The role of executive function in childhood anxiety disorders

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Jessica Faber

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Monica Luciana, PhD, Stephanie Carlson, PhD

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Dedication

I dedicate this thesis, the culmination of my graduate studies and personal mental health struggles, to the families who inspired this work, and, most importantly, to those who renew their commitment to mental health on a daily basis. Here's to our continued mental fortitude and resilience in the face of those who deny the existence of mental health diagnoses. For those, we will strive endlessly to offer the knowledge, resources and support to foster their understanding.

Abstract

The current review examines anxiety disorders in childhood, with particular focus on mechanisms that would conceivably rely on processes supported by executive function. In accordance with the DSM-V organization, the following anxiety disorders are considered based on typical age of onset and prevalence in early childhood: separation anxiety, social anxiety, and specific phobia. Following this exploration of anxiety disorders, this review will present an overview of executive function, including normative developmental trajectory, prominent models of executive function organization, influential factors, and associations with long-term outcomes. Drawing from the research bases of executive function and psychopathology, this paper will explore potential theoretical connections between executive function and anxiety in addition to critical examination of empirical support linking executive function based skills to anxiety. In particular, the role of executive function in the maintenance of anxiety will be investigated. Intervention for anxiety will also be examined with a focus on mechanisms of change that draw upon executive function skills.

Keywords: executive function, anxiety disorders, child anxiety

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Anxiety disorders are the most common form of psychopathology in children and adolescents (Beesdo, Knappe, Dipl-Psych, & Pine, 2009; Beesdo-Baum & Knappe, 2012; Stein, Scott, de Jonge, & Kessler, 2017; Whalen, Sylvester, & Luby, 2017). Clinically significant anxiety represents a critical area of mental health to examine, as many anxiety disorders manifest in childhood as early as the preschool period and are likely to persist into adulthood if left untreated (APA, 2013; Stein et al., 2017; Whalen et al., 2017). The "lifetime prevalence of 'any anxiety disorder' in studies with children and adolescents" ranges from 15-20% (Beesdo et al., 2009, p. 5; Beesdo-Baum & Knappe, 2012; Kessler et al., 2012). This range may vary based on the measures used to assess anxiety, source of report, and cultural variations in the expression of anxiety (Beesdo et al., 2009). In addition, anxiety disorders are highly comorbid with each other as well as other mental health disorders (Stein et al., 2017). The scope of this review will include studies on trait anxiety, state anxiety, and the three most common types of anxiety disorders in early childhood: 1. separation anxiety disorder, 2. social anxiety disorder (social phobia), and 3. specific phobia, arranged according to typical age of onset as in the DSM-V (APA, 2013; Whalen et al., 2017).

Executive function (EF) encompasses higher-order based skills that enable control of thought and goal-directed action, such as resistance to interference, error detection and correction, and mental manipulation of temporarily stored information (Carlson, 2005; Carlson, Zelazo, & Faja, 2013; Diamond, 2013). Executive function emerges early and continues its developmental trajectory into early adulthood (Carlson, Zelazo, & Faja,

2013; Davidson, Amso, Anderson, & Diamond, 2006; Diamond, 2013). During this progression, childhood and adolescence represent developmentally sensitive windows for executive function. Executive function has been associated with several long-term outcomes- notably, academic achievement, socio-emotional functioning, and health (Best, Miller, & Naglieri, 2011; Diamond, 2013; Diamond & Lee, 2011).

Deficits in executive function have been linked to externalizing psychopathology, neurodevelopmental disorders, obsessive-compulsive disorders, and trauma- and stressor-related disorders in adults (Aupperle, Melrose, Stein, & Paulus, 2012; Biederman et al., 2004; Diamond, 2013; Fairchild et al., 2009; Rosenthal et al., 2013; Snyder, Kaiser, Warren, & Heller, 2015). Less well studied is the role of executive function in the context of anxiety. During the preschool years, the most commonly experienced anxiety disorders include separation anxiety, social anxiety (social phobia), and specific phobia. According to a recent review, generalized anxiety disorder (GAD) is also commonly experienced among preschoolers, although the age of onset for GAD is typically older according to other sources (Whalen et al., 2017). The remaining anxiety disorders- agoraphobia, selective mutism, and panic disorder- are beyond the scope of this paper.

Trauma and stressor-related disorders tend to have wide variability in their clinical characteristics. Although some cases can be understood from an anxiety- or fear-based perspective, according to the DSM-V the most prominent clinical features can be split into three categories: 1. anhedonia or dysphoria, 2. aggression or anger, or 3. dissociation. (APA, 2013). Due to this heterogeneous presentation, this class of disorders

was excluded from the present review of the literature available on anxiety disorders and executive function.

Additionally, following the categorization used in the DSM-5, Obsessive-Compulsive and related disorders were also excluded from the present review. While the American Psychiatric Association acknowledges the close relationships between anxiety disorders and some of the obsessive-compulsive disorders, they remain distinct from anxiety disorders, in part to reflect the clinical utility of grouping the obsessive-compulsive disorders together (APA, 2013).

While the role of executive function in externalizing disorders is extensively researched, little is known regarding the role of executive function in clinical anxiety, especially among preschoolers (Biederman et al., 2004; Whalen et al., 2017). The present review will consider deficits in broad executive function, as well as specific impairment in cognitive flexibility, working memory, and inhibitory control. Towards the potential role of executive function in the maintenance of anxiety, studies examining the role of disengagement from maladaptive anxiety, generating alternative attributions, and shifting from maladaptive cognitive distortions to adaptive counter-thoughts will be considered. In addition, studies exploring the influence of emotional stimuli on working memory capacity will be discussed, with the expectation that diminished capacity could contribute to lack of responsiveness to conventional interventions. Moreover, anxiogenic stimuli may impede an individual's ability to effectively manipulate the information under consideration, such as cognitive distortions and their counter-thoughts. With respect to

the potential influence of inhibitory control, individuals with poor inhibition may struggle with restraining maladaptive behaviors, or conversely, individuals with excessive inhibitory control may contribute to the maintenance of anxiety through an overuse of such control.

First, I will present a brief review of the four most common anxiety disorders in preschoolers, followed by an overview of executive function, including its developmental trajectory. Subsequently, I will propose a rationale for the involvement of executive function in anxiety, based on theoretical models of anxiety as well as a review of empirical evidence of executive function performance in children with anxiety. Based on availability of early childhood studies in this area, additional studies among adolescents and adults will also be considered. Furthermore, I will examine clinical interventions for anxiety with particular attention to how executive function could plausibly contribute to successful skills building from existing treatments for anxiety. Finally, I will present a perspective on the state of the field, with consideration of study limitations and future directions.

Defining Anxiety

Clinically Diagnosed Anxiety

From a broad perspective, anxiety disorders share an underlying intense anxiety, physiological symptoms, maladaptive behaviors, and corresponding impairment in daily functioning (Beesdo et al., 2009; Whalen et al., 2017). According to the DSM-V, the most prominent diagnostic classification system in the United States, prominent features

of the anxiety cluster of disorders are excessive and persistent fear or anxiety (APA, 2013). Within this framework, fear encompasses the emotional response to real or perceived imminent threat, and is more closely associated with the autonomic arousal evoked in the fight or flight response. Anxiety, however, reflects anticipation of future threat, and is more closely associated with vigilance and cautious or avoidant behaviors (APA, 2013; Kendall & Chansky, 1991). In addition to an increased perception of threat, danger, and fear, the underestimation of an individual's own ability to cope with the perceived threats drives anxiety (Kendall & Chansky, 1991). One account for persistent fear posits that anxiety stems from overgeneralization of the feared stimuli to neutral stimuli (Lissek & Grillon, 2015). Other models of anxiety point to attentional biases as being associated with anxiety disorders, including anxiety disorders in youth (Carmona et al., 2015). The role of metacognitions has also been investigated in etiology and maintenance of pathological anxiety. For example, individuals with anxiety tended to hold more negative metacognitive beliefs about the danger, suspiciousness, and uncontrollability of thoughts (Smith & Hudson, 2013). In addition, youth with clinical anxiety endorsed greater confidence in their beliefs than non-anxious youths (Smith & Hudson, 2013).

A recent review of the prevalence of anxiety disorders in preschool places a median age of onset occurring around age 6 years (Whalen et al., 2017). With onset occurring as early as preschool, separation anxiety is the most prevalent anxiety disorder in children younger than 12 years, emerging as early as 1-2 years (APA, 2013; Beesdo et

al., 2009; Gullone, 2000; Whalen et al., 2017). Onset of a diagnosis of separation anxiety is more rare in adolescence, and rarer still in adulthood (APA, 2013). According to the DSM-5, age of onset of social anxiety disorder for approximately 75% of individuals occurs between 8 and 15 years (APA, 2013; de Lijster, 2017) Typically, specific phobia develops in childhood, with a median age of onset between 7-11 years, and an average age of onset around 10 years (APA, 2013; de Lijster, 2017). Age at onset for GAD is spread over a wide range, and may take the form of anxious temperament in early childhood. The majority of GAD cases rarely occur before adulthood (APA 2013; de Lijster et al., 2017).

With regard to gender differences, females more frequently than males experience an anxiety disorder at all, develop multiple anxiety disorders, and experience earlier ages of onset (Beesdo et al., 2009; Chaplin, Gillham, & Seligman, 2009; McLean & Anderson, 2009; McLean, Asnaani, Litz & Hoffman, 2011; Stein et al., 2017; WHO, 2017). For example, females are more than twice as likely as males to present with GAD, and tend to present earlier in life compared to males (Beesdo et al., 2009). Females are also more likely to develop co-morbid internalizing disorders; in contrast, males are more likely to develop co-morbid externalizing disorders (APA, 2013; MacLean, Asnaani, Litz & Hofman, 2011; Noyes, 2001).

Amongst the anxiety disorders, the cognitive ideation and the types of objects or situations that evoke fear, anxiety, and the accompanying avoidance behaviors are what drives the differentiation (APA, 2013). Diagnoses of anxiety disorders in childhood and

adolescence are ideally based on a multimodal approach of diagnostic interviews with the child and parent, parent- and teacher-report symptom questionnaire, and direct observation of the child in anxiogenic situations (APA, 2013; Whalen et al., 2017). Assessment enables collection of data on whether the severity of an individual's fear or anxiety exceeds what is considered developmentally normative, or persists beyond developmentally appropriate periods (APA, 2013; Whalen et al., 2017).

Clinical assessments for child anxiety include the Achenbach Child Behavior Checklist Ages 6-18 (CBCL) (Achenbach & Rescorla, 2001), the Behavioral Assessment System for Children- third edition (BASC-3) (Kamphaus & Reynolds, 2015), and the Multidimensional Anxiety Scale for Children- second edition (MASC-2) (March, 2012). Other anxiety assessments include the Child and Adolescent Psychiatric Assessment (CAPA), the Preschool Age Psychiatric Assessment (PAPA) (Angold & Costello, 2000), Screen for Child Anxiety-Related Emotional Disorders (SCARED) (Monga et al., 2000), Spence Children's Anxiety Scale (Spence, 1998), Preschool Anxiety Scale (Edwards, Rapee, Kennedy, & Spence, 2010).

