right	Supplementary motor area (BA 6)	36	12	10	66	21.79
	Right	Precentral gyrus (BA 6)	30	32	-2	46	18.79
Main Effect of PT							
	Right	Middle temporal gyrus/middle occipital gyrus (BA 37/19)	1006	52	-70	2	91.56
	Left	Middle temporal gyrus/middle occipital gyrus (BA 19)	341	-46	-74	4	60.5
	Right	Inferior parietal lobe/superior parietal lobe (BA 40)	300	42	-52	42	22.53
	Left	Inferior parietal lobe (BA 40)	211	-36	-50	48	33.95
	Right	Middle frontal gyrus (BA 46)	155	42	32	20	29.03

	Right	Fusiform gyrus (BA 37)	151	42	-52	18	43.25
	Right	Middle frontal gyrus (BA 8)	139	38	32	50	28.00
	Right	Lingual gyrus	130	18	-88	-6	63.41
	Right	Precuneus (BA 7)	122	8	-78	50	24.86
	Right	Cuneus	121	8	-96	8	51.16
	Left	Cuneus	117	-4	-98	6	35.91
	Left	Middle frontal gyrus (BA 9)	84	-40	28	42	27.09
	Right	Middle occipital gyrus	57	28	-90	14	24.34
	Right	Superior parietal lobe (BA 7)	51	20	-68	60	20.57
	Left	Fusiform gyrus	37	-34	-74	-16	23.01
	Left	Lingual gyrus	36	-14	-86	0	22.99
	Right	Lingual gyrus	33	22	-96	-16	17.43
Group x Emotion							
	Left	Inferior parietal lobe (BA 40)	47	-52	-48	50	25.04
Group x PT							
	Left	Cerebellum	94	-22	-82	-32	24.55
	Left	Fusiform gyrus (BA 19)	50	-28	-74	-8	26.61
	Right	Lingual gyrus	48	20	-86	-12	22.16
	Right	Inferior occipital gyrus	34	42	-74	-2	24.28
Emotion x PT							
	Left	Middle occipital gyrus	176	-36	-90	2	26.92
	Left	Cerebellum	83	-26	-82	-38	34.68
	Left	Calcarine gyrus	62	-4	-100	6	30.3
	Right	Middle occipital gyrus	44	29	-86	12	24.21
Group x Emotion x PT							
	Right	Precentral gyrus (BA 4)	80	20	-28	60	21.85
	Left	Middle cingulate cortex/paracentral lobe (BA 5)	39	-4	-36	52	18.76
	Left	Cerebellum	32	-46	-74	-32	21.16
	Left	Precentral gyrus (BA 4)	30	-22	22	58	27.98

BA = Brodmann Area; PT = perspective-taking demands.

Note: Voxel-height and cluster-extent thresholds of $p < 0.001$ and $k = 30$.

Intercept. The intercept revealed frontal activity within the dorsal medial prefrontal cortex, medial prefrontal cortex, ventral medial prefrontal cortex, orbitofrontal cortex/rectal gyrus, bilateral middle frontal gyrus, bilateral superior frontal gyrus, and bilateral precentral gyrus/postcentral gyrus; limbic activity within bilateral inferior frontal gyrus, bilateral anterior insula, left posterior insula, dorsal and subgenual anterior cingulate cortex, middle cingulate cortex, and right thalamus; striatal activity within bilateral caudate; parietal activity within left posterior cingulate cortex, bilateral precuneus, bilateral inferior parietal lobule (including bilateral supramarginal gyrus and left angular gyrus), and bilateral superior parietal lobule; temporal activity within the right amygdala, bilateral fusiform gyrus, left hippocampus, right inferior temporal gyrus, left temporal pole, bilateral middle temporal gyrus, bilateral superior temporal gyrus, and right transverse temporal gyrus (Heschl's gyrus); occipital activity within bilateral lingual gyrus, bilateral calcarine gyrus, bilateral cuneus, bilateral inferior occipital gyrus, and bilateral middle occipital gyrus; as well as left cerebellar activity. (See Table 8 and Figure 7.)

Main Effect of Group. The main effect of group revealed no significant activity.

Main Effect of Emotion. The main effect of emotion revealed activity within the right middle frontal gyrus (precentral gyrus and supplementary motor area), right superior frontal gyrus, bilateral inferior parietal lobe, right supramarginal gyrus, bilateral superior temporal gyrus, bilateral occipital cortex, and right cerebellum. Post-hoc *t*-tests revealed that participants recruited greater activity during embarrassment clips within the right precentral gyrus, right supplementary motor area, left inferior parietal lobe, right inferior parietal lobe, right supramarginal gyrus, and bilateral lingual gyrus. Participants recruited greater activity during pride clips within the left superior frontal gyrus, bilateral superior temporal gyrus, and right cerebellum.

Main Effect of Perspective-Taking Demands. The main effect of PT demands revealed activity within the right middle frontal gyrus, right superior parietal lobe (including precuneus), left inferior parietal lobule, right fusiform gyrus, and bilateral occipital cortices. Post-hoc *t*-tests revealed that participants recruited greater activity during clips with low PT demands within bilateral lingual gyrus . Participants recruited greater activity during clips with high PT demands within the left middle frontal gyrus, right middle frontal gyrus, bilateral inferior parietal lobe, right precuneus, right superior parietal lobe, bilateral middle temporal gyrus, bilateral fusiform gyrus, left lingual gyrus (more posterior than the two clusters that revealed greater activity during clips with low PT demands), left cuneus, right cuneus, and right middle occipital gyrus.

Interaction Effect between Group and Emotion. The interaction effect between group and emotion revealed activity within the left inferior parietal lobe, $F(1,50) = 20.60$, $p < 0.001$. Parameter estimates were entered into a 2 (group) x 2 (emotion) repeated measures ANOVA. The main effect of group was not significant, $F(1,50) = 0.03$, $p = 0.874$; but the main effect of emotion was significant, $F(1,50) = 4.27$, $p = 0.047$, such that participants recruited greater activity during embarrassment clips. Post-hoc *t*-tests exploring the interaction effect revealed that the NT group recruited relatively greater activity during pride compared to embarrassment clips, $t(24) = -4.38$, $p < 0.001$; while the ASD group recruited similar activity during embarrassment and pride clips, $t(26) = 1.88$, $p = 0.071$. The NT and ASD groups recruited similar activity during both embarrassment clips, $t(50) = -1.40$, $p = 0.171$; and pride clips, $t(50) = 1.59$, $p = 0.117$.

Interaction Effect between Group and Perspective-Taking Demands. The interaction between group and PT demands revealed activity within the left fusiform gyrus, bilateral occipital regions, and left cerebellum. Parameter estimates for each cluster were entered into 2 (group) x 2 (PT demands) repeated measures ANOVAs.

Left fusiform gyrus. There was a significant interaction effect between group and PT demands within the left fusiform gyrus, $F(1,50) = 26.27$, $p < 0.001$. There was no main effect of group, $F(1,50) = 2.41$, $p = 0.127$; nor main effect of PT demands, $F(1,50) = 0.06$, $p = 0.809$. Post-hoc *t*-tests revealed that the NT group recruited greater activity during clips with low, relative to high, PT demands, $t(24) = 3.01$, $p = 0.006$; while the ASD group recruited greater activity during clips with high, relative to low, PT demands, $t(26) = -4.45$, $p < 0.001$. The NT and ASD groups recruited similar activity during clips with low PT demands, $t(50) = -0.29$, $p = 0.771$; however, the ASD group recruited greater activity than the NT group during clips with high PT demands, $t(50) = -2.58$, $p = 0.013$.

Left lingual gyrus. There was a significant interaction effect between group and PT demands within the left lingual gyrus, $F(1,50) = 24.58$, $p < 0.001$. While the main effect of group was not significant, $F(1,50) = 0.65$, $p = 0.423$; the main effect of PT demands was significant, $F(1,50) = 5.83$, $p = 0.019$, such that participants recruited greater activity during clips with low PT demands. Post-hoc *t*-tests exploring the interaction effect revealed that the NT group recruited greater activity during clips with low, relative to high, PT demands, $t(24) = 4.82$, $p < 0.001$; while the ASD group recruited similar activity during clips with low and high PT demands, $t(26) = -1.95$, $p = 0.062$. The NT and ASD groups recruited similar activity during clips with low PT demands, $t(50) = 1.84$, $p = 0.073$; as well as high PT demands, $t(50) = -0.25$, $p = 0.803$.

Right inferior occipital gyrus. There was a significant interaction effect between group and PT demands within the right inferior occipital gyrus, $F(1,50) = 28.32$, $p < 0.001$. While the main effect of group was not significant, $F(1,50) = 1.24$, $p = 0.270$; the main effect of PT demands was significant, $F(1,50) = 25.16$, $p < 0.001$, such that participants recruited greater activity during clips with high PT demands. Post-hoc *t*-tests exploring the interaction effect revealed that the NT group recruited similar activity during clips with low and high PT demands, *t*(24) = 0.24, *p* = 0.815; while the ASD group recruited greater activity during clips with high, relative to low, PT demands, *t*(26) = -6.87, *p* < 0.001. The NT and ASD groups recruited similar activity during clips with low PT demands, *t*(50) = -0.17, *p* = 0.870; however, the ASD group recruited marginally greater activity than the NT group during clips with high PT demands, *t*(50) = -2.01, *p* = 0.052.

Left cerebellum. There was a significant interaction effect between group and PT demands within the left cerebellum, *F*(1,50) = 26.91, *p* < 0.001. There was no main effect of group, *F*(1,50) = 0.44 , *p* = 0.512; nor main effect of PT demands, *F*(1,50) = 2.34, *p* = 0.141. Post-hoc *t*-tests exploring the interaction effect revealed that the NT group recruited greater activity during clips with low, relative to high, PT demands, *t*(24) = 2.36, *p* = 0.027; while the ASD group recruited greater activity during clips with high, relative to low, PT demands, *t*(26) = -5.26, *p* < 0.001. The NT and ASD groups recruited similar activity during clips with low PT demands, *t*(50) = 0.76, *p* = 0.448; while the ASD group recruited marginally greater activity than the NT group during clips with high PT demands, *t*(50) = -5.26, *p* = 0.057.

Interaction Effect between Emotion and Perspective-Taking Demands. There were significant interaction effects between emotion and PT demands within bilateral occipital regions and the left cerebellum. Parameter estimates from each cluster were entered into 2 (emotion) x 2 (PT demands) repeated measures ANOVAs.

Left calcarine gyrus. There was a significant interaction effect between emotion and PT demands within the left calcarine gyrus, *F*(1,51) = 32.80, *p* < 0.001. There was a main effect of emotion, *F*(1,51) = 29.22, *p* < 0.001, such that participants recruited greater activity during embarrassment clips; and a main effect of PT demands, *F*(1,51) = 20.60, *p* < 0.001, such that participants recruited greater activity during clips with high PT demands. Post-hoc *t*-tests exploring the interaction effect revealed that participants recruited greater activity during embarrassment clips with high, relative to low, PT demands, $t(51) = -6.33$, $p < 0.001$; but recruited similar activity during pride clips with low and high PT demands, $t(51) = 1.74$, $p = 0.088$. When PT demands were low, participants recruited similar activity for embarrassment and pride clips, $t(51) = 1.68$, $p = 0.098$; however, when PT demands were high, participants recruited greater activity during embarrassment, relative to pride, clips, $t(51) = 6.57$, $p < 0.001$.

Left middle occipital gyrus. There was a significant interaction effect between emotion and PT demands within the left middle occipital gyrus, $F(1,51) = 25.60$, $p < 0.001$. The main effect of emotion was significant, $F(1,51) = 60.07$, $p < 0.001$, such that participants recruited greater activity during embarrassment clips. The main effect of PT demands was not significant, $F(1,51) = 2.19$, $p = 0.145$. Post-hoc *t*-tests exploring the interaction effect revealed that participants recruited greater activity during embarrassment clips with high, relative to low, PT demands, $t(51) = -4.35$, $p < 0.001$; and recruited greater activity during pride clips with low, relative to high, PT demands, $t(51) = 2.37$, $p = 0.022$. Participants recruited greater activity during embarrassment, relative to pride, clips when PT demands were low, $t(51) = 2.51$, $p = 0.015$; and high, $t(51) = 8.56$, $p < 0.001$.

Right middle occipital gyrus. There was a significant interaction effect between emotion and PT demands within the right middle occipital gyrus, $F(1,51) = 23.06$, $p < 0.001$. There was a main effect of emotion, $F(1,51) = 55.51$, $p < 0.001$, such that participants recruited greater activity during embarrassment clips; as well as a main effect of PT demands, $F(1,51) = 9.16$, $p = 0.004$, such that participants recruited greater activity during clips with high PT demands. Post-hoc *t*-tests exploring the interaction effect revealed that participants recruited greater activity during embarrassment clips with high, relative to low, PT demands, $t(51) = -4.97$, $p < 0.001$; but participants recruited similar activity during pride clips with low and high PT demands, $t(51) = 1.21$, $p = 0.231$. Participants recruited greater activity during embarrassment, relative to pride, clips when PT demands were low, $t(51) = 2.84$, $p = 0.006$; and high, $t(51) = 9.68$, $p < 0.001$.

