Social Anxiety, Theory of Mind, and Executive Function in Late Adolescence and Early Adulthood

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Abstract

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Studies that have investigated the relation between social anxiety and theory of mind or executive function have shown that individuals with deficits in these cognitive processes have high levels of social anxiety. However, methodological problems make past findings questionable and difficult to interpret. The current study investigated whether deficits in theory of mind and executive function predicted symptoms of social anxiety in 99 older adolescents and young adults (18-29). On average, participants had moderate levels of social anxiety. Performance on measures of theory of mind and executive function did not predict symptoms of social anxiety. This lack of associations could be due to characteristics of the current sample, methodological differences in the current study compared to past studies, or the type of social anxiety and theory of mind measure used. Implications and directions for future research are discussed.

Keywords: social anxiety, theory of mind, executive function, late adolescence, early adulthood

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Overview

Social anxiety (SA) is characterized by an intense fear of social situations, which includes interactions, performances, and being evaluated by others (Segal, et al., 2015). It is believed that a negative information processing bias is a main component underlying SA (Liang, 2018), which impacts judgments and appraisal of information. It is highly likely that this processing bias is associated with inefficiencies in understanding and interpreting the mindset of others during social situations (theory of mind), as well as in controlling and regulating thought processes (executive function). Theory of mind (ToM), which refers to the ability to reason about mental states in oneself and others (Premack & Woodruff, 1978; Washburn et al., 2016), and executive function (EF), which refers to cognitive mechanisms that that help to control and regulate thought processes (Im-Bolter et al., 2016; Miyake & Friedman, 2012), are critical for successful social interaction. Although there is research that investigates the relation between SA and ToM (e.g., Hezel & McNally, 2014; Lenton-Brym et al., 2018; Washburn et al., 2016), and between SA and EF (e.g., Ajilchi & Nejati, 2017; Liang, 2018, Segal et al., 2015), it is limited and flawed. These flaws are due to the inconsistent way that ToM is defined in the literature, which has led to the questionable assessment of ToM (Ahmed & Miller, 2011; Dziobek et al., 2006; Oakley et al., 2016;), and the use of impure measures of EF. As a result, the findings are mixed and we have an incomplete understanding of the association between ToM or EF and SA. Moreover, the literature shows that EF is an important contributor to ToM (Im-Bolter et al., 2016), yet EF has not been considered in research investigating SA and ToM. Therefore, the goal of the current study is to investigate the relation between SA, ToM, and EF in a sample of older adolescents

and young adults. This developmental period is of particular interest since anxiety disorders are prevalent in this age group and research regarding SA and ToM in this population is scarce.

Social Anxiety Disorder

SA disorder, previously known as social phobia, is one of the most common psychiatric disorders (Kessler, Chiu et al., 2005; Schreiber et al., 2012; Stein et al., 2000) in late adolescence and early adulthood (Leigh & Clark, 2018; Moffitt et al., 2010; Newman et al., 1996), with a 12-month prevalence rate of 6.8% (Kessler, Chiu et al., 2005) and lifetime prevalence rate of 12.1% (Kessler, Berglund et al., 2005); 4.9% and 9.5% in males and females, respectively (Magee et al., 1996; Wittchen et al.1999). The average age of onset for SA disorder is early to mid-adolescence (Anderson & Hope, 2009; Kessler, Berglund et al., 2005; Ranta et al., 2007). SA disorder is characterized by an extreme and persistent fear of social situations, which includes interactions, performances, and observations, where evaluation, scrutiny, and embarrassment may occur (American Psychiatric Association, 2013; Segal et al., 2015; Stein et al., 2000). Public speaking, meeting new people, working, talking in class, and being observed in public are some common examples of feared social situations (National Collaborating Centre for Mental Health, 2013).

The fear experienced in these situations is typically disproportionate to the actual threat that exists (National Collaborating Centre for Mental Health, 2013). Individuals with SA disorder tend to avoid these types of social situations (safety behaviour), a common behavioural symptom of SA, but experience intense distress when avoidance is not possible (Christensen et al., 2003; Essau et al., 1999). Other behavioural symptoms of SA might include avoiding eye contact, being submissive in conversations (Flett et al., 2017), and isolating oneself while at social gatherings. While in social situations, individuals with SA disorder shift their focus inwards (a cognitive symptom of SA), focusing on their physiological symptoms (e.g., blushing,

heart rate, sweating), thoughts, and behaviours (Segal et al., 2015), which are skewed by a negative information processing bias that leads to processing social information more negatively. A widely adopted cognitive model of SA disorder, originally proposed by Clark and Wells (1995), suggests that three different negative biases in social information processing underlie, perpetuate, and exacerbate SA disorder: attentional, interpretation, and memory.

Attentional Bias

A bias for attending to negative and threatening stimuli in social situations and difficulty disengaging from such stimuli are considered aspects of attentional bias, which is thought to contribute to the maintenance of SA (Buckner et al., 2010; Ferreri et al., 2011). It has been well documented that individuals with high SA or SA disorder tend to disproportionately focus their attention on negative and threatening stimuli (e.g., Gilboa-Schechtmanet al., 1999; Klumpp & Amir, 2009; Mogg et al., 2004; Pishyar et al., 2004), such as negative facial expressions (e.g., anger, disgust). For example, Pishyar et al. (2004) found that individuals with higher SA had a tendency to focus their attention (i.e., attentional bias) on negative faces (i.e., threatening evaluations) whereas those with low SA focused their attention on positive faces. It is not surprising that individuals with high SA disproportionately attend to negative (or socially threatening) stimuli, as SA disorder is characterized by a fear of evaluation by others. Hofmann (2007) describes that the fear of evaluation increases social apprehension, which leads individuals with high SA to be highly self-focused; they monitor and observe themselves in a negative manner, therefore, producing more anxiety responses. These tendencies heighten the attention of an individual with SA towards threatening social cues. However, not only do individuals with high SA or SA disorder disproportionately attend to negative stimuli, but they also have difficulty disengaging from such stimuli.

The ability to disengage one's attention from threating stimuli, known as attentional disengagement, has been found to be impaired in individuals with high SA or SA disorder (Amir et al., 2003; Buckner et al., 2010; Fox et al., 2001; Schofield et al., 2012). For instance, in one study participants with and without SA disorder were presented with social threat (e.g., stupid, humiliated), positive (e.g., delighted, confident), and neutral (e.g., dishwasher, tile) word cues (Amir et al., 2003). Participants were then required to detect a probe (*) appearing in one of two different locations on a computer screen. For invalid trials, where the probe appeared in a different location than the cue, participants with SA disorder had significantly longer response times than participants without SA disorder when the cue word was a threat word. This suggests that individuals with SA disorder have difficulty disengaging from threatening stimuli (i.e., social threat cue words) in order to detect the probe, which was in a different location.

Buckner et al. (2010) found similar results using eye tracking, which offers a more direct measure of attention than response time paradigms. Buckner et al. presented their participants with social cues (happy or disgust faces) and non-social cues (non-facial photos: e.g., buildings, nature scenes) which were matched for valence (positive vs. negative), threat (high vs. low), and arousal (high vs. low). Participants higher in SA had difficulty disengaging from the disgust faces (negative social cues) compared to the happy faces and the non-facial photos. Similarly, Schofield et al. (2012) used eye-tracking to show that higher levels of SA were not only significantly associated with a greater attentional focus on emotional faces (angry, happy, fear), but also difficulty disengaging from the angry (threat) faces. Research in this area indicates that social threats are problematic for individuals with SA and that they likely have difficulty disengaging from attending to threatening perspectives of others.

Heightened awareness of threatening stimuli (e.g., evaluations by others) and difficulty

disengaging from threatening stimuli could prevent socially relevant information from counteracting an individual's negative interpretation of social events (Buckner et al., 2010). This would also impair the ability to accurately understand the perspective of someone else. For example, a socially anxious individual might be so focused on negative stimuli (e.g., an expression of anger) that they fail to attend to other relevant stimuli in the environment (e.g., who the anger is directed towards). Due to their fear that the negative stimuli is directed at them, even though it is not, the individual focuses on the negative stimuli and evaluative perspective of the other person, thus biasing their attention and their interpretation of the event.

Interpretation Bias

Interpretation bias refers to the negative interpretation of social situations (Hirsch & Clark, 2004; Miers et al., 2008), which biases the judgments and appraisals of social information. In individuals with SA, the biased interpretation of information is exacerbated by a fear of being negatively evaluated (Segal et al., 2015). Furthermore, during social situations, anxiety and social fear increases focus an individual's their own thoughts, physiological sensations, and behaviors, particularly their negative self-evaluative thoughts (e.g., "I'm boring"), which also contribute to a negative interpretation bias (Coles et al., 2001; Hirsh & Clark, 2004; Mellings & Alden, 2000). This interpretation bias in individuals with SA appears to influence biased appraisals of four types of social situations or events (ambiguous, mildly negative, profoundly negative, positive), and has been reported in a number of studies (Amin et al., 1998; Constans et al., 1999; Stopa & Clark, 2000; Voncken et al., 2003). Stopa and Clark (2000) found that individuals with SA disorder were more likely to interpret ambiguous social events as negative and catastrophize unambiguous mildly negative social events compared to individuals with other anxiety disorders and those with no anxiety. Consistent with Stopa and Clark, Voncken et al.

(2003) showed that compared to individuals with low SA, individuals with high SA interpreted ambiguous, negative (mildly negative and profoundly negative), and positive social events as negative or very negative.

The negative interpretation bias in individuals with SA is well documented and has consistently been shown to influence the interpretation of ambiguous, negative, and positive social events. This leads to negative judgments and appraisals of social information, which help maintain high levels of SA. The negative interpretation bias demonstrated by individuals with SA in social situations can also have lasting effects after the social event has ended, which can result in post-event rumination and biased recollections or memories of the social event.

Memory Bias

A memory bias refers to a social information processing bias characterized by excessive rumination following a perceived socially threatening or fearful event (Mellings & Alden, 2000). This results in stronger encoding of negatively interpreted social information in long term memory, thus biasing recollections of past social events (Mellings & Alden, 2000). After the social event, individuals with SA reappraise the past social event (Anderson & Hope, 2009), focusing on their anxious feelings, negative self-images, and negative self-perceptions (Anderson & Hope, 2009; Clark & Wells, 1995; Coles et al., 2001; Hofmann, 2007; Mellings & Alden, 2000). For example, Mellings and Alden (2000) found that individuals with high SA attended to more negative self-related information and engaged in more post-event rumination compared to individuals without SA. It is worth noting that depression did not influence the results. Similarly, Hackmann et al. (1998) found that when individuals with high SA were asked to think about a past situation where they felt anxious, they were more likely to experience anxious self-images compared to individuals without SA. Individuals with high SA also recalled more negative self-

images and these self-images tended to be from an observer's perspective (external point of view) rather than the first-person perspective typically seen in individuals without SA.

The tendency for individuals with high SA to take on an observer perspective has been found by other researchers (e.g., Coles et al., 2001; Wells et al., 1998). This observer's perspective creates memories from a negatively biased external point of view, which results in a tendency to monitor the self for flaws that others might notice (Coles et al., 2001). This alteration of perspective also creates a tendency to ignore other individuals in the social situation, whose behaviour could counteract the negative self-evaluations (Wells et al., 1998). As a result, the observer perspective prevents external information from counteracting the negative self-beliefs held by an individual with high SA. This indicates that those with high SA have negatively biased recollections and also have distorted perceptions regarding what they believe others think and see. Therefore, post-event rumination is thought to reactivate memories and lead to stronger encoding of negative interpretations in memory (Mellings & Alden, 2000), which biases future recollections of the social event as being more negative than it originally was (Anderson & Hope, 2009; Mellings & Alden, 2000). Furthermore, prior to a new social event, individuals with high SA tend to recall previous social failures, thus contributing to the maintenance, exacerbation, and perpetuation of SA fears and the possibility of avoidance behaviours (Anderson & Hope, 2009).

These three negative social information processing biases – attentional, interpretation, and memory – which underlie, perpetuate, and exacerbate SA appear to be associated with an individual's ability to understand and interpret the thoughts, beliefs, and emotions of others, which is known as theory of mind. Moreover, these biases also appear to be related to an individual's ability to control and regulate their thoughts and actions or EF.

Theory of Mind

Initially conceptualized by Premack and Woodruff (1979), ToM refers to the ability to understand and reason about mental states in oneself and others, such as one's thoughts, beliefs, desires, and emotions (Miller, 2009). This social cognitive skill is essential for successful social interaction (Dziobek et al., 2006) and starts to emerge in early childhood, representing an important milestone in childhood development and a shift in perspective taking where children start to realize that mental representations (e.g., beliefs) can differ from reality (Miller, 2009). The development of ToM is thought to evolve through two stages: 1) first-order ToM and 2) second-order ToM. First-order ToM typically emerges around age four, becoming adult-like by age 5, and refers to the ability to understand and reason about the perspective of another person (e.g., A believes X; Miller, 2009). This includes the realization that what an individual believes or says can differ from reality (i.e., false belief reasoning); realizations that lead children to discover how to tease and deceive others but also how to console and comfort others (Miller, 2009). Second-order ToM or higher-order ToM is a more complex form of mental state reasoning that has a recursive nature and typically develops around age 7 (Perner & Wimmer, 1985). It involves the ability to understand and reason about another person's reasoning of yet another's perspective (e.g., A believes that B believes X; A thinks that B thinks X).

First-order ToM is typically measured with false belief tasks; the most common involve change in location (Wimmer & Perner, 1983), deceptive contents (Perner et al., 1987), and appearance reality (Flavell et al.,1983). The change in location task involves a story where person A changes the location of an object (X to Y) when person B is not in the room. False belief reasoning is assessed by asking where person B would look for the object when they return. ToM is demonstrated by understanding that person B would look for the object in its

original location (X) because they have a false belief of the object's location. In the deceptive contents task, an easily recognizable object (e.g., smarties box or milk carton) is revealed to contain different contents (e.g., pencils or confetti). ToM is demonstrated with the understanding that another person would not identify the deceptive contents due to their false belief of what the object contains. Similarly, the appearance reality task involves an object (e.g., sponge) that appears to be something else (e.g., rock). Understanding that the object would be identified as what it appears to be (e.g., rock) unless that false belief is revealed shows ToM.

Preschool age children have been the primary focus of ToM research since this is the age it first emerges; however, interest in how ToM continues to develop has shifted the focus to school aged children, adolescents, and adults. In fact, research has shown that ToM continues to develop and mature into adolescence and adulthood (Dumontheil et al., 2010). This continued development and maturation has been proposed to be associated with the continued development of the prefrontal cortex (both structurally and functionally), which is associated with mental state attribution (Dumontheil et al., 2010). As a result, there is more interest regarding ToM in school aged children, adolescents and adults, and researchers have incorporated methods from fields such as cognitive psychology and neuroscience (Apperly, 2012). This expansion in ToM research has led to differences in the way that ToM has been conceptualized and defined. As a result, this expanded literature tends to refer to processes that may not be related to ToM as it was originally conceptualized (Schaafsma et al., 2014).

For example, Sabbagh (2004) redefined ToM, to make it more compatible with the field of cognitive neuroscience, as consisting of two processes: decoding and reasoning. ToM decoding refers to the ability to decode thoughts and feelings based on available observable behavioural information, such as facial expressions, eye gazes, body gestures, vocal tone, and

actions. ToM reasoning refers to the ability to interpret or reason about the thoughts, beliefs, and actions of others by utilizing pre-existing knowledge of the other person or assessing contextual information. For example, if Sally is crying because she received a poor mark on her exam, and John knew she studied a lot, then John first decodes the observable information (e.g., crying, sadness) then reasons that Sally is crying because she studied a lot yet did poorly on the exam. A problem with Sabbagh's conceptualization of ToM is that the decoding process requires minimal understanding of the other person's mental state, which is the essence of ToM and relies, for the most part, on emotion recognition. As a result, research that incorporates Sabbagh's definition of ToM utilizes questionable assessments of ToM; this is specifically a problem in the limited research investigating ToM and SA.

The most commonly used measures of second-order or higher order ToM can be narrowed down to three tasks: the Reading the Mind in the Eyes task (Baron-Cohen et al., 1997), the Movie for the Assessment of Social Cognition (Dziobek et al., 2006), and the Strange Stories (Happé, 1994), with the Mind in the Eyes and Movie task most commonly used in SA literature. Originally developed by Baron-Cohen et al. (1997), the Mind in the Eyes task assesses higher-order ToM by requiring an individual to look at photographs of eyes and then selecting one of two mental state terms that best matches the eyes in the photograph. The mental state terms are either "basic" (e.g., happy, sad, angry, afraid) or "complex" (e.g., reflective, arrogant, scheming, planning). Baron-Cohen et al. found that compared to a control group, individuals with autism or Asperger's syndrome performed worse. This was consistent with previous research with the Strange Stories (a previously established higher-order ToM measure; Happé, 1994). Baron-Cohen et al. also included a basic emotion recognition task as a control measure and found no performance differences among the groups. However, it should be noted that all groups achieved

ceiling performance which could reflect the lack of difficulty of the task.