While there is a criterion for duration of symptoms within the DSM-V, a minimum age criterion is not listed for a clinical diagnosis. However, between adults and children, allowance of shorter duration of symptoms or fewer criteria is often seen with children (APA, 2013). For example, the duration of symptoms listed in the DSM-V is six months for both adults and children, children must only meet one criterion out of the six listed under GAD, whereas adults must meet three of the six criteria. Diagnostics for

children are complicated by reliance on verbal skills, which depending on a child's age and development, may not be at a level to express their internal experience of anxiety or their level of distress (Beesdo et al., 2009; Egger & Emde, 2011). For example, in younger children, separation anxiety is not verbalized in specific fears or worries; in contrast, once verbal skills are further developed as in older children, anxiety is expressed in terms of definite threats.

The following review of the most common anxiety disorders in early childhood is organized based on typical age of onset (Franz et al., 2013; Whalen et al., 2017). Following a developmental sequence aligns with the DSM-V and facilitates examination of the cognitive ideation that distinguishes anxiety disorders from each other. Accordingly, separation anxiety is presented first, followed by social anxiety, and specific phobia.

Separation anxiety.

Based on the DSM-V, separation anxiety is characterized by persistent and excessive worry about losing a major attachment figure, including perceived threats that would culminate in the loss of a major attachment figure, such as a car accident or medical illness. Common worries during adolescence include moving away from loved ones for college, moving, or changing schools- all of which share an underlying theme of separation from major attachment figures (APA, 2013). While separation anxiety disorder may persist into adulthood, prevalence generally declines with age (APA, 2013). Deviating from the typical gender ratio characteristic of most anxiety disorders with

higher ratio of females to males, separation anxiety is equally common in females and males.

Social anxiety disorder (social phobia).

Social Anxiety disorder is characterized by intense fear of or anxiety in social situations during which an individual is in a position to be scrutinized by others. Development of social anxiety may emerge from childhood shyness, be set in motion by a stressful or humiliating experience, or manifest gradually (APA, 2013; de Lijster, 2017). As onset in adulthood is rare, this disorder is relevant to the present focus of childhood anxiety disorders. This disorder has a prevalence rate of 7%, and is typically higher among females (between 1.5-2.2 females for every male) (APA, 2013; Asher, Asnaani, & Aderka, 2017). Similar to separation anxiety, prevalence rates for social anxiety decrease with age.

In individuals with social anxiety, the expectation is that such scrutiny will result in negative evaluations from others, such as incompetent, anxious, crazy, dirty, or unlikable. In addition, the individual feels excessive worry that he or she will exhibit visible signs of anxiety, including trembling, sweating, blushing, stumbling that will similarly engender negative evaluations by others. Within collectivistic cultures, fear of offending others and consequent rejection may also be a primary fear. Conversely, behavior that might appear socially anxious could be considered socially appropriate, for example, as showing deference to elders (APA, 2013).

An important consideration for social anxiety in differential diagnosis in children is the presence of intense anxiety in situations with peers, not just adults. Moreover, children may evince intense fear through tantrums, crying, freezing, failing to speak in social situations, or clinging to their attachment figure(s). Adolescents tend to endorse anxiety related to age-appropriate expectations, such as dating. As a result of anxiety that is disproportionate to the actual threat, children avoid or endure situations that would expose them to close examination by others. Furthermore, the fear or anxiety significantly impacts day-to-day functioning or generates clinically significant distress (APA, 2013).

Specific phobia.

Specific phobia is characterized by an intense fear or anxiety about a specific object or situation that is disproportionate to the actual danger that the phobic stimulus presents (APA, 2013). Prevalence of specific phobia increases from 5% in children to 7-9% in adults (APA, 2013; Kessler et al., 2012). Females are more frequently diagnosed than males, with a 2:1 ratio, with some variability across phobic stimuli. Of note, specific phobia that emerges in childhood or adolescence waxes and wanes, and most individuals have more than 1 phobia. In children such fear can be expressed through tantrums, freezing, crying, or clinging (APA, 2013).

Trait and State Anxiety

Across studies, one predictor of developing an anxiety disorder can be consistently found in trait anxiety. Trait anxiety captures more stable individual

differences in proneness to anxiety and has been found to be moderately heritable (Legrand, McGue, & Iacono, 1999). State anxiety, in contrast, reflects fluctuations in apprehensiveness and nervousness in response to situational stressors (Legrand et al., 1999). Of note, trait anxiety may also influence state anxiety. Specifically, individuals with greater proneness to anxiety, or trait anxiety, are more likely to appraise stimuli as negative and to respond to situational stressors with greater state anxiety in comparison to individuals with low trait anxiety (Legrand et al., 1999). In the context of development of childhood anxiety, high trait anxiety increases a child's vulnerability for a later diagnosis of anxiety disorder (Muris, Merckelbach, Schmidt, & Tierney, 1999).

Development of Childhood Anxiety

Risk Factors

In addition to trait anxiety, child temperament, personality, and neural substrates were additionally found to impact the likelihood of an anxiety disorder (Beesdo et al., 2009). In particular, behavioral inhibition, or the tendency to withdraw and avoid novel situations and unfamiliar faces, is a reliable risk factor of anxiety (Beesdo et al., 2009; Hudson & Dodd, 2012). According to a more recent path analysis, behavioral inhibition not only predicted anxiety, but also demonstrated specificity to social anxiety (Muris, van Brakel, Arntz, & Schouten, 2011). In terms of personality constructs, neuroticism and trait-anxiety both contribute to accumulative risk of anxiety disorders (Beesdo et al., 2009). Regarding neurobiological risk factors, increased sensitivity in the amygdala may also represent a risk factor for anxiety in youth (Beesdo et al., 2009).

Factors such as parental anxiety or the likelihood of anxiety in family history can contribute to a genetic vulnerability for developing the disorder (Murray, Creswell, & Cooper, 2009). This heightened vulnerability may manifest in two forms: biased information processing or behavioral inhibition. Biased information processing occurs when children of caregivers who model negative, dysfunctional cognitions (e.g., catastrophizing, overattributing threat) similarly develop these dysfunctional cognitive tendencies (Murray et al., 2009). Another study of caregiver modeling of anxious behaviors found specific, intergenerational effects, such that parent negative problem orientation and cognitive avoidance led to child negative problem orientation and cognitive avoidance, which subsequently led to child worry (Donovan, Holmes, Farrell, & Hearn, 2017).

Apart from adopting a bias for negative thinking styles, children may also learn to exhibit behavioral inhibition, or a tendency to avoid novel situations and people, rather than approaching novelty. A behaviorally inhibited child may exhibit certain behaviors that compel a caregiver to exercise greater overprotectiveness than that caregiver might have otherwise (Murray et al., 2009). This is especially likely if this bidirectional influence occurs in the context of children with higher behavioral inhibition and parents who have anxiety (Murray et al., 2009). Caregivers may also contribute to child risk for anxiety by shaping life events, for example a parent's change of significant other (Murray et al., 2009).

Behavioral Inhibition

Behavioral inhibition has been the focus of extensive research examining the developmental trajectory that culminates in an anxiety disorder (Biederman et al., 2001; Biederman et al., 1993; Degnan, Almas, & Fox, 2010; Degnan & Fox, 2007; Hirshfeld et al., 1992; Murray et al., 2009; Rosenbaum et al., 2009; White, McDermott, Degnan, Henderson, & Fox, 2011). Behavioral inhibition refers to a temperamental predisposition to exhibit fearfulness, reticence, or restraint towards unfamiliar places and unknown faces (Hirshfeld-Becker et al., 2007). A child with this trait would consistently demonstrate a pattern of fearful reactions to novel stimuli, situations, or unknown people (Hirshfeld-Becker et al., 2007). This behavior would typically be captured through laboratory observations, for example, a child's behaviors in an unfamiliar setting would be quantified and classified as inhibited or uninhibited (Biederman et al., 2001; Hirshfeld et al., 1992).

Research spanning infancy, childhood, and middle adolescence consistently points to the continuity of behavioral inhibition (Degnan & Fox, 2007; Fox, Henderson, Marshall, Nichols, & Ghera, 2005; Hudson & Dodd, 2012; Kagan & Moss, 1962; Kagan, Reznick, & Snidman, 1987; Marshall & Stevenson-Hinde, 1998). For example, infants who react negatively to novel stimuli are more likely to continue this aversion to unfamiliar stimuli in comparison to infants who do not react negatively to novel stimuli (Rothbart, 2007; Rothbart, Ahadi, Hershey, & Fisher, 2001). Similarly, in toddlers, an aversion towards novel situations or people manifests in childhood in the form of increased shyness and social reticence in comparison to non-inhibited toddlers (Fox et al.,

2005; Rubin, Burgess, & Hastings, 2002). However, a behaviorally inhibited child does not necessarily inevitably arrive at a diagnosis of anxiety disorder. Factors such as executive function can play a role in the development of anxiety disorders (White et al., 2011). Gramszlo and Woodruff-Borden (2015) posited that executive function in the role of directing emotional control and attentional control would mediate the relation between emotionally reactive temperaments and worry symptoms, linking child temperament and development of anxiety.

Executive Function

Collectively, executive function refers to the higher-order cognitive processes supported by the prefrontal cortex that enable goal-directed behavior (Carlson, Zelazo, & Faja, 2013). Such processes are generally thought to consist of inhibitory control, cognitive flexibility, and working memory, as in a prominent model proposed by Miyake and colleagues (2000). These support higher-level cognitive skills, including goal-directed problem solving, planning, and reasoning (Diamond, 2013; Gerlach, Spreng, Gilmore, & Schacter, 2011; Zelazo, Carlson, & Kesek, 2008). Inhibitory control enables individuals to withhold inappropriate responses based on situational circumstances. For example, in the context of child behavior this aspect of executive function defines a child's ability to put the brakes on their actions. Another component of these higher order skills is cognitive flexibility- an individual's capacity to shift between tasks, or shift mental sets of information (e.g., rules during a card sorting task) (Zelazo et al., 2013). To

complete the three-factor model of EF, working memory reflects the ability to hold information in mind, manipulate, and update it (Diamond, 2013).

Childhood encompasses a known period of immense prefrontal cortical development, and co-occurring rapid development of executive function skills (Anderson, 2002; Zelazo & Mueller, 2002). Although executive function appears to be less differentiated in early childhood, one compelling theory of executive function (EF) posits that in adults the involvement of each of the differentiable executive functions varies based on the nature of the task at hand (Miyake et al., 2000; Wiebe et al., 2011; Hughes, Ensor, Wilson, & Graham, 2010). Some research suggests that individual differences in executive function, including deficits, remain largely stable from late adolescence into adulthood (Biederman et al., 2007; Carlson, Mandell, & Williams, 2004; Friedman et al., 2016; Miyake & Friedman, 2012).

Additionally, executive function has been shown to play a crucial role in long-term adult outcomes, such as academic achievement, socio-emotional functioning, and health (Best et al., 2011; Diamond, 2013; Diamond & Lee, 2011; Moffitt et al., 2011). In terms of academic success, the emergence of executive function skills from as early as preschool can impact a child's ability to engage and learn within a classroom setting. The strong association of executive function skills with school success has been demonstrated in clinical populations, children experiencing homelessness, and a typically developing national sample (Best et al., 2011; Biederman, et al., 2004; Masten et al., 2012).

With the advent of developmentally sensitive measures of executive function, demonstrable advances have been shown during the preschool period (Carlson, 2005). Gains in executive function continue and become incrementally larger in toddlerhood and the preschool period (2-5 years of age), including planning, evaluation of performance, working memory capacity, cognitive shifting, and inhibition of response tendencies (Carlson et al., 2013; Diamond, 2013). With advancing age, executive function begins to differentiate into independent developmental trajectories (Wiebe et al., 2011). Taken together, the trend portrays greater unity of executive function in childhood and increased differentiation as executive function matures.

Working Memory

The ability to hold one or two things in mind has been shown to develop as early as infancy, as can be seen in an increasing ability to retain items over longer delays (Diamond, 2013). For example, infants as young as 7 to 8 months can draw upon their working memory to retrieve an object after it has been hidden (Carlson et al., 2013). From there, working memory capacity increases from age 1 to 5 years, and continues to improve throughout childhood (Diamond, 2013). Updating-specific processes are thought to consist of either a gating mechanism, preventing irrelevant, distracting stimuli from interfering or controlled retrieval of information from long-term memory in service of an individual's goal (Miyake & Friedman, 2012; Friedman & Miyake, 2004).

The ability to hold multiple pieces of information in mind or to mentally manipulate temporarily held information follows a more protracted development

(Diamond, 2013; Luciana, Conklin, Hooper, & Yarger, 2005). Luciana and colleagues (2005) found that the recall-guided action for single units of spatial information developed until 11 to 12 years while the ability to mentally manipulate many spatial units progressed until approximately 13 to 15 years. Widely used working memory tasks include the Corsi Block test, Digit Span subtest of the WAIS-V (Sequencing), and n-back tasks (Diamond, 2013).

Cognitive Flexibility

Cognitive flexibility emerges as early as 2 ½ years old (Diamond, 2013). The progression of cognitive flexibility follows a U-shaped trajectory across the lifespan, peaking in one's early 20's (Diamond, 2013; Carlson et al., 2013; Zelazo et al., 2013 SRCD Monograph). Depending on the complexity of the task, toddlers from 2 to 3 years can meet task demands of cognitive shifting. For example, in a card sorting task, the rules may alternate between sorting cards based on color (e.g., red or blue) or shape (e.g., triangle vs. circle). Generally, toddlers are able to shift their response mapping to a stimulus if the stimulus is held constant (e.g., sort cards on color only, not shape) (Diamond, 2013). While toddlers at 3 years of age could verbalize a rule switch-namely, to sort by two dimensions, color and shape, after previously sorting based on a single dimension, such as only shape- they were not able to demonstrate this mental shift in their task performance. Despite their verbalized understanding of the rule switch, they perseverated based on the first rule they learned. This resulted in poorer accuracy during

the card-sorting task, and consequently adversely impacted overall performance (Carlson et al., 2013).

Within the preschool period, the capacity to reliably shift between conflicting mental representations evolves to meet higher demands, for example, executing a rule switch in a card-sorting task (Diamond, 2013; Carlson et al., 2013). Using the dimensional change card sort task (DCCS), 4-year-olds demonstrated the ability to accurately switch between two different rules. Accordingly, the general consensus is that the ability to reliably shift between tasks develops at 4 years of age and improves moving forward (Diamond, 2013).

As children move into adolescence and adulthood, meeting demands of cognitive flexibility becomes more complex, involving costs of task switching, such as longer response latencies, (Carlson et al., 2013). Eventually, this initial increase in reaction times progresses into increased efficiency with managing task demands, such that both reaction times and performance accuracy improve.

Inhibitory Control

Inhibitory control develops in late infancy and continues to develop with age. As children enter school age and middle childhood period (6-12 years of age), continued growth in executive function skills becomes evident in improved ability to inhibit attention from distracting stimuli, selectively direct attention, mental flexibility, plan, and organize more complex problems (Carlson et al., 2013; Diamond, 2013). While accuracy in children's performance is not at the level of adults, a general trend of improved

inhibitory control is evident on tasks requiring the inhibition of prepotent responses, or go/no-go tasks such as the Grass-Snow and Day-Night Stroop tests (Carlson, 2005; Diamond, 2013; White et al., 2011). In the Grass/Snow task (Carlson & Moses, 2001) children are asked to place their hands on top of two child-sized, felt hand shapes that are positioned beneath a white card and a green card on a table. Initial task instructions are to name the color of the grass (green) and snow (white). After this round, the experimenter asks children to play a silly game in which they point to the white card when the experimenter says "grass," and point to the green card for every time that she says "snow." Children complete a practice round and 16 consecutive test trials. Performance on the Grass/Snow task is evaluated based on accuracy of their first responses. (Carlson, 2005).

Hot and Cool Executive Function

Recent conceptualizations of executive function follow a "hot" or "cool" distinction based on motivational and emotional influences. Accordingly, top down executive function processes that occur in emotional or motivational contexts are classed as "hot"; conversely, executive function carried out in emotionally neutral contexts are viewed as "cool EF" (Carlson et al., 2013). Development of hot EF in comparison to cool EF is unclear, as the evidence is mixed and task-dependent, such that hot EF appears to develop faster for some tasks (e.g., risky decision making for others) and slower on others (e.g., risky decision making for self) (Kerr & Zelazo, 2004; Zelazo & Carlson, 2012). Furthermore, individual differences in "hot" EF are more evident and more likely

to persist throughout adulthood in comparison to "cool" EF, which tends to be more tightly correlated with age (Carlson et al., 2013; Zelazo, Qu, & Mueller, 2014).

Unity and Diversity of Executive Function

Based on recent appraisals of the field of development of executive function, the nature of executive function begins as a unitary factor (Diamond, 2013; Carlson et al., 2013; Wiebe et al., 2011). As children progress in their development, executive function becomes increasingly differentiated into a dissociable, but correlated array of skills. From infancy through middle childhood, demonstrable gains in working memory, inhibitory control, and cognitive flexibility are consistently found (Conklin, Luciana, Hooper, & Yarger, 2007; Huizinga et al., 2006; Luciana et al., 2005; Luna, Garver, Urban, Lazar, & Sweeney, 2004; Luna, Padmanabhan, & O'Hearn, 2010). While inhibitory control and working memory emerge in infancy, the shifting component does not emerge until later in development, during the preschool years, mirroring the time period during which symptoms of anxiety have been noted to surface (Carlson, Faja, & Beck, 2016; Whalen et al., 2017).

Executive Function in Anxiety

Numerous studies point to a link between executive function and various mental health concerns. Neuropsychological disorders such as Attention-Deficit Hyperactivity Disorder (ADHD) and Autism Spectrum Disorder (ASD), are notable for executive function deficits (Schoechlin & Engel, 2005). Executive dysfunction has additionally been implicated in externalizing disorders, including Oppositional Defiant Disorder

(ODD) and Conduct Disorder (CD) (Clark, Prior, & Kinsella, 2002; Mayes & Calhoun, 2007).

With regards to internalizing disorders, executive dysfunction has been demonstrated in major depressive disorder (Deveney & Deldin, 2006; Fossati, Ergis, & Allilaire, 2002; Han et al., 2016; Snyder, 2013). For example, a review of executive function in unipolar depression showed that patients mainly exhibited deficits in cognitive inhibition, problem-solving, and planning (Fossati et al., 2002). Another study similarly found that deficits in inhibition were associated with depression; moreover, this study showed an association between deficits in cognitive flexibility and past depressive symptoms (Bredemeier, Warren, Berenbaum, Miller, & Heller, 2016).

Some studies have examined the role of executive function in the development and maintenance of anxiety disorders while simultaneously examining associations with depression in adults (Han et al., 2016; Kertz et al., 2016; Lundy et al., 2010). Fewer studies have examined associations between executive dysfunction in pediatric anxiety disorders. Prior to reviewing studies that associate executive function and anxiety, potential theoretical connections are explored.

Theoretical Relations Between Executive Function and Anxiety

Cognitive therapy is a widespread intervention applied to reduce symptomatology among individuals with a variety of anxiety disorders (Beck, 2005; Berry & Cooper, 2012). Uncontrollable, excessive worry is a core feature of GAD and a common symptom in other anxiety disorders. As children progress in their development, the ability

to think about future events emerges and parallels development of the prefrontal cortex. As children age, the cognitive capacity to imagine future events develops and their verbal skills advance, contributing to the ability to worry (Geronimi, Patterson, & Woodruff-Borden, 2016).

In an appraisal of the state of cognitive therapy, Beck (2005) proposed that across psychopathological disorders individuals process both internal and external stimuli through a biased lens. Accordingly, such individuals construct their experiences based off of a systematic distortion of events that subsequently produces an array of what is known as cognitive errors (Beck, 2005). Examples of cognitive errors include overgeneralization, selective abstraction, and personalization. Behind these persistent, aberrant interpretations lie dysfunctional beliefs that become assimilated into durable cognitive schemas (Beck, 2005; Beck & Clark, 1988; Clark & Beck, 2010). Once these schemas are established, they are open to activation by external events or internal factors (e.g., endocrine). Upon being activated, individuals tend to bias the information being processed and, consequently, generate cognitive content that is typical for a given disorder.

This leads to Beck's outline of the cognitive specificity hypothesis (Beck, 2005). Under this framework, specific cognitive profiles can be delineated for various psychiatric disorders. Applying the cognitive specificity hypothesis to anxiety disorders, the pervasive themes of cognitive content are threat and vulnerability. The underlying basis of a biased information-processing model is consistent with other studies examining

cognitive therapy in the context of an anxiety disorder (Berry & Cooper, 2012; Clark & Beck, 2010). In addition, the dysfunctional coping behaviors such biased processing produces, including avoidance, reinforces the harmful cycle of interpreting future events or internal stimuli as contributing to threat and vulnerability.

Avoidance of anxiogenic stimuli is a common behavioral response in clinical anxiety and is a criterion of anxiety disorders in the DSM-V (APA 2013; Salkovskis, 1991). This, in turn, contributes to functional impairment, in the case where avoidance of anxiety-related stimuli interferes with social, academic, occupational functioning. For example, a child with a phobia of wind avoids going outside on windy days, ultimately resulting in missing school, not engaging in social activities, and interfering with activities of daily living. Such avoidance may contribute to maintenance of anxiety by preventing disconfirmation of threat (Salkovskis, 1991).

The target of cognitive therapy then becomes increasing an individual's insight into these maladaptive processes. Through the high level of structure, collaboration, and problem-oriented approach built into cognitive therapy, individuals are given a space within which they may identify, monitor, and subsequently, modify maladaptive thoughts, attitudes, and beliefs. The cumulative effect would thus be to deactivate the detrimental processing biases that produce their anxiety (Clark & Beck, 2010).