Left cerebellum. There was a significant interaction effect between emotion and PT demands within the left cerebellum, $F(1,51) = 28.64$, $p < 0.001$. There was no main effect of emotion, $F(1,51) = 1.48$, $p = 0.229$; nor main effect of PT demands, $F(1,51) = 0.07$, $p = 0.790$. Post-hoc *t*-tests exploring the interaction effect revealed that participants recruited greater activity during embarrassment clips when PT demand were low, relative to high, $t(51) = 3.56$, $p = 0.001$; but participants recruited greater activity during pride clips when PT demands were high, relative to low, $t(51) = -3.55$, $p = 0.001$. When PT demands were low, participants recruited greater activity during embarrassment, relative to pride, clips, $t(51) = 2.81$, $p = 0.007$; but when PT demands were high, participants recruited greater activity for pride, relative to embarrassment, clips, $t(51) = -5.31$, $p < 0.001$.

Interaction Effect between Group, Emotion, and Perspective-Taking Demands. There were significant interaction effects between group, emotion, and PT demands within bilateral precentral gyrus, left paracentral lobe/middle cingulate cortex, and left cerebellum. Parameter estimates for each cluster were entered into 2 (group) x 2 (emotion) x 2 (PT demands) repeated measures ANOVAs.

Left precentral gyrus. There was a significant three-way interaction effect within the left precentral gyrus, $F(1,50) = 29.70$, $p < 0.001$. There was no main effect of group, $F(1,50) = 0.02$, $p = 0.881$; no main effect of emotion, $F(1,50) = 0.81$, $p = 0.374$; nor main effect of PT demands, $F(1,50) = 0.10$, $p = 0.748$. There was no interaction effect between group and emotion, $F(1,50) = 0.17$, $p = 0.680$; nor between group and PT demands, $F(1,50) = 1.53$, $p = 0.222$. There was a significant interaction effect between emotion and PT demands, $F(1,50) = 4.66$, $p = 0.036$; however, post-hoc *t*-tests revealed that participants recruited similar activity during embarrassment clips with low and high PT demands, $t(51) = -0.97$, $p = 0.337$; and during pride clips with low and high PT demands, $t(51) = 1.24$, $p = 0.219$. Participants recruited similar activity during embarrassment and pride clips when PT demands were low, $t(51) = -1.71$, $p = 0.093$; as well as when PT demands were high, $t(51) = 0.327$, $p = 0.745$.

Post-hoc *t*-tests exploring the three-way interaction effect revealed that the NT group recruited similar activity during embarrassment clips with low and high PT demands, $t(24) = -0.01$, $p = 0.991$; and during pride clips with low and high PT demands, $t(24) = -1.38$, $p = 0.181$. When PT demands were low, the NT group recruited greater activity during pride, relative to embarrassment, clips, $t(24) = -4.18$, $p < 0.001$; however, when PT demands were high, the NT group recruited similar activity during embarrassment and pride clips, $t(24) = 1.85$, $p = 0.077$. The ASD group recruited similar activity during embarrassment clips with low and high PT demands, $t(26) = -0.94$, $p = 0.357$; and during pride clips with low and high PT demands, $t(26) = 0.15$, $p = 0.882$. When PT demands were low, the ASD group recruited similar activity during embarrassment and pride clips, $t(26) = 1.01$, $p = 0.322$; as well as when PT demands were high, $t(26) = -1.84$, $p = 0.077$. Comparisons across groups revealed that the NT and ASD groups recruited similar activity during embarrassment clips with low PT demands, $t(50) = -0.91$, $p = 0.369$; and during embarrassment clips with high PT demands, $t(50) = 0.86$, $p = 0.396$. The NT group recruited greater activity than the ASD group during pride clips with low PT demands, $t(50) = 2.21$, $p = 0.032$; however, the NT and ASD groups recruited similar activity during pride clips with high PT demands, $t(50) = -1.44$, $p = 0.156$.

Right precentral gyrus. There was a significant three-way interaction effect within the right precentral gyrus, $F(1,50) = 26.25$, $p < 0.001$. There was no main effect of group, $F(1,50) = 1.00$, $p = 0.321$; no main effect of emotion, $F(1,50) = 0.06$, $p = 0.807$; nor main effect of PT demands, $F(1,50) = 0.49$, $p = 0.486$. There was no interaction effect between group and emotion, $F(1,50) = 0.07$, $p = 0.789$; between group and PT demands, $F(1,50) = 0.49$, $p = 0.486$; nor between emotion and PT demands, $F(1,50) = 1.88$, $p = 0.176$.

Post-hoc *t*-tests exploring the three-way interaction effect revealed that the NT group recruited greater activity during embarrassment clips with high, relative to low, PT demands, $t(24) = -3.04$, $p = 0.006$; but greater activity during pride clips with low, relative to high, PT demands, $t(24) = 2.79$, $p = 0.010$. When PT demands were low, the NT group recruited greater activity during pride, relative to embarrassment, clips, $t(24) = -2.84$, $p = 0.009$; however, when PT demands were high, the NT group recruited greater activity during embarrassment, relative to pride, clips, $t(24) = 2.54$, $p = 0.018$. In comparison, participants in the ASD group recruited similar activity during embarrassment clips with low and high PT demands, $t(26) = 1.10$, $p = 0.280$; but greater activity during pride clips with high, relative to low, PT demands, $t(26) = -2.80$, $p = 0.009$. When PT demands were low, the ASD group recruited similar activity during embarrassment and pride clips, $t(26) = 1.59$, $p = 0.123$; however, when PT demands were high, the ASD group recruited greater activity during pride, relative to embarrassment, clips, $t(26) = -2.09$, $p = 0.047$. Comparisons across groups revealed that the NT and ASD groups recruited similar activity during embarrassment clips with low PT demands, $t(50) = -0.38$, $p = 0.707$; but the NT group recruited greater activity than the ASD group during embarrassment clips with high PT demands, $t(50) = 2.23$, $p = 0.030$. The NT group recruited greater activity than the ASD group during pride clips with low PT demands, $t(50) = 2.53$, $p = 0.015$; but the NT and ASD groups recruited similar activity during pride clips with high PT demands, *t*(50) = -1.04, *p* = 0.303.

Left paracentral lobule/middle cingulate cortex. There was a significant three-way interaction effect within the left paracentral lobule/middle cingulate cortex; $F(1,50) = 21.54$, $p < 0.001$. There was no main effect of group, $F(1,50) = 0.40$, $p = 0.528$; no main effect of emotion, $F(1,50) = 0.96$, $p = 0.331$; nor main effect of PT demands, $F(1,50) = 1.70$, $p = 0.198$. There was no interaction effect between group and emotion, $F(1,50) = 0.09$, $p = 0.770$; between group and PT demands, $F(1,50) = 0.05$, $p = 0.830$; nor between emotion and PT demands, $F(1,50) = 0.25$, $p = 0.623$.

Post-hoc *t*-tests exploring the three-way interaction effect revealed that the NT group recruited greater activity during embarrassment clips with high, relative to low, PT demands, $t(24) = -3.12$, $p = 0.005$; but similar activity during pride clips with low and high PT demands, $t(24) = 1.78$, $p = 0.088$. When PT demands were low, the NT group recruited greater activity during pride, relative to embarrassment, clips, $t(24) = -3.07$, $p = 0.005$; however, when PT demands were high, the NT group recruited similar activity during embarrassment and pride clips, $t(24) = 1.08$, $p = 0.290$. In comparison, the ASD group recruited similar activity during embarrassment clips with low and high PT demands, $t(50) = 1.89$, $p = 0.070$; but greater activity during pride clips with high, relative to low, PT demands, $t(50) = -3.68$, $p = 0.001$. When PT demands were low, the ASD group recruited greater activity during embarrassment, relative to pride, clips, $t(26) = 2.50$, $p = 0.019$; however, when PT demands were high, the ASD group recruited greater activity during pride, relative to embarrassment, clips, $t(26) = -2.62$, $p = 0.014$. Comparisons across groups revealed that the NT and ASD groups recruited similar activity during embarrassment clips with low PT demands, $t(50) = -1.16$, $p = 0.253$; and during embarrassment clips with high PT demands, $t(50) = 1.88$ $p = 0.066$. The NT group recruited greater activity than the ASD group during pride clips with low PT demands, $t(50) = 2.23$, $p = 0.030$; however, the NT and ASD groups recruited similar activity during pride clips with high PT demands, $t(50) = -0.91$, $p = 0.366$.

Left cerebellum. There was a significant three-way interaction effect within the left cerebellum, $F(1,50) = 22.12$, $p < 0.001$. There was no main effect of group, $F(1,50) = 1.52$, $p = 0.224$; nor main effect of PT demands, $F(1,50) = 0.41$, $p = 0.524$; however, there was a main effect of emotion, $F(1,50) = 5.59$, $p = 0.022$, such that participants recruited greater activity during pride clips. There was no interaction effect between group and emotion, $F(1,50) = 3.02$, $p = 0.088$; between group and PT demands, $F(1,50) = 0.88$, $p = 0.353$; nor between emotion and PT demands, $F(1,50) = 0.11$, $p = 0.740$.

Post-hoc *t*-tests exploring the three-way interaction effect revealed that the NT group recruited similar activity during embarrassment clips with low and high PT demands, $t(24) = -1.84$, $p = 0.078$; but greater activity during pride clips with low, relative to high, PT demands, $t(24) = 3.11$, $p = 0.005$. When PT demands were low, the NT group recruited greater activity during pride, relative to embarrassment, clips, $t(24) = -4.12$, $p < 0.001$; however, when PT demands were high, the NT group recruited similar activity during embarrassment and pride clips, $t(24) = 0.05$, $p = 0.961$. In comparison, the ASD group recruited similar activity during embarrassment clips with low and high PT demands, $t(26) = 1.46$, $p = 0.158$; but greater activity during pride clips with high, relative to low, PT demands, $t(26) = -3.12$, $p = 0.004$. When PT demands were low, the ASD group recruited similar activity during embarrassment and pride clips, $t(26) = 1.80$, $p = 0.084$; however, when PT demands were high, the ASD group recruited greater activity during pride, relative to embarrassment, clips, $t(26) = -3.29$, $p = 0.003$.

Comparisons across groups revealed that the ASD group recruited greater activity than the NT group during embarrassment clips with low PT demands, $t(50) = -2.63$, $p = 0.011$; but the NT and ASD groups recruited similar activity during embarrassment clips with high PT demands, $t(50) = -0.42$, $p = 0.679$. The NT and ASD groups recruited similar activity during pride clips with low PT demands, $t(50) = 1.62$, $p = 0.111$; however, the ASD group recruited greater activity than the NT group during pride clips with high PT demands, $t(50) = -2.06$, $p = 0.044$.

Specific Contrasts of Interest. Given the specific aims of this dissertation, group differences for each condition were investigated. (See Table 10 and Figure 9.) There were no significant group differences during embarrassment clips when PT demands were low (EmbLo > Neutral), nor during embarrassment clips when PT demands were high (EmbHi > Neutral). However, there were significant group differences when comparing activity during embarrassment clips with high PT demands relative to low PT demands ((EmbHi > Neutral) vs (EmbLo > Neutral)) within the right postcentral gryus and right anterior insula. There were significant group differences during pride clips when PT demands were low (PrideLo > Neutral) within the right inferior temporal gyrus and right middle occipital gyrus. There were no significant group differences during pride clips when PT demands were high (PrideHi > Neutral). There were significant group differences when comparing activity during pride clips with high PT demands relative to low PT demands ((PrideHi > Neutral) vs (PrideLo > Neutral)) within the dorsal anterior cingulate cortex, left inferior parietal lobe, bilateral cuneus, left lingual gyrus, and bilateral cerebellum.

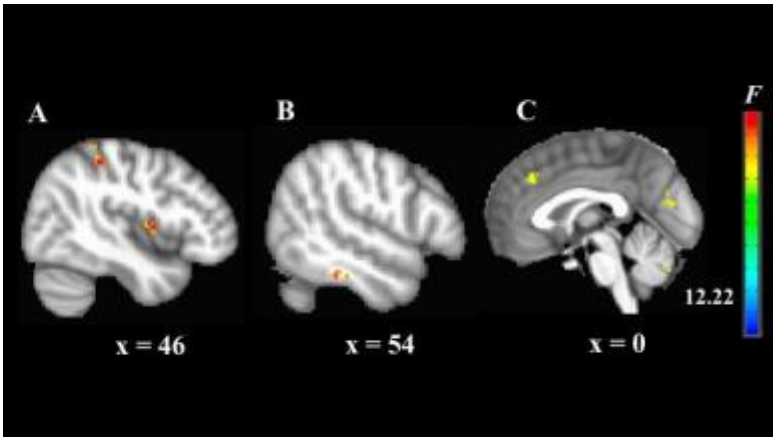

Figure 9. Group comparisons of interest during self-conscious emotion processing

Panel A) NT vs ASD ((EmbHi > Neutral) vs (EmbLo > Neutral)) within the right anterior insula and right postcentral gyrus. **Panel B)** NT vs ASD (PrideLo > Neutral) within the right inferior temporal gyrus (not shown: right middle occipital gyrus). **Panel C)** NT vs ASD ((PrideHi > Neutral) vs (PrideLo > Neutral)) within the dorsal anterior cingulate cortex, left cuneus, and left cerebellum (not shown: left superior parietal lobe, right cuneus/precuneus, right lingual gyrus, and right cerebellum).

ASD = Autism Spectrum Disorder; NT = Neurotypical. ASD = Autism Spectrum Disorder; EmbLo = embarrassment with low PT demands; EmbHi = embarrassment with high PT demands; NT = Neurotypical; PrideLo = pride with low PT demands; PrideHi = pride with high PT demands; PT = perspective-taking demands.

Note: Voxel-height and cluster-extent thresholds of $p < 0.001$ and $k = 30$.

Table 10. Group Comparisons of Interest during Self-Conscious Emotion Processing

Contrast	Hemisphere	Region	k	x	y	z	t/Z
NT vs ASD (EmbLo > Neutral)							
	-	-	-	-	-	-	-
NT vs ASD (EmbHi > Neutral)							
	-	-	-	-	-	-	-
NT vs ASD ((EmbHi > Neutral) vs (EmbLo > Neutral))							
	Right	Postcentral gyrus (BA 2)	47	46	-32	50	22.55
	Right	Anterior insula (BA 13)	30	44	0	6	22.08
NT vs ASD (PrideLo > Neutral)							
	Right	Inferior temporal gyrus (BA 20)	40	54	-34	-22	4.34
	Right	Middle occipital gyrus	37	34	-94	4	4.55
NT vs ASD (PrideHi > Neutral)							
	-	-	-	-	-	-	-
NT vs ASD ((PrideHi > Neut) vs (PrideLo > Neutral))							
	Left	Superior parietal lobe (BA 7)	97	-34	-70	48	19.66
	Right	Cerebellum	86	8	-80	-34	21.22
	Right	Lingual gyrus	73	10	-58	-4	32.35
	Left	Cuneus	72	0	-76	18	17.8
		Dorsal anterior cingulate cortex (BA 9)	47	-2	34	36	20.15
	Left	Cerebellum	43	-46	-72	-32	24.12
	Right	Cuneus (ext. precuneus)	30	20	-74	20	19.06

ASD = Autism Spectrum Disorder; BA = putative Brodmann Area; EmbLo = embarrassment with low PT demands; EmbHi = embarrassment with high PT demands; NT = Neurotypical; PrideLo = pride with low PT demands; PrideHi = pride with high PT demands.

Note: Voxel-height and cluster-extent thresholds of $p < 0.001$ and $k = 30$.

NT vs ASD (EmbHi > Neutral vs EmbLo > Neutral). There were significant group differences during embarrassment clips with high and low PT demands within the right postcentral gyrus and right anterior insula.

Right postcentral gyrus. Post-hoc *t*-tests revealed that the NT group recruited greater activity during embarrassment clips with high, relative to low PT demands, $t(24) = -6.44$, $p < 0.001$; while the ASD group recruited similar activity during embarrassment clips with low and high PT demands, $t(26) = -0.04$, $p = 0.971$. The NT and ASD groups recruited similar activity during embarrassment clips with low PT demands, $t(50) = -1.92$, $p = 0.061$; and during embarrassment clips with high PT demands, $t(50) = 1.06$, $p = 0.294$.

Right anterior insula. Post-hoc *t*-tests revealed that the NT group recruited greater activity during embarrassment clips with high, relative to low, PT demands, $t(24) = -4.80$, $p < 0.001$; while the ASD group recruited greater activity during embarrassment clips with low, relative to high, PT demands, $t(26) = 3.52$, $p = 0.002$. The ASD group recruited greater activity than the NT group during embarrassment clips with low PT demands, $t(50) = -2.38$, $p = 0.021$; while the NT and ASD groups recruited similar activity during embarrassment clips with high PT demands, $t(50) = 1.88$, $p = 0.066$.

NT vs ASD (PrideLo > Neutral). There were significant group differences during pride clips with low PT demands within the right posterior inferior temporal gyrus (anterior to the preoccipital notch) and right middle occipital gyrus. Post-hoc *t*-tests revealed that the NT group recruited greater activity than the ASD group within the right posterior inferior temporal gyrus,

$t(50) = 5.64$, $p < 0.001$, and right middle occipital gyrus, $t(50) = 4.89$, $p < 0.001$, during pride clips with low PT demands.

NT vs ASD (PrideHi > Neutral vs PrideLo > Neutral). There were significant group differences during pride clips with high and low PT demands within the dorsal anterior cingulate cortex, left superior parietal lobe, right lingual gyrus, bilateral cuneus, and bilateral cerebellum.

Dorsal anterior cingulate cortex. Post-hoc *t*-tests revealed that the NT group recruited marginally greater activity during pride clips with low, relative to high, PT demands, $t(24) = 2.03$, $p = 0.054$; while the ASD group recruited greater activity during pride clips with high, relative to low, PT demands, $t(26) = -4.72$, $p < 0.001$. The NT group recruited greater activity than the ASD group during pride clips with low PT demands, $t(50) = 2.04$, $p = 0.046$; while the ASD group recruited greater activity than the NT group during pride clips with high PT demands, $t(50) = -2.06$, $p = 0.045$.

Left superior parietal lobe. Post-hoc *t*-tests revealed that the NT group recruited greater activity during pride clips with low, relative to high, PT demands, $t(24) = 2.76$, $p = 0.011$; while the ASD group recruited greater activity during pride clips with high, relative to low, PT demands, $t(26) = -3.86$, $p = 0.001$. The NT and ASD groups recruited similar activity during pride clips with low PT demands, $t(50) = 1.89$, $p = 0.064$; while the ASD group recruited marginally greater activity than the NT group during pride clips with high PT demands, $t(50) = -1.93$, $p = 0.060$.

Right lingual gyrus. Post-hoc *t*-tests revealed that the NT group recruited greater activity during pride clips with low, relative to high, PT demands, $t(24) = 5.00$, $p < 0.001$; while the ASD group recruited greater activity during pride clips with high, relative to low, PT demands, $t(26) = -4.15$, $p < 0.001$. The NT and ASD groups recruited similar activity during pride clips with low

PT demands, $t(50) = 0.60$, $p = 0.553$; however, the ASD group recruited greater activity than the NT group during pride clips with high PT demands, $t(50) = -2.70$, $p = 0.009$.

Left cuneus. Post-hoc *t*-tests revealed that the NT group recruited greater activity during pride clips with low, relative to high, PT demands, $t(24) = 3.27$, $p = 0.003$; while the ASD group recruited greater activity during pride clips with high, relative to low, PT demands, $t(26) = -3.61$, $p = 0.001$. The NT and ASD groups recruited similar activity during pride clips with low PT demands, $t(50) = 0.10$, $p = 0.922$; however, the ASD group recruited greater activity than the NT group during pride clips with high PT demands, $t(50) = -2.82$, $p = 0.007$.

Right cuneus (extending into precuneus). Post-hoc *t*-tests revealed that the NT group recruited greater activity during pride clips with low, relative to high, PT demands, $t(24) = 3.17$, $p = 0.004$; while the ASD group recruited greater activity during pride clips with high, relative to low, PT demands, $t(26) = -4.12$, $p < 0.001$. The NT and ASD groups recruited similar activity during pride clips with low PT demands, $t(50) = 0.86$, $p = 0.396$; however, the ASD group recruited greater activity than the NT group during pride clips with high PT demands, $t(50) = -2.71$, $p = 0.009$.

Left cerebellum. Post-hoc *t*-tests revealed that the NT group recruited greater activity during pride clips with low, relative to high, PT demands, $t(24) = 2.77$, $p = 0.011$; while the ASD group recruited greater activity during pride clips with high, relative to low, PT demands, $t(26) = -4.35$, $p < 0.001$. The NT group recruited greater activity than the ASD group during pride clips with low PT demands, $t(50) = 2.07$, $p = 0.044$; while the ASD group recruited greater activity than the NT group during pride clips with high PT demands, $t(50) = -2.43$, $p = 0.019$.

Right cerebellum. Post-hoc *t*-tests revealed that the NT group recruited greater activity during pride clips with low, relative to high, PT demands, $t(24) = 3.19$, $p = 0.004$; while the ASD group recruited greater activity during pride clips with high, relative to low, PT demands, $t(26) = -4.76$, $p < 0.001$. The NT and ASD groups recruited similar activity during pride clips with low PT demands, $t(50) = 1.79$, $p = 0.079$; however, the ASD group recruited greater activity than the NT group during pride clips with high PT demands, $t(50) = -2.81$, $p = 0.007$.

Regions of Interest Analyses

The intercept represented activity recruited during SCE processing, collapsed across group, emotion, and PT demands. Thus, these neural patterns represent clusters that were engaged during SCE processing relative to neutral stimuli, controlling for low-level visual, auditory, and semantic processes. Ten clusters from the intercept, which represented *a priori* regions of interest (ROIs), were selected for further analysis. These ROIs represented activity within the medial prefrontal cortex (BA 9/10) extending into the dorsal medial prefrontal cortex; dorsal anterior cingulate cortex (BA 32) extending into the dorsal medial prefrontal cortex; orbitofrontal cortex/ventral medial prefrontal cortex (BA 11); orbitofrontal cortex (BA 11); left inferior frontal gyrus (BA 47); left inferior frontal gyrus (BA 11); right inferior frontal gyrus (BA 45/47/13, extending into the right anterior insula); left anterior insula (BA 13/47); and left temporal pole (BA 38). Parameter estimates for each cluster were entered into 2 (group) x 2 (emotion) x 2 (PT demands) repeated measures ANOVAs. Significant main effects and interaction effects were reported, as well as significant *t*-tests exploring group differences for specific conditions (i.e., EmbLo, EmbHi, PrideLo, PrideHi). When necessary, analyses were corrected for unequal variances. (See bolded clusters in Table 8 and Figure 10.)

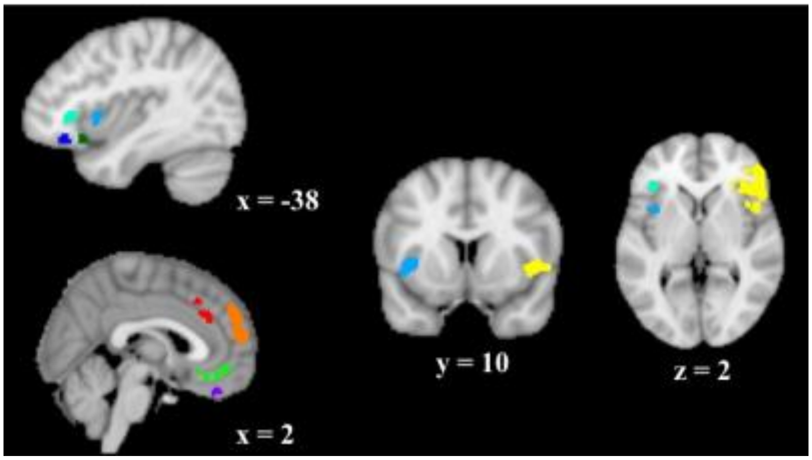

Figure 10. Intercept ROIs during self-conscious emotion processing

Note: Voxel-height and cluster-extent thresholds of $p < 0.001$ and $k = 30$.

Medial Prefrontal Cortex (BA 9/10; MNI coordinates: 4, 58, 14). There were no main effects nor interaction effects within a cluster peaking in anterior rostral aspects of the medial prefrontal cortex and extending into the dorsal medial prefrontal cortex. However, the NT group recruited significantly greater activity than the ASD group during embarrassment clips with low PT demands, $t(50) = 2.23$, $p = 0.030$.

Dorsal Anterior Cingulate Cortex (BA 32; MNI coordinates: -8, 28, 30). There was a significant interaction effect between group, emotion, and PT demands within a cluster peaking in the dorsal anterior cingulate cortex and extending into the dorsal medial prefrontal cortex, $F(1,50) = 4.78$, $p = 0.033$. Post-hoc *t*-tests revealed that the NT group recruited similar activity during embarrassment clips with low and high PT demands, $t(24) = -1.60$, $p = 0.122$; and during pride clips with low and high PT demands, $t(24) = 0.56$, $p = 0.580$. When PT demands were low, the NT group recruited greater activity during pride, relative to embarrassment, clips, $t(24) = -2.56$, $p = 0.017$. When PT demands were high, the NT group recruited similar activity during embarrassment and pride clips, $t(24) = -0.00$, $p = 0.998$. In comparison, the ASD group recruited similar activity during embarrassment clips with low and high PT demands, $t(26) = -0.07$, $p = 0.944$; but greater activity during pride clips with high, relative to low, PT demands, $t(26) = -3.01$, $p = 0.006$. When PT demands were low, the ASD group recruited similar activity during embarrassment and pride clips, $t(26) = 0.58$, $p = 0.566$; as well as when PT demands were high, $t(26) = -1.76$, $p = 0.091$. Comparisons across groups revealed that the ASD group recruited greater activity than the NT group during embarrassment clips with low PT demands, $t(50) = -2.01$, $p = 0.050$; but the NT and ASD groups recruited similar activity during embarrassment clips with high PT demands, $t(50) = -0.74$, $p = 0.461$. The NT and ASD groups recruited similar activity during pride clips with low PT demands, $t(50) = 0.22$, $p = 0.829$; but the ASD group recruited marginally greater activity than the NT group during pride clips with high PT demands, $t(50) = -1.95$, $p = 0.056$.

Orbitofrontal Cortex/Ventral Medial Prefrontal Cortex (BA 11/25; MNI coordinates: -4, 30, -14). There was a significant main effect of emotion within a cluster representing the orbitofrontal cortex/ventral medial prefrontal cortex, $F(1,50) = 8.97$, $p = 0.004$, such that participants recruited greater activity during pride clips. This main effect of emotion was qualified by a significant interaction effect between emotion and PT demands, $F(1,50) = 8.97$, $p = 0.004$. Post-hoc *t*-tests exploring the interaction revealed that participants recruited similar activity during embarrassment clips with low and high PT demands, $t(51) = -1.65$, $p = 0.105$; but greater activity during pride clips with low, relative to high, PT demands, $t(51) = 2.67$, $p = 0.010$. When PT demands were low, participants recruited greater activity during pride, relative to embarrassment, clips, $t(51) = -3.86$, $p < 0.001$; but when PT demands were high, participants recruited similar activity during embarrassment and pride clips, $t(51) = 0.56$, $p = 0.576$.

Orbitofrontal Cortex (Rectal Gyrus; BA 11; MNI coordinates: -2, 40, -26). There were no main effects nor interaction effects within a second cluster representing the orbitofrontal cortex (rectal gyrus).

Left Inferior Frontal Gyrus (BA 11/47; MNI coordinates: -36, 34, -14). There was a significant main effect of emotion within a cluster representing the left inferior frontal gyrus, $F(1, 50) = 5.71$, $p = 0.021$, such that participants recruited greater activity during pride clips.

Left Inferior Frontal Gyrus (BA 47; MNI coordinates: -34, 20, -16). There was a marginally significant main effect of PT demands within a second cluster representing the left inferior frontal gyrus, $F(1,50) = 3.72$, $p = 0.059$, such that participants recruited marginally greater activity when PT demands were high.

Left Inferior Frontal Gyrus (BA 47; MNI coordinates: -38, 28, 2). There were no main effects nor interaction effects within a third cluster representing the left inferior frontal gyrus.

Right Inferior Frontal Gyrus (BA 45/47/13; MNI coordinates: 48, 24, 0). There was a significant interaction effect between group, emotion, and PT demands within a cluster representing the right inferior frontal gyrus extending into the right anterior insula, $F(1,50) = 4.09$, $p = 0.048$. Post-hoc *t*-tests revealed that the NT group recruited similar activity during embarrassment clips with low and high PT demands, $t(24) = -0.41$, $p = 0.687$; and during pride clips with low and high PT demands, $t(24) = 0.52$, $p = 0.607$. When PT demands were low, the NT group recruited similar activity during embarrassment and pride clips, $t(24) = -0.08$, $p = 0.934$; as well as when PT demands were high, $t(24) = 0.84$, $p = 0.410$. In comparison, the ASD group recruited similar activity during embarrassment clips with low and high PT demands, $t(26) = 1.17$, $p = 0.251$; but marginally greater activity during pride clips with high, relative to low, PT demands, $t(26) = -2.01$, $p = 0.055$. When PT demands were low, the ASD group recruited similar activity during embarrassment and pride clips, *t*(26) = 1.92 *p* = 0.065; as well as when PT demands were high, *t*(26) = -1.13, *p* = 0.271. Comparisons across groups revealed that the NT and ASD groups recruited similar activity during embarrassment clips with low PT demands, *t*(50) = -0.86, *p* = 0.394; and with high PT demands, *t*(50) = 0.28, *p* = 0.780. The NT and ASD groups also recruited similar activity during pride clips with low PT demands, *t*(50) = 0.80, *p* = 0.430; and with high PT demands, *t*(50) = -1.01, *p* = 0.320.

Left Anterior Insula (BA 13/47; MNI coordinates: -42, 12, -6). There was a significant interaction effect between group, emotion, and PT demands within a cluster representing the left anterior insula, *F*(1,50) = 4.25, *p* = 0.044. Post-hoc *t*-tests revealed that the NT group recruited similar activity during embarrassment clips with low and high PT demands, *t*(24) = -0.26, *p* = 0.796; as well as during pride clips with low and high PT demands, *t*(24) = 1.92, *p* = 0.066. The NT group recruited similar activity during embarrassment and pride clips when PT demands were low, *t*(24) = -1.16, *p* = 0.257; as well as when PT demands were high, *t*(24) = 1.14, *p* = 0.267. The ASD group recruited similar activity during embarrassment clips with low and high PT demands, *t*(26) = 1.59, *p* = 0.124; and during pride clips with low and high PT demands, *t*(26) = -0.36, *p* = 0.723. The ASD group recruited similar activity for embarrassment and pride clips when PT demands were low, *t*(26) = 0.94, *p* = 0.358; as well as when PT demands were high, *t*(26) = -1.04, *p* = 0.308. Comparisons across groups revealed that the NT and ASD groups recruited similar activity during embarrassment clips with low PT demands, *t*(50) = -1.33, *p* = 0.188; and with high PT demands, *t*(50) = 0.21, *p* = 0.834. The NT and ASD groups also recruited similar activity during pride clips with low PT demands, *t*(50) = 0.13, *p* = 0.896; and with high PT demands, *t*(50) = -1.60, *p* = 0.117.

Left Temporal Pole (BA 38; MNI coordinates: -44, 14, -20). There was a marginally significant interaction effect between group and PT demands within a cluster representing the left temporal pole, $F(1,50) = 3.72$, $p = 0.059$. Post-hoc *t*-tests revealed that the NT group recruited similar activity during clips with low and high PT demands, $t(24) = 1.57$, $p = 0.129$. The ASD group also recruited similar activity during clips with low and high PT demands, *t*(246 = -1.11, $p = 0.279$. The NT and ASD groups recruited similar activity during clips with low PT demands, $t(50) = -0.63$, $p = 0.533$; however, the ASD group recruited greater activity than the NT group during clips with high PT demands, $t(50) = -2.40$, $p = 0.020$. Furthermore, the ASD group recruited significantly greater activity than NT group during pride clips with high PT demands, $t(50) = -2.67$, $p = 0.010$.

CHAPTER VII

STUDY II DISCUSSION: THE NEURAL CORRELATES OF SCES

The goal of the second study was to investigate neural activation patterns during SCE processing recruited by adolescent males with high functioning ASD compared to neurotypical adolescent males matched on age and level of intellectual functioning. This study aimed to explore similarities and differences between groups during embarrassment and pride processing, as well as the potential modulatory role of heightened PT demands on these neural patterns. Broadly, adolescents with ASD recruited similar neural patterns as neurotypical adolescents, including activity within lateral prefrontal, limbic, medial and lateral parietal, lateral temporal, occipital, and cerebellar regions. However, results revealed several noteworthy group differences within social cognition regions (cortical midline structures and extensions within the cerebellum), visual processing regions (fusiform gyrus, inferior temporal gyrus, and occipital cortex), salience regions (anterior insula and dorsal anterior cingulate cortex), and somatosensory regions (precentral gyrus, postcentral gyrus, and paracentral lobe/middle cingulate cortex), which were differentially modulated by PT demands/changes in the situational context. These findings may shed light onto how adolescents with ASD and neurotypical adolescents differentially process SCEs within the real world.

Neural Activity Associated with Self-Conscious Emotion Processing

The current study explored neural activity associated with SCE processing using the SCET-C, a novel, more ecologically-valid, emotion recognition task. The intercept represented activity broadly recruited during SCE processing, averaged across both emotion types and levels of PT demands, and collapsed across groups. The intercept is relevant to the current study because it represents an interaction between SCEs (embarrassment and pride) and neutral emotion. Thus, it broadly reflects activity associated with SCE processing (such as activity subserving affective inference, mental state attribution, social conceptual knowledge processing, and empathy), controlling for low-level visual, auditory, and semantic surface-level features. Adolescents broadly recruited activity within medial prefrontal; middle and superior prefrontal; somatosensory; limbic; striatal; medial, inferior, and superior parietal; medial, inferior, middle, and superior temporal; occipital; and cerebellar regions. These neural patterns strongly resemble prefrontal, limbic, temporoparietal, occipitotemporal, and cerebellar activity recruited during emotional facial processing, including key regions such as the amygdala, fusiform gyrus, insula, inferior frontal gyrus, superior temporal sulcus, orbitofrontal cortex, and occipital cortex, which are believed to support facial identification; biological motion; and emotional salience, arousal, and valuation (Adolphs, 2002a, 2002b; Fusar-Poli et al., 2009; Trautmann et al., 2009). These neural patterns also resemble activity recruited during emotional prosody perception, including activity within the superior temporal gyrus (Heschl's gyrus/transverse temporal gyrus), as well as the medial prefrontal cortex, premotor cortex, inferior frontal gyrus, and insula (Alba-Ferrara, Hausmann, Mitchell, & Weis, 2011; Mitchell, Elliott, Barry, Cruttenden, & Woodruff, 2003; Witteman, Van Heuven, & Schiller, 2012). Furthermore, research investigating moral cognition and moral emotion processing has reported the engagement of similar neural networks, which include the medial prefrontal cortex, dorsolateral prefrontal cortex, orbitofrontal cortex/ventral medial prefrontal cortex, superior temporal sulcus, temporal poles, and amygdala (Moll et al., 2008; Moll et al., 2005). Taken together, these findings broadly serve as proof of concept that the SCET-C successfully recruited robust activity associated with visual and auditory emotion processing and the evaluation of social norms. Furthermore, it suggests that any observed group differences in neural patterns in this dissertation reflect group differences in SCE processing and the modulatory roles of emotion type and PT demands on neural recruitment.

When exploring group-specific neural patterns, adolescents with ASD and neurotypical adolescents recruited activity from strikingly similar regions. Neurotypical adolescents recruited activity within medial prefrontal; middle and superior prefrontal; somatosensory; limbic; medial and inferior parietal; inferior, middle, and superior temporal; occipital; and cerebellar regions. Adolescents with ASD recruited activity within middle and superior prefrontal; somatosensory; limbic; striatal; medial and inferior parietal; inferior and middle temporal; occipital; and cerebellar regions. These results suggest that SCE processing in ASD and neurotypical development are broadly supported by similar brain regions, although groups may demonstrate quantitative differences that are modulated by emotion type and PT demands.

Group Differences in Neural Activity Associated with Self-Conscious Emotion Processing

Results from this dissertation failed to reveal a main effect of group, suggesting that adolescents with ASD do not broadly overactivate or underactivate specific brain regions during SCE processing. However, interaction effects with group highlight the modulatory roles of emotion type and PT demands on differential neural patterns between groups. SCE research has predominantly investigated embarrassment processing associated with low PT demands (such as when targets act embarrassed in embarrassing situations); this suggests that the generalizability of past findings may be limited. The wider scope of this dissertation has the potential to enhance our understanding of SCE processing in ASD. Interestingly, the majority of group differences were observed when PT demands were high (when targets expressed emotions that did not match the situational context, such as when targets acted proud in embarrassing situations). Group differences were observed within regions associated with social cognition (cortical midline structures and cerebellar extensions), visual perception (occipital-temporal structures, including the fusiform gyrus), salience processing (anterior insula and dorsal anterior cingulate cortex), and sensorimotor processing (precentral gyrus, postcentral gyrus, and paracentral lobule). Thus, findings from this dissertation may offer a more nuanced understanding of SCE processing in ASD, and may shed light onto differential s strategies adopted by youths on the spectrum.

Social Cognition Regions. The social cognition network represents a set of cortical midline structures (particularly the medial prefrontal cortex, temporal poles, superior temporal sulcus, and temporoparietal junction), which aid in understanding others, including the ability to infer mental states, emotional states, and intentions (Blakemore, 2008; Castelli, Happé, Frith, & Frith, 2000; Frith & Frith, 2003; Gallagher et al., 2000; Saxe & Kanwisher, 2003). ASD is often associated with atypical recruitment of the social cognition network, which researchers have interpreted as representing poor Theory of Mind and PT abilities (Castelli et al., 2002; Frith, 2001; White, Frith, Rellecke, Al-Noor, & Gilbert, 2014). In this dissertation, adolescents with ASD and neurotypical adolescents demonstrated differential neural recruitment of the social cognition network during SCE processing, which was driven by changes in PT demands/the situational context. Converging with previous findings, adolescents with ASD demonstrated hypoactivation when PT demands were low (i.e., when targets conveyed emotions that matched the situational context), particularly during embarrassment processing. In addition, adolescents with ASD demonstrated hyperactivation when PT demands were high (i.e., when targets conveyed emotions that did *not* match the situational context), particularly during pride processing. Group differences were observed within the medial prefrontal cortex, the temporal pole, as well as the cerebellum, a proposed extension of the social cognition network.