Recognizing that there were flaws in the Mind in the Eyes task, Baron-Cohen et al. (2001) made several changes; most importantly, they eliminated the basic mental states category, which included basic emotions that are universally recognized even by young children (Ekman & Friesen, 1971). Baron-Cohen et al. also increased the response options from two to four to decrease chance guessing and incorporate distractors that were equal in valence to the target word. Despite these changes, there are still glaring concerns with the revised version of the Mind in the Eyes task that calls into question its validity as a measure of ToM. For example, although complex mental states are used, matching them to eye photographs does not necessarily require reasoning about another person's perspective based on the social context, which is commonly used in ToM tasks (Oakley et al., 2016). Instead, the Mind in the Eyes task relies on emotion recognition based on facial cues (Oakley et al., 2016; Pequet & Warnell, 2019), which can be improved through accumulated experiences. As such, performance differences found between the Mind in the Eyes (original or revised) and the basic emotion recognition control task may be due to differences in the difficulty level between basic (high exposure) and complex (less exposure) emotions. If so, this indicates that the Mind in the Eyes is better suited as an assessment of complex emotion recognition and that Baron-Cohen et al. actually found a deficit in complex emotion recognition in individuals with autism and Asperger's syndrome, not ToM.

These assertions are supported by Oakley et al.'s (2016) research investigating individuals with Alexithymia, which is commonly linked to deficits in emotion recognition and often co-occurs with autism spectrum disorder. Oakley et al. found that Alexithymia rather than autism spectrum disorder predicted performance on the Mind in the Eyes task, which suggests it primarily taps emotion recognition. These findings also suggest that emotion recognition and

ToM are separate cognitive processes, which means that individuals who perform well on the Mind in the Eyes may have deficits in ToM and those who perform poorly may have intact ToM (Oakley et al., 2016). Research that shows young adults with conduct disorder have impaired emotion recognition yet intact ToM (Fairchild et al., 2009) and adults with impaired ToM and intact emotion recognition (Freedman et al., 2013) lend support to this claim. Considering the popularity of the Mind in the Eyes task, research using this task as a measure of ToM needs to be reconsidered.

The Movie task, developed by Dziobek et al. (2006), is a multidimensional assessment of social cognition that taps emotion recognition, facial recognition, body language recognition, and mental state reasoning. This task includes a 15-minute movie that features four characters (Sandra, Betty, Michael, Cliff) interacting at a dinner party (social context) with each character displaying different emotional and mental states. Multiple choice questions about the characters thoughts (e.g., "what is Cliff thinking?"), feelings or emotions (e.g., "What is Cliff feeling?"), and intentions (e.g., What is Cliff's intention?") are asked at 46 different planned pauses throughout the movie. The 46 questions include seven regarding thoughts, 17 regarding emotions (13 negative, 2 positive, 2 neutral), and 18 about the characters' intentions. Responses are scored as correct and incorrect.

Dziobek et al. (2006) found differences between individuals with and without Asperger's syndrome on the Movie task, as well as the Mind in the Eyes, Strange Stories, and Basic Emotion Recognition tasks. The latter result contradicts Baron-Cohen et al. (1997) who found no differences in a basic emotion recognition task. Interestingly, Dziobek et al. used a more difficult version of the Basic Emotion Recognition task (seven response options instead of two) than Baren-Cohen et al. That individuals with Asperger's syndrome had performance deficits on both

the Basic Emotion Recognition Task and the Mind in the Eyes task compared to controls supports previous assertions that Baron-Cohen et al.'s (1997) lack of findings were due to task difficulty. Additionally, Dziobek et al. found the Movie task best discriminated the group with Asperger's syndrome from those without. Although the Movie task relies less on emotion recognition in comparison to the Mind in the Eyes task (Oakley et al., 2016), it remains a multidimensional assessment of social cognition that taps processes other than ToM (i.e., emotion recognition). In fact, performance on the Movie task is associated with performance on both emotion recognition tasks (Dziobek et al., 2006), which provides evidence of the Movie task's multidimensional nature. As a result, caution should be used when using the Movie task to assess ToM (Oakely et al. 2016). Comparatively, the Strange Stories task, a well-established measure of higher order ToM that is not correlated with the Mind in the Eyes or Basic Emotion Recognition tasks (Dziobek et al., 2006), is designed to focus on mental state reasoning.

Developed by Happé (1994), the Strange Stories task involves 24 contextually embedded short vignettes or stories that depict realistic everyday situations where people say things they do not literally mean (e.g., "Oh yes, a lovely day for a picnic alright!" in the context of a rainy day). The 24 stories consist of two stories that depict a white lie, lie, joke, misunderstanding, sarcasm, double bluff, pretend, persuasion, forget, contrary emotions, and appearance reality. Mental state reasoning is determined by evaluating the explanation of the main character's intention. Explanations that refer to mental states (e.g., "because she's being sarcastic") demonstrate higher order ToM. Using the Strange Stories task, Happé found differences between individuals with and without autism spectrum disorder regarding mental state attributions. The use of the Strange Stories task for assessing ToM ability was later supported with children (Brent et al., 2004; Devine & Hughes, 2013 Kaland et al., 2005; White et al., 2009) and adults (Jolliffe & Baron-

Cohen, 1999; Saltzman et al., 2000; White et al., 2009). Moreover, the Strange Stories task has been shown to detect age-related changes in ToM (Im-Bolter et al., 2016; O'Hare et al., 2009) and have good reliability and validity (Devine & Hughes, 2016; Hayward & Homer, 2017). Thus, the Strange Stories task has empirical support as a reliable and valid assessment of ToM across development that also discriminates between typical and atypical populations (Devine & Hughes, 2016). However, research investigating SA and ToM in late adolescence and early adulthood does not typically include the Strange Stories task and instead, focus on more questionable assessments of ToM, such as the Mind in the Eyes and Movie tasks.

Theory of Mind and Social Anxiety

As previously discussed, negative social information processing biases (attention, interpretation, memory) underlie, exacerbate, and perpetuate SA and likely contribute to deficits in ToM. One framework proposed to explain this relation is the deficit framework (Nikolić et al., 2019; Pequet & Warnell, 2021). The deficit framework, which aligns with Clark and Wells (1995) cognitive model of SA, suggests that deficits in social information processing (e.g., ToM) are associated with SA. Negative biases in processing social information would increase difficulty in accurately interpreting the thoughts, beliefs, and intentions of others. This, in turn, increases the likelihood of fear of negative evaluation and avoidance of social situations due to inaccurate appraisals and the unpredictability of social situations (Nikolić et al., 2019). Therefore, deficits in ToM would be associated with SA. In comparison, the hypersensitivity framework suggests that individuals with good ToM, which is generally thought to be socially advantageous, may be hypersensitive to the thoughts, beliefs, and opinions of others (Nikolić et al., 2019). This would make individuals with good ToM more aware of being the target of another's attention and potential negative evaluation, thus increasing self-consciousness (Bogels

et al., 1996; Nikolić et al., 2016) and fear of negative evaluation (Nikolić et al., 2019). Therefore, in contrast to the deficit framework, good ToM would be associated with SA.

Research examining the relation between SA and ToM is limited. In childhood, a period of development where SA starts to emerge (An & Kochanska, 2021; Nikolić et al., 2019), poor ToM is associated with high levels of SA (Banerjee & Henderson, 2001; Colonnesi et al., 2016). Banerjee and Henderson (2001) showed that 6- to 11-year-olds who had difficulty interpreting the mental states of others in social situations demonstrated high SA. Colonnesi et al. (2016) found poor performance on a false belief task in children aged 4 to 9 to be associated with behaviours indicative of SA (e.g., negative shyness or avoidant behaviours such as negative facial expressions, avoidant eye gaze and head aversion). These studies provide support for the deficit framework as poor ToM was associated with high levels of SA. In contrast, Nikolić et al. (2019) claim that results from their study with 8- to 12-year-old children provide evidence for both the deficit and hypersensitivity framework. Using the Mind in the Eyes task, Nikolić et al. found a quadratic (u-shaped) relation between ToM and SA. Poor performance was associated with clinical levels of SA, supporting the deficit framework, and good performance (top 30%) was associated with high (but not clinical) levels of SA, supporting the hypersensitivity framework.

Although Nikolić et al. (2019) appear to provide empirical evidence that both poor and good ToM are associated with high levels of SA, their findings are undermined by the use of an emotion recognition task (Mind in the Eyes) to assess ToM. Nikolić et al.'s findings more likely reflect an association between poor and good emotion recognition with SA, rather than ToM. In fact, when An and Kochanska (2021) attempted to replicate Nikolić et al.'s findings in 4- and 5-year-olds using well established ToM tasks (e.g., unexpected location, unexpected contents),

they found that poor performance, and not good performance, was associated with high SA. Thus, providing further support for the deficit framework not the hypersensitivity framework. It is possible that previous studies showing good ToM to be associated with high SA (e.g., Nikolić et al., 2019; Sutterby et al., 2012) are a result of flawed assessments of ToM. Overall, the childhood literature supports the possibility that poor ToM is associated with SA (deficit framework). It is important to note, however, that there is one study with 7- to 12-year-olds that did not find any association between ToM and SA using the Mind in the Eyes, Strange Stories, and Faux Pas tasks (Pequet & Warnell, 2021). This lack of association could be due to a floor effect with respect to SA. Pequet and Warnell (2021) note that their sample had low levels of SA, which was likely the result of their SA measure. Pequet and Warnell used a parent report measure that screens for anxiety disorders in general (e.g., generalized anxiety disorder, separation anxiety) rather than SA specifically. Moreover, parents tend to underestimate their children's level of SA (Bowers et al., 2020; Rappaport et al., 2017).

Compared to the childhood literature, research investigating SA and ToM in late adolescence and early adulthood, a developmental stage where anxiety disorders are among the most prevalent and psychiatric disorders peak (Castaneda et al., 2008), is contradictory. This is likely due to the use of measures such as the Mind in the Eyes, which primarily assesses emotion recognition, and the Movie task, which assesses a range of social cognitive processes. In general, studies that utilize the Mind in the Eyes task have shown that individuals who have difficulty recognizing emotions of positive, neutral, or negative valence are associated with high SA (Alvi et al., 2020; Hezel & McNally, 2014; Lenton-Brym et al. 2018; Maleki et al., 2020; Ozturk et al., 2020; Washburn et al., 2016). Therefore, it may be more accurate to conclude that deficits in emotion recognition are linked to higher levels of SA. There is, however, contradictory research

that shows no association between SA and ToM using the Mind in the Eyes task (Pequet & Warnell, 2021), as well as research that shows an association between better performance on the Mind in the Eyes task and high SA in female undergraduate students (Sutterby et al., 2012). Considering the Mind in the Eyes task is likely an assessment of emotion recognition, not ToM, these findings do not provide a clear contribution to whether there is an association between ToM and SA or support for the deficit or hypersensitivity framework regarding ToM and SA.

Research using the Movie task, which measures a range of social cognitive process including ToM, has shown that individuals who make more "excessive ToM" errors are more likely to have clinical versus nonclinical levels of SA (Hezel & McNally, 2014; Washburn et al., 2016). It has been suggested that individuals who "overinterpret" (Washburn et al., 2016, pg. 75) the thoughts, beliefs, and intentions of others and attribute more intense emotions when it is not contextually appropriate (e.g., attributing *extreme outrage* when *anger* is more appropriate) have high levels of SA (Hezel & McNally, 2014; Washburn et al., 2016). However, this finding was not replicated by Lenton-Brym et al. (2018) using a non-clinical sample. Although "excessive ToM" errors on the Movie task appears to suggest that individuals with poor ToM have high SA, which supports the deficit framework, a problem with the Movie task is that poor performance could be due to social cognitive difficulties other than ToM. This could explain why Lenton-Brym et al.'s findings are contradictory and shows a need for research investigating the possible association between ToM and SA using measures that specifically assess mental state reasoning.

Based on the current evidence from research examining ToM and SA in childhood, there appears to be some evidence for the deficit framework (poor ToM associated with high SA; e.g., Banerjee & Henderson, 2001; Colonnesi et al., 2016) but no valid support for the hypersensitivity framework (good ToM associated with high SA) despite previous claims (e.g.,

Nikolić et al., 2019). Regarding late adolescence and early adulthood, questionable evidence exists for the deficit framework (e.g., Hezel & McNally, 2014; Washburn et al., 2016) but, like the childhood literature, no support for the hypersensitivity framework. This lack of support for the hypersensitivity framework in late adolescence and early adulthood literature could be attributed to the fact that most studies in this age group predate the inception of the hypersensitivity framework. Regardless, in general, few studies have investigated the association between ToM and SA and the little research that exists is difficult to interpret, in part, due to the current operationalization of ToM that has led to the use of questionable measures. Moreover, the ToM literature shows that EF is an important contributor to ToM in childhood and early adolescence (Im-Bolter et al., 2016), as well as in adulthood (Ahmed & Miller, 2011; Apperly, 2012; Fischer et al., 2017), yet EF is generally not considered in research investigating ToM and SA. The limited research that exists is questionable and further emphasizes the importance of including EF when investigating the relation between ToM and SA. Especially, since EF also appears to be associated with SA (e.g., Ajilchi & Nejati, 2017; Liang, 2018; Segal et al., 2015).

Executive Function and Social Anxiety

EF is an umbrella term that refers to high level cognitive processes that assist with mental control and self-regulation (Miyake & Friedman, 2012), and continues to develop throughout late adolescence until early adulthood (approximately 25 years of age; Arain, et al., 2013; Taylor et al., 2013). In a landmark study, Miyake et al. (2000) showed that EF could be described as three related but separable components: updating of the contents of working memory (updating), shifting of mental sets (shifting), and inhibition of prepotent responses (inhibition). Updating refers to the ability to monitor and update information in working memory so that old irrelevant information is replaced with new relevant information (Im-Bolter et al.,

2016; Liang, 2018; Miyake & Friedman, 2012; Miyake et al., 2000; Visu-Petra et al., 2013). For example, being able to store negative or threatening social information in memory, such as an angry facial expression, while also being able to monitor the social situation and update working memory with socially relevant information, such as who that anger is directed towards, involves updating. Shifting, also known as cognitive flexibility, is the ability to flexibly shift between tasks or mental sets (Im-Bolter et al., 2016; Liang 2018; Miyake & Friedman, 2012; Miyake et al., 2000; Visu-Petra et al., 2013). For example, being able to shift from negative interpretations of threatening social stimuli to neutral or positive interpretations of social events. Inhibition is the ability to deliberately inhibit or resist a prepotent or automatic response (Im-Bolter et al., 2016; Liang 2018; Miyake & Friedman, 2012; Miyake et al., 2000; Visu-Petra et al., 2013). For example, when faced with a fearful social situation, such as answering a question in class, some individuals might avoid the situation and remaining silent. Overriding this behavioural response involves inhibition.

Research that specifically focuses on the relation between EF and SA is limited (Ajilchi & Nejati, 2017; Liang, 2018; Segal et al., 2015; Topçuoğlu et al., 2009) and often includes questionable measures of EF, which make the findings difficult to interpret. A good measure of EF should primarily assess one aspect of EF, updating for example, and not other aspects of EF or other non-EF cognitive processes. Miyake et al. (2000) referred to this as the task impurity problem. Impure EF tasks tend to be complex (e.g., Wisconsin Card Sorting Task, Tower of Hanoi; Miyake et al., 2000) and either assess more than one aspect of EF or do not measure the specific EF in question. These kinds of tasks are problematic because they require multiple cognitive processes and therefore, make it difficult to determine where an impairment in EF exists. For example, a widely used task to measure EF is the Wisconsin Card Sorting Task

(Ajilchi & Nejati, 2017; Miyake et al., 2000); however, this task assesses working memory (Coulacoglou & Saklofske, 2017), inhibition (Miyake et al., 2000), problem solving abilities, and cognitive flexibility (Ajilchi & Nejati, 2017; Miyake et al., 2000; Topçuoğlu et al., 2009). As a result, poor performance on this task could reflect a variety of cognitive impairments. Using purer measures of EF that are designed to assess one aspect of EF, such as the n-back task, allows for more conclusive and valid findings. In the n-back task, a series of stimuli are presented sequentially, and the individual must determine whether each incoming stimulus is the same as the stimulus presented "n" items ago. For example, in a 2-back task, the individual must determine whether the current stimulus is the same as the one that had been presented two items ago. As a result, the individual must continually update the contents of their working memory as each new stimulus becomes the relevant target stimulus.