Executive function may be perceived as playing a role in the maintenance of anxiety as a result of deficits in cognitive flexibility and working memory, and either an excess or deficit in inhibitory control. In addition, executive function involves goal

directed problem solving, a process that is disrupted during distress associated with symptoms of GAD (Salters-Pedneault, Roemer, Tull, Rucker, & Mennin, 2006).

An alternative account of the potential impact of executive function on anxiety asserts that anxiety did not necessarily impair the quality of performance on cognitive tasks (Eysenck, Derakshan, Santos, & Calvo, 2007). Eysenck and colleagues (2007) posited that anxiety results in a reduction of efficient use of available cognitive resources. Within this framework, efficiency refers to the amount of cognitive resources called upon to support performance accuracy (Eysenck et al., 2007). Specifically, rather than directly impacting performance effectiveness, anxiety is thought to detrimentally affect efficiency by demanding compensatory efforts to account for the loss of cognitive power occupied by anxiety (Eysenck et al., 2007). In other words, while high performance accuracy may be achieved through low or high efficiency, in the case of high efficiency, performance effectiveness is secured with minimal resources. This allows the individual to accomplish the intended task with minimal use of cognitive resources. However, in the case of low efficiency, the individual must resort to compensatory strategies, such as enhanced effort or greater processing power, in order to achieve a similar level of performance. Thus, producing the desired output with the use of compensatory strategies becomes more costly (Eysenck et al., 2007). Accordingly, individuals with high anxiety would typically expend more processing resources than those with low anxiety in order to achieve a comparable performance. While not explicitly discussed in Eysenck and colleagues'

model (2007), to better understand the relationship between performance effectiveness and efficiency, Baddeley's (2003) working memory model will be discussed.

Working memory.

As described previously, working memory involves temporarily holding information in mind and performing an operation. Under Baddeley's (2003) model, working memory consists of a phonological loop, a visuospatial sketchpad, both of which serve as temporary storage capacities, as well as a central executive. Within the central executive, control is split between automatic habits, and an attentional system. This supervisory activating system enables an individual to override habitual control (Baddeley, 2003). A deficit in the executive function component of working memory manifesting as a failure to override a schema of threat and danger could play a role in the maintenance of anxiety. An additional aspect of working memory includes updating existing information to account for newly available, potentially contradictory information. Accordingly, in the context of clinical anxiety a deficit in working memory updating could result in a constant stream of negative stimuli, such as negative self-talk or signs of threat. Moreover, failure to incorporate new information, such as non-threatening stimuli, signs of safety, positive self-talk, or counterexamples to dysfunctional cognitions, could contribute to maintaining existing anxiety (Andreotti et al., 2013; Lagatruta & Kramer, 2017).

Inhibitory control.

One compelling model proposed a gateway mechanism based on deficits in attentional control as a pathway for repetitive, negative thoughts. In this model, deficits in inhibition lead to poor attentional control, which creates a loose filter for negative thoughts. Through this dysfunctional gating mechanism, information that is negative potentiates similarly negative schemas. Subsequently, this produces negative rumination. Given that inhibition reflects the ability to intentionally restrain dominant or prepotent responses, the failure to restrain negative thoughts is viewed as a failure of inhibitory control. Thus, inhibitory control may contribute to the maintenance of anxiety when considered in the role of gating information (De Raedt & Koster, 2010).

Furthermore, when lack of inhibition leads this gating mechanism to fail, the dominant response of engaging in negative rumination becomes stronger with each episode. Of consequence, the likelihood of inducing future episodes increases, and ultimately perpetuates activation of negative ruminative processes (DeRaedt & Koster, 2010). This contrasts findings by White and colleagues (2011), which pointed to high levels of inhibitory control, as measured by the Day-Night Stroop and the Grass-Snow Stroop tests, increasing the risk of an anxiety disorder in children with high levels of behavioral inhibition. One possible explanation for the contradictory findings between the two studies could depend on the individual's developmental stage. For example, perhaps high levels of inhibitory control are associated with increased anxiety during early childhood, but with decreased anxiety in adulthood, as proposed by De Raedt and Koster (2010). Moreover, this association may only hold specifically for children with

high levels of behavioral inhibition. Alternatively, it may be that either extreme- an excess of or a deficit in- inhibitory control is responsible for the association with increased anxiety.

Executive function directs valuable cognitive resources, such as attention, towards the stimuli of interest in goal-directed thought. Criteria for determining what particular stimuli are of interest may be determined by a variety of factors, such as a given set of rules or an individual's end goal. This connection may be seen in Derryberry and Reed's (1997; 2002) studies of how trait anxiety influences an individual's capacity to direct attention. While these investigations are limited to trait anxiety rather than a diagnosed anxiety disorder based on DSM-V criteria, their findings support difficulties in the ability to direct attention as a function of anxiety (Derryberry & Reed, 1997; 2002).

Cognitive flexibility.

An important role of executive function involves monitoring conflict, both from internal and external sources, and selectively focusing attention in the face of distracters. In the context of childhood psychopathology, the use of cognitive inflexibility during this monitoring for threats may be a potential mechanism behind the maintenance of anxiety. As discussed in Gramszlo and Woodruff-Borden (2015), cognitive flexibility in typically developing children would enable a child to flexibly shift attention between confirmatory as well as disconfirmatory information related to potential threats. In the case of blocked access or deficits in cognitive flexibility, this may go awry, resulting in decreased control of attention (Carlson et al., 2013).

Due to difficulty in shifting, children would struggle to attend flexibly to both types of information. Consequently, attention would be predominantly directed to information indicative of a looming threat, creating a spotlight effect on negatively biased stimuli. Sustained attention to negative stimuli could thus be viewed as deficits in the shifting component of executive function (Kertz, Belden, Tillman, & Luby, 2016). Consequently, information that would disconfirm threat would not be attended to as well (Gramszlo & Woodruff-Borden, 2015). Deficits in cognitive flexibility would thus contribute to maintenance of anxiety by 1) preventing disengagement from threatening or negatively valenced stimuli and, 2) preventing a shift to other types of stimuli, such as non-threatening stimuli. Indeed, studies indicating increased difficulty with shifting in children with anxiety will be reviewed. In one such study, attention shifting moderated the association between behavioral inhibition assessed at 2 years of age and anxiety assessed during the preschool years (White et al., 2011). In particular, high levels of attention shifting as measured by the Dimensional Change Card Sort Task (DCCS) lowered the risk for anxiety problems in children who were high in behavioral inhibition (White et al., 2011).

Based on Beck's model, an individual with anxiety will be predisposed to disproportionately attend to negatively valenced stimuli, thereby perpetuating a cycle that locks their mentality into a continuously stressed mode. Physiological hyperarousal related to fear subsequently contributes to an increased vulnerability specific to anxiety (Beesdo et al., 2009). From this perspective, anxiety may be considered in relation to the

executive function components of inhibitory control, such as poor gating and cognitive flexibility, such as disengagement from threat-related stimuli to engagement of non-threat related stimuli. Additionally, a deficit in the executive function component of working memory, specifically, updating to take into account emergent information, could contribute to maintenance of anxiety. Failure to update would include failing to incorporate new information that would disconfirm threat.

Executive function and temperament.

Previous longitudinal studies have established temperament as a risk factor in future development of anxiety symptoms (Rapee, 2014; Wirtz, Hofmann, Riper, & Berking, 2014; Schwartz, Snidman, & Kagan, 1999). From the perspective of temperament, high levels of negative reactivity serve as a risk factor for development of pathological anxiety. In this context, executive function would play a role in the ability to inhibit attention from, and disengage (i.e., shift) from negative stimuli. Heightened emotional reactivity coupled with deficits in executive function could provide a pathway to pediatric anxiety through increased negative affect and development of worry symptoms (Beesdo et al., 2009; Gramszlo & Woodruff-Borden, 2015). Current interventions for anxiety address symptoms such as uncontrollable worry. The following section explores how Cognitive Behavioral Therapy (CBT), a widely used intervention for children and adolescents, relies on executive function based skills (James, James, Cowdrey, Soler, & Choke, 2013; James, Soler, & WEatherall, 2005; Otto, Smits, & Reese, 2004).

Cognitive Behavioral Therapy for Anxiety- Role of Executive Function

According to the National Institute of Mental Health, the earlier that treatment for anxiety is started, the more likely an individual is to benefit from therapy ("Child and Adolescent," 2017). Options available include the widely used Cognitive Behavioral Therapy (CBT), with established efficacy for children and adolescents, Acceptance and Commitment Therapy (ACT), or another form of psychotherapy. For children with clinical anxiety as young as 3 years through adolescence CBT, in particular, has been demonstrated to be especially beneficial (Donovan & March, 2014; Minde, Roy, Bezonsky, & Hashemi, 2010; Silverman & Henshaw, 2008). Accordingly, the role of executive function is principally explored in the context of CBT.

The nature of CBT is scaffolded to start with the building blocks, including understanding anxiety, the connection between emotions, thoughts, and behaviors, our body's physical symptoms of anxiety, identifying emotions, and using social cues to read emotions in ourselves and others (Kendall, 2006). Once these skills are established, the therapist then guides the child as he/she learns to practice awareness of maladaptive thoughts. With increased awareness, the program then teaches evaluating content, creating counter-thoughts, and incrementally adding steps.

As a mechanism of reducing anxiety, a core feature of CBT involves the rewriting of automatic worry thoughts, which can take the form of overgeneralizing, catastrophizing, or downer thoughts (e. g., "I'm not strong enough"). In this context, worry thoughts may be viewed as the prepotent response, thus a deficit in inhibitory

control would prevent an individual from inhibiting the automatic response of attending to worry thoughts. CBT helps to address themes of low self-efficacy, inadequate coping, or the general attitude that anxiety is too overwhelming for their skillset. Of note, such themes are emphasized as a predictor of GAD, and one study demonstrated that this prospective link points to replacing the prominence of downer thoughts with thoughts that would serve to build greater self-efficacy as a mechanism for anxiety reduction (Zainal & Newman, 2017).

Another of the goals in CBT for anxiety disorders is increasing awareness of bodily sensations, thoughts, emotions, and behaviors (Kendall, 2006). Upon establishing awareness of these CBT elements, the subsequent step is to identify anxiety related thoughts. These are then labeled as being unhelpful thoughts. Such unhelpful thoughts can then be categorized under catastrophizing thoughts or downer thoughts, for instance. In response to these unhelpful thoughts, the child and therapist collaboratively create counter-thoughts designed to combat the negativity induced by their anxious thoughts (Kendall, 2002; 2006; Pincus et al., 2008). This process calls upon working memory to self-monitor, hold an emotion, thought, and behavior in mind to draw the connection between them, mentally manipulate this information held in mind, and implement goal-directed problem solving. Over time, this becomes the overlearned, or "prepotent" response instead of engaging in negative self-talk or other dysfunctional cognitions. In this way, a component of cognitive behavior therapy can be conceptualized as rewriting an anxious individual's prepotent response of dysfunctional cognitions and maladaptive

coping mechanisms (e.g., avoidance) to more adaptive responses, such as counter-thoughts and adaptive coping skills.