Medial Prefrontal Cortex. A highly-studied region within the social cognition network is the medial prefrontal cortex, which is believed to directly support mental state attribution and intention inference (Brunet, Sarfati, Hardy-Baylé, & Decety, 2000; Castelli et al., 2000; Gallagher et al., 2000; Van Overwalle, 2011). The medial prefrontal cortex has been associated with feelings of self-consciousness (Somerville et al., 2013); and several studies that have explicitly investigated embarrassment processing (Berthoz et al., 2002; Takahashi et al., 2004) and pride processing (Gilead, Katzir, Eyal, & Liberman, 2016; Roth et al., 2014) reported medial prefrontal activity. This suggests that the medial prefrontal cortex may subserve the ability to adopt others' perspective or to reference others' mental states. Autism neuroimaging research has revealed medial prefrontal hypoactivity during mentalizing (Castelli et al., 2002; Happé et al., 1996; O'Nions et al., 2014; Wang, Lee, Sigman, & Dapretto, 2007) and self-other referential processing (Lombardo & Baron- Cohen, 2010; Pfeifer et al., 2013). For example, adults with ASD recruit attenuated medial prefrontal activity when making mental state attributions for animated shapes (Castelli et al., 2002), as well as when making contextualized emotion inferences for unknown peers (using context cues to infer which emotions targets feel) (Kana, Patriquin, Black, Channell, & Wicker, 2016).

Results from the current study converge with previous findings. Adolescents with ASD recruited reduced medial prefrontal activity during SCE processing, although this pattern was only observed during embarrassment processing when PT demands were low (when targets sang well and acted embarrassed). As summarized above, previous neuroimaging research has predominantly required participants to make mental or emotional state attributions that matched the situational context (similar to the low PT demands condition in this dissertation). Thus, the current findings demonstrate that medial prefrontal hypoactivation may extend to more complex

SCE processing, but may be limited to instances when PT demands are low (when individuals must infer mental or emotional states that match the situational context).

Temporal Pole. Another key region of the social cognition network is the anterior temporal lobe/temporal pole, which has been implicated in abstract social contextual knowledge processing (Moll et al., 2008; Zahn et al., 2007; Zahn et al., 2008). Previous research has highlighted the importance of this region in both moral reasoning and SCE evaluation, when participants must reference abstract social norms/rules to judge the moral permissibility/social appropriateness of specific actions. Neurotypical adults recruit temporal pole activity when evaluating both intentional and unintentional social norm violations (Berthoz et al., 2002). This suggests that the temporal poles are involved in norm-based social evaluations, but may not be critical for mentalizing. Temporal pole activity is also recruited during SCE evaluations, including during embarrassment, guilt, and pride processing (Takahashi et al., 2004; Zahn et al., 2007). These findings lend support for the valence-independent role of the temporal poles in social value judgments. Interestingly, research exploring the neural correlates of irony processing (which requires contextualized mental state inference) has distinguished the role of the temporal poles, which are believed to support the assessment of the social context, from the medial prefrontal cortex, which is believed to support intention attribution (Wakusawa et al., 2007).

In the current study, adolescents with ASD recruited greater temporal pole activity than neurotypical adolescents during SCE processing when PT demands were high, particularly during pride processing (i.e., when targets acted proud but sang poorly). These findings converge with research by Wang and colleagues (2006), who reported that children with ASD recruit greater temporal pole activity than neurotypical children during irony processing. Framed within the context of previous findings, these results suggest that temporal pole hyperactivity may reflect greater engagement of social conceptual knowledge processing, such that when PT demands are high and targets express contextually-inappropriate pride, adolescents with ASD may recruit greater activity from regions implicated in social norm referencing. This interpretation converges with behavioral findings from the first study of this dissertation (as well as previous research) to suggest that individuals with ASD may engage in greater social norm referencing during social cognitive processing, perhaps serving as a compensatory mechanism for reduced reflexive mentalizing or for difficulties integrating mental state and contextual information (Baez et al., 2012; Zalla et al., 2011).

Cerebellum. The cerebellum is a proposed extension of the social cognition network. Although this region is most readily associated with its role in motor coordination, recent research has advocated for its role in higher-order social cognition, including emotion perception, recognition, and regulation (Adamaszek et al., 2017; Adamaszek et al., 2014; Clausi et al., 2017). Using an analogy similar to that of the motor system, Schmahmann (Schmahmann, 1998) proposed that the cerebellum is responsible for coordinating cognitive and affective processes, or "dysmetria of thought". Research investigating patients with cerebellar lesions and cerebellar cognitive affective syndrome have linked cerebellar dysfunction with cognitive and emotional impairments, which includes many symptoms commonly observed in ASD, such as impaired social communication, executive functioning deficits, and language delays (Hoche, Guell, Sherman, Vangel, & Schmahmann, 2016; Schmahmann, 1998; Schmahmann & Sherman, 1998). A large-scale meta-analysis of over 350 social cognition studies offers empirical support for the distinct role of the cerebellum in "higher abstraction mentalizing", but not in mirroring or mentalizing (Van Overwalle, Baetens, Mariën, & Vandekerckhove, 2014). Thus, cerebellar activity, similar to temporal pole activity, may indirectly support social cognition via abstract social conceptual knowledge processing.

The current study revealed group differences in cerebellar recruitment, particularly during pride processing, which were modulated by changes in PT demands. Adolescents with ASD demonstrated cerebellar hypoactivity during pride processing when PT demands were low (when targets expressed emotions that matched the situational context), but cerebellar hyperactivity during pride processing when PT demands were high (when targets expressed emotions that did not match the situational context). This pattern of hypoactivity during low PT demands and hyperactivity during high PT demands mirrors the aforementioned neural patterns observed within the prototypical social cognition network (i.e., within the medial prefrontal cortex and temporal pole), as well as lends further support for an association between ASD and cerebellar atypicalities (Wang, Kloth, & Badura, 2014). One possible interpretation of the current findings is that adolescents with ASD engage in greater higher-level abstraction mentalizing (as reflected by cerebellar hyperactivity) when they observe targets expressing emotions that conflict with contextual cues. Supporting this interpretation, Schmahmann (1998) proposed that the cerebellum promotes contextually-appropriate behaviors and monitors incongruencies between intended and observed outcomes. An alternative, although not mutually-exclusive, interpretation relies on research implicating cerebellar activity in multisensory integration (Ronconi et al., 2017; Wang et al., 2014). Accordingly, cerebellar hyperactivity during SCE processing when PT demands are high may represent more effortful integration of multimodal contextual cues (i.e., visual cues, auditory cues, etc.) when adolescents with ASD observe targets expressing contextually-inconsistent emotions.

Integration of Results Across the Social Cognition Network. Taken together, results from the current study extend previous findings by suggesting that individuals with ASD do not demonstrate global hypoactivation of the social cognition network, but that activity may be differentially modulated by changes in PT demands and/or the situational context. These neural patterns may reflect different strategies adopted by youths with ASD during emotion attribution. When PT demands are low, adolescents with ASD demonstrate hypoactivation of a social cognition network, perhaps reflecting reduced reflexive mentalizing; however, when PT demands are high, they demonstrate hyperactivation of this network and its extensions, perhaps reflecting a greater need to access social conceptual knowledge when integrating discrepant contextual cues.

Visual Regions. The current study also revealed group differences within occipital-temporal regions, including the fusiform gyrus, inferior temporal gyrus, lingual gyrus, cuneus, and inferior and middle occipital cortices; which have been implicated in visual perception processing. Similar to neural patterns observed within the social cognition network, group differences in occipital-temporal recruitment were modulated by PT demands, particularly during pride processing. Adolescents with ASD demonstrated hypoactivation during SCE processing when PT demands were low, but hyperactivation when PT demands were high. Within-group comparisons offered converging evidence. Adolescents with ASD recruited greater activity when PT demands were high, compared to low; while neurotypical adolescents recruited greater activity when PT demands were low, compared to high.

Occipital and posterior temporal regions are believed to play key roles in visual perception processing (Haxby, Hoffman, & Gobbini, 2000), particularly when individuals evaluate social and affective stimuli (Adolphs, 2002a). While the fusiform gyrus is most commonly associated with emotional facial processing (Kanwisher & Yovel, 2006), this region has also been implicated in emotional body processing (De Gelder, 2006; Peelen & Downing, 2005). Meanwhile, lateral occipital-temporal regions may be selective for bodies (Downing, Jiang, Shuman, & Kanwisher, 2001). Individuals with ASD commonly demonstrate hypoactivation within the fusiform gyrus and occipital cortices during facial processing (Pierce, Müller, Ambrose, Allen, & Courchesne, 2001), including during emotion recognition tasks and affective empathy tasks that use decontextualized static photographs of faces (Greimel et al., 2010; Hall, Doyle, Goldberg, West, & Szatmari, 2010; Hubl et al., 2003); decontextualized animated photographs of faces (Sato, Toichi, Uono, & Kochiyama, 2012); well as static photographs of faces paired with matching prosodic voices (Hall, Szechtman, & Nahmias, 2003). Thus, previous studies have been limited to using emotion recognition tasks with low PT demands. Findings from this dissertation both confirm and extend past research by suggesting that individuals with ASD may demonstrate attenuated visual attention during SCE processing when PT demands are low (Dichter, 2012), but heightened visual attention when PT demands are high, which may serve as a compensatory mechanism for less reflexive mentalizing. The current findings cannot dissociate if increased occipital-temporal recruitment reflects greater attention to facial features, body postures, or more effortful visual search, in general. However, a lack of group differences within the posterior superior temporal sulcus, a region implicated in biological motion (Allison, Puce, & McCarthy, 2000) and perceptual deficits in ASD (Pelphrey, Adolphs, & Morris, 2004), suggests that group differences may reflect atypical feature detection when integrating discrepant visual and contextual information, and not atypical intention attribution according to changes in facial (e.g., eye gaze) and body cues (Allison et al., 2000; Haxby et al., 2000).

Salience Regions. Neuroimaging research has defined an intrinsically-connected salience network, with hubs located within the anterior insula and dorsal anterior cingulate cortex (Menon & Uddin, 2010; Seeley et al., 2007). This network is believed to integrate sensory, emotional, and cognitive cues, in order to detect and highlight stimuli that are self-relevant, emotionally-arousing, or novel (Menon, 2015). The anterior insula has been implicated in interoceptive-awareness, visceral arousal, salience detection, and attention to/integration of multisensory information (Craig, 2009; Critchley, Wiens, Rotshtein, & Dolan, 2004; Immordino-Yang, McColl, Damasio, & Damasio, 2009; Nelson et al., 2010); while the dorsal anterior cingulate cortex has been implicated in response selection and conflict monitoring (Botvinick, Braver, Barch, Carter, & Cohen, 2001). Particularly relevant to this dissertation, the anterior insula and dorsal anterior cingulate cortex are posited to play key roles in empathy processing (Bernhardt & Singer, 2012; Fan et al., 2011), including empathy for physical pain (Singer et al., 2004), social pain (Masten, Morelli, & Eisenberger, 2011), embarrassment (Krach et al., 2015); disgust (Deen, Pitskel, & Pelphrey, 2010; Jabbi, Swart, & Keysers, 2007); and enjoyment (Jabbi et al., 2007).

ASD is associated with atypical salience network function and connectivity (Di Martino et al., 2009; Uddin, 2015; Uddin & Menon, 2009), which may play a key role in autistic symptomatology (Uddin et al., 2013). Researchers have been particularly interested in exploring group differences in the neural correlates of empathy processing, in an effort to better understand interpersonal challenges commonly experienced by individuals with ASD. Past studies have yielded mixed results, including reports of insular hyperactivity (Gu et al., 2015), hypoactivity (Krach et al., 2015; Morita et al., 2016; Morita et al., 2012), and an absence of group differences (Klapwijk et al., 2016; Pantelis et al., 2015), which may reflect the modulatory role of the situational context in salience network recruitment.

In support of this theory, the current study revealed significant three-way interactions within bilateral dorsal anterior insula and dorsal anterior cingulate cortex, highlighting the interacting, modulatory roles of diagnostic group, emotion type, and PT demands in the recruitment of salience network activity during SCE processing. Two key patterns emerged. First, adolescents with ASD recruited greater activity than neurotypical adolescents within the right anterior insula during embarrassment processing when PT demands were low. In addition, adolescents with ASD recruited greater activity within the dorsal anterior cingulate cortex during embarrassment processing when PT demands were low. Thus, adolescents with ASD demonstrated salience network hyperactivation when they observed peers acting embarrassed in embarrassing situations.

Second, adolescents with ASD recruited greater activity than neurotypical adolescents within the dorsal anterior cingulate cortex during pride processing when PT demands were high. In contrast, neurotypical adolescents recruited greater activity within the dorsal anterior cingulate cortex during pride processing when PT demands were low. Thus, adolescents with ASD demonstrated salience network hyperactivation when they observed peers acting proud in embarrassing situations, but hypoactivation when they observed peers acting proud in pride-inducing situations.

Within-group comparisons revealed similar patterns. Adolescents with ASD recruited greater salience network activity during embarrassment processing when PT demands were low relative to high; and during pride processing when PT demands were high relative to low. In contrast, neurotypical adolescents recruited greater activity during embarrassment processing when PT demands were high relative to low; and during pride processing when PT demands were low compared to high.

Broadly, these findings suggest that adolescents with ASD recruit enhanced salience network activity not only when they observe embarrassed targets in embarrassing situations, but also when observe proud targets in embarrassing situations. This suggests that the embarrassing context (moreso than the expression of embarrassment) may drive salience network hyperactivation in ASD. Consequently, group differences in salience network recruitment appear to be driven by changes in the situational context, such that adolescents with ASD recruit greater activity during embarrassment-evoking situations (when they expect embarrassment/failure), but reduced activity during pride-evoking situations (when they expect pride/success).

There are several possible interpretations for these differential neural patterns. First, adolescents with ASD might find embarrassing situations more emotionally distressing; thus, salience network hyperactivation in ASD may reflect heightened affective arousal. This interpretation coincides with findings from behavioral research showing that individuals with ASD have an increased tendency to feel personal distress on behalf of others (Adler et al., 2015; Dziobek et al., 2008; Lombardo et al., 2007; Patil et al., 2016; Rogers et al., 2007). Particularly relevant to this interpretation, Gu and colleagues (2015) reported that adults with ASD demonstrate heightened autonomic arousal and neural responsivity during empathic physical pain processing, including elevated skin conductance, anterior insular hyperactivity, and anterior insular hyperconnectivity (which the authors interpreted as a failure to inhibit). Adults with ASD also demonstrate a stronger correlation between elevated skin conductance and anterior insular hyperactivity, which may suggest a stronger relationship between autonomic and affective arousal during empathy for pain. Findings from this dissertation extend previous research by suggesting that adolescents with ASD may not only experience heightened affective arousal when they *directly* observe others in pain, but also when they observe others in situations that would *typically* elicit these feelings (regardless if targets express these emotions or not). Anterior insula dysfunction may serve as an underlying neural mechanism, given its proposed role in contextualized, interoceptive predictions (Gu et al., 2015). Individuals with ASD may be hypersensitive to these signals and/or fail to inhibit them (Gu et al., 2015); consequently, individuals with ASD may be more strongly influenced by the situation context during emotional inference, particularly when making embarrassment attributions, which may evoke affective hyperarousal.

A second interpretation is that salience network hyperactivation during embarrassment-evoking situations may reflect hypersensitivity to rule violations in ASD. This interpretation is supported by research linking the anterior insula to attention allocation (Menon & Uddin, 2010) and the dorsal anterior cingulate cortex to conflict monitoring (Botvinick et al., 2001). During the SCET-C, participants were told that they would watch video clips of singers performing in a singing competition. Thus, an implicit rule of this task is that singers should sing well. Framed with this context, adolescents with ASD may have perceived singers who sang poorly as having violated this rule. Previous research has reported that children, adolescents, and adults with ASD demonstrate enhanced recruitment of the anterior insular and dorsal anterior cingulate cortex, as well as hyperconnectivity between these regions, during the perception of social and nonsocial rule violations (Bolling et al., 2011; Dichter, Felder, & Bodfish, 2009). Given that individuals with ASD demonstrate a strict adherence to rule-following (Zalla et al., 2011), the current findings may suggest that youths with ASD allocate greater attention to detecting rule violations, which may modulate neural responsivity during social interactions.

A third interpretation is that embarrassing situations may be more salient and personally relevant to adolescents with ASD, while pride-evoking situations may be more salient and personally-relevant to neurotypical adolescents. Youths with ASD experience greater peer rejection and bullying, while neurotypical youths experience greater peer acceptance and social support (Symes & Humphrey, 2010). Despite documented mentalizing difficulties, youths with ASD can offer personal accounts of peer exclusion, which suggests that youths with ASD are both cognizant of and distressed by negative social interactions (Ochs, Kremer- Sadlik, Solomon, & Sirota, 2001). Relatedly, adults with ASD demonstrate greater proneness to feeling shame, compared to neurotypical adults (Davidson, Vanegas, & Hilvert, 2017). Thus, salience network hyperactivity during embarrassing situations in the current study may represent heightened awareness or perceived importance on the neural level, which may reflect a history of social exclusion/social rejection in ASD.

Sensorimotor Regions. Results also revealed significant three-way interactions within lateral frontal and parietal regions, including the left and right precentral gyrus, right postcentral gyrus, and paracentral lobule/middle cingulate cortex. These patterns highlight the interacting, modulatory roles of diagnostic group, emotion type, and PT demands in the recruitment of somatosensory and motor regions during SCE processing. Neurotypical adolescents recruited greater activity than adolescents with ASD during pride processing when PT demands were low (when targets sang well and acted proud), as well as during embarrassment processing when PT demands were high (when targets sang well and acted embarrassed). This suggests that neurotypical adolescents recruited greater sensorimotor regions than adolescents with ASD during pride-evoking situations. Within-group comparisons revealed converging findings. Neurotypical adolescents recruited greater activity when targets sang well compared to when they sang poorly (regardless of the emotions they conveyed), while adolescents with ASD recruited greater activity when targets sang poorly compared to when they sang well (regardless of the emotions they conveyed). Thus, group differences in sensorimotor recruitment appear to have been modulated by the situational context.

Somatosensory and premotor/motor regions have been broadly implicated in bottom-up information processing, such as low-level sensory and motor simulation during face perception (Zaki, Weber, & Ochsner, 2012). These regions are believed to serve as sensory afferents and motor efferents to the anterior insula and anterior cingulate cortex within a larger salience network (Uddin & Menon, 2009). Research exploring empathic pain processing has highlighted distinct sensory and affective-motivational components of a putative pain matrix, which are supported by sensorimotor regions and the anterior insula/anterior cingulate cortex, respectively (Avenanti, Bueti, Galati, & Aglioti, 2005; Han et al., 2009; Lamm et al., 2011). Thus, group differences in sensorimotor recruitment during SCE processing may represent atypical sensorimotor resonance. It is worth noting that the sensorimotor regions reported in the current study are not part of the putative mirror neuron system (i.e., the inferior frontal gyrus and inferior parietal lobule), which supports affective empathy through action observation and motor simulation (Van Overwalle & Baetens, 2009). Indeed, research suggests that sensorimotor activity during empathic pain processing represents visual processing of sensorimotor cues (i.e., body parts engaged in pain processing), and not the explicit mirroring of somatosensory states (Lamm et al., 2011). Thus, group differences in sensorimotor recruitment in the current study may reflect enhanced processing of contextual cues that are uniquely salient for each group (pride-relevant cues for neurotypical adolescents and embarrassment-relevant cues for adolescents with ASD), which, in turn, may be associated with group differences in empathy processing.

Absence of Group Differences within the Amygdala and Temporoparietal Junction

The current study failed to detect significant group differences within the amygdala and temporoparietal junction, two regions which are commonly recruited during social cognitive processing. The amygdala is broadly implicated in emotion processing and may be particularly responsive to emotional valence (Breiter et al., 1996). While a popular theory of autism proposes that amygdala dysfunction may underlie social cognitive impairments in ASD (Baron-Cohen et al., 2000), previous research investigating the neural correlates of personal embarrassment (Morita et al., 2016; Morita et al., 2012) and empathic embarrassment (Krach et al., 2015; Pantelis et al., 2015) in adults with ASD failed to detect group differences in amygdala recruitment. One possible explanation is that the amygdala may play a more critical role in basic, nonsocial emotion processing than in complex, social emotion processing (such as SCE attribution and empathy). In support of this interpretation, Schultz (2005) argued the amygdala supports early-stage, automatic emotion processing, such as signaling affective arousal and emotional salience, while higher-level cortical structures support more advanced emotional inference. Thus, the current findings suggest that adolescents with high-functioning ASD may have intact foundational emotion recognition abilities, as reflected in similar amygdalar recruitment as neurotypical adolescents, but typical advanced social cognitive abilities, as reflected in atypical temporal polar and cerebellar recruitment.

The current study also failed to detect group differences in temporoparietal junction recruitment. The temporoparietal junction has been proposed to play a critical role in social cognition and ToM (Saxe & Kanwisher, 2003), and dysfunction within this region has been associated with social cognitive impairments in ASD (Lombardo, Chakrabarti, Bullmore, Baron-Cohen, & Consortium, 2011). One possible explanation for a lack of group differences in the current study is related to differences in paradigm design. Previous studies that found group differences in temporoparietal junction recruitment required participants to engage in complex social reasoning and cognitive inference, such as reading short sentences describing social norm violations, inferring targets' intentions, and using this information to make moral evaluations (Berthoz et al., 2002; Young et al., 2007). In comparison, the current study may have engaged in less cognitively demanding, more affective, and less reflexive processing, such as identifying familiar emotional facial and postural cues, and using this information to make emotional state attributions. According to this interpretation, adolescents with ASD may not demonstrate global temporoparietal junction dysfunction during social cognitive processing, and group differences in temporoparietal junction recruitment may be task-specific, modulated by cognitive inferential demands.

Strengths, Limitations, and Future Directions

This dissertation is associated with several strengths, relative to previous neuroimaging research. First, previous studies investigating emotion processing have predominantly used photographic stimuli. In comparison, the current study used dynamic video stimuli, which is more engaging and may evoke more robust neural activity compared to static images (Trautmann et al., 2009). Second, previous studies have often used simplified stimuli (such as images of only the eye region of the face), which may reflect the engagement of only one type of cognitive strategy (limited by the task design). In comparison, the complex video stimuli used in the current study provided diverse, multisensory affective cues, including eye gaze, facial features, body postures, and prosody, which may more accurately represent the multiple, concurrent strategies that are likely adopted during real-world social interactions. Third, most neuroimaging studies have investigated empathy processing using photographs of body parts in pain (e.g., a hand being pricked by a needle or hit with a hammer), which limits the generalizability of these findings to empathic *physical* pain. One of the few studies to explore empathy for *social* pain in individuals with ASD used drawings of targets in stereotypically embarrassing social situations and participants rated how empathically embarrassed they felt for the targets (Krach et al., 2011). The current study offered the advantage of studying more realistic and implicit empathic social pain processing using video clips that in some ways more closely resemble real-world social interactions with peers.

Despite these advantages, this dissertation is also associated with several limitations. First, the current study used multimodal stimuli that provided multiple affective cues. While these stimuli may be more ecologically-valid, this study was unable distinguish which types of cues each group used, and if groups differentially prioritized using some types of cues over others. Future research should manipulate the types of cues provided (e.g., cues from the eyes versus the mouth versus body posture) or the modality of cues provided (i.e., visual, auditory, or verbal cues), either by varying which types of cues are presented (Wang et al., 2006) or by instructing participants to pay attention to only certain types of cues during specific blocks. Combining neuroimaging and eye-tracking methodologies may also prove useful.

A second limitation is that the current study was unable to distinguish which cognitive/affective processes each group engaged in during SCE processing (i.e., emotion recognition, empathy, etc.). Future research could manipulate this, such as by explicitly instructing participants to focus on the targets' emotions (emotional inference), their own emotions for the targets (empathic processing), or the targets' singing quality (contextual knowledge processing). Indeed, previous research has demonstrated that changes in task demands significantly modulate group differences in neural recruitment during social cognitive processing (Alaerts, Swinnen, & Wenderoth, 2017).

Finally, as proposed in the discussion of Study I, future research should recruit both male and female participants and investigate the modulatory role of gender on SCE processing. Previous research has demonstrated that neurotypical males and females may recruit differential neural patterns during emotion attribution and empathy processing (Schulte-Rüther, Markowitsch, Shah, Fink, & Piefke, 2008). Unfortunately, previous autism neuroimaging research has predominantly included all-male samples or samples with gender ratios that reflect the male dominance of the disorder (4 or 5 males to 1 female). Research investigating gender differences could have both theoretical implications, such as providing evidence in support of or conflict with the Extreme Male Brain Theory of Autism (Baron-Cohen, 2002), and clinical implications for intervention design, since individuals with ASD demonstrate gender-specific symptom profiles (Lai, Lombardo, Auyeung, Chakrabarti, & Baron-Cohen, 2015).

CHAPTER VIII

CONCLUDING REMARKS

The aim of this dissertation was to explore the subjective experience and neural correlates of self-conscious emotion understanding in adolescent males with high-functioning autism. Despite the stereotyped characterization of autism as an “empathy disorder” (Gillberg, 1992) associated with “mindblindness” (Baron-Cohen et al., 1985; Frith, 2001), findings from this dissertation demonstrate that adolescents with ASD are indeed capable of recognizing complex social emotions conveyed by their peers; and they do, in fact, feel empathic social emotions on behalf of their peers. What is more, adolescents with ASD demonstrate preserved detection sensitivity; they can infer self-conscious emotions and feel empathic self-conscious emotions with similar intensity as neurotypical adolescents. While individuals with ASD are broadly characterized by impaired or atypical perspective-taking abilities (according to self-report, parent-report, and performance on experimental ToM tasks), findings from this dissertation suggest that their ability to make emotion attributions and to feel empathic emotions for others is not inhibited by increased perspective-taking demands. Indeed, adolescents with ASD appear to be similarly impacted by changes in the situational context as neurotypical adolescents. Thus, interpersonal challenges observed within the real world may likely reflect difficulties translating affective information into socially appropriate responses, and not impaired inferential or empathic abilities.

Interestingly, investigating incongruent emotion attributions offered a more nuanced understanding of self-conscious emotion processing in ASD. Findings from this dissertation suggest that while adolescents with ASD are able to correctly identify and rate the intensity of self-conscious emotions conveyed by their peers, they *additionally* infer more intense emotions that are reflect the situational context (even when targets do not explicitly convey these emotions). This suggests that the emotional inferences of individuals with ASD may be more strongly impacted by personal expectations of situationally-appropriate reactions, which may reflect a strict adherence to rule-following. Indeed, results from Study I demonstrate that youths who report lower levels of cognitive empathy within the real world tend to make more intense incongruent SCE inferences, which suggests that an over-reliance on contextual cues may serve as a compensatory strategy for poor perspective-taking abilities (or less reflexive mentalizing).

Results from Study II lend support for this interpretation. While ASD is commonly characterized by broad neural dysfunction within social cognition and emotion networks, the current findings suggest that adolescents with ASD recruit strikingly similar neural patterns as neurotypical adolescents during self-conscious emotion processing. When group differences were observed, they were often modulated by perspective-taking demands or the situational context, suggesting that adolescents with ASD do not demonstrate global dysfunction. Adolescents with ASD demonstrated differential recruitment of brain regions implicated in social cognitive processing, visual perceptual processing, salience processing, and sensorimotor/somatosensory processing, which were modulated by perspective-taking demands and the situational context. One interpretation, which converges with results from the behavioral study, is that adolescents with ASD may engage in greater social norm referencing/social conceptual knowledge processing when they observe targets expressing contextually-inappropriate emotions. This over-reliance on abstract rule-following may serve as a compensatory mechanism for less reflexive mentalizing or for difficulties integrating discrepant mental state and contextual information. In addition, adolescents with ASD may be particularly sensitive to social rule violations or embarrassing situations, which they may perceive as more emotionally salient.

Research and clinical work often appear to adopt a deficits approach, with research seemingly aimed at confirming what individuals with ASD *cannot* do, and clinical work frequently emphasizing the importance of teaching fundamental skills, even to older, higher functioning individuals. It is time to stop thinking about adolescent/adult autism as merely an extension of childhood autism. Findings from this dissertation demonstrate that high functioning adolescents with ASD *do* possess many foundational social cognitive skills, and they are more capable than society often portrays them to be. By emphasizing areas of impairment, we do a disservice to individuals with ASD and fail to propel the field forward. Instead, we must promote researching and teaching more advanced social cognitive skills, in order to better understand how they may be differentially applied by individuals with ASD within the real world. Overall, this will advance our theoretical understanding of the disorder and help us to better accommodate individuals with ASD.

APPENDIX

SUPPLEMENTARY MATERIALS

Social Cognitive Measures

Revised Self-Consciousness Scale-Child. Participants completed the Revised Self-Consciousness Scale for Children (RSCS-C) (Scheier & Carver, 1985), a 29-item questionnaire used to assess the tendency to feel self-conscious and socially anxious. The RSCS-C has three subscales: Public Self-Consciousness (11 items), Private Self-Consciousness (11 items), and Social Anxiety (7 items). Example items include: "I often check the way I look", "I'm always trying to understand myself", and "I feel scared when I meet someone new". Participants rated the descriptiveness of these statements using a 5-point Likert scale, ranging from "Strongly disagree" to "Strongly agree". Public Self-Consciousness and Private Self-Consciousness subscale scores were calculated. Subscales missing more than 1 item and measures missing more than 3 items were not scored.

Toronto Alexithymia Scale-20 Item. Participants completed the Toronto Alexithymia Scale-20 Item (TAS-20) (Bagby et al., 1994) a 20-item questionnaire used to assess alexithymic tendencies. Alexithymia reflects meta-cognitive abilities (particularly for internalized emotions) and has been associated with empathic abilities. The TAS-20 has three subscales: Difficulty Identifying Feelings (7 items), Difficulty Describing Feelings (5 items), and Externally-Oriented Thinking (8 items). Example items include: "I am often confused about what emotion I am feeling", "It is difficult for me to find the right words for my feelings", and "I prefer to analyze problems rather than just describe them". Participants rated the descriptiveness of these statements using a 5-point Likert scale, ranging from "Strongly disagree" to "Strongly agree", and all three subscale scores were calculated. According to TAS-20 scoring instructions, subscales missing more than 1 item and measures missing more 2-3 items were not scored.

Reading the Mind in the Eyes Task. Participants completed the Reading the Mind in the Eyes Task (RMET) (Baron-Cohen, Wheelwright, Spong, Scahill, & Lawson, 2001), a 28-item task used to assess cognitive empathy. Participants viewed photographs of the eye region of targets' faces and inferred their emotional or mental state by selecting one of four labels. Example labels include: "angry", "friendly", "unkind", and "a bit worried". A total score was calculated.

Strange Stories Task-Revised. Participants completed the Strange Stories Task-Revised (White, Hill, Happé, & Frith, 2009), a 16-vignette task used to assess cognitive empathy. Eight vignettes featured scenarios representing double-bluffs, white lies, and advanced PT demands to assess mental state attribution (ToM); and 8 vignettes assessed physical state attribution. Answers received a score ranging from 0 to 2, and total ToM scores were calculated.

Interpersonal Reactivity Index. Participants completed the Interpersonal Reactivity Index (IRI) (Davis, 1983), a 28-item questionnaire used to assess empathic tendencies. The IRI has four subscales, consisting of 7 items: Perspective-Taking (the tendency to spontaneously adopt others' psychological point of view), Fantasy (the tendency to imaginatively adopt the feelings and actions of fictitional characters in movies, books, or plays), Empathic Concern (the "other-oriented" tendency to feel sympathy and concern for unfortunate others), and Personal Distress (the "self-oriented" tendency to feel personal anxiety and unease in stressful interpersonal settings) (Davis, 1983). Example items include: "I try to look at everybody's side of an argument before I make a decision", "I really get involved with the feelings of the characters in a story", "I often have tender, concerned feelings for people less fortunate than me”, and “In emergency situations, I feel worried and anxious”. Participants rated the descriptiveness of these statements using a 5-point Likert scale, ranging from “Does not describe me well” to “Describes me very well”. The Perspective-Taking, Empathic Concern, and Personal Distress subscales were of particular interest, and the Fantasy subscale was included in exploratory analyses (given that participants may have adopted the perspectives of unknown targets during the SCET-C or empathized with unknown targets during the SCERT). Thus, all four subscale scores were calculated. Subscales missing more than 1 item and measures missing 3 or more items were not scored.

Basic Empathy Scale. Participants completed the Basic Empathy Scale (BES) (Jolliffe & Farrington, 2006), a 20-item questionnaire used to assess empathic tendencies. The BES has two subscales, Cognitive Empathy and Affective Empathy, which consist of 9 and 11 items, respectively. Jolliffe and Farrington (2006) argued that the BES and IRI may assess distinct empathy constructs. Affective Empathy scores on the IRI may best reflect the tendency to feel sympathy for others, while Affective Empathy scores on the BES may best reflect the tendency to emotionally resonate with others. Cognitive Empathy scores on the IRI may best reflect the ability and tendency to adopt others’ perspectives, while Cognitive Empathy scores on the BES may best reflect the ability and tendency to understand others’ mental states. Example items from the BES include: “I have trouble figuring out when my friends are happy” and “After being with a friend who is sad about something, I usually feel sad”. Participants rated the descriptiveness of these statements using a 5-point Likert scale, ranging from “Strongly disagree” to “Strongly agree”, and both subscale scores were calculated. Subscales missing more than 1 item and measures missing 2 or more items were not scored.

Autism Symptomatology/Traits Measures

Social Responsiveness Scale. Parents/guardians completed the Social Responsiveness Scale (SRS) (Constantino, 2002), a 65-item questionnaire that assesses autism-related social impairments and distinguishes ASD from other psychological disorders. The SRS consists of five subscales: Social Awareness (8 items), Social Cognition (12 items), Social Communication (22 items), Social Motivation (11 items), and Autistic Mannerisms (12 items). Example items include: “Expressions on his or her face don’t match what he or she is saying”, “Has more difficulty than other children with changes in his or her routine”, and “Is socially awkward, even when he or she is trying to be polite”. Parents/guardians rated the descriptiveness of these statements using a 4-point Likert scale, ranging from “Not true” to “Almost always true”, and a total T score was calculated. Missing items were replaced with median scores provided in the SRS manual. Participants in the ASD group were included in the dissertation if they received a T score of 55 or above. Participants in the NT group were included in the dissertation if they received a T score of 59 or less.

The SRS manual states that T scores of 76 or greater typically represent children within the “severe range”, T scores of 60-75 typically represent children within the “mild to moderate range”, and T scores of 59 or less typically represent children in the “normal range”. However, the manual also states that T scores of 55-59 may represent children with very mild, “high functioning” ASD. Thus, participants in the ASD group who fell within this range and met criteria on both the ASRS and ADOS were included in the dissertation.

Autism Spectrum Rating Scale. Parents/guardians completed the Autism Spectrum Rating Scale (ASRS) (Goldstein & Naglieri, 2013), a 71-item questionnaire used to assesses symptoms and behaviors associated with ASD, which also supports diagnostic decision-making and intervention design. The ASRS consists of three ASRS subscales (Social/Communication, Unusual Behaviors, and Self-Regulation), which combine to make an ASRS total score; a DSM-V total score; and eight treatment subscales (Peer Socialization, Adult Socialization, Social/Emotional Reciprocity, Atypical Language, Stereotypy, Behavioral Rigidity, Sensory Sensitivity, and Attention). Example items include: “share fun activities with others”, “insist on doing things the same way each time”, and “become bothered by some fabrics or tags on clothes”. Parents/guardians rated the descriptiveness of these statements using a 5-point Likert scale, ranging from “Never” to “Very frequently”. An ASRS total T score (reflecting the tendency to endorse behavioral traits similar to those demonstrated by individuals with ASD), and an ASRS DSM-V total score (reflecting symptoms directly related to DSM-V diagnostic criteria), were calculated, along with two treatment subscales of interest, Peer Socialization (reflecting an attenuated interest and ability to successfully participate in activities that support the development and maintenance of peer relationships), and Social/Emotional Reciprocity (reflecting an attenuated ability to appropriately emotionally respond to others in social situations). Missing items were prorated, according to the ASRS manual. T scores of 70 to 85 classified as “very elevated”; T scores of 65-69 classified as “elevated”; T scores of 60 to 64 classified as “slightly elevated”; T scores of 40 to 59 classified as “average”; and T scores of 25-39 classified as “low”. Participants in the ASD group were included in the dissertation if they scored as “very elevated”, “elevated”, or “slightly elevated” (60 or greater) on the ASRS total T score and ASRS DSM-V total score. Participants in the NT group were included in the dissertation if they scored as “average” or “low” on both scores.

Autism Quotient-Adolescent. Parents/guardians completed the Autism Quotient (AQ-Adolescent) (Baron-Cohen, Hoekstra, Knickmeyer, & Wheelwright, 2006), a 50-item questionnaire used to assess autistic traits (not restricted to clinical symptoms). Example items include: “S/he finds social situations easy”, “S/he tends to notice details that others do not”, and “S/he prefers to do things the same way over and over again”. Parents/guardians rated the descriptiveness of these statements using a 4-point Likert scale, ranging from “Definitely disagree” to “Definitely agree”, and a total score was calculated. Missing items were addressed as described above, which is consistent with the approach recommended by Auyueng and colleagues (2008). (Measures missing 5 or more items were not scored.) While the ASRS and SRS are frequently used in diagnostic decision-making, the AQ is not. Thus, the AQ was not used as an exclusionary measure for this dissertation.

Social Competence Measures

Social Competence with Peers Questionnaire- Pupil. Participants completed the Social Competence with Peers Questionnaire- Pupil (SCQ-Pu) (Spence, 1995), a 10-item questionnaire used to assess social competence. Example items include: “I get on well with my classmates”, “I find it easy to make friends”, and “I see my friend or friends on weekends”. Participants rated the descriptiveness of these statements using a 3-point Likert scale, ranging from “Not true” to “Mostly true”, and a total score was calculated. Measures missing more than 1 item were not scored.

Social Competence with Peers Questionnaire- Parent. Parents/guardians completed the Social Competence with Peers Questionnaire- Parent (SCQ-Pa) (Spence, 1995), a 9-item questionnaire used to assess social competence. Statements included on the SCQ-Pa were mostly overlapping with the SCQ-Pu. Parents/guardians rated the descriptiveness of these statements using a 3-point Likert scale, ranging from “Not true” to “Mostly true”, and a total score was calculated. Measures missing more than 1 item were not scored.

Demographics Measures

Weschler Abbreviated Scales of Intelligence-II. To assess generalized intelligence levels, participants completed the Weschler Abbreviated Scales of Intelligence-2nd edition (WASI-II) (Wechsler, 2011). The WASI-II includes four subtests: Block Design, Vocabulary, Matrix Reasoning, and Similarities. In the interest of time, only the Vocabulary and Matrix Reasoning subtests were administered, resulting in a 2-subscale Full Scale IQ (FSIQ) score.

Pubertal Development Scale. Participants completed the male version of the Pubertal Development Scale (PDS) (Petersen, Crockett, Richards, & Boxer, 1988), a 6-item questionnaire used to assess sex-specific pubertal development. Items on the male version assessed changes in height, facial hair growth, body hair growth, skin changes, and voice deepening, as well as an item assessing perceived development relative to one's peers. Mean PDS scores were calculated by averaging across all items except the comparative item. Pubertal categories were also calculated using scoring guideline provided by Crockett and colleagues (1988). Total scores were calculated for items assessing facial hair growth, body hair growth, and voice changes: pre-puberty = 3; early puberty = 4 or 5 (no 3-point responses); mid-puberty = 6-8 (no 4-point responses); late puberty = 9-11, and post puberty = 12. In cases where participants made a 3-point response but scored within the early puberty range, or made a 4-point response but scored within the middle puberty range, scores were assigned to the next consecutive category (middle puberty and late puberty, respectively).