Segal et al. (2015) used a 2-back task to investigate updating and SA. They found that young adults (21 to 25 years) with high SA showed an impairment in updating positive information compared to individuals with low SA. Using the Wisconsin Card Sorting Task, Topçuoğlu et al. (2009) found that young adults who had high SA had impaired working memory, which suggests difficulties with updating. However, since the Wisconsin Card Sorting Task taps a variety of cognitive processes (i.e., is an impure measure of EF), it makes it difficult to state with any certainty that only working memory is impaired. This is especially true when we consider that Ajilchi and Nejati (2017) concluded that young adults with high SA had impaired shifting compared to those with low SA based on poor performance on the Wisconsin Card Sorting Task. Research that shows young adults with high SA have worse inhibition than individuals with low SA (Ajilchi & Nejati, 2017; Liang, 2018) is less contentious since these findings are based on what are considered to be focused measures of inhibition, namely the

Stroop task and the antisaccade task. In the Stroop task, individuals must name the ink colour of colour words. When the ink colour is different than the colour word, the colour word must be effortfully inhibited due to an automatic reading response. In the antisaccade task, individuals are required to look in the opposite direction of a visual stimulus that is presented on a screen. We have an automatic tendency to look in the direction of a visual stimulus (saccade), by asking the individual to look in the opposite direction (antisaccade), the individual must effortfully inhibit this automatic tendency. Using a mixed antisaccade task, which consisted of single-task blocks (prosaccades or antisaccades) and mixed-blocks (prosaccades and antisaccades), Liang (2018) concluded that young adults with high SA had impaired inhibition compared to those with low SA. Furthermore, although the results were not conclusive regarding a shifting impairment, Liang did find that young adults with high SA were slower than those with low SA at shifting in the mixed blocks, suggesting that a shifting impairment may exist. Taken together, the studies that specifically examine EF indicate that each aspect of EF is impaired in young adults with high SA. It is reasonable to propose that this conclusion can also be extended to older adolescents with high SA.

Other studies that provide some insight into the EF of individuals with high SA are those that focus on neurocognitive functioning in these individuals. Although these studies do not examine EF specifically, measures of EF are included (e.g., the Wisconsin Card Sorting Task, the Trail Making Test). Individuals with high SA were found to have poor performance on the Wisconsin Card Sorting Task (Fujii et al., 2013; Graver & White, 2007), especially when exposed to a stressful situation (Graver & White, 2007); however, this finding is difficult to interpret due to the different cognitive processes required in this task. Studies that have incorporated the Trail Making Test (viewed as measuring the shifting aspect of EF) show mixed

results; some find deficits in individuals with high SA compared to those with low SA (Cohen et al., 1996; Graver & White, 2007) whereas others find no differences (Airaksinen et al., 2005; Asmundson et al., 1994; Fujii et al., 2013; Smitherman et al., 2007). The mixed results are likely due to the lack of control for psychomotor speed in the shifting condition (Trails B, which requires the individual to alternate between sequencing numbers and letters). Of these studies, only Cohen et al. (1996) controlled for psychomotor speed (with Trails A, which requires the individual to sequence numbers as quickly as they can).

Overall, research examining the relation between EF and SA focuses on broad measures of EF, which give us little information regarding the associations between updating, shifting, and inhibition and SA. EF is important for the control and regulation of thought processes and actions, which is a critical aspect of how individuals process social information and formulate interpretations of social events and the mental states of others. In order to understand how EF is associated with SA, research has to move beyond broad measurement of EF, which can involve a variety of cognitive processes and make findings difficult to interpret. To our knowledge, no study has specifically examined the three aspects of EF and SA. As such, little is known about EF and SA in this age group. However, we know that EF is an important predictor of ToM (Ahmed & Miller, 2011; Apperly, 2012; Im-Bolter et al., 2016), but this relation appears to change with development. Inhibition is no longer associated with ToM beyond early childhood, likely due to a decreased need for this ability with increased working memory capacity (Ahmed & Miller, 201; Im-Bolter et al., 2016). However, regardless of how these relations change, EF remains an important predictor of ToM and there is evidence of an association between poor EF and high SA (e.g., Ajilchi & Nejati, 2017; Liang, 2018; Segal et al., 2015). As such, it is likely that deficits in ToM are exacerbated by poor EF. Therefore, deficits in EF may account for some

of the relation between ToM and SA found in past literature, making it crucial to account for EF when examining the relation between ToM and SA.

Goals of the Study

The current study investigates the relation between ToM, EF, and SA in older adolescents and young adults. Adolescents and young adults are of particular interest since this is a developmental stage where psychiatric disorders peak (Castaneda et al., 2008) and novel social situations are common (e.g., college/university classes or events, new jobs). Although anxiety disorders are among the most prevalent disorders in late adolescence and early adulthood, research examining psychological disorders in this age group tends to focus on obsessive-compulsive disorder (Castaneda et al., 2008).

Hypotheses

1. Consistent with past research (e.g., Ahmed & Miller, 2011; Apperly, 2012; Fischer et al., 2017; Im-Bolter et al., 2016), updating and shifting are expected to be significantly associated with ToM, but inhibition is not.
2. Given that individuals with deficits in ToM (Banerjee & Henderson, 2001; Colonnesi et al., 2016) and EF (Ajilchi & Nejati, 2017; Liang, 2018; Segal et al., 2015) seem to have high SA, it is hypothesized that ToM and all aspects of EF will predict severity of SA symptoms, but that ToM will be the stronger predictor since EF is associated with ToM.
3. Social information processing biases (attentional, interpretation, memory) appear to underlie, exacerbate, and perpetuate SA (Amir & Bomyea, 2010; Kuckertz & Amir, 2014), which require the use of cognitive processes, such as ToM and EF (Van Nieuwenhuijzen et al., 2017). Therefore, it is hypothesized that ToM and all aspects of EF will show a stronger correlation to cognitive symptoms of SA compared to behavioural symptoms of SA.

4. Based on evidence that individuals with high SA interpret neutral and ambiguous social situations more negatively (Amin et al., 1998; Constans et al., 1999; Stopa & Clark, 2000; Voncken et al., 2003), it is hypothesized that individuals with higher SA will display worse ToM specifically in neutral and ambiguous (requiring inferencing due to ambiguity surrounding the mental states of others) contexts compared to individuals with lower SA.

Method

Participants

The current study used a subsample of Trent University undergraduate students who participated in a larger study examining social cognition in older adolescents and young adults. Participants were recruited from both the Durham GTA and Peterborough campuses and received course credit in exchange for their participation. Written consent was obtained from each participant.

Participants were included if the following criteria were met: 1) estimated performance IQ within the average range (i.e., 75-125) on the *Wechsler Abbreviated Scale of Intelligence-Second Edition: Matrix Reasoning*, 2) estimated language ability within the average range (i.e., standardized score of 5-15) on the *Clinical Evaluation of Language Fundamentals-Metalinguistics Figurative Language* subtest, 3) English spoken as their first language, 4) age range between 18-29 years old, and 5) completed the seven online questionnaires above the 20-minute threshold.

Procedure

The study was completed in two parts: 1) an online survey completed through SONA, and 2) an in-person interview. In the first part, participants completed an online questionnaire that measured symptoms of SA. Additional questionnaires not relevant to the current study were

also completed during the online portion. The online portion of the study took approximately 30- to 45-minutes to complete. The second part of the study was in-person and ranged in length from 2.5 to 3.0 hours and included an assessment of IQ, language, ToM, and EF (updating, shifting, inhibition), as well as other measures not relevant for the current study. All measures from the online portion were eventually transitioned to the in-person portion of the study. Breaks throughout the in-person interview were provided as necessary.

Measures

Estimated Intelligence

The *Matrix Reasoning* subtest of the *Wechsler Abbreviated Scale of Intelligence-Second Edition* (WASI-II; Wechsler, 2011) was used to estimate and screen for IQ. The Matrix Reasoning subtest consists of 30 items that contain a 2 x 2 matrix of a visual pattern in which one square is blank. Participants were asked to choose the piece that best completed the pattern from five options. The Matrix Reasoning subtest provides a standard score, which was used to estimate IQ.

Language

The *Metalinguistics Figurative Language* subtest of the *Clinical Evaluation of Language Fundamentals-Fifth Edition* (CELF-5; Wiig et al., 2013) was used to screen for language ability. The Metalinguistics Figurative Language subtest examines an individual's ability to identify and interpret figurative expressions (e.g., idioms) in different contexts. This subtest provides a standardized scaled score, which was used to estimate language ability.

Socioeconomic Status

Since socioeconomic status (SES) is associated with cognitive processes such as IQ (Von Stumm & Plomin, 2015), it was included in case it had to be controlled for in the analyses. The

occupation of the participant's mother and father was coded using the Blishen Scale (Blishen et al., 1987) and used as an indicator of SES. Scores on the Blishen scale range from 17.81 (newspaper carriers and vendors) to 101.74 (dentists). The higher score between the mother and father was used to represent the participant's SES.

Social Anxiety

Symptoms of SA were measured using the *Liebowitz Social Anxiety Scale Self-Report* (Liebowitz, 1987). The Liebowitz Social Anxiety Scale Self-Report is a 24-item self-report scale that is used to measure the severity of SA symptoms, focusing on fear and avoidance of social situations (Rytwinski et al., 2009). The 24 items are divided into two categories: social interaction (11 items; e.g., talking to people of authority) and public performance (13 items; e.g., working while being observed). Participants rated each item using two Likert scales ranging from 0 to 3 on the extent to which they experience fear or anxiety (0 = none to 3 = severe) and avoidance (0 = never to 3 = usually). The fear and anxiety Likert scale was used to assess cognitive symptoms of SA and the avoidance subscale was used to measure behavioural symptoms of SA. Scores for the cognitive and behavioral symptoms of SA can range from 0 to 72 and the score for overall SA ranges from 0 to 144. Higher scores indicate more severe SA symptoms; overall SA scores are categorized as low (0-29), mild (30-49), moderate (50-64), marked (65-79), severe (80-95), and very severe (>95; Liebowitz, 1987). The Liebowitz Social Anxiety Scale Self-Report has high test-retest reliability (r = .83), high internal consistency (Cronbach's α = .95), and strong convergent and discriminate validity (Baker et al., 2002).

Higher Order Theory of Mind

Higher order ToM was measured using the Happé *Strange Stories* task (Happé, 1994), which consists of 12 different types of short vignettes or stories that depict realistic everyday

situations where people say things they do not literally mean. Participants were required to demonstrate an understanding of the mental states of characters in each story. Based on pilot research (Im-Bolter et al., 2009) which showed some vignettes to be ambiguous and therefore, lack reliability (e.g., child forgetting that their classmate was at school that day), five of the 12 vignettes were omitted from the current study. The seven remaining types of vignettes were presented as follows: 1) double bluff, 2) joke, 3) misunderstanding, 4) idiom, 5) sarcasm, and 7) white lie. Each story was read out loud to the participants and also presented in print to decrease cognitive demands on memory. Afterwards, two questions were asked. The first question was a comprehension question ("Was it true what X said?") and the second question was a mental state reasoning question ("Why did X say that?").

The comprehension question assessed whether participants understood the story and was scored as correct (1) or incorrect (0). The mental state reasoning question examined higher order ToM by assessing whether the participants were able to determine the protagonist's intention. The mental state reasoning question was scored as either 0 (factually incorrect response), 1 (factually correct physical or literal response, e.g., "her hair is short"), 1.5 (factually correct responses that were not quite a mental state response but also not a physical response, e.g., "it's an expression", 2 (factually correct mental state response that indicated the thoughts, feelings, traits, or dispositions of the protagonist and included a mental state term, e.g., "He *wanted* to be funny"), and 2.5 (factually correct recursive thinking or mental states of both characters were indicated, e.g., "He *thought* it was funny and he was making a joke to his friend, who probably *thought* it was funny too"). Based on the seven vignettes given, a total ToM score of 17.5 was possible. Scores reflect the proportion of this total score.

Considering research has shown that individuals with high SA interpret neutral and

ambiguous social situations more negatively (Amin et al., 1998; Constans et al., 1999; Stopa & Clark, 2000; Voncken et al., 2003), participants with high SA may demonstrate worse ToM in contexts that are neutral and ambiguous. Vignettes from the Happé Strange Stories task were therefore categorized as being neutral and ambiguous if they contained neither positive or negative contexts and if inferencing was needed due to ambiguity surrounding characters' mental states. Of the seven Happé Strange Stories vignettes used, three were both neutral and ambiguous (joke, idiom, persuasion: ToM score of 7.5 was possible).

Interrater reliabilities of at least .80 were achieved on a sample not included in the current study before scoring of the actual study data began. Kappa coefficients for the vignettes were as follows: double bluff (k = 1.00, p < .001), joke (k = .92, p < .001), misunderstanding (k = .91, p < .001), idiom (k = .80, p < .001), sarcasm (k = 1.00, p <. 001), persuasion (k = .87, p < .001), white lie (k = .85, p < .001).

Executive Function

The *letter memory test* (Miyake et al., 2000), the *plus-minus task* (Miyake et al., 2000)**,** and the *antisaccade task* (Miyake et al., 2000; Im-Bolter et al., 2016; Im-Bolter et al., 2006) were used to measure updating, shifting, and inhibition, respectively. Each measure was found by Miyake et al. (2000) to load most highly on each aspect of EF (.63, .59, .57, respectively).

The letter memory test is a computer task comprised of 20 lists containing 5, 7, 9 or 11 letters that were serially presented for 2000 ms per letter. Participants were required to recall the last 4 letters presented from each list out loud. This ensured that updating occurred and could be detected. For example, if the letters in a list were "M, S, C, L, G, T, R", the participant needed to say "M…MS…MSC…MSCL…SCLG…CLGT…LGTR". At the end of each list, a series of questions marks appeared ("???") which indicated to the participant to repeat the last four letters

of the list again; “LGTR” from the previous example. Prior to beginning the test, participants were given practice trials on cue cards to ensure they understood the instructions. Participants completed four practice trials consisting of 5, 7, 9, and 11 letters, respectively, after which, the participants completed 16 test trials. The updating score, calculated for both the practice and test trials, reflects the proportion of successfully updated letters.

In the plus-minus task, participants were given a single piece of 8.5- x 11-inch paper that consisted of three columns of 30 two-digit numbers ranging from 10 to 99 (randomly generated without replacement). Participants were instructed to add 3 to each number in the first column and subtract 3 from each number in the second column, writing down their answer next to each number. On the third and final column, they were instructed to alternate between adding and subtracting 3 from each number; beginning with addition (i.e., add 3 to the first number, subtract 3 from the second number, and so on). Participants were instructed to complete each column as quickly and accurately as possible, however they were told they could slow down, if necessary, to minimize error. Participants were instructed when to begin each column and that their responses would be timed. Total time to complete each column was hand-timed using a digital stopwatch. The difference between the time taken to complete the third column and the average of the first and second columns was used to calculate the cost of shifting between the addition and subtraction operations.

The antisaccade task is a computer task where participants sat approximately 18 inches away from the computer with eye level at the vertical middle of the screen. All stimuli were presented at fixation; with a fixation point at the center of the screen that randomly varied in length between 1500 and 3500 ms in 250-ms intervals, followed by a blank screen for 50 ms and then a visual cue (small black box) on either side of the screen (e.g., right) for 225 ms. This was

followed by a blank screen for 50 ms after which, a target stimulus (light gray arrow pointing left, right, or up inside a open square) appeared for 100 ms on the opposite side of the screen (e.g., left) before it was masked by a grey box. Participants were told to ignore the initial visual cue (small black box), which is a reflexive response (i.e., saccade), and to look toward the opposite side of the screen (i.e., antisaccade) so they could see the direction of the arrow. Participants indicated the direction of the arrow (left, right, or up) by pressing the corresponding arrow key on a keyboard. A total of 22 practice trials and 90 target trials were presented. The location of the visual cue and the direction of the arrow was counterbalanced for all trials and was presented in a randomized order for each individual. Response latencies (in milliseconds) and accuracy of responses were recorded by the computer and the score reflected the proportion of correct responses.

Prior to completing the antisaccade task, participants completed a response mapping task in order to memorize the arrow key responses on the keyboard (left, right, up). Fixation presentation was the same as in the antisaccade task; after fixation, a 100 ms blank screen occurred followed by a light gray arrow which appeared in the center of the screen for 100 ms before it was masked by a grey box. Participants were instructed to indicate the direction of the arrow (left, right, or up) by pressing the corresponding arrow key on the keyboard. Incorrect responses were signaled by the computer by a noise. Participants completed two blocks of 18 trials each. Similar to the antisaccade task, arrow direction was counterbalanced for each block and presented randomly in each block. Response latencies (in milliseconds) and accuracy of responses were recorded by the computer and the score reflected the proportion of correct responses. Participants were required to achieve an accuracy score of at least 80% prior to moving on to the antisaccade task.

Results

Data Screening

The sample consisted of 99 participants. Prior to conducting data analyses, distributions were examined for univariate normality. Data that did not meet the criteria for univariate normality was transformed (see below for details) resulting in univariate normality and no outliers. All assumptions of each analysis conducted were met (e.g., normality, independence, absence of outliers).

Sample Characteristics

Participants had a mean age of 21.13 (*SD* = 2.98, range: 18-29 years old) of which 83 were female (84%) and 16 were male (16%). Participants had a mean estimated nonverbal IQ and language score within the average range (*M* = 99.20, *SD* = 10.31, range: 77-124 and *M* = 9.07, *SD* = 1.76, range: 5-13, respectively). All participants identified English to be their first language and on average came from middle-class backgrounds (*M* = 53.89, *SD* = 15.86, range: 23.70-101.32). The most prominent level of education achieved by a participant's parent was a college education (37.40%), followed by a university education (24.20%), high school education (22.20%), postgraduate education (14.10%), and an apprenticeship (2%). A correlation analysis indicated that age and IQ were significantly correlated to symptoms of SA. As a result, age and IQ were controlled for in relevant analyses. SES was not significantly associated with SA.

Social Anxiety

Participants displayed symptoms of overall SA, cognitive SA (e.g., fear and anxiety), and behavioural SA (e.g., avoidance) that would be considered moderate (*M* = 56.42, *M* = 29.88, *M* = 26.19, respectively). Categorically, 17.20% (17) of participants had low symptoms of SA, 29.30% (29) had mild symptoms, 18.20% (18) had moderate symptoms, 16.20% (16) had

marked symptoms, 8.10% (8) had severe symptoms, and 11.10% (11) had very severe symptoms.

Higher Order Theory of Mind

Recall that scores reflect proportions for total ToM and ToM in neutral/ambiguous contexts. Higher proportion scores indicate a better ability to accurately understand and interpret the mental states of others. Participants had a total ToM score of .70 (*SD* = .06, range: .54-.83) and a ToM score in neutral and ambiguous contexts of .65 (*SD* = .11, range: .33-.87). These scores indicate that, on average, participants are not consistently displaying mental state reasoning (i.e., proportion score of at least .80).

Executive Function

Three aspects of executive function were assessed: updating of the contents of working memory, shifting of tasks or mental sets, and inhibition of prepotent responses. On average, participants achieved a score of 29.04% (*SD* = 15.97) on the updating trials of the letter memory test and experienced a shifting cost of 22.80 seconds (*SD* = 17.76) on the plus-minus task. Participants correctly identified the arrow direction 93.03% (*SD* = 5.66) of the time on the antisaccade task, which indicates, on average, that participants had very good inhibition skills.

Relation between Executive Function and Higher Order Theory of Mind

A power analysis showed that a minimum sample size of 84 for Pearson's correlation was required to achieve 80% power for detecting a medium effect, at significance criterion of α = .05. Thus, the obtained sample size (n = 99) was sufficient. Data from the letter memory test was transformed using a square root function. Data from the antisaccade task was transformed using an arcsine square root function. Pearson's correlation coefficient was used to examine the relation between EF and ToM (see Table 1). Updating and shifting were significantly correlated

all ToM scores. Inhibition was not significantly correlated with any ToM scores. Thus, better updating of the contexts of working memory and better shifting of mental sets were associated with better total ToM and ToM in neutral/ambiguous contexts. Hypothesis one was therefore supported, in that the updating and shifting aspects of EF were associated with ToM but inhibition was not.

Table 1

Bivariate Correlations between Total ToM and ToM in Neutral/Ambiguous Contexts, and Updating, Shifting, and Inhibition (n = 99)

	Updating	Shifting	Inhibition
ToM Proportion Score			
Total	.23*	-.22*	.12
Neutral/Ambiguous Contexts	.21*	-.22*	.09

Note. *$p < .05$; Updating and Inhibition scores reflect percentage correct; Shifting score reflects seconds

Relation between Symptoms of Social Anxiety to Theory of Mind and Executive Function

Data from Liebowitz Social Anxiety Scale was transformed using a square root function. Pearson's correlation coefficient was used to examine the relation between symptoms of SA to ToM and EF. Total ToM and ToM in neutral/ambiguous contexts were not significantly correlated to symptoms of SA, with or without the effects of age and IQ (see Table 2). Similarly, aspects of EF were also not significantly associated with symptoms of SA, with or without the effects of age and IQ (see Table 3). Due to these nonsignificant associations, a regression analysis was not conducted (hypothesis 2) and comparisons of strength of associations were not made (hypothesis 3).

Table 2

Bivariate Correlations between Symptoms of SA, Total ToM, and ToM in Neutral/Ambiguous Contexts, with and without Age and IQ Partialled Out (n = 99)

	ToM: Total	ToM: Neutral/Ambiguous Contexts
SA Symptoms		
Overall	.04 (.12)	-.07 (-.02)
Cognitive	.04 (.14)	-.07 (-.02)
Behavioural	.00 (.07)	-.07 (-.02)

Note. Bivariate correlations with age and IQ partialled out are presented in parentheses; ToM scores reflect proportions.

Table 3

Bivariate Correlations between Symptoms of SA and Aspects of Executive Function, with and without Age and IQ Partialled Out (n = 99)

	Updating	Shifting	Inhibition
SA Symptoms			
Overall	-.10 (-.08)	-.08 (-.06)	.12 (.14)
Cognitive	-.08 (-.06)	-.15 (-.13)	.17 (.20)
Behavioural	-.09 (-.07)	.01 (.03)	.04 (.06)

Note. Bivariate correlations with age and IQ partialled out are presented in parentheses; Updating and Inhibition scores reflect percentage correct; Shifting score reflects seconds.

Discussion

The current study investigates the relation between SA, ToM, and EF in a sample of older adolescents and young adults. One of the four hypotheses is supported, in that updating and shifting are associated with ToM but inhibition is not. Contrary to hypotheses, ToM and aspects

of EF do not predict the severity of SA symptoms, there is no relation between symptoms of SA and ToM or aspects of EF, and ToM, specifically in neutral/ambiguous contexts, was not related to symptoms of SA.

Relation between Executive Function and Higher Order Theory of Mind

In support of our first hypothesis, our findings indicate that two aspects of EF, the ability to update the contexts of working memory (updating) and the ability to shift between tasks or mental sets (shifting), are associated with ToM (total and neutral/ambiguous). This is consistent with past research that shows updating (Fischer et al., 2017) and shifting (Ahmed & Miller, 2011; Im-Bolter et al., 2016) are associated with higher order ToM beyond early childhood. Our results suggest that individuals who are better at updating and shifting are better able to understand and reason about the mental states of others (e.g., thoughts, beliefs, desires, emotions) generally, but also specifically in neutral or ambiguous contexts. Better updating allows individuals to consistently update their working memory with recent information (e.g., verbalizations made by others) that is relevant to understanding and interpreting the mental states of others. Meanwhile, better shifting allows individuals to simultaneously consider the perspective of the self and other, proficiently shifting between the two. Thus, potential interpretations regarding the mental states of others can be taken into account making it more likely that a correct interpretation is chosen. Neutral or ambiguous contexts require greater inferencing to ascertain the mental intentions of others, which involves more cognitive processes such as updating and shifting to assist with the inferencing process in these contexts.

As expected, we find that inhibition is not associated with ToM, which is consistent with other research that has explored the relation between EF and higher order ToM in adolescents and adults (e.g., Ahmed & Miller 2011, Im-Bolter et al., 2016). Researchers have suggested that

the relation between EF and ToM may vary at different stages of development as certain aspects of EF may be become more or less important as ToM matures into adolescence and adulthood (Ahmed & Miller, 2011; Apperly et al., 2009; Im-Bolter et al., 2016). Im-Bolter et al. (2016) proposed that in early childhood, limitations in working memory or mental capacity (i.e., amount of relevant information that can be remembered at one time) create a situation where successful ToM requires inhibition in order to create space to hold information that is useful for interpreting the mental states of others. However, as individuals age, their mental capacity increases, which reduces the need to create space in their working memory (i.e., inhibition), but shifting is still required to consider possible interpretations of the mental states of others. Moreover, individuals gain more experience with ToM throughout development, which automatizes certain processes required for ToM, further decreasing the need for inhibition. Our findings support the idea that both updating and shifting remain important for ToM into adulthood and that the relation between EF and ToM changes throughout development.

Relation between Symptoms of Social Anxiety to Theory of Mind and Executive Function

Contrary to our second and third hypothesis, that ToM and all aspects of EF would predict the severity of SA symptoms and show a stronger association to cognitive versus behavioural symptoms of SA, respectively, we did not find any associations between ToM or aspects of EF and symptoms of SA. There are several possible explanations for these findings. First, in comparison to past research, the lack of relation between ToM or EF and SA could be explained by our use of a specific measure of ToM, as well as the use of empirically validated EF tasks that have been shown to mainly tap one aspect of EF. Of the limited research that exists between ToM or EF and SA, the majority have used questionable measures of ToM (e.g., Mind in the Eyes task, Movie task) and EF (e.g., Wisconsin Card Sorting Task). The more widely used

measures of ToM either do not assess mental state reasoning (e.g., Mind in the Eyes task) or measure a range of social cognitive processes including ToM (e.g., Movie task). Similarly, the EF measures typically used in this literature often assess multiple aspects of EF or other cognitive processes (e.g., planning, abstract thinking, problem-solving). This has made previous findings regarding ToM or EF and SA questionable and difficult to interpret. It is entirely possible that there is no relation between ToM or EF and SA and previous findings are a result of flawed research methodology (including failing to control for EF in the ToM and SA literature). If so, then our findings regarding ToM and SA would support the assertion that research using the Mind in the Eyes task shows emotion recognition difficulties in individuals with SA, not deficits in ToM, and that emotion recognition and ToM are separate cognitive processes as suggested by Oakley et al. (2016). Future research is needed that clarifies the relation between ToM, emotion recognition, and SA. This research should explore these relations in both nonclinical and clinical samples and include the Mind in the Eyes task, a well-established emotion recognition task, and a ToM task that measures mental state reasoning. This would help determine whether performance on the Mind in the Eyes task assesses emotion recognition or mental state reasoning and if emotion recognition and ToM are separate processes.

Second, the lack of relation between ToM or EF and SA may be explained by the characteristics of the current sample, which are mostly female and consist of undergraduate university students between the ages of 18 and 29 (late adolescence to early adulthood). It is possible no association between ToM or EF and symptoms of SA exists in females and is only evident in males. However, past research that has shown impairments in these cognitive processes tend to be demonstrated mostly by females (e.g., Washburn et al., 2016; Liang., 2018), who have a higher prevalence of SA disorder (Kessler, Chiu et al., 2005; Kessler, Berglund et al.,

2005) and level of SA (Caballo et al., 2008; 2014) compared to males. Regarding the education element, undergraduate students are regularly evaluated in performance situations (e.g., oral presentations) that tend to elicit SA. It is therefore possible that undergraduate students adapt or become accustomed to their experiences of SA or learn to function despite their levels of SA. A limitation of the Liebowitz Social Anxiety Scale used in this study, and other commonly used self-report measures of SA, are that they fail to address the distress and/or impairment associated with the symptoms of SA (Lenton-Brym et al., 2020). As such, we did not determine whether participants in our study with high symptoms of SA experience any distress or impairment regarding their SA or if their high levels of SA affect their everyday functioning. If our participants with high levels of SA do not experience any distress or impairment as a result of their SA, this could be reflected in their performance on the study tasks. Examining a sample of participants with varying education experiences would help to clarify whether practice with SA provoking situations is related to lack of impairments in ToM or EF. In addition, future research examining the relation between ToM or EF and symptoms of SA should include SA measures that examine distress and impairment associated with symptoms of SA (e.g., Ryerson Social Anxiety Scale; Lenton-Brym et al., 2020).

Third, the lack of association between ToM and SA could be due to the overall poor performance on the ToM measure (Strange Stories task) by our participants (i.e., floor effect). Performance on the Strange Stories task indicates that the participants, on average, are not using mental state reasoning to explain behavior. This suggests that participants in the current study are not able to effectively take the perspective of others and understand their mental intentions. It is possible that ToM performance was similar across symptoms of SA because the vignettes of the Strange Stories task do not reflect typical social situations where social judgement is possible

(i.e., do not provoke SA). Without the potential for social judgment and the possibility of some level of SA being provoked, participants with high SA may perform similarly to those with low SA. This might also explain why those with higher SA in our sample did not have worse ToM in neutral/ambiguous contexts as we had predicted (hypothesis four). An adapted ToM measure, similar to the Strange Stories task, that consists of vignettes or stories that provoke SA may better differentiate ToM in those with high and low SA. It is possible that SA is not related to ToM in general, but only in situations where social judgment is evident. Future research should explore the relation between ToM and symptoms of SA using this type of adapted ToM measure.

Fourth, the level of SA displayed by the participants in the current sample, on average, is moderate rather than high or at clinical levels. Previous research (e.g., Aljilchi & Nejati, 2017; Hezel & McNally, 2014; Liang, 2018) included samples of individuals with high or clinical levels of SA and compared them to individuals with low SA. It is possible that deficits in ToM and aspects of EF are only evident in individuals with high or clinical levels of SA. A certain threshold of severity with respect to symptoms of SA may therefore be required before deficits in ToM and aspects of EF might be observed. If this is the case, then the moderate symptom level of SA found in the current study sample may not be severe enough to detect difficulties in the ability to understand and reason about the mental states of others (ToM) or control and regulate one's thoughts and related actions (EF). A clinical sample may therefore provide more informative findings with respect to whether these deficits exist with SA.

A final possibility is that the hypothesis that EF would be associated with, and predict severity of, symptoms of SA was based on the faulty premise that symptoms of SA have a linear relation with all aspects of EF. It is possible that the relation between symptoms of SA and EF is actually more complex. Certain aspects of EF (updating and shifting) may have a linear relation

with symptoms of SA whereas other aspects of EF (inhibition) have a nonlinear relation. Although past research (Aljilchi & Nejati, 2017; Liang, 2018; Segal et al., 2015) has collectively shown that individuals with high levels of SA have deficits in each aspect of EF, participants in our sample with high cognitive symptoms of SA actually have better inhibition than individuals with low cognitive symptoms of SA (nonsignificant trend). Therefore, it could be that specific aspects of EF (like inhibition) on either extreme (low or high) increase specific symptoms of social anxiety. Past research examining EF and SA is limited and has not simultaneously examined all aspects of EF. This could explain why a possible nonlinear relation between symptoms of SA and aspects of EF has not been shown before. If a threshold of severity with respect to symptoms of SA is required before highly focused inhibition (i.e., overinhibiting) is observed, then the moderate symptom level of SA found in the current study sample may not be severe enough to detect it. Therefore, research is needed to examine a potential nonlinear relation between aspects of EF and symptoms of SA in a clinical sample.

Summary

In conclusion, the current study shows a relation between certain aspects of EF and ToM, supporting the idea that the association between EF and ToM changes throughout development and the need for research exploring the relation between ToM and symptoms of SA to control for EF. However, the current study showed no relation between ToM or aspects of EF and symptoms of SA in a sample of older adolescents and young adults. Due to methodological differences in the current study (focused measure of mental state reasoning, empirically validated tasks that tap one aspect of EF) compared to past studies, sample characteristics, and type of the ToM and SA measures used, it is unclear whether no relations actually exist or this is due to a lack of threshold levels of SA being reached. The amount of distress and impairment associated

with SA may also be an important factor with respect to these associations. Future research, with additional measures of ToM and SA (that incorporate impairment in daily functioning), is needed to clarify the association between ToM or EF and symptoms of SA, both in nonclinical and clinical samples. Understanding these associations would help to better inform intervention goals for SA that may differ depending on individual differences in cognitive processes. Moreover, if a nonlinear relation exists between certain aspects of EF and symptoms of SA, then intervention approaches like cognitive behavioural therapy may need to be individualized based on extremes (high or low) of executive abilities.

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