Another technique integrated into CBT involves "Playing the Detective," or examining the content of anxious thoughts, evaluating their veracity, summoning evidence that counters the content of the thought, and directing attention to this counter-evidence instead of the original anxiogenic thoughts (Pincus et al., 2008). This exhaustive process is taught and practiced in session, and continued outside of clinic as homework.

One particular study demonstrated both the initial efficacy of cognitive behavior therapy immediately following treatment, as well as the continued positive effects at a six-month follow-up using a preschool-aged population (Donovan & March, 2014). In comparison to the waitlist control group, children who were diagnosed with anxiety exhibited reduced symptom expression, reduced overall internalizing behaviors, and overall increased level of functioning, (Donovan & March, 2014). Furthermore, these treatment gains were maintained six months after the intervention. In particular, the positive effects of CBT on clinical severity, anxiety symptoms, and internalizing behavior were pervasive and the majority of the sample was free of their primary diagnosis (Donovan & March, 2014).

When applied to anxiety in a community sample of elementary school-aged children, one study found that rather than a distinction based on prepotency to negative stimuli, the developmental level of a child was more strongly associated with the impact of cognitive behavior therapy (CBT), specifically in their ability to generate alternate

interpretations for events (Berry & Cooper, 2012). This practice of disengaging from one interpretation and devising an alternative would tap into the executive function component of cognitive flexibility. Of further interest, both the low anxiety and high anxiety groups exhibited the ability to modify negative self-referent cognitions, often a focal point of CBT (Berry & Cooper, 2012).

In addition to psychotherapy, research shows heightened benefit when therapy is combined with medication for anxiety, the most common of which include the class of Selective Serotonin Reuptake Inhibitor (SSRIs), benzodiazepines, and beta-blockers (DSM-V, Beesdo, 2009). However, SSRIs are generally not recommended for children, adolescents, or young adults due to the risk for suicidal ideation and behavior. As beta-blockers counteract the physical symptoms associated with the fight or flight response in anxiety, this class of medications is especially beneficial to target social anxiety or panic disorder, and accordingly may also be included in treatment for anxiety, but medications are generally not recommended for younger age groups (Whalen et al., 2017).

Empirical Connection of Executive Function to Anxiety

The present review focused on studies investigating executive function in common childhood anxiety disorders and included neuropsychological tasks that tap into executive function. Studies that focused on anxiety rather than anxiety plus a comorbid disorder were prioritized. Similarly, studies that were inclusive of children from preschool years were prioritized over adult studies.

Correlational and other non-experimental studies.

Typical population- child.

An investigation into the impact of environmental bisphenol A (BPA) exposure on executive function provides a glimpse into the incidence of anxiety and executive function development. Based on a birth cohort (n=240) that was followed until 3 years of age, Braun et al. (2011) found a negative association between BPA exposure level and parent ratings of executive function, using the Behavior Rating Inventory of Executive Function-Preschool (BRIEF-P) (Gioia, Andrews, & Isquith, 1996). Additionally, they showed positive associations between BPA level and internalizing behavior, as measured by the Behavior Assessment System for Children- 2nd edition (BASC-2). Their study found that with greater BPA exposure, anxious behavior increased and was accompanied by poor inhibitory control (β = 9.1 for girls; β = -6.3 for boys) (Braun et al., 2011). Although their study did not directly investigate the association between anxious behavior and inhibitory control, the outcomes of their investigation allowed a rare, simultaneous view into inhibitory control and anxious behavior.

Kertz and colleagues (2016) demonstrated a connection between anxiety and executive function within a longitudinal cohort of children aged 3 to 7.11 years (at baseline) (n=188). Their study revealed that cognitive deficits in executive function domains were associated with increased anxiety; moreover, this association was maintained over 7.5 years of development. Within their study, executive function was assessed using a parent questionnaire, the Behavior Rating Inventory of Executive

Function – Preschool (BRIEF-P) and Behavior Rating Inventory of Executive Function (BRIEF). In particular, they pulled the "Inhibit" and "Shift" scales, representing the ability to put the brakes on actions and the ability to move from one task to another, respectively. Thus, the inhibit scale aligns with inhibitory control, and the shift scale corresponds to cognitive flexibility. To assess symptoms of anxiety, the Preschool Age Psychiatric Assessment (PAPA) and Child and Adolescent Psychiatric Assessment (CAPA) were administered as interviews to caregivers, depending on the age of the participants. For children between ages 3 to 7.11 years, the PAPA was administered. From 8 to 8.11 years old, the CAPA was administered to caregivers only. Once participants reached 9 years of age, both children and caregivers were administered the CAPA. These assessments are based on DSM criteria for anxiety disorders.

Notably, deficits in both the "Inhibit" and "Shift" scales were associated with greater severity in anxiety over time. In particular, a deficit in the "Shift" scale at baseline (ages 3-6 years old) was significantly associated with greater anxiety severity through school age at Time 1 and Time 3.5. Similarly, deficits in inhibition taken at baseline were significantly associated with greater anxiety severity across five consecutive time points from Time 3.5 to Time 7.5 (Kertz et al., 2016). Higher baseline BRIEF Inhibit and Shift scores were not significantly associated with greater anxiety at baseline. Overall, their study pointed to the impact of early childhood executive function on future severity of anxiety up to seven years after the initial assessment wave.

In one study exploring how individual differences in executive function and anxiety influenced attention to emotional stimuli, age, poorer executive function, and higher levels of anxiety significantly predicted attention biases (Lagattuta & Kramer, 2017). Age, task instructions, and emotional valence of stimuli (pictures of faces) were examined to determine related to attention. Participants (n=173) were part of a larger, ongoing study of social cognition and future-oriented reasoning. Due to research pointing to developmental differences in control of attention based on age, child participants were divided into the four following age groups: 4-5 years, 6-7 years, 8-10 years, and adults 18 years onward. All participants completed free-viewing and directed versions of the task, during which the image they looked at first, last, and for the greatest amount of time were examined. In the directed viewing task, participants were given the instruction to look only at happy faces. Executive function was assessed in the form of a working memory subtest, Memory for Sentences, from the Stanford Binet Intelligence Scales, 4th edition and two inhibitory control tasks consisting of modified Stroop tasks.

In addition to exploring the link between attention and a negativity bias, the current study examined the link between anxiety and a negativity bias, in particular towards threat-related stimuli (Lagattuta & Kramer, 2017). To this end, individuals higher in anxiety would initially orient their attention, or first looks, last looks, and longer looks towards negative emotional faces. In particular, this effect was more pronounced for negative emotional faces with threat-relevant expressions, specifically for faces of fear or anger over faces demonstrating sadness or disgust. Broadly, performance on the

free-viewing task carried no relation to executive function. In contrast, during the directed-viewing task, individual differences in working memory and inhibitory control accounted for a substantial amount of variance, such that children and adults with stronger executive function performance were better at looking last ($\Delta R^2 = .11$, $p < 0.001$) and looking longer ($\Delta R^2 = .09$, $p < 0.001$) at happy faces. Regarding their secondary hypotheses, higher levels of anxiety predicted more first looks to angry faces during the directed viewing task ($F(4, 676) = 8.04$, $\eta^2_p = .05$).

Collectively, evidence suggests to individuals with high levels of anxiety may show poorer executive function performance compared to non-anxious individuals (Eysenck, 2007). Their study demonstrated such an association between anxiety and executive function, specifically, working memory ($r = -0.16$, $p<0.05$) as a significant predictor of last looks and attention bias, but not first looks. Strengths of their approach included the use of direct assessment of executive function; additionally, the structure of their age groups took into account the developmental gains made in executive function.

Using a cohort of n=335 children spanning 6-11 years of age, Lundy and colleagues (2010) examined associations between anxiety, depression and executive function. Within their study, anxiety was reflected in the Anxious/Depressed scale of the Child Behavior Checklist (CBCL)- parent version. Executive function was captured through Wechsler Abbreviated Scale of Intelligence (WASI) Similarities and Matrix Reasoning subtests, Trail Making Test A & B, Animal Fluency test from the Controlled Oral Word Associations Test (COWAT), and the Children's Auditory Verbal Learning

Test –second edition (CAVLT-2). Other measures included the Wechsler Intelligence Scale for Children- third edition (WISC-3) Digit Span, Coding, and Symbol Search subtests as well as the Woodcock Johnson –Revised edition.

Several negative correlations were found between Anxious/Depressed scale and the study's subtests for executive function, namely Similarities ($r=-0.11$, $p=0.05$), Matrix Reasoning ($r=-0.14$, $p=0.01$), Trails A ($r=-0.06$, $p=0.01$), and Trails B ($r=-0.15$, $p = 0.02$) (Lundy et al., 2010). The study's findings would have been stronger with the inclusion of explicit executive function assessments. While the Trail Making Tests are generally applied to capture EF, the WAIS-IV subtests (Matrix Reasoning, Similarities) are typically used to gauge abstract reasoning, fluid intelligence, and spatial and verbal reasoning, respectively. The exclusion of assessments designed to capture executive function may have reduced the strength of the observed correlations, as the measures in the study did not specifically parcel out executive function abilities.

In one study using structural equation modeling to examine executive function and anxiety in children and adolescents, both positive and negative associations were found between executive function and psychopathology (White et al., 2017). The study's sample ($n=152$) was drawn from the Philadelphia Neurodevelopmental Cohort- a community-based sample of patients seeking pediatric services at the Children's Hospital of Philadelphia (White et al., 2017). The current sample included participants with data from at least one EF task, yielding a mean age of participants of 14.23 years ($SD= 3.64$). In the sample, 52% were girls; 57% were Caucasian; 32% were African-American; and

11% were of mixed or other race. Moreover, maternal and paternal educations averaged 14.5 years (SD= 2.4) and 14.3 years (SD= 2.7), respectively. None of the participants were seeking services in psychiatry, or as part of any medical conditions that would impact brain function. Other exclusionary criteria included lack of English proficiency, as this could interfere with task completion.

Executive function was conceptualized as four components: 1. attentional vigilance, 2. response inhibition, 3. conceptual flexibility, and 4. working memory. Three EF tasks from the Penn Computerized Neurocognitive Battery were used: 1) Penn Continuous Performance Task (PCPT), 2) Penn Conditional Exclusion Test (PCET), and 3) Penn Letter N-Back Test. The PCPT measured response inhibition and attentional vigilance (sustained attention). The PCET was used as a measure of cognitive flexibility. Finally, the Penn Letter N-Back test assessed working memory. Anxiety was represented in "anxious-misery," based on previous work that grouped mental disorders into three categories: externalizing, anxious-misery, and fear. The current study also included a general psychopathology domain and a psychosis domain, for a total of five dimensional domains of mental health (White et al., 2017).

Within a community-based sample spanning 8-21 years of age, this study demonstrated associations between executive function deficits and the "anxious-misery" domain of psychopathology (White et al., 2017). In particular, a composite index of executive function was significantly related to both general psychopathology (β= -0.172) and the anxious-misery domains (β= -0.292), such that lower total scores of executive

function were associated with greater clinical symptoms (White et al., 2017). Of the five clinical domains evaluated, the anxious-misery and psychosis domains exhibited significant associations with all components of executive function (White et al., 2017). The anxious-misery domain had negative associations with attentional vigilance (β= -1.007), response inhibition (β= -0.472), conceptual flexibility (β= -0.228), working memory (β= -1.294), and general executive function (β= -0.292) (White et al., 2017).

Moreover, interaction effects between executive function and the symptom domains emerged across age and gender. Stronger executive function skills were associated with fewer symptoms in the anxious-misery domain for boys; however, better executive function in girls was associated with more anxious-misery symptomatology. Specifically, for girls, general executive function and response inhibition was associated with more anxious-misery symptoms (White et al., 2017). With regards to age, younger children showed more pronounced associations between higher general psychopathology symptoms and poor general executive function, working memory, and response inhibition. Furthermore, the positive association between cognitive flexibility and higher general psychopathology was found to be stronger in younger children. Similarly, across EF components, in younger children large associations emerged within the fear domain, such higher fear symptoms were related to higher EF.

Another study examined state anxiety, anxious/depressed domain, and executive function within an all male cohort (n=38) of 9-11 year old typically developing children. Executive function was assessed using the Trail Making test, parts A and B, as well as the

Concept Formation subtest from the Woodcock-Johnson Test of Cognitive Abilities. The concept formations test reflects a child's ability to conceptualize solutions to increasingly difficult problems that are based on abstract rules of categorization, inclusion and exclusion, including color, shape and size. The measure yields a score based on total number correct. State anxiety was assessed using the A-State scale from the STAI-C (Spielberger et al., 1973), a self-report scale that requires children to report how they generally feel. Depression was measured using the Children's Depression Inventory (Kovacs & Beck, 1977), self-report inventory of cognitive, behavioral, and neurovegetative (e.g., insomnia, loss of appetite) signs associated with depression. To determine group assignment for state anxiety, scores at or above the 67th percentile were defined as high anxiety. Participants were identified as "depressed" if their CDI score was at or above the 67th percentile; in contrast, participants were considered "non-depressed" if their score was at or below the 33rd percentile.

From this study, a correlation between state anxiety, depression, and executive function emerge. In particular, anxiety was found to be associated with performance errors, but not reaction time on executive function tasks (Emerson, Mollet, & Harrison, 2005). Both the anxious-depressed and the non-anxious/non-depressed groups required significantly less time to complete Trails A in comparison to Trails B. No significant difference in completion time was found between groups on Trails B $F(1,36)= 64.14$ ($p<0.001$). However, a group by condition interaction was shown, such that performance time on Trails B for the anxious-depressed participants was greater than the performance

time for the non-anxious, non-depressed participants, $F(1,36)= 2.80$ ($p<0.51$). Furthermore, anxious-depressed participants made significantly more errors in the mixed letter-number sequencing condition (Trails B) compared to non-anxious, non-depressed participants, $F(1, 36)= 8.93$ ($p<.003$). This points to greater difficulty with task performance when the additional component of cognitive flexibility is required, as is the case with Trails B.

Generally, across typically developing children deficits in executive function were associated with higher levels of anxiety. Few studies focused on the typical developmental trajectory in the preschool period. Moreover, some studies did not employ measures designed to directly assess executive function abilities.

Atypical population- child.

Poor inhibition may play a role in children with Generalized Anxiety Disorder (GAD) through the mechanism of cognitive avoidance. Amidst features embedded in the conceptualization of GAD, cognitive avoidance involves discriminately avoiding threatening stimuli. As framed in one study by Donovan, Holmes, & Farrell, (2016), cognitive avoidance also includes strategies that aim to suppress unwanted content. In either form, the authors posit that cognitive avoidance strategies may be applied intentionally or unintentionally. From the perspective of executive function, attention to threatening or anxiogenic stimuli may be seen as the prepotent reaction in anxious children, thus use of cognitive avoidance could be viewed as an inhibition of the prepotency to focus on such stimuli (Donovan et al., 2016).

Other studies, however, did not find significant links between anxiety on measures of cognitive switching or attention even when threat-related stimuli were used (Dalgleish et al., 2003; Kindt, Bogels, & Morren, 2003). In one such study, on a modified Stroop task comprising neutral, threat-related, and depression related content, the performance of children and adolescents between 7 to 18 years of age diagnosed with clinical anxiety (n=24) did not significantly differ in comparison to the control group (n=26) or the comparison group of individuals with clinical depression (n=19) (Dalgleish et al., 2003).

A separate study similarly did not find a threat-related attention bias in children with anxiety disorders (n=40), as reflected in non-significant differences in response latencies on an emotional Stroop task when compared to typically developing control group (n=14) (Kindt et al., 2003). Furthermore, when performance was examined between groups based on "pure" diagnoses of social phobia, separation anxiety disorder, or generalized anxiety disorder, the same study failed to find significant main effects for emotional valence, word type, or group. This suggests a lack of domain-specific processing bias based on the nature of the anxiety disorder (Kindt et al., 2003).

Across these child-based studies, findings are mixed in atypical samples. This may indicate that associations between executive function and anxiety may manifest differently in an atypical course of development. As less is known regarding the role of executive function in childhood anxiety, the following section will present findings based on an adult population.

Typical population- adult.

Beyond impacting verbal fluency, high trait anxiety was shown to impair inhibitory control performance on the emotional Stroop task in a group of female graduate students (n=40), in particular during trials with threatening words (Darvishzadeh, Aguilar-Vafaie, & Moradi, 2012). Furthermore, individuals with high trait anxiety performed significantly worse on the Wisconsin Card Sorting Task, including higher rates of perseverative responses, fewer correct sets, and greater errors in comparison to the low trait anxiety group. In addition, high anxious participants reported significantly higher mental effort than the low anxious group for the Emotional Stroop Task and the Wisconsin Card Sorting Task. Combined, these disparities in performance suggest that trait anxiety negatively relates to cognitive flexibility as well as inhibitory control (Darvishzadeh et al., 2012). Consistent with Eysenck's attentional control theory, their findings point to reduced switching processing efficiency within the high trait anxiety group, compared to the low trait anxiety group (Darvishzadeh et al., 2012). Due to the relationship between anxiety and attentional bias, greater interference in inhibitory control and cognitive switching may be seen. In a separate study, self-reported anxiety levels were not found to have a significant correlation with executive function measures in an all male undergraduate sample (Leininger & Skeel, 2012).

Atypical population-adult.

Among the adult population, one particular study explored the prospective influence an individual's executive function can exert nine years later (Zainal &

Newman, 2017). Although their study includes the use of an older adult cohort (n= 2,605, *M* = 55 years), it demonstrates that performance on executive function measures can predict both the diagnosis of Generalized Anxiety Disorder (GAD) and the severity of the diagnosis, even as far out as nine years (Zainal & Newman, 2017). Notably, their battery of neuropsychological assessments captured working memory, set shifting, and inhibition (Zainal & Newman, 2017). Inhibition, set-shifting, and working memory updating were assessed using the Stop-and-Go Switch Task. With the addition of the Backward Digit Span, Categorical Verbal Fluency, Number Series, 30-Seconds- And-Counting-Task, Zainal and Newman (2017) created a composite score for global cognition.

Tempesta and colleagues (2013) demonstrated significant performance differences in executive function associated with anxiety. Within an adult sample (n=40, 24 females) aged 20-35 years, participants were selected from an outpatient psychiatric facility based on a clinical diagnosis of Generalized Anxiety Disorder (GAD). Participants diagnosed with GAD were split into two groups: receiving pharmacotherapy (n=18, 10 females) and drug-naïve (n=22, 14 females). Inclusion criteria dictated no previous engagement of evidence-based psychotherapy. Participants in the GAD groups experienced an average duration of 8 months with a diagnosis of GAD at the time of study. Individuals with comorbid axis I disorders were excluded. Thirty-one university age and sex-matched subjects with no medical or psychiatric history, and no use of psychopharmacological drugs comprised the control group (n=31, 21 females).

All participants were administered the State-Trait Anxiety Inventory (STAI) (Spielberger & Gorsuch, 1983), the Beck Depression Inventory (BDI), and the Pittsburgh Sleep Quality Index (PSQI). Both GAD groups reported significantly higher scores than the control group on all scales. However, they did not have comorbid psychiatric diagnoses; additionally, the BDI scores were below the cut-off score for depression.

Overall, findings revealed significantly poorer performance on measures of executive function in the groups with GAD compared to the control group on three neuropsychological assessments: 1) Wisconsin Card Sorting Test (WCST), 2) Rey-Osterrieth Complex Figure Test (ROFCT), and 3) letter cancellation. Specifically, on the Wisconsin Card Sorting Test (WCST), a task of cognitive flexibility and inhibitory control, both GAD groups committed a greater number of total errors and a greater number of non-perseverative errors than controls. Higher rates of non-perseverative errors indicate greater difficulty avoiding distraction. Thus, aberrant inhibitory control might hamper the ability to ignore task-irrelevant stimuli and attend to the task at hand. A closer look revealed that the GAD group receiving pharmacotherapy made significantly more perseverative errors relative to the control group, pointing to difficulties with tracking previous responses, inhibiting incorrect responses, or disengaging from a failing strategy to shift to a novel strategy. This effect was not found between the drug naïve group and the control group.

Further performance differences emerged in the Rey-Osterrieth Complex Figure Test (ROFCT) measuring visuospatial working memory. Each of the clinically anxious

groups exhibited diminished immediate recall, suggesting poorer working memory compared to the control group. Following a longer delay before recall, the GAD group in pharmacotherapy performed significantly worse than the control group, an effect not echoed in the drug naïve GAD group. All significant differences between groups remained significant after controlling for STAI scores.

Neuropsychological performance also varied significantly between groups on the letter cancellation task. In their study, this task was used to assess inhibitory control. Task instructions are to find and mark target letters within a matrix of non-target letters under a time constraint. The GAD group in pharmacotherapy achieved significantly fewer hits (i.e., found and marked fewer target letters) in comparison to the control group, while drug-naïve GAD participants performed similarly to controls. This may be more closely related to a malfunction in an attentional-gating mechanism.

The observed variations in performance between the two GAD groups limit the generalizability of the results and preclude determination of the extent to which a shared trait (vs. treatment status) among all GAD participants drove performance. Strengths of the study include use of direct assessment of executive function through reliable and valid neuropsychological measures. Despite the small sample size, which may have contributed to lack of findings in other neuropsychological tasks, performance in the executive function tasks of participants with GAD yielded moderate to large effect sizes. Although this study sample also demonstrated significant differences in depression, as

measured by the Beck Depression Inventory (BDI), the observed differences in performance remained significant after controlling for self-ratings of depression.

Future research could examine whether neuropsychological performance in the GAD groups can be attenuated by severity of GAD, such that greater severity would correspond to greater impairment on neuropsychological measures. To heighten generalizability of the current findings, future paradigms could employ a randomized design for the GAD group. Additionally, as the letter cancellation task used to assess inhibitory control generally reflects attentional vigilance, future studies could include more conventional tasks that measure inhibitory control.

Based on the significantly poorer performance of the GAD participants on neuropsychological assessments, this study provides support for the negative association between anxiety and cognition, particularly when executive function is involved. Poorer performance accuracy among the individuals with GAD further suggests difficulty shifting between task demands. One potential mechanism may be that the worry component of anxiety diverts attentional resources from the cognitive task to a ruminative loop. Uncontrollable worry may also weaken the ability to disengage and shift from such perseverative engagement. Review of adult studies allows insight into the association between EF and anxiety, both of which emerge early and remain stable into adulthood.

One study evaluated neuropsychological impairments in Swedish citizens from age 20-64 years (Airaksinen, Larsson, & Forsell, 2005). Based on a combined sample of mixed anxiety disorders, executive function impairment as measured by the Trail Making

Test (TMT) was seen in the clinically anxious group (n=112) in comparison to a control group (n=175) (Airaksinen et al., 2005). The Trail Making Test is a test of visual attention and task switching that requires the individual to connect dots as quickly as possible while maintaining accuracy. Part B of the TMT demands a shift between numbers and letters.

Further analyses indicated that panic disorder with and without agoraphobia continued to evince impaired executive function performance above the other anxiety disorders and the control group (Airaksinen et al., 2005). Of note, each respective anxiety disorder varied dramatically in the number of individuals included in the study; accordingly, it is possible that a more evenly matched distribution of participants per anxiety disorder group would reveal executive function deficits similar to those found for panic disorder (Airaksinen et al., 2005). Furthermore, approximately half of the mixed anxiety disorders group also had comorbid diagnoses ranging from depression to substance abuse (Airaksinen et al., 2005).

A separate study examined executive function and severity of anxiety in adults with social anxiety disorder (SAD) (n=30) and typically developing controls (n=30) (Fujii et al, 2013). Participants had a mean age of 23.9 years in the SAD group, and 25.6 years in the control group. Patients were excluded if under 16 years or over 60 years of age, if they received neurotropic medication apart from SSRIs, and if they had organic brain disease. Notably, this study excluded participants with comorbid diagnosis of depression, given that memory, learning, attention, and problem solving might be

affected by depression (Biringer et al., 2005; Han et al., 2016; Kertz et al., 2016; Snyder, 2013). All participants completed the self-report version of the Liebowitz Social Anxiety Scale, the STAI, Global Assessment of Functioning (GAF) and Beck Depression Inventory- second edition (BDI-II). Executive function was assessed through the WCST, Continuous Performance Test (CPT), Trail Making Test (TMT), Word Fluency test (WFT), and the Rey Auditory Verbal Learning Test (AVLT).

Given significant group differences in BDI-II and STAI scores, both were used as covariates. In comparison to the control group, patients with SAD showed significantly poorer performance on the WCST category achievement and perseverative error. However, there were no significant differences found in TMT, WFT, CPT, and AVLT. The anxiety score from the LSAS and the GAF was significantly correlated with perseverative errors from the WCST. Additionally, the correlation between the LSAS category achievement on the WCST trended towards significance (Fujii et al., 2013).

Overall, this study points to an association between severity of anxiety disorder and executive function performance in adults. As an index of adherence to sorting cards based on criteria from the previous set despite a change in set, perseverative errors on the WCST point to cognitive rigidity. Limitations of the study included dosage of antidepressants in the patient group, which may affect cognitive function. However post-hoc analyses with patients who were drug-naïve upheld significantly worse performance on the WCST in terms of perseverative errors in comparison to controls (Fujii et al., 2013).

In an adult sample of individuals with ADHD (n=102) spanning 18 to 64 years, sluggish cognitive tempo (SCT) predicted deficits in executive function skill beyond ADHD and internalizing symptoms, where SCT refers to a cluster of symptoms that includes hypoactivity, drowsiness, day- dreaminess, lethargy, and apathy (Leikauf & Solanto, 2017). ADHD was assessed through clinical interview, while internalizing symptoms were assessed by the State - Trait Anxiety Inventory and Beck Depression Inventory. Sluggish cognitive tempo was assessed through Barkley's nine-item parent questionnaire on SCT. However, after sluggish cognitive tempo, internalizing symptoms were found to contribute unique variance to total executive function, as measured by the Barkley Deficits in Executive Functioning Scale– Children and Adolescents (BDEFS-CA) questionnaire, such that internalizing symptoms were able to predict executive function deficits beyond those accounted for by ADHD alone (Leikauf & Solanto, 2017). Yet, other studies found that clinical anxiety accounted for a minimal amount of unique variance on the trail making tests and on measures of attention (Hill, Smitherman, Pella, O'Jile, & Gouvier, 2008).

An inherent limitation of the aforementioned forays into the nature of executive function in a presentation of childhood anxiety is the lack of causality in correlational studies. Participants were either adults or taken from a study without the primary aim of examining executive function in anxiety, but rather as part of a much larger design that may impact their suitability for investigating this relationship.

Experimental studies.

Typical population - child.

Using a within-subjects design, Ng and Lee (2015) assessed trait test anxiety, state anxiety, and working memory. Participants were drawn from low to middle socioeconomic families in Singapore, (n= 128, 73 females) with an average age of 11 years. Trait anxiety was assessed with the Test Anxiety Inventory (TAI). State anxiety was represented by the change in State version of the State-Trait Anxiety Inventory for Children (STAIC) scores pre- and post-test. Participants completed a mental arithmetic task and memory recall task across a low, medium, and high working memory load in both low and high situational stress conditions (Ng & Lee, 2015). In the low stress condition, participants were told the task was not a test and they were not given performance feedback. In the high stress condition, participants were told the tasks were a test, and were given false negative performance feedback 75% of the time. Low working memory load consisted of six of the same letters. Medium load consisted of six different letters, but arranged in a consecutive order. Finally, high working memory load included six different letters in random order. Exposure to the memory load set was followed by the mental arithmetic task and a memory recall of the presented letter set. Participants were instructed to repeat the set aloud while completing a mental arithmetic problem, then they were asked to recall the letter set.

Performance outcomes included reaction time and accuracy for both tasks. Accuracy scores were used to reflect performance effectiveness, based on Eysenck's

attentional control theory (Eysenck et al., 2007). These scores were divided by reaction time to yield an index of performance efficiency (Eysenck et al., 2007). In their study, trait test anxiety was found to negatively impact working memory performance (Ng & Lee, 2015).

Trait anxiety has been shown to detrimentally impact cognitive flexibility in middle childhood and pre-adolescence. One particular study investigated the influence of trait anxiety on cognitive flexibility and affective cognitive flexibility, where affective cognitive flexibility referred to applying cognitive flexibility to emotionally laden stimuli (Marcus, Stanciu, MacLeod, Liebregts, & Visu-Petra, 2016). Participants were split into two groups of 11-12 year-old and 13-14 year-old typically developing individuals (n=112, 50 females). Each group completed a trait anxiety self-report questionnaire, the Revised Child Anxiety and Depression Scale (RCADS), and subsequently completed two computerized cognitive flexibility tasks- one with emotional stimuli and the other with non-emotional stimuli.

Using a modified version of the Flexible Item Selection Task (FIST), cognitive flexibility was reflected in response times and performance accuracy with geometric stimuli that varied on two out of three possible dimensions, specifically, shape, size, and color. A given trial would display four shapes, either square, triangle, or circle, that were either red, blue, or yellow, and of small, medium, or large size. This performance was then compared to performance on the Emotional FIST, where the stimuli consisted of emotional expressions with three dimensions- size (small, medium, large), identity

(person 1, 2, or 3), and emotional expression (happy, angry, neutral). Performance on these cognitive flexibility tasks was assessed in both response times and accuracy on flexible and non-flexible trials. Across trials, participants were instructed to match two out of four objects on one dimension then a second dimension out of three possible criteria, without advance knowledge of the criteria (i.e., color, size, shape), Flexible trials required that participants use one stimulus in both classifications, thus demanding that participants shift from the initial perspective to a different perspective using the same object. Within non-flexible trials, a stimulus item would not be used twice, precluding the need to shift between different classifications for an item (Marcus et al., 2016).

As hypothesized, older children outperformed younger children on the FIST and EM-FIST task, based on response times. Furthermore, accuracy was higher on average in the non-flexible condition in comparison to the flexible condition for both the FIST and EM-FIST tasks. Thus, the demand of shifting between alternative dimensions of the same stimulus increased task difficulty. Importantly, trait anxiety only adversely affected performance when shifting between processing emotional stimuli on alternative dimensions, or on affective cognitive flexibility (Marcus et al., 2016).

From the EM-FIST, an age group interaction with condition was also observed, such that older children showed greater cognitive flexibility than younger children. While both groups had slowed RTs in the flexible condition when compared to the non-flexible condition, the extent to which RTs slowed was greater in the younger group. Additionally, gender moderated the extent to which the flexible condition altered

performance, as hypothesized. In particular, boys showed a greater rate of RT slowing between the flexible condition and the non-flexible condition as compared to girls. Finally, higher levels of trait anxiety were observed to have longer latencies in RTs. Consistent with the authors' hypothesis under the ACT theory, trait anxiety significantly moderated the impact of flexibility condition. Specifically, the length of latency in RT in the flexible condition relative to the non-flexible condition increased in correspondence with increases in trait anxiety level on the EM-FIST (Marcus et al., 2016). There were no age-related differences in accuracy, though the direction of performance in the flexible condition relative to the non-flexible condition across age groups indicates that the task assesses development of cognitive flexibility in this age range.

With an emotionally based task, this study demonstrated that anxiety exerts the greatest degree of impairment when the demand for executive function was higher and stimuli involved processing emotional information. This is consistent with attentional control theory (ACT) (Eysenck, 2007), when taking into account how anxiety directs the attentional system to prioritize certain stimuli, thereby opening an avenue for interference from task irrelevant, but potentially anxiogenic information (i.e., emotional stimuli). Moreover, the authors point to rigid rule reiteration as a possible account of observed performance. This could also be seen as struggling with prepotent response of engaging with potentially anxiogenic stimuli, or inhibiting attention from task-irrelevant, but emotionally biased content.

This study assessed the ability to generate different perspectives towards an object or emotional content, rather than the ability to switch between task rules. The authors recommend future studies employ multiple measures of trait anxiety. This could be further modified to include multiple sources, such as teacher and/or parent report. Future studies could further these findings by investigating performance in a clinically anxious sample within a similar developmentally sensitive window to determine if performance impairment serves as a predictor of clinical anxiety. In addition, the development of the relation between affective cognitive flexibility and emotional regulation skills could be investigated in future studies, providing insight into building emotional regulation skills as an intervention.

Combined, these studies point to state and trait anxiety as influential factors with respect to EF performance, in particular, higher levels of anxiety adversely impacted working memory and cognitive flexibility. These findings occurred in the context of a typical developmental trajectory. The following section explores whether a similar pattern of performance is observed in an atypical developmental trajectory.

Atypical population - child.

Examining the impact of treating anxiety on known executive function deficits can provide another perspective into the relation between executive function and anxiety. One study explored whether treating clinical anxiety disorder ameliorated executive function impairments in children with a comorbid diagnosis of ADHD (Denis, Guay, Foldes-Busque, & BenAmor, 2016). Participants ranged from 8 to 12 years of age, and

were split into two groups: a treatment group (n= 11) and a waitlist group (n=13). Some participants in the treatment group were taking medication for ADHD, but were asked to not take the medication on the day of testing.

Within the treatment group, children were assessed at pre-treatment, post-treatment, and at 6-month follow up using the Anxiety Disorders Interview Schedule for DSM-IV: Child Version (ADIS-C), the Child Behavior Checklist (CBCL), and a battery of neuropsychological measures. To assess neuropsychological functioning, participants completed the D-KEFS Color Word Interference Test, Continuous Performance Test –II (CPT-II), the Walk Don't Walk subtest from the Test of Everyday Attention for Children (TEA-Ch), the Spatial Span and Digit Span subtests from the Wechsler Intelligence Scale for Children –Fourth Edition (WISC-IV).

At baseline, no significant differences were observed across clinical and neuropsychological assessments between the treatment and waitlist groups, with the exception of Digit Span total score. Participants in the treatment group had significantly higher scores than did the waitlist group. At post-treatment, there was no short-term effect of treatment on either cognitive deficits or behaviors associated with ADHD (Denis et al., 2016). However, children with co-morbid diagnoses of anxiety and ADHD exhibited significant effects on the D-KEFS Color Word Interference Test (CWIT). Specifically, a significant effect with a large effect size ($p=.003$, $n^2= .42$) was observed for condition 3, a measure of automatic response inhibition, such that speed of execution improved dramatically between pre- and post-treatment, as well as between pre-treatment

and at the 6-month follow up. Moreover, total number of errors decreased significantly between all measurement times, with large effect size (p=.001, n^2= .41) (Denis et al., 2016). In condition 4 of the CWIT, a measure of automatic response inhibition and flexibility, results revealed a significant effect of time, with a large effect size (p=.003, n^2=.38). Speed of execution improved significantly between pre-treatment and post-treatment, as well as between pre-treatment and 6-month follow up. No significant effects for speed were observed between post-treatment and the 6-month follow up. However, total number of errors decreased significantly between pre-treatment and the 6-month follow up, with a large effect size (p=.02, n^2= .25) (Denis et al., 2016).

With regards to long-term effects of reducing anxiety on the remaining measures, no significant effects were found on the CPT-II, which captures sustained attention and motor response inhibition. This was also true for the Walk, Don't Walk subtest, another measure of motor response inhibition. Similarly, no long-term effects were observed for Digit Span or Spatial Span, measures of verbal and spatial working memory, respectively.

This study demonstrated that treating anxiety disorder yielded significant, long-term effects at post-treatment and at 6-month follow up for automatic response inhibition and flexibility. In addition, anxiety treatment resulted in a decrease in behaviors associated with ADHD at 6-month follow up. Limitations of the study include small sample size and a limited number of non-medicated participants, precluding a rule-out of a pharmacological effect. Future studies could explore the ameliorative effects of anxiety

treatment for children with more pronounced cognitive deficits associated with ADHD (Denis et al., 2016).

These results point to a negative effect of anxiety disorders on executive function. As anxiety symptoms ameliorated, child EF performance improved in response inhibition and cognitive flexibility. Thus far, such a finding is consistent with the pattern noted in correlational studies: EF performance suffers with increased anxiety. To examine whether this anxiety exerts similar effects in adults, the following section will present findings on the role of executive function in both typical and atypical adult-based populations.

Typical population - adult.

Support for the role of anxiety in directing attention may be found in a reaction time task with a sample of undergraduate students (n=114) (Derryberry & Reed, 2002). This study examined the contribution of individual differences in attentional control for trait anxiety. The authors predicted that good attentional control would allow anxious individuals to constrain their threat-related bias when given long delays. The study paradigm captured anxiety-related threat bias using trait anxiety, attentional control, and reaction times to “safe” and “threatening” cues.

As predicted, all anxious participants exhibited the threat-related bias at short delays, but those with stronger attentional control had better success at suppressing this bias at long delays. Attentional control was found to modulate performance across both the low and high anxious groups, such that anxious individuals showed longer latency

when shifting from a hard (threatening) cue to an uncued target than the low anxious individuals. Anxious participants with poor attention were slower to disengage, or shift attention away from, threat in comparison to those with good attention (Derryberry & Reed, 2002). Moreover, this study demonstrated that anxious individuals showed stronger orientation to safe stimuli at long delays, with cues.

Another study based on a sample of undergraduate students examined the impact of trait and state anxiety on executive function performance as measured by the Trail Making Test (TMT) and verbal fluency tests, in which participants produce as many words as possible in a given category in a set amount of time (Horwitz & McCaffrey, 2008). From this study, high trait anxiety was found to have a facilitating effect under a low stress condition, but a detrimental effect under stress induced by the presence of a third party observer (Horwitz & McCaffrey, 2008). Moreover, the interaction between the observation condition and high trait anxiety individuals especially impacted performance on verbal fluency tests (Horwitz & McCaffrey, 2008). Combined, these explorations into suppression and shifting abilities reflect a pattern of worse performance on certain aspects of EF with higher anxiety.

Conclusion

State of the Field

Based on extensive research, risk factors for developing a clinical anxiety disorder include gender, child temperament, trait-anxiety, behavioral inhibition, and family history of an anxiety disorder. Insight into protective factors is less well known. Among children,

separation anxiety is most common, followed by social anxiety disorder, and specific phobia. Generalized anxiety disorder was included given the availability of studies across the most common childhood anxiety disorders. Prominent intervention programs for children, adolescents, such as the Coping Cat and Cat Project, are based on cognitive behavior therapy (CBT), which has been applied successfully with preschool children (Kendall, 2006).

Executive function skills have been shown to emerge as early as infancy and toddlerhood, with developmentally sensitive windows in early childhood and adolescence. The developmental trajectory of executive function skills emerges as a unitary factor, progresses into a two-factor model, culminating in a three-factor model in adolescence and adulthood. This three-factor model consists of an underlying common EF factor, inhibitory control, cognitive flexibility, and working memory.

Deficits in executive function skills may contribute to the etiology and maintenance of clinical anxiety disorders. Drawing from principles across Eysenck's attentional control theory, Beck's cognitive model of anxiety, and other models of anxiety (see: Donovan et al., 2017), executive function's role in directing attentional resources may play a primary role in anxiety. This effect results in a decrease in performance efficiency, especially on complex, cognitively demanding tasks.

CBT can be viewed as operating on executive function skills. For example, executive function skills support self-monitoring, updating, inhibiting maladaptive coping mechanisms, inhibiting attention to dysfunctional cognitions, dismantling dysfunctional

cognitions, and shifting mindset. Such reliance on executive function skills points to executive function impairment in the maintenance of anxiety disorders. Furthermore, an individual's level of executive function could influence their response to treatment, such that an individual with impairments in some executive function skills would struggle with meeting the cognitive demands of intervention. Other potential mechanisms of executive function may be reflected in individual differences in cognitive flexibility. For example, executive function could relate to differential abilities to disengage from rumination, and shift from maladaptive to more adaptive cognitions and emotional states. Moreover, deficits in working memory may play a role in maintenance of anxiety by failing to update with incoming information signaling safety, or non-threatening stimuli.

Based on a review of the extant body of research on the role of executive function performance in clinical anxiety amongst children and adolescents, results overall support an association between executive function and anxiety. While a couple of studies suggest otherwise, there does seem to be a link between cognitive flexibility, working memory, and inhibitory control with anxiety, including trait and clinically significant anxiety. In studies of state and trait anxiety, children high in trait anxiety overall seem to exhibit significantly poorer performance on measures of attention, shifting, flexibility, and working memory, as seen in response time on the trail making tests (Cheie, Visu-Petra, & Miclea 2012; Ng & Lee, 2016; Visu-Petra, Miclea, Cheie, & Benga, 2009). Adult studies similarly point to a connection between executive function and anxiety, establishing a precedent for anxiety impairing cognitive performance.

Likely mechanisms for the maintenance of anxiety include an attention bias for threat-related or negatively valenced emotional content, inhibition of unwanted content, generating alternative attributions, and updating to include information that would disconfirm threat. Such mechanisms may also be seen in anxiety interventions, such as CBT. This is further supported by evident amelioration of executive function deficits following treatment for anxiety.

Limitations

Notably, child studies that explore the nature of the relation between executive function and clinical anxiety disorders in children younger than 8 years are lacking. With regards to participants, wide age bands, unequal samples, mix of drug-naïve and active medication users, as well as small sample sizes represent further limitations (Emerson et al., 2005; Dalgleish et al., 2003; Kindt et al., 2003). Additionally, lack of multimodal assessments of anxiety and limited use of direct assessments designed to capture executive function further complicate these forays into anxiety and neuropsychological performance.

Future Directions

To build on the extant research base, future studies could be conducted within a younger age base of both typically developing individuals and clinically anxious children using a combination of parent report and direct assessment of executive function. Parent report of child behavior is also a widely used approach to gather insight into child anxiety and executive function. One drawback of parent report is the consistent pattern of

underestimating the presence or severity of such behaviors in their own child. Direct assessment of both anxiety and executive function would similarly address this limitation and provide a more accurate appraisal of child functioning. In studies involving undergraduate samples, anxiety and executive function were commonly assessed through self-report questionnaires, which may be influenced by social desirability and may yield associations due to method invariance. These could be complemented with direct assessment inclusive of developmentally sensitive measures of executive function for young children (Carlson, 2005).

To explore whether attention processing bias has an effect specific to the target of a given anxiety disorder, for example, themes of loss or separation from primary attachment figures in separation anxiety, further studies could draw upon larger, balanced samples of children or adolescents for the anxiety disorders of interest. With regard to capturing anxiety, findings would be strengthened by the utility of multimodal assessment tools from multiple informants, rather than a single measure of anxiety, such as the State-Trait Anxiety Inventory.

Future studies would advance understanding of executive function in childhood anxiety by employing developmentally appropriate measures for younger age groups, including preschoolers. For example, the D-KEFS has a cutoff of 8 years, while the WCST cutoff is 6.5 years. One such tool, the Minnesota Executive Functions Scale (MEFS) (Carlson & Zelazo, 2014) would enable direct assessment of EF in children as young as 2 years. By capturing executive function skills in a graded-fashion, exploration

into clinical severity of anxiety symptoms could also be permitted, allowing insight into the complex outcomes of individuals with comorbid executive function disorders and anxiety disorders. Additionally, further study is needed to explore whether better executive function skills are associated with fewer symptoms in the anxiety for boys and more symptoms for girls, as seen in one study (White et al., 2017).

At this point, research on whether EF deficits predict onset of anxiety or whether they represent an acute symptom of clinical anxiety could benefit from further exploration. Moreover, it would be interesting to determine if a dose-response relationship exists between executive function intervention and anxiety symptomatology. From a clinical intervention perspective, studies examining whether children with greater EF impairment derive the greatest benefit from therapy would be beneficial and highlight the importance of early detection. On that note, further efforts could be directed to examine whether the severity of anxiety is associated with level of cognitive performance- for example, if heightened severity corresponds to greater cognitive impairment.

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