Center for Epidemiological Studies Depression Scale for Children. Participants completed the Center for Epidemiological Studies Depression Scale for Children (CESD-C) (Weissman, Orvaschel, & Padian, 1980), a 20-item questionnaire used to assess self-reported depression symptomatology experienced over the past week. Example items include: "I felt down and unhappy" and "I felt sad". A total score was calculated. Measures missing more than 1 item were not scored.

Demographics Questionnaire. Parents completed an in-house demographics questionnaire (unpublished) used to assess participants' ethnicity, their parents' education level, and annual household income.

Addressing Missing Data

Missing data were addressed according to procedures provided in task-specific manuals. When no specific instructions were provided, missing data were addressed via imputation: total scores were calculated as the raw total plus the raw mean times the number of missing items. Measures with greater than 10% missing data were not scored (and subscales with greater than 10% missing data were also not scored).

Self-Conscious Emotions Task Paradigm Design

Song Selection. A list of popular songs (predominantly songs sung on televised singing competitions, such as American Idol, or found on pop song compilation disks) were compiled and piloted by a group of 37 middle school students for level of familiarity, likeability, and likelihood of being sung in a singing competition. The aim of the pilot was to exclude songs that were either relatively unfamiliar or broadly disliked by adolescents. Familiarity was assessed using a binary score of 0 or 1. Likeability was assessed using a 3-point Likert scale, where 1 represented "Don't like", 2 represented "OK", and 3 represented "Like". Likelihood of being sung in a singing competition was assessed using a 3-point Likert scale, where 1 represented "No", 2 represented "Maybe", and 3 represented "Yes".

Songs were included in the final list if over two-thirds (66.66%) of pilot participants rated them as familiar, over half (50%) rated them as likeable, and over half (50%) rated them as likely to be sung in singing competition. Of the songs included in the final stimuli set, 71.05-100% of pilot participants rated them as familiar (rated them as a 1), 63.33-100% of pilot participants rated them as likeable (rated them as a 2 or 3, representing “OK” or “Like”), and 56.25-87.01% rated them as likely to be sung in a singing competition (rated them as a 2 or 3, representing “Maybe” or “Yes”). (See Table S1 for title and artists of included songs.)

Table S1. Song Titles and Artists

Title	Artist
A Thousand Years	Christina Perry
All of Me	John Legend
Am I Wrong	Nico and Vinz
A Thousand Years	Christina Perry
Counting Stars	One Republic
Give Your Heart a Break	Demi Lovato
Grenade	Bruno Mars
Hallelujah	Rufus Wainwright
Hey Soul Sister	Train
I'm Not the Only One	Sam Smith
Lean on Me	Bill Withers
Payphone	Maroon 5
Rather Be	Clean Bandit
Rolling in the Deep	Adele
Rumor Has It	Adele
She Will Be Loved	Maroon 5
Skyfall	Adele
Somebody that I Used to Know	Gotye
Someone Like You	Adele
Stay	Rihanna
Stay with Me	Sam Smith
Style	Taylor Swift
Sugar	Maroon 5
Take Me to Church	Hozier
This is Me	Demi Lovato
Titanium	David Guetta
Treasure	Bruno Mars

Note: This list includes titles and artists of songs featured in both the practice task and SCET-C. In cases where a song was featured in multiple video clips, different parts of the song were featured.

Video Creation. Video clips included male and female adolescent actors pretending to compete in a singing competition. Actors were recruited from local middle and high school choir and drama groups and national singing competitions. Videos were recorded at local middle schools, high schools, and on the University of Oregon campus. Actors were instructed to select two songs from a list of pre-piloted songs to sing *a capella*. Each actor was assigned a short clip (~10s) from each selected song and were instructed to sing each clip four different ways: 1) EmbLo: sing poorly, act embarrassed; 2) EmbHi: sing well, act embarrassed; 3) PrideLo: sing well, act proud; 4) PrideHi: sing poorly, act proud. Thus, each actor provided multiple clips which were later piloted.

Actors were instructed to convey feelings of embarrassment and pride using facial expressions and postural gestures, based on previous psychological research. To convey embarrassment, actors were encouraged to tilt their head downward and sideways, direct their eye gaze downwards and away from the audience, touch their face with their hands, hunch and slump their shoulders, and narrow their chest (Keltner, 1995, 1996; Keltner & Buswell, 1997; Tracy, Robins, & Schriber, 2009). Judges also gave personalized feedback for conveying embarrassment, including instructing actors to shift their gaze up and down (towards and away from the audience) and acting fidgety (e.g., touching their hair, rubbing their arms). Actors were instructed to convey embarrassment similarly during both embarrassment conditions (EmbLo and EmbHi) to ensure that differences in subjective ratings and/or neural activity did not reflect differences in affective expression or emotional intensity.

To convey pride, actors were recommended to tilt their head upwards and backwards, direct their eye gaze towards the audience, arch their back, expand their chest, rest their hands on their hips, and smile (Tracy et al., 2009; Tracy & Matsumoto, 2008; Tracy & Robins, 2004b, 2007c, 2008). Actors were instructed to convey pride similarly during both pride conditions (PrideLo and PrideHi), to ensure that differences in subjective ratings and/or neural activity did not reflect differences in affective expression or emotional intensity. Actors were not instructed to convey a specific subtype of pride (authentic pride versus hubristic pride); however, research suggests that individuals express authentic pride and hubristic pride using similar facial expressions and postural gestures (Tracy & Robins, 2007d).

While actors were given instructions and feedback on their performance, ultimately, they were encouraged to act natural. As such, actors were encouraged to give performances that were emotionally salient and capable of evoking feelings of empathic embarrassment or empathic pride, while also being realistic. Actors performed in front of a pair of judges (one male and one female actor) sitting in front of them at a table. Actors stood in front of a white screen facing the judges and the camera. Actors were videotaped from the waist up, so participants could view their emotional facial expressions and postural gestures. Only the backs of the judges' heads could be viewed, so participants could not observe the judges' facial expressions and use them as cues for emotion ratings.

Actors were also recorded standing alone (with judges out of view) in front of a white screen, while conveying a neutral facial expression. These clips were used as neutral control clips.

Video Piloting. Video clips were piloted by 21 undergraduate and graduate students. Pilot participants rated each actor's singing performance (singing ability) using a 5-point Likert scale (1 = "Very bad", 5 = "Very good"). Pilot participants also rated each actor's perceived level of embarrassment and pride (inferred embarrassment and inferred pride) using a 4-point Likert scale (1 = "None", 2 = "Low", "3" = "Medium", "4" = "High"). In addition, pilot participants rated their own level of embarrassment and pride for each actor (empathic embarrassment and empathic pride), using a 4-point Likert scale (1 = "None", 2 = "Low", 3 = "Medium", 4 = "High"). Video clips were selected according to mean singing quality (scores of 1-2.5 for EmbLo and PrideHi clips; scores of 3.5-5 for EmbHi and PrideLo clips) and mean inferred emotion (scores of 2.5-4 for EmbLo and EmbHi; scores of 2.5-4 for PrideLo and PrideHi). No actor was featured in more than one condition (including neutral emotion); no singing clip was featured in more than one condition; and gender ratio was similarly distributed across conditions (EmbLo: 2 males, 4 females; EmbHi: 2 males, 4 females; PrideLo: 1 male, 5 females; PrideHi: 1 male, 5 females; Neut: 3 males, 3 females).

Six video clips representing each condition were selected for the final MRI stimuli set. (See Table S2 for more information.) Independent sample *t*-tests confirmed that there were no significant differences in mean singing quality or the intensity of mean inferred emotion ratings across conditions (EmbLo vs EmbHi; PrideLo vs PrideHi; EmbLo vs PrideLo; EmbHi vs PrideHi; as well as EmbLo vs PrideHi; and PrideLo vs EmbHi; see Table S3). (In addition, there were no significant differences in the intensity of mean empathic emotion ratings between conditions of similar PT demands; e.g., EmbLo vs PrideLo; EmbHi vs PrideHi). There were differences in the intensity of mean empathic emotion ratings between conditions of different PT demands (e.g., EmbLo vs EmbHi; PrideLo vs PrideHi), but this was expected. Five additional clips (one for each condition) were selected for the practice task, to be viewed prior to the MRI scan.

Table S2. Mean Pilot Ratings

Condition	Singing Quality	Inferred Emotion	Empathic Emotion
EmbLo	4.05	3.08	3.09
EmbHi	4.22	3.10	2.11
PrideLo	3.93	3.35	3.05
PrideHi	3.98	3.11	2.02

EmbLo: embarrassment, low PT demands; EmbHi: embarrassment, high PT demands; PrideLo: pride, low PT demands; PrideHi: pride, high PT demands.

Table S3. Comparison Statistics for Pilot Ratings

Factor	Comparison	Statistic
Singing Quality	EmbLo vs EmbHi	$t(10) = -0.17$, $p = 0.872$
	PrideLo vs PrideHi	$t(10) = -1.65$, $p = 0.130$
	EmbLo vs PrideLo	$t(10) = 0.00$, $p = 1.00$
	EmbHi vs PrideHi	$t(10) = -1.28$, $p = 0.227$
Inferred Emotion	EmbLo vs EmbHi	$t(10) = -0.15$, $p = 0.881$
	PrideLo vs PrideHi	$t(10) = 1.36$, $p = 0.205$
	EmbLo vs PrideLo	$t(10) = -1.12$, $p = 0.288$
	EmbHi vs PrideHi	$t(10) = -0.17$, $p = 0.868$
Empathic Emotion	EmbLo vs EmbHi	$t(10) = 5.84$, $p < 0.001$**
	PrideLo vs PrideHi	$t(10) =7.83$, $p < 0.001$**
	EmbLo vs PrideLo	$t(10) = 0.26$, $p = 0.802$
	EmbHi vs PrideHi	$t(10) = -0.81$, $p = 0.434$

EmbLo: embarrassment, low PT demands; EmbHi: embarrassment, high PT demands; PrideLo: pride, low PT demands; PrideHi: pride, high PT demands.

Note: ** $p < 0.001$. Singing quality scores for clips when targets sang poorly were reversed, such that higher scores represented greater intensity (irrespective of valence).

Video Editing. Video clips were converted from MTS files to mp4 files using Free MTS M2TS Converter. Clips were edited using Adobe Premiere Pro and modified as little as possible to maintain greatest ecological validity. Emotion clips were edited for length using the trim function (8-12s; M = 9.89s), exported as mp4 files, and saved to a consistent resolution (1080 x 608) and frame rate (30 frames/s). Background noise was filtered across all clips using the denoiser filter. A high-pass filter was used to filter out low frequency background noise, and minor modifications to lighting aperture using the Lumetri Color editing panel to adjust white balance (temperature = -49.7, tint = .6) and tone (exposure = 0.5, contrast = 0.6, highlights = 35.5, whites = 21.3, blacks = 3.2) were made, as necessary (one day of recording for lighting aperture modifications). Clips were not modified to be the same volume, to preserve natural variations in auditory output associated with the expression of different emotions (i.e., proud singers often sing louder than embarrassed singers). However, volume modifications were made, as necessary, to ensure that the volume of all clips was within a consistent range (-12 to -27 decibels).

Neutral emotion control clips were edited for length using the trim function (8-10s; M = 9.50s), exported as mp4 files, and saved to a consistent resolution (1080 x 608) and frame rate (30 frames/sec). The video clips' original audio tracks were replaced with audio clips of instrumental version of songs, with separately recorded audio tracks of announcers (one male and one female) introducing the singers. Visual blurring was applied using a Gaussian blur set to 55 with repeated edge pixels, so that fine grain facial features and expressions could not be detected. A high-pass filter was used to filter out low frequency background noise, and minor modifications to lighting aperture using the Lumetri Color editing panel to adjust white balance (temperature = -49.7, tint = .6) and tone (exposure = 0.5, contrast = 0.6, highlights = 35.5, whites = 21.3, blacks = 3.2) were made, as necessary (one day of recording for lighting aperture modifications).

Table S4. Self-Conscious Emotions Task-Child Stimuli Presentation Order

Run	Trial	Condition
Run 1	1	PrideHi
	2	Neutral
	3	EmbLo
	4	EmbHi
	5	PrideLo
	6	PrideHi
	7	EmbLo
	8	Neutral
	9	PrideLo
	10	EmbHi
	11	EmbLo
	12	PrideHi
	13	PrideLo
	14	Neutral
	15	EmbHi
Run 2	1	EmbHi
	2	Neutral
	3	PrideLo
	4	PrideHi
	5	EmbLo
	6	PrideLo
	7	EmbHi
	8	EmbLo
	9	Neutral
	10	PrideHi
	11	EmbHi
	12	PrideLo
	13	Neutral
	14	EmbLo
	15	PrideHi

EmbLo: embarrassment, low PT demands; EmbHi: embarrassment, high PT demands; PrideLo: pride, low PT demands; PrideHi: pride, high PT demands.

Note: Videos were presented in a fixed order for all participants. However, the order of embarrassment and pride ratings (whether participants made embarrassment ratings first or pride ratings first) was counterbalanced across participants.

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