Cognitive flexibility in young children:
the impact of arousal and temperament

by

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B.Sc. (Hons.), University of Northern British Columbia, 2011

Thesis Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Arts

in the

Educational Psychology Program

Faculty of Education

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SIMON FRASER UNIVERSITY

Summer 2015

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Date Defended/Approved: July 24, 2015

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Abstract

This study investigated the effects of arousal on cognitive flexibility of young children. Participants were 119 6-year old children. A within-subjects repeated measures experimental design was used to evaluate differences in the effect of exposure to threat and neutral stimuli under low- and high-conflict conditions. On average, children responded more accurately to threat versus neutral stimuli. Moreover, children responded slower to threat stimuli relative to neutral stimuli under low-conflict conditions; however, in high-conflict conditions, differences in reaction time response to stimuli were not statistically detectible. Children's self-reported fearfulness towards snakes and parent-report of children's general propensity to fearfulness did not moderate response to threat on the cognitive flexibility task. Findings are discussed within the framework of the bidirectional model of executive functions and the Yerkes-Dodson law.

Keywords: executive functions; arousal; young children; fearfulness; temperament

I dedicate this thesis to my beloved grandfather. His ceaseless pursuit of truth, happiness, and excellence was both inspiring and infectious.

Acknowledgements

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Chapter 1.   Introduction

Our lives frequently draw on our abilities to multi-task, switch between activities, and adapt to changing circumstances. Furthermore, we are often required to perform such tasks under emotional arousal, such as stress or excitement. Executive functions (EFs) refer to a set of cognitive processes that underlie performance on these tasks. EFs are used in the control of attention, thought, emotions and action, and include planning, inhibition, working memory and cognitive flexibility (Goldstein, Naglieri, Princiotta, & Otero, 2014). While an executive system of cognitive resources can be accessed to control emotional arousal, recent models propose that the system is also influenced by these automatic processes (Blair & Ursache, 2011). For example, emotional arousal to threat has been shown to impact cognitive flexibility in adults (Paulitzki, Risko, Oakman, & Stolz, 2008; Schimmack, 2005); however, it remains unknown whether these relations hold for young children whose executive systems are emerging (Neuenschwander, Roebers, & Blair, 2014). The present research aims to address this issue by investigating the impact of emotional arousal, specifically response to threat, on the cognitive flexibility of young children.

Three important features of Blair and Ursache's (2011) bidirectional model of executive functions highlight its relevance for present research. First, the model predicts that cognitive flexibility influences and is influenced by emotional arousal in response to threat; in this way, the relations between cognitive flexibility and emotional arousal in response to threat are bidirectional and transactional (Luu & Tucker, 2004). Second, the model is consistent with the Yerkes-Dodson (1908) principle that predicts the effect of emotional arousal, such as response to threat, on cognitive flexibility is curvilinear. Robert Yerkes and John Dodson published an article asserting that accuracy of performance increases with arousal, but only up to a certain point, at which performance begins to decline. The relationship can be best illustrated by an inverted U shape. Similarly, Blair and Ursache state that the emotional arousal facilitates performance on

EFs tasks up to a certain threshold; however, a very high level of emotional arousal has a detrimental effect on performance. Third, the model proposes temperament involves a set of predispositions to focus attention, either automatically or reflexively, and to react emotionally, either positively or negatively. Emotional reactivity serves as a source of inter-individual differences in emotional arousal (Neuenschwander et al., 2014). The latter claim is well supported in the temperament literature (Rothbart, Derryberry, & Posner, 1994; Kagan, 1994; Talge, Donzella, & Gunnar, 2008).

This study focuses on cognitive flexibility within a general executive system. Cognitive flexibility is an ability that is vital for daily functioning, as it facilitates adaptation of behaviour to fit environmental needs (Davidson, Amso, Anderson, & Diamond, 2006), and involves shifting among rules (Jacques & Zelazo, 2005). While much research has been dedicated to rule-shifting in children (Bialystok & Martin, 2004; Fisher, 2011; Davidson et al., 2006), little is known about how this process is affected by emotional arousal (Neuenschwander et al., 2014). Hence, in the present study, children's cognitive flexibility under conditions that vary in the level of threat will be explored.

An additional focus of the research is on how temperament, specifically child fearfulness, may relate to cognitive flexibility under conditions of mild threat. It is anticipated that children who are more temperamentally fearful will experience greater arousal under conditions of mild threat than those who are less temperamentally fearful and that this greater arousal may influence their cognitive flexibility.

The primary aim of the present investigation is to extend our understanding of the impact of arousal to mild threat on children's cognitive flexibility, in particular, their ability to self-regulate attention to the shifting of rules. In addition, the association between child fearfulness and cognitive flexibility under conditions of mild threat will be explored.

1.1. Cognitive Flexibility

In a broad sense, cognitive flexibility can be described as a capacity to effectively adapt one's behaviour to changing situations (Davidson et al., 2006). Cognitive flexibility underlies set-shifting and task-switching (Jacques & Zelazo, 2005), both of which are integral parts of daily life. For example, juggling simple tasks, like shifting from writing an email to answering the phone, or switching activities in the classroom, all draw on cognitive flexibility.

Cognitive flexibility interacts with multiple other cognitive processes. Attention, inhibition, working memory, and perception have all been implicated in successful performance on cognitive flexibility tasks (Ionescu, 2012). Ionescu (2012, p. 191) states that, "cognitive flexibility requires the interaction of several mechanisms […] that respond to certain environmental demands (such as rule changes) in order to achieve flexible behavior (such as solving a problem in a new way)."

Cognitive flexibility has been extensively researched in children in the context of rule-shifting. Children are typically asked to apply a set of rules as they respond to a small set of stimuli (Baker, Friedman, & Leslie, 2010). One of the most widely used measures of rule-shifting and cognitive flexibility is the Dimensional Change Card Sort (DCCS) (Zelazo, 2006). In this task, children sort stimuli according to one dimension until they are able to follow this rule successfully. In the second part of the task children are asked to sort the same stimuli according to another dimension, which results in conflicting rules (Zelazo, 2006; Wiebe, 2014). In this way, children are required to treat one stimulus in two ways. The rule switch requires them to inhibit previously relevant information, while attending to previously ignored information (Jacques, Zelazo, Kirkham, & Semcesen, 1999). Accuracy of performance after the rule switch is often all-or-none in younger children (3-5 years of age), resulting in an all-correct or incorrect pattern of responding (Wiebe, 2014). However, hindered performance, such as lower accuracy and/or slower reaction time after the rule switch is observed throughout an age spectrum of 4-45 years (Davidson et al., 2006). This is referred to as a switch cost (Diamond & Kirkham, 2005).

In summary, cognitive flexibility is a capacity to navigate changing environments, such as performing a task with changing rules. Cognitive flexibility is interrelated with a number of other cognitive processes, such as attention and inhibition (Ionescu, 2012). Performance on rule-switch tasks is marked by a switch cost, which can take the form of slower reaction time, less accurate responding, or both (Davidson et al., 2006).

1.2. Bidirectional Model of Executive Functions

Executive functions are commonly conceptualized as serving a top-down role. Top-down processing refers to higher-order functions, such as regulation of emotion or behaviour (Ochsner & Gross, 2005; Miller & Cohen, 2001). According to Miller and Cohen (2005), these cognitive resources are critical in situations that demand the individual to adapt to rapidly changing or unconventional circumstances. The bidirectional model proposes that the executive system influences, but is also influenced by emotional arousal and stress response systems (Blair & Ursache, 2011).

Gray (2004) asserts that emotions adaptively bias cognition to meet situation specific demands, "emotional states may […] convert diverse, fairly abstract contextual cues into an overall assessment of the situation and into an embodied, coordinated response, with emotion tuning the overall cognitive system to respond as effectively as possible to the situation" (p. 47). This is especially evident during decision-making and choosing between two or more conflicting alternatives. For example, university students who self-reported threat-related stress due to impending exams made choices in favour of short-term, as opposed to long-term, gains, although these decisions resulted in greater overall costs (Gray, 1999). Moreover, Gray (2001) reports that emotional reactivity affects cognition in general and EFs specifically. Evidence of this claim comes from a study where adult participants were shown a video prior to completing a verbal and nonverbal working memory task. The participants who were shown a comedy video demonstrated enhanced verbal working memory performance and participants who were shown a horror video demonstrated an enhanced spatial working memory. These findings suggest that the quality of emotional arousal (i.e., excitement versus fear) influences the working memory system in different ways.

Blair and Ursache (2011) link bottom-up and top-down perspectives in the bidirectional model of EFs and further relate these processes to self-regulation. They define self-regulation as the "volitional management of attention and arousal, including stress physiology and emotional arousal, for the purposes of goal-directed action" (p. 305). EFs support planning, impulse inhibition, and the organization of information (Naglieri & Goldstein, 2013). However, the system of EFs resources is not impervious to external influence, as demonstrated by research using stimuli to induce threat during task performance (McGlynn, Wheeler, Wilamowska, & Katz, 2008). In McGlynn et al's (2008) study, exposure to threat stimuli (i.e., photos of snakes) was found to impede performance on an EFs task for snake-fearful participants, but not snake-tolerant participants. The snake-fearful participants exhibited an attention bias, typical of anxious individuals. These findings affirm Blair and Ursache's (2011) contention that EFs and self-regulatory processes are interrelated, and influenced by emotional arousal, attention, and stress response systems. The relationship is described as bidirectional, as feedback loops connect top-down and bottom-up processes within the executive system.

1.2.1. The Yerkes-Dodson law

The Yerkes-Dodson law (1908) stresses two principles that are relevant to understanding the relations between emotional arousal and cognitive flexibility. First, arousal influences the speed of habit formation; as arousal increases, so does performance on a cognitive task, but only up to a certain threshold. Second, this trend is only observed in complex learning tasks. The Yerkes-Dodson law is represented by an inverted U shape, where the upward side of the curve characterizes the energizing effect of arousal, and the downward portion of the curve portrays impeded performance. These findings have been replicated in studies of animals (Arnsten & Goldman-Rakic, 1998); however, the principle has been less researched in humans.

Interestingly, Watters, Martin and Schreter (1997) found support for the Yerkes-Dodson law, by manipulating caffeine dosages to induce different levels of arousal. Each participant (undergraduate students) attended two sessions. Participants consumed caffeine tablets (maximum dosage was equivalent to three strong cups of coffee) in one

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of the sessions, and a placebo (vitamin B tablet comparable in size, shape, and colour) in the other. Cognitive performance was measured with numerical (counting forward and backward from initial value by a constant increment) and alphabetical (generating an alphabetical sequence from an initial letter with a particular alphabetical increment and decrement) tasks. Participants ingested caffeine tablets in between trials within each task. Dosages of caffeine reached a maximum 600 mg; however, the dosage of 400 mg resulted in optimal cognitive performance. The inverted U hypothesis was supported in the experimental, but not the placebo condition. Furthermore, research findings with geriatric populations demonstrate that mild levels of anxiety lead to improved verbal learning and memory, while extreme levels of anxiety have detrimental effects on the same processes (Bierman, Comijs, Rijmen, Jonker, & Beekman, 2007). One of the critical implications of the Yerkes-Dodson law is that higher than optimal levels of emotional arousal are detrimental to performance. This has been demonstrated repeatedly in research on cognitive flexibility in adults.

Support for the Yerkes-Dodson law also comes from neuroscience research. Arnsten's (2009) review of research on nonhuman primates and rodents showed that both noradrenaline (stress hormone) and dopamine (pleasure hormone) have an inverted U effect on EFs, where too little or too much arousal, whether positive or negative, impairs brain activity within the prefrontal cortex (Arnsten & Goldman-Rakic, 1985; Sawaguchi & Goldman-Rakic, 1991). Specifically, under conditions of fatigue and stress, firing of neurons in the prefrontal cortex during the oculomotor delayed response task, a measure of visual working memory, was changed (Funahashi, Bruce, & Goldman-Rakic, 1989). At optimal levels, both noradrenaline and dopamine serve an excitatory role and result in a state of alertness. Interestingly, mild stress levels increase dopamine release in the prefrontal cortex (Deutch & Roth, 1990). These findings indicate that at the peak of the inverted U, performance is facilitated. However, depletion or excess of noradrenaline and dopamine suppresses neuronal firing and has a detrimental effect on EFs. This captures the upward and downward curves of the inverted U.

1.3. Cognitive Flexibility, Emotional Arousal, and Emotion Regulation

According to the bidirectional model of EFs proposed by Blair and Ursache, (2011), bottom-up processing refers to automatic responding to stimuli with salient, perceptual characteristics, while top-down processing refers to management of that response (i.e., emotion regulation); however, these systems are interactive and work in tandem with each other. The efficiency of the overall system depends on the level of arousal experienced. By manipulating characteristics of stimuli, researchers are able to evaluate the influence of emotional arousal on EFs. To date, most of the research on this issue has investigated the effect of emotional arousal on attention and cognitive inhibition in adults.

The emotional Stroop task (for a review, see Williams, Mathews, & C. MacLeod, 1996) is often utilized as a measure of attention and inhibition. In the emotional Stroop task, similarly to the classic variant (Stroop, 1935), participants are asked to name the colour of the ink a word is printed in, without reading the word aloud; however, a portion of the words are potentially emotionally arousing while the remainder of the words are neutral. Emotionally arousing words are typically processed differently than neutral words; moreover, the effect produced by reading an emotionally arousing word sometimes spills onto the next trial with a neutral word (Frings, Englert, Wentura, & Bermeitinger, 2010). Specifically, participants perform slower on a neutral word following a trial featuring an emotionally arousing word.

In a study conducted by Watts, McKenna, Sharrock, & Trezise (1986), an adapted version of the emotional Stroop task was created and spider-phobic adult participants were presented with emotionally arousing words relevant to their fear, such as "crawl" and "hairy," along with fear-irrelevant words (e.g., "dizzy," "sweating"). Spider-phobic participants read the emotionally arousing words slower than non-phobic participants (Watts et al., 1986). These procedures and findings have been replicated with clinical populations (e.g., anorexia, anxiety), using emotionally arousing words relevant to the disorder in question (Williams et al., 1996).

Constantine, McNally, and Hornig (2001) designed and utilized a pictorial emotional Stroop task in which pictures of animals (i.e., snakes, bunnies, and cows) were stripped of their original colour and transformed into three categories: cyan-red, magenta-green, and yellow-blue. Undergraduate students, high and low in snake fearfulness, were required to name the colour of the filtered images. While all participants showed slower responding to emotionally arousing stimuli (i.e., snake and bunnies) than non-arousing stimuli, participants highly fearful of snakes exhibited the slowest performance in response to snake stimuli (Constantine et al., 2001). Constantine et al. suggest that emotional stimuli (positive and negative) result in Stroop interference; however, individuals with extreme levels of anxiety (participants with greatest snake fear) experience an enhanced interference effect when responding to threat stimuli.

Other studies have examined the effect of emotional arousal on the cognitive flexibility of adults. Paulitzki et al. (2008) designed a study that assessed the effects of emotional arousal on the ability of adults to switch rules within a cognitive flexibility task. Participants were presented with pictures of spiders, with a digit written on each spider's body. Participants switched attention between physical features of the spider on two tasks. On one task, they identified the texture (hairy versus smooth) of the spider's body, and on the other task, they identified the properties of the number (odd versus even) on the spider's body. The two tasks were presented in the AABB order, with two trials of the texture task followed by two trials of the number task. Participants fearful of spiders demonstrated a higher switch cost, as indicated by an increased error rate when switching from the texture task to the number task.

Schimmack (2005) presented participants with photographs that differed in level of emotional arousal potential while they were required to switch between solving math problems and identifying a location of a line (top or bottom of the screen). Photographs that elicited the strongest emotional arousal (highly unpleasant pictures and photos of attractive models), as self-reported by participants, resulted in the greatest interference on task performance by increasing the magnitude of response latencies. Interestingly, this study also utilized photographs of snakes, but these photographs did not result in significant interference with task switching. Schimmack suggests that because the photographs of snakes were rated only mildly arousing compared to other stimuli utilized

in the study, snake photographs did not create sufficient emotional arousal to interfere with performance.

Interestingly, findings from the study conducted by Schimmack (2005) did not replicate those of Constantine's et al. (2001), in spite of using similar stimuli (i.e., snakes); however, adult participants in Schimmack's (2005) study were not unusually snake-fearful and rated their arousal toward snake photographs as lower, compared to their arousal to more unpleasant photos or photos of models.

Taken together, findings from studies that have examined the impact of emotional arousal on EFs in adults suggest that when attention is directed to regulation of the emotional arousal, performance on EFs tasks declines. While the effect of emotional arousal on EFs in children has not been explored at length, a considerable body of literature exists that has investigated children's response to threat and neutral stimuli on attention tasks. If performance on EFs tasks is expected to be impacted by emotional arousal in children, as was found in studies of adults, a valuable first step would be to show that children attend differentially to threat and neutral stimuli.

Consistent with this expectation, studies that employ visual search paradigms report that reaction time to responses is faster when children search for a threat compared to a neutral target (LoBue & DeLoache, 2008; Waters & Lipp, 2008; Ohman, Flykt, & Esteves, 2001). In a series of experiments, LoBue and DeLoache (2008) presented 120 children (ages 3-5) with a modified visual search task. Participants were asked to locate one threat target (snake) among eight neutral targets (flowers, frogs, or caterpillars) or vice versa. Responses were made on a touch screen monitor. Children were faster at locating a single target, threat stimulus than a neutral stimulus, regardless of their previous experience with snakes. Employing similar methodology, Waters and Lipp (2008) replicated LoBue and DeLoache's findings with older participants (ages 9-13 years). Another study, which took into consideration children's fearfulness towards animals, reported that participants who were highly fearful of the animals represented by the threat stimuli showed facilitated search for the feared targets; however this effect was lost when participants reported a low level of fear towards the animal represented by the threat stimuli (Ohman et al., 2008). Taken together, these study findings suggest

that on average, children are more vigilant to threat stimuli relative to neutral stimuli (LoBue & DeLoache, 2008; Waters & Lipp, 2008).

1.4. Fearfulness

Child temperament can be described as "constitutionally-based individual differences in reactivity and self-regulation, in the domains of affect, activity, and attention" (Rothbart & Bates, 2006, p.100). Temperament moderates whether a situation is perceived as stressful (Schermerhorn et al., 2013; Strelau, 1995), and further accounts for inter-individual differences in emotional arousal (Rothbart, Ahadi, Hershey, & Fisher, 2001). In this way, the same stimulus can have varying effects on children: Some children may become excited, while others may feel fearful.

Fearfulness is of particular interest in the current investigation. This temperamental dimension can be defined as a "tendency to negative affect and inhibition or withdrawal in response to novelty, challenge, or signals of punishment" (Rothbart & Jones, 1998, p. 482). It has also been referred to as behavioural inhibition (Kagan, 1994; Rothbart & Jones, 1998). Fearful children are cautious toward novel objects/events, and may react to them with psychological or physical arousal, which results in an attention bias toward the object or an escape route (Rothbart et al., 1994).

Kagan (1994) describes a similar childhood profile of fearfulness. From birth, some infants are more emotionally reactive than others; these infants demonstrate high levels of fear to unfamiliar circumstances and have higher heart rates, as well as higher heart rate acceleration to novel stimuli (Kagan, 1994). They are thought to have inherited a lower threshold for arousal (Kagan, 1994), which activates the emotion, attention, and stress response systems. Findings from a study conducted by Talge et al. (2008) affirmed that fearful children (3-5 years old), according to parental report on the Child Behavior Questionnaire (CBQ; Rothbart, Ahadi, Hershey, & Fisher, 2001), have greater fear reactivity, as demonstrated by higher cortisol levels, during novel situations (approach of a stranger, novel room).

To date, few studies on the relations between temperament and emotional arousal on EFs are available. Neuenschwander, Roebers, and Blair (2014) randomly assigned children from two age groups (four years old and six years old) into a control and an experimental group. In the experimental group, mild arousal was induced in the form of the social evaluation threat (i.e., "All the other children did an excellent job and now we will see how good you are", p. 196). All children completed four measures of EFs: Go/no go (Archibald & Kerns, 1999), Flanker (Eriksen & Eriksen, 1974), Backwards colour recall (Schmid, Zoelch, & Roebers, 2008), and Fruit Stroop task (Archibald & Kerns, 1999). Child temperament was assessed through parent-report on the CBQ (Rothbart et al., 2001). The researchers focused on three subscales: Inhibitory Control, Attentional Focusing, and Fear. The level of arousal of children in response to statements that represented social evaluation threat was self-reported. The findings reported by Neuenschwander and his colleagues (2014) revealed no main effect of social evaluation threat on EFs between the groups of children. The authors suggest that the emotional arousal in response to threat of social evaluation may not have been potent enough to cause a significant effect.

Schwartz, Snidman, & Kagan, (1996) demonstrated that adolescents, who were inhibited as children, exhibited the longest response latencies on threatening words during a Stroop task (1935). Participants in this study were 74 adolescents (mean age was 13.03), who were classified as either inhibited or uninhibited at 21 or 31 months of age. Participants were presented with threat (e.g., fail, worry, snake), neutral (e.g., dash, museum, wash), and positive (e.g., smile, sunny, candy) words during a Stroop task. While participants performed almost identically on the neutral words, responding to threat words was significantly slower in the inhibited group, when compared to the uninhibited group. This study demonstrates both the stability of temperament over time and the detrimental effects of emotional arousal on attention and inhibition processes in adolescents with inhibited temperament.

1.5. Current Investigation

The current study aims to further investigate whether arousal to mild threat impacts cognitive flexibility in young children. Moreover, a second aim of the research is to determine whether a fearful temperament influences young children's performance on a cognitive flexibility task. The specific research questions and hypotheses are as follows.

One question asks whether exposure to mild threat impacts children's cognitive flexibility. In accordance with previous research on threat and cognitive flexibility (Paulitzki et al., 2008), children's performance on a cognitive flexibility task is expected to be less accurate and less efficient (slower) in the presence of stimuli that represent a mild threat, compared to stimuli that represent no appreciable threat.

A second question addresses whether cognitive flexibility under conditions of threat is affected by the level of self-reported, specific fear toward threat stimuli or by children's general propensity to fearfulness. Previous research demonstrates that performance on cognitive flexibility tasks is highly variable, depending on the level of arousal experienced. Participants extremely fearful of threatening stimuli (i.e., snakes) exhibit the slowest performance (Constantine's et al., 2001), while participants who report mild levels of fear appear unaffected (Schimmack, 2005). Furthermore, as highly fearful children have been demonstrated to exhibit a bias toward threatening stimuli (Rothbart et al., 1994), and are at-risk for higher stress reactivity (Kagan, 1994), it seems plausible that such characteristics will also affect the accuracy and efficiency of rule-shifting under conditions of threat. Consequently, a negative association is anticipated between children's reported levels of specific fear toward the threatening stimuli and cognitive flexibility. Also, parental reports of children's fearfulness are expected to be negatively associated with cognitive flexibility under conditions of threat. This association is expected to reduce to non-statistically detectible under conditions of no appreciable threat.

Chapter 2.   Method

The literature on the bidirectional influence of children's fearfulness on executive functions discussed in the introduction led to the hypothesis that children's cognitive flexibility will be reduced in the face of a mild- to moderate threat compared to no appreciable threat. The Child Emotional Cognitive Flexibility Task (ECFT) permits the testing of this hypothesis.   A second hypothesis states that children's level of fearfulness, as reported by either parents or children themselves will be negatively associated with their cognitive flexibility in the presence of a mild- to moderate level of threat. The adequacy of this hypothesis can be tested by computing correlations between children's self- or parent- report of fearfulness and children's cognitive flexibility on the ECFT.

2.1. Participants

The participants were 119 children (66 male) between the ages of 5.9 and 7.2 years (M = 6.3; SD = 0.3). Children were recruited from neighbourhood community centres, local aquariums and science centres, public and private schools, and after-school care programs in Greater Vancouver, a large metropolitan area in Western Canada. The final sample included children whose families lived in culturally diverse neighbourhoods that were representative of a range of socio-economic status (low – middle – high). The children's languages of origin reflected the language diversity in this region of Canada (Statistics Canada, 2012) where the majority of families (57%) identify English as the language spoken in their home, 7.2% speak French, 13.6% speak Cantonese, 9.4% speak Mandarin, and 3.5% speak Spanish. As shown in Table 2.1, the language diversity among children selected for participation in the study is representative of the general linguistic diversity described by census data. The sample consisted of 50 monolingual, English speaking children (42% of sample) and 69 multilingual children (57.9% of total sample). French was also spoken in 11 families

(9.2% of total sample). The most common non-official languages spoken by children in the study were Mandarin (24.4%), Cantonese (13.4%), Japanese (4.2%), and Spanish (4.2%).

All sample children had conversational competencies in spoken English; however, average performance of children on a standardized measure of English vocabulary knowledge fell at the low end of the average range (*SS* = 8.4; *SD* = 2.15) compared to age norms. This relatively low English vocabulary score is consistent with previous research that suggests multilingual children typically score lower on norm-referenced vocabulary measures than their native-speaking age peers in each of their languages (Bialystok & Feng, 2009). The six children who scored more than 1.5 standard deviations below the mean on the Vocabulary measure had no exposure to the English language until after the age of 18 months, and English is not the primary language spoken in their homes. Average performance of children in the sample on a measure of visual fluid reasoning fell in the mid-average range (*SS* = 11.8; *SD* = 3.54) relative to age-norms.

Table 2-1.   **Sample characteristics.**

Characteristic	N	%
Sex		
Male	66	55.5
Female	53	44.5
Handedness		
Right	108	90.8
Left	5	4.2
Primary Language in the Home		
Monolingual English	50	42.0
Multilingual	68	57.9
Languages Spoken by Child		
English	119	100
Mandarin	29	24.4
Cantonese	16	13.4
French	11	9.2
Japanese	5	4.2
Spanish	5	4.2
Other	14	11.8
Parents' Level of Education		
Elementary School	3	1.3
High School	29	12.6
Technical School	50	21.7
Bachelor's Degree	113	49.1
Master's Degree	28	12.2
PhD	5	2.2

Note. Percentage estimates in each categorical description do not add up to 100% due to missing data.

2.2. Measures

2.2.1. The Child Emotional Cognitive Flexibility Task (ECFT)

Stimuli. Caution toward snakes is theorized as an evolutionarily adaptive response to threat (LoBue & Rakison, 2013). It follows that snakes represent a common childhood fear (Muris, Merckelbach, & Collaris, 1997), and in the present study, photographs of snakes were utilized as stimuli that represent a mild- to moderate threat to children. Images of snakes have been studied thoroughly in literature and have been shown to elicit arousal in adults (Waters, Lipp, Randhawa, 2011), children (Waters, Lipp, & Spence, 2004), and primates (Shibasaki & Kawai, 2009). Infants as young as nine months of age, respond with more alertness and a higher heart rate to snake stimuli, when played sounds of ancient threats (e.g., snake hissing), modern threats (e.g., exploding bomb), and positive sounds (e.g., child laughter; Erlich, Lipp, & Slaughter, 2013). Photographs of snakes have been shown to capture more attention and are processed faster compared to non-fear-relevant stimuli (Flykt, Esteves, & Ohman, 2007). Neuroscientific studies also reveal that photographs of snakes draw greater attention than photographs of other animals or objects (LoBue & Rakison, 2013).

The stimuli used in the ECFT were modeled after the stimuli used in a series of studies conducted by Lipp and Waters (2007), with the authors' permission. In this program of research, photographs of birds and snakes were used to investigate attention capture (i.e., preferentially drawn attention to a particular stimuli, which may disrupt other processing) in the presence of threat. Birds are commonly used to represent neutral, non-fear-relevant stimuli and snakes are used to represent threat stimuli (Lipp & Waters, 2007). Purkis and Lipp (2009) found individuals between the ages of 17 to 42 years rated birds as more pleasant and less feared in comparison to snakes, spiders, dogs, and fish. Images of birds and snakes for the ECFT were retrieved from a Google Image search. Images were matched on size (260x195 pixels), colour resolution, and the direction the animal faced.

A target array on the ECFT was a horizontal row of either two orange birds, two orange snakes, an orange bird and a yellow bird, or an orange snake and a yellow

snake. First, in the Habituation phase of the ECFT, children were to respond with a right button press if two orange birds appeared on the screen and with a left button press if two orange snakes appeared on the screen. The purpose of the Habituation phase was to ensure that children's pre-potent response to the presence of two orange birds or two orange snakes was to make a right or left button press, respectively. This phase required cognitive flexibility to move between two "novel" rules. After completing the Habituation phase, the two rules were considered "familiar and well-practiced" rules. Next, the Conflict phase of the ECFT was administered. Children were to respond to the two familiar rules previously practiced in the Habituation phase and to two, additional novel, unfamiliar rules. The two new rules in the Conflict phase were signalled by the presence of a yellow snake or a yellow bird. When a yellow bird was shown with an orange bird, or a yellow snake was paired with an orange snake, children were to respond with a button press that was opposite to the one previously learned when they saw two orange birds or orange snakes together. Children made a button press to the left when they saw a yellow bird and an orange bird together on the screen, and they responded with a button press to the right when they saw a yellow snake with an orange snake on the screen. Retrieval of stable representations of the two familiar, and practiced rules in long term memory was expected to be more fluid compared to retrieval of partially formed representations of novel rules in long term memory. Moreover, when responding to a new rule where a yellow bird was paired with an orange bird or a yellow snake was paired with an orange snake, children had to inhibit this fluid, pre-potent response to orange snakes and orange birds. The level of conflict, or the need to inhibit a pre-potent response was greater when responding to two novel rules compared to responding to two familiar rules. Therefore, "high conflict" and "low conflict" conditions were created, based on whether children were responding to unfamiliar or familiar rules, respectively.

The ECFT was programmed in E-Prime software (Schneider, Eschman, & Zuccolotto, 2002) and presented on an ASUS Zenbook laptop (screen size = 33.78 cm). Reponses on the task were indicated via an Xbox 360 console. Each stimulus subtended 1.14 degrees of visual angle and the contours of the adjacent stimuli were separated by 0.22 degrees. The sets of snake or bird stimuli subtended a total of 3.43

degrees. Trials with an array of target stimuli were preceded by a trial with a fixation cross.

ECFT procedures. Each child completed the Habituation and Conflict phases of the ECFT on an Asus Laptop computer. Two children completed the experimental sessions at a time, facing away from each other, with the researcher seated between them. Children held the X-box controller in one hand, with their index finger from each hand placed on the corresponding top left and right buttons. Each administration of the ECFT began with the researcher modeling the button press on the Xbox controller and having children push the buttons to ensure that they were able to flexibly use both the left and right button press without difficulty or confusion. At the beginning of the practice session in the Habituation phase, children were told, "We are going to play a game where we will feed birds and snakes. When you see two orange birds, you will feed them food from this circle bowl by pressing this button (experimenter points to the left button). When you see two orange snakes, you will feed them food from this star bowl by pressing this button (researcher points to the right button)." The researcher modelled making an accurate button press response to threat stimuli and to neutral stimuli. Then, a practice trial with two orange birds and a trial with two orange snakes were presented one at a time to illustrate the two rules that guided a left or right button press on the Xbox controller. Children were then given an opportunity to complete eight practice trials with encouragement and feedback from the researcher. If a child responded incorrectly to one or more practice trials, the complete set of eight practice trials was repeated again. A similar procedure was followed during the practice component of the Conflict phase. Once children were able to respond accurately to all eight practice trials in either the Habituation phase or the Conflict phase, the experimental trials in each phase were presented. The Habituation phase and Conflict phase were presented in fixed order.

A session of the ECFT consisted of 16 practice trials and two blocks of 20 experimental trials in each block within the Habitation phase and four blocks of 20 experimental trials in each block within the Conflict phase (total: 132 trials). In the Habituation phase, each trial represented one of two levels of threat (threat, neutral) in random order. In the Conflict phase, each trial represented one of four conditions in

equal proportions and in random order: two levels of threat (threat, neutral) x two levels of conflict (high, low). Accuracy and reaction time (RT) were recorded.

As illustrated in Figure 2.1, each trial in the Habituation phase began with a blank screen for a period of 500 milliseconds (ms) followed by the brief presentation of a fixation cue for 500 ms. Target stimuli then appeared and children responded by pressing either the right or left top button on the Xbox console. The two stimuli remained on the screen for a maximum of 1500 ms or until a response was made. Accuracy and response time for each trial were recorded.
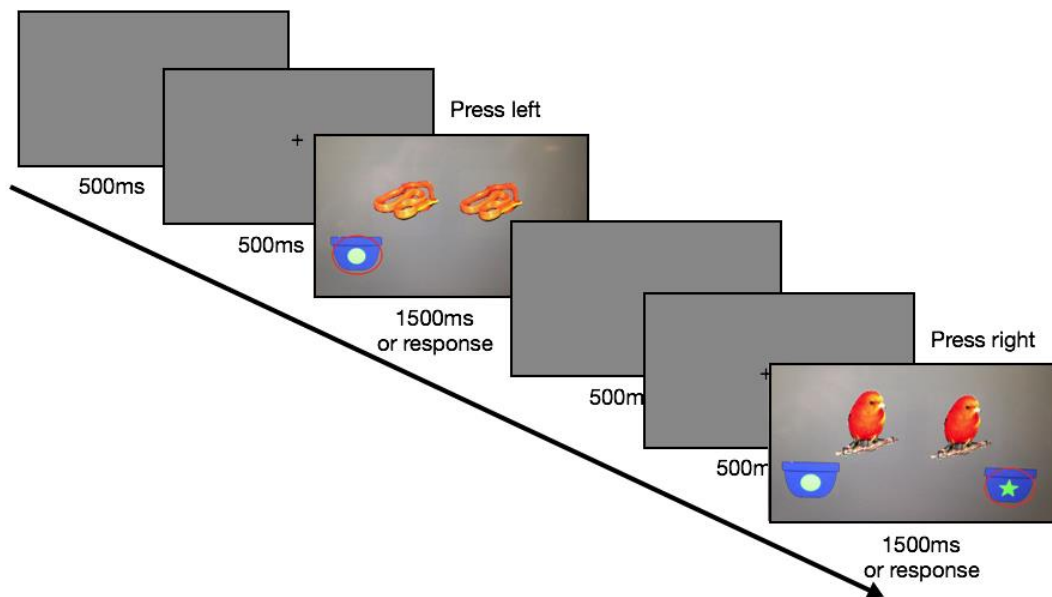
Figure 2-1.   Habituation phase.

As illustrated in Figure 2.2, the Conflict phase consisted of the same sequence of trials as presented in the Habituation phase; however, children switched between four rules: two previously learned rules in response to two orange birds or two orange snakes, and two novel rules in response to a yellow bird with an orange bird or yellow snake with an orange snake. As shown in Figure 2.3, the location of the yellow bird stimuli and yellow snake stimuli relative to the orange bird or orange snake stimuli was counterbalanced across trials within the high conflict conditions on the Conflict phase of the ECFT.
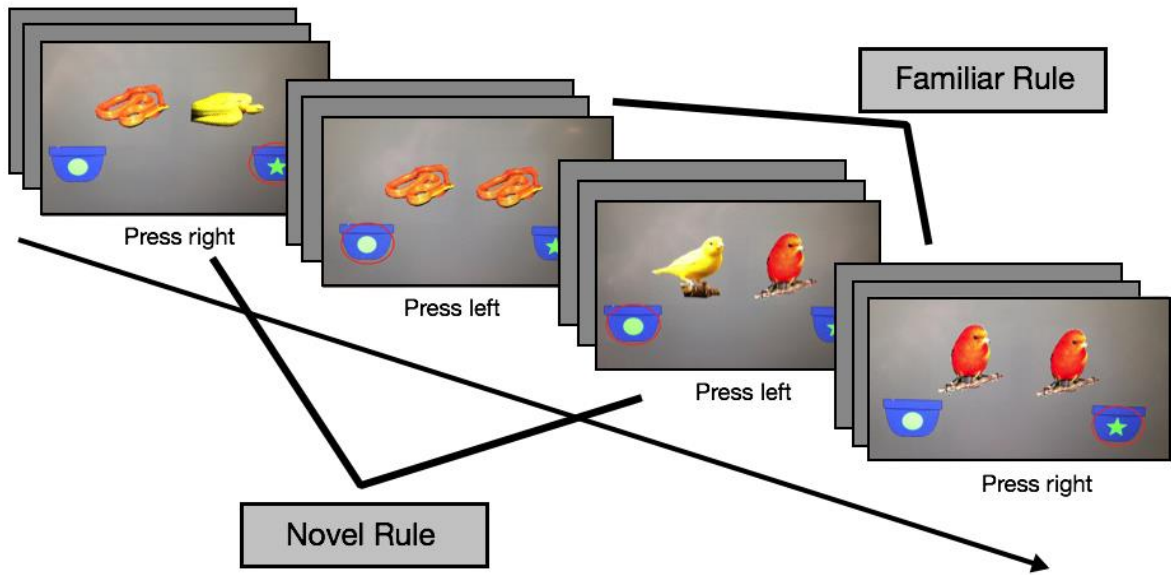
Figure 2-2.   Conflict phase.

Figure 2-3.   All possible trials during the conflict phase.

2.2.2. Child ratings of ECFT stimuli

Prior to administration of the ECFT, participants were asked to rate their fearfulness to the stimuli used in the experiment (i.e, orange or yellow snakes and orange or yellow birds). They were also asked to rate their fearfulness to six other photographs: three other types of snake, two spiders, and a fish to assess whether or not a response bias was present. Children were asked to rate each photograph in accordance with how fearful it made them feel. They responded by circling one of a series of 5 faces, ranging from a very unhappy face to a very happy face. Children's responses were recorded on a five point numerical Likert scale, with five indicating low fear of the animal stimuli, and one indicating high fear of the animal stimuli. Reliability was calculated on 32% of the sample by having children respond to the same measure administered by a different adult approximately two hours following the first administration. The test-retest reliability coefficient was 0.78.

2.2.3. Children's Snake Anxiety Questionnaire (SNAQ-C)

The Children's Snake Anxiety Questionnaire (SNAQ-C) was adapted from the Snake Anxiety Questionnaire for adults (Klieger, 1987). Consistent with the adult survey, the SNAQ-C assessed emotional (e.g., "Do snakes make you feel worried?") and behavioural (e.g., "Would you visit a zoo that has a lot of snakes?") fear of snakes. The survey consisted of 23 questions that were read aloud to the child. Four additional questions were included to assess children's previous experience with live snakes (e.g., "Have you touched a live snake?"). Children's responses to each question were recorded on a binominal scale representing a "yes" or "no" response. An item analysis based on the entire sample showed the SNAQ-C had a high level of internal consistency, as determined by a Cronbach's alpha of 0.857.

2.2.4. Children's Temperament: Fearfulness

Temperament was assessed by the Short Form of the Children's Behavior Questionnaire (CBQ) (Rothbart, Ahadi, Hershey, & Fisher, 2001). The CBQ is a parent-report survey of children's temperament in early to middle childhood (3-7 years of age).

Parent ratings were made on a 7-point Likert scale ranging from extremely true to extremely untrue. The short form consists in total of 94 items that are aggregated to 15 subscales. In the current study, the six items on the Fear subscale were of particular interest. Sample items on the Fear subscale include, "My child is afraid of loud noises," and "My child is rarely frightened by 'monsters' seen on TV or at movies" (reverse scored).

2.3. Procedure

Children were first asked to complete the ratings of the ECFT stimuli. This was done to verify that the snake stimuli were interpreted as more fearful than the bird stimuli by children in the sample, to minimize the influence of novelty effects, and to remove any children from the study who found the snake stimuli too upsetting. All children in the sample agreed to further participation in the study after viewing the snake stimuli. Then, children were administered the ECFT, which took approximately 7-12 minutes. After children completed the task, they were administered the SNAQ-C. Overall, the completion of all measures took approximately 15-20 minutes. Children's parents were asked to fill out the CBQ when they dropped-off or picked-up their children. Children were provided with a sticker reward at the completion of the task.

Chapter 3.   Results

3.1. Data Analysis

All reaction times (RT) faster than 250 seconds or slower than 2000 seconds on the ECFT were eliminated from analyses, as they indicate either random responding or failure to respond during the presentation of the frame. Data were analyzed with SPSS 22. Partial eta^2-values (η_p^2) are reported as an estimation of the effect size.

Review of scatterplots showed that there was a bias in responding in the Conflict phase among 22 children. Five children applied the two rules learned in the Habituation phase throughout the Conflict phase and ignored the presence of the yellow birds and snakes; six children applied the two new rules learned in the Conflict phase and ignored the presence of two orange birds or two orange snakes together; five children responded only to threat (snake) stimuli, and six children responded exclusively to neutral (bird) stimuli. This pattern of responding on cognitive flexibility tasks is common among young children, whose accuracy of performance after a rule switch is often all-or-none. The procedures designed to test the hypotheses of the study required that children respond to conditions of both low and high conflict; therefore, the responses of these children were eliminated from the data submitted for further analysis.

Close to one-half of the children in the sample were multilingual, and five children in the sample were left-handed. To estimate the influence of English language competency and handedness on results, all analyses were repeated twice; once with the data from six children with English vocabulary standard scores less than six removed and again with the data from five children who were left-handed excluded from the analysis. Exclusion of data from the two analyses altered the level of significance in the results, but these changes did not reflect a change in the pattern of significant results (i.e., findings that were statistically detectible or not detectible remained consistent).

3.2   Child ratings of ECFT stimuli

Children in the sample were asked to rate pictures of the threat (snake) and neutral (bird) stimuli in terms of fearfulness. The stimuli were presented in the colours orange and yellow. As expected, results showed that on average, children rated threat stimuli as more frightening (M = 6.45; SD = 2.94; lower scores indicated greater fear) than the neutral stimuli (M = 9.61; SD = 1.16; t(96) = 9.80, p < .001). Ratings of stimuli fearfulness made by girls (M = 9.80, SD = .54) and boys (M = 9.43, SD = 1.5) were not significantly different on bird stimuli, (t(95) = -1.66, p = .102); however, ratings made by girls on snake stimuli (M = 5.67, SD = 3.13) were lower (more fearful) than boys (M = 7.16, SD = 2.60; t(95) = 2.55, p = .012).

3.3   Emotional Cognitive Flexibility Task (ECFT)

Table 3.1 shows the mean response accuracy and reaction time for correct responses for each level of threat within the Habituation phase of the ECFT. A paired-samples t-test was conducted to compare means on threat (snakes) trials with neutral (birds) trials. Results showed that mean differences in accuracy (t(98) = -.80, p = .425) and RT for correct responses (t(98) = -.74, p = .463) were not statistically detectible between threat and neutral trials. Taken together, the results show differences in the influence of threat and neutral stimuli on accuracy of responding within the Habituation phase of the ECFT, where children learned two new rules were not statistically detectible.

Table 3-1.   Response to threat and neutral stimuli in the Habituation phase.

	Neutral		Threat			
	M	SD	M	SD	t	p
Accuracy	14.21	2.04	14.37	2.43	-.80	.425
RT	995.23	192.95	1005.62	187.36	-.67	.505

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In the Conflict phase, a 2 (level of threat: neutral, threat) X 2 (level of conflict: low, high) within-subjects repeated measures analysis of variance (ANOVA) on accuracy scores and RT to accurate responses was conducted. Table 3.2 shows the means and standard deviations for accuracy and RT to correct responses.

The interaction between level of conflict and level of threat, $F(1,96) = .47$, $p = .497$, $\eta_p^2 = .01$ on response accuracy in the Conflict phase was not statistically detectible. However, the main effects of level of threat, $F(1, 96) = 3.93$, $p = .050$, $\eta_p^2 = .04$, and level of conflict, $F(1, 96) = 21.24$, $p < .001$, $\eta_p^2 = .18$, on response accuracy were statistically significant. On average, children's responses were more accurate to threat stimuli versus neutral stimuli. Moreover, on average, children were more accurate in their responses under conditions of low conflict versus high conflict. As shown in Table 3.3, follow-up focused comparisons using paired t-tests and a Bonferroni correction revealed that differences in response accuracy attributable to level of threat were found only when comparisons simultaneously compared performance between high and low conflict conditions.

Table 3-2. **Total sample response to threat and neutral stimuli under conditions of low and high conflict.**

		Level of Threat			
		Neutral		Threat	
Level of Conflict		M	SD	M	SD
Low	Accuracy	16.81	4.83	17.68	4.37
	RT	1112.30	208.78	1143.29	184.06
High	Accuracy	14.79	4.42	15.26	4.32
	RT	1206.70	200.01	1195.96	211.66

Table 3-3.   Adjusted alpha levels on analysis of ECFT accuracy scores.

Within Subject Factor 1	Within Subject Factor 2	Adjusted p
High Conflict Neutral	High Conflict Threat	1.00
High Conflict Neutral	Low Conflict Neutral	.006
High Conflict Neutral	Low Conflict Threat	< .001
High Conflict Threat	Low Conflict Neutral	.162
High Conflict Threat	Low Conflict Threat	< .001
Low Conflict Neutral	Low Conflict Threat	.384

As illustrated in Figure 3.1, an interaction between level of conflict and level of threat approached significance, $F(1,96)$ = 3.75, p = .056, η_p^2 = .04, on the outcome variable of RT to correct responses. Follow-up paired t-tests showed that on average, children responded slower to threat- relative to neutral stimuli in low conflict conditions ($t(96)$ = -2.19 p = .031); however, average differences in RT to correct responses between threat and neutral stimuli under conditions of high conflict were not statistically detectible ($t(96)$ = .64 p = .522).
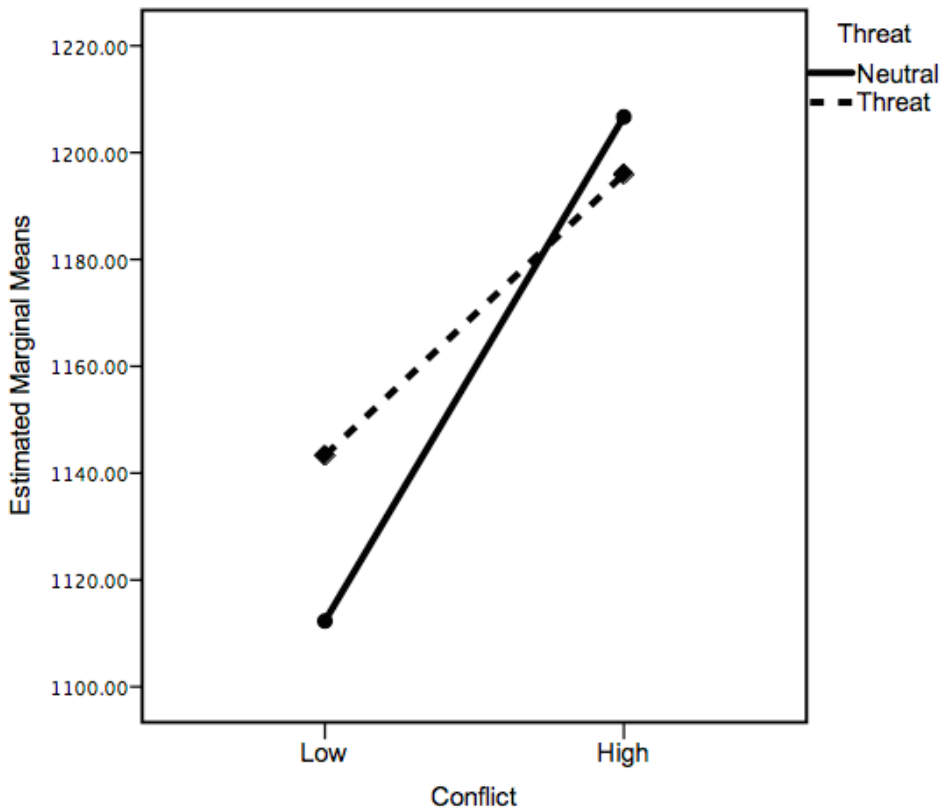
Figure 3-1.   Interaction effects between conflict and threat on reaction time to correct responses.

3.4 Relationship between child fearfulness and task performance

The distribution of ratings on SNAQ-C was bimodal, and a response bias either to fearfulness or non-fearfulness of snakes was reported by the majority of children in the sample. Of the 91 respondents who showed this response bias, 54 (59%) children rated their fearfulness toward snakes in environmental contexts as low (mean score = 5.31; SD = 2.38) and 37 (34%) children rated their fearfulness towards snakes in environmental contexts as moderate to high (mean score = 15.00; SD = 2.35). The six remaining children in the sample rated their fearfulness towards snakes as highly variable, depending on the environmental context they were asked to evaluate. Ratings on CBQ-Fear were normally distributed. There were no significant sex differences on SNAQ-C scores, $t(89)$ = -1.11, p = .269, or CBQ-Fear scores, $t(92)$ = -.10, p = .919. Seventy-seven percent of the 54 children who self-reported low snake fear also reported they had seen a live snake, 50% of the low-fearful children reported they had touched a live snake, and 40% of the low-fearful children reported they had a family member who is afraid of snakes. Twenty-three percent of the 37 children who reported a high level of fearfulness towards snakes also reported they had seen a live snake, 10% of the highly fearful children reported they had touched a live snake, and 57% of the highly fearful children reported they had a family member who is afraid of snakes.

Due to the finding that the distribution of scores on the SNAQ-C was bimodal, two groups of children were formed based on their reported fearfulness towards snakes. Table 3.4 shows the group mean ratings on child reported fearfulness towards snakes (SNAQ-C), and parental report of children's general propensity towards fearfulness (CBQ-Fear).

Table 3-4.   Children's self-report and parent-report of child fearfulness.

Measure	Low Fearfulness[1] M (sd)	High Fearfulness[2] M (sd)	t	p
Fear towards snakes (SNAQ-C)	5.31 (2.38)	15.00 (2.35)	-18.15	<.001
General fearfulness (CBQ-Fear)	3.80 (.88)	4.43 (.89)	-3.06	.003

[1]n=54; [2]n=34

Within the low-fearful group, the correlation between child ratings of fearfulness on the SNAQ-C and parent ratings of general fearfulness on the CBQ was not statistically detectible ($r(53) = -.02$, $p = .889$). Within the moderate- to highly-fearful group, the correlation between the two measures of child fearfulness was positive and statistically significant ($r(29) = .38$, $p = .044$).

To estimate the relations between children's reported level of fearfulness and their response to the ECFT, a 2 (group fearfulness: low, moderate to high) x 2 (level of threat: neutral, threat) X 2 (level of conflict: low, high) mixed-design ANOVA on response accuracy and RT to correct responses was conducted. The means and standard deviations are presented in Table 3.5. The interaction between fear group and level of threat, $F(1, 83) = .09$, $p = .771$, $\eta_p^2 < .01$, as well as fear group and level of conflict, $F(1, 83) = .01$, $p = .909$, $\eta_p^2 < .01$, on accuracy scores were not statistically detectible. The main effect of fear group on accuracy scores in general was also not significant, $F(1, 83) = .01$, $p = .961$, $\eta_p^2 < .01$.

The interaction between fear group and level of threat, $F(1, 83) = .32$, $p = .575$, $\eta_p^2 < .01$, as well as fear group and level of conflict, $F(1, 83) = 2.16$, $p = .146$, $\eta_p^2 = .03$, on the outcome of reaction time to accurate responses were also not statistically detectible. The main effect of fear group across trials and conditions on RT was also not significant, $F(1, 83) = 3.26$, $p = .075$, $\eta_p^2 = .04$.

Table 3-5. **Low fear and moderate-high fear group response to threat and neutral stimuli under conditions of low and high conflict.**

Level of Conflict		Low Fearful Group				Moderate- to High- Fearful Group			
		Neutral		Threat		Neutral		Threat	
		M	SD	M	SD	M	SD	M	SD
Low	Accuracy	16.91	4.56	17.63	4.16	17.10	5.16	17.65	4.62
	RT	1165.15	174.78	1185.84	157.09	1071.26	212.99	1109.94	179.16
High	Accuracy	14.98	4.55	15.35	4.42	15.32	4.33	15.45	3.91
	RT	1238.90	170.13	1236.81	177.52	1193.67	217.02	1201.63	214.44

To further explore the relations between children's reported general fearfulness and performance on the ECFT, data from the total sample was submitted to an analysis where parent ratings of their child's general fearfulness (CBQ-Fear) was correlated with accuracy and RT for all conditions within the conflict phase of the ECFT. As shown in Table 3.6, all correlations failed to reach significance.

Table 3-6.   Correlations between child fearfulness and performance under conflict task conditions.

CBQ-fear	Low Conflict		High Conflict	
	Neutral	Threat	Neutral	Threat
Accuracy	.10	.12	.18	.15
RT	.02	-.01	.03	-.03

Note: All p's > .05

In summary, the results of the analyses yielded the following three important findings:

1) On average, children respond more accurately to threat versus neutral stimuli; and to low conflict versus high conflict conditions on the ECFT.

2) On average, children responded more slowly to threat stimuli relative to neutral stimuli under low- conflict conditions; however, in high-conflict conditions, differences in response to threat stimuli were not statistically detectible.

3) The association between children's reported fearfulness towards snakes and performance on the ECFT was not statistically detectible; also the association between parental report of their child's general fearfulness and performance on the ECFT was not statistically detectible.

Chapter 4.   Discussion

This research study had two aims. The first was to investigate whether exposure to mild threat impacts children's cognitive flexibility. In contrast to the hypothesis, findings from the research affirm that when cognitive demands are high (i.e., Conflict phase) the accuracy of performance on a cognitive flexibility task is on average, more accurate in the presence of stimuli that represent a mild threat compared to stimuli that represent no appreciable threat. This finding is consistent with the bidirectional model of EFs (Blair & Ursache, 2011) that suggests an executive system of cognitive resources influences and is influenced by lower order processes, such as emotional arousal to threat stimuli. While it is well established that EFs serve a critical top-down role in behaviour and emotion regulation (e.g., directing attention; Ochsner & Gross, 2005; Miller & Cohen, 2001), the reverse is also true, and emotional arousal can influence EFs. This finding is consistent with previous research with adults that demonstrated emotional arousal, such as fear arousal induced by a horror video, can bias cognition and enhance spatial working memory (Gray, 2001).

Furthermore, according to the Yerkes-Dodson principle and the bidirectional model of EFs, the impact of emotional arousal serves a facilitatory role on higher order functions, such as EFs, but only when the level of arousal is not extreme. As originally described by the Yerkes-Dodson law (1908), the bidirectional model of EFs (Blair & Ursache, 2011) claims that the relationship between EFs performance and arousal is curvilinear. Performance on complex cognitive tasks increases with arousal, but only up to a certain point. When the level of arousal becomes too high, higher order cognitive functions are disrupted. As such, a mild level of arousal can facilitate EFs performance. Photographs of snakes served as a source of mild threat, and therefore mild arousal, in the present study, while photos of birds were not viewed as a source of threat. As expected, when stimuli represented a mild threat, children's responses were more accurate. Conversely, when stimuli represented no appreciable threat, and therefore

lesser levels of arousal, responses were less accurate. Mild arousal served a facilitatory role in children's cognitive flexibility and stimulated more accurate responding.

This finding is consistent with results of previous research on the relations between EFs and emotional arousal with adults. In a study that assessed the effects of fear and other emotional chemosignals on cognitive performance, Chen, Katdare, and Lucas (2006) asked female participants to complete a simple cognitive task: they were presented with word pairs and asked to press one keyboard key if the words were associated and press another key if they were not associated in meaning. While performing the task, participants smelled one of three types of olfactory stimuli: fear sweat (collected form participants watching horror videos), neutral swear (collected from participants watching neutral videos), and no sweat. Participants in the fear sweat conditions were more accurate on the cognitive task compared to participants in the neutral or no sweat conditions. Both of these studies serve as further evidence of the bidirectional model of EFs and the effect of bottom-up processing affiliated with emotional arousal on EFs.

The interaction effect found between level of threat and level of conflict on reaction time to responding in the conflict phase of the ECFT showed that children's reaction time to threat stimuli relative to neutral stimuli changes depending upon the cognitive demands of the EF task. Specifically, children had a slower reaction time in responding to threat compared to neutral stimuli in the low-, but not the high-conflict condition. In the low conflict condition, children applied rules that had been previously practiced, and as expected, their response accuracy was greater than in the high conflict condition, where they applied two, unfamiliar and unpractised rules. The executive system supported the flexible movement between two highly familiar rules in the low conflict condition.

As children were more accurate, but slower in responding to mild threat compared to neutral stimuli when they flexibly moved between two known rules, this pattern is consistent with a speed-accuracy trade-off. While both speed and accuracy are central to successful performance, they are often contradictory to one another (Edwards, 1961). Longer reaction time allows for greater caution and inhibition of task-

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irrelevant information, leading to a more accurate performance. When taken together, these findings suggest that the relationship between emotional arousal to threat and EFs may be more nuanced than predicted by either the Yerkes-Dodson law (1908) or the bidirectional model of EFs (Blair & Ursache, 2011). That is, in the low conflict condition, children exerted greater cognitive control, and as a result were more cautious, resulting in a speed-accuracy trade-off. However, in the high conflict condition, attentional resources were likely allocated to the efficient retrieval of unfamiliar rules, while suppressing attention to simultaneously activated, and more familiar rules that were previously learned and practiced.

It is important to note that differences in reaction time between threat and non-threat were not statistically detectable in either the Habituation phase or under conditions of high conflict in the Conflict phase on the ECFT. In both the Habituation phase and in the high conflict condition, participants were required to learn two novel rules associated with two novel stimuli. As actions associated with the rules were not practiced, mental representations of these actions were unstable; therefore, attentional resources in the executive system were needed to support the efficient retrieval of rules that were not completely formed or unstable in long-term memory. Further, in the high conflict condition, children had to suppress attention to a more familiar set of rules in order to attend to learning of a new set of rules. Taken together, these findings suggests that experiencing a mild threat in an immediate context is likely to have little effect on children's cognitive flexibility until they are able to flexibly move among the rules that guide their actions.

Another interpretation of the findings relates to the familiarity of both the threat and neutral stimuli encountered by children in the Habituation phase and under conditions of high conflict in the Conflict phase of the ECFT. Kagan and Snidman (2009) argue that many environmental events are feared, not because they are inherently dangerous, but because they are unfamiliar. Specifically, they refer to neurobiological research, which demonstrates that the brain stem responds to unexpected or discrepant events whether or not they are potentially harmful. However, reactivity of such neurons habituates, often rapidly, as the event loses its novelty and becomes more familiar.

When the stimuli encountered is novel and the task demands are not routine, such as during the Habituation phase and under conditions of high conflict, the executive system may bypass the emotional response to arousal and allocate attentional resources equally to the monitoring and to the regulation of actions with novel stimuli. As such, cognitive flexibility performance was similar in response to stimuli that represented a mild threat or a no-appreciable threat during the Habituation phase and under conditions of high conflict. When actions are practiced, and an individual has more stable representations of such actions, the EFs system is more susceptible to emotional arousal evoked by different stimuli.

These interpretations are consistent with the bidirectional model of EFs (Blair & Ursache, 2011). The bidirectional model of EFs expanded previous understanding of the relationship between emotion, self-regulation, and the EFs system by positing that emotion is capable of biasing cognition. This relationship is bidirectional, as EFs are commonly conceptualized as serving a top-down role, such as during emotion or behaviour regulation (Ochsner & Gross, 2005; Miller & Cohen, 2001). This notion has been frequently utilized in discussions of treatment of fear in psychotherapy (Schore, 2012). Encountering a threat in the environment (e.g., snake at the zoo) may elicit a rapid response (e.g., desire to escape). In such cases, the executive system mobilizes affective regulation. Affective regulation can occur consciously (i.e., through self-talk) or unconsciously (i.e., through a direct limbic connections with subcortical amygdala nuclei) and transform stress arousal into regulated and tolerated adaptive emotions. In other words, accessing an executive system of cognitive resources can change the way one feels by changing the way one thinks (Schore, 2012). However, this system shuts down under conditions of high stress (Schore, 2012), consistent with the Yerkes-Dodson law (1908). In temperament literature, a related term is effortful control (Jones, Rothbart, & Posner, 2002), which is an ability to suppress a dominant response, detect errors, and focus one's attention, including while experiencing heightened emotion (Jones et al., 2002).

The second aim of the present research was to investigate whether children's level of fearfulness, either specifically to snakes, or to general events influences their cognitive flexibility under conditions of threat. Contrary to the hypothesis stated at the

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beginning of the research, child fearfulness was not associated with differences in accuracy or in reaction time to responses to threat- versus neutral stimuli.

These findings contradict those found in studies investigating the influence of specific animal fear on EFs in adults. For example, Constine, McNally, and Hornig (2001) found that participants high in snake fear exhibited the slowest RT in response to snake stimuli on a pictorial Stroop task. Slower performance by spider-phobic participants was also reported by Watts and colleagues (1986) on a traditional Stroop task. Another study (Paulitzki et al., 2008) reported that spider-phobic adults who completed a set-shifting task where they had to switch between solving math problems and judging the physical features of spiders had lower response accuracy than non-spider phobic participants.

As the child participants in the current sample were not unusually snake fearful, it is plausible that individual differences in level of fearfulness did not result in sufficient variance among the sample to find differences in responding. It is also critical to note that previous EFs research cited above (Paulitzki et al., 2008; Constantine's et al., 2001; Ohman et al., 2008) studied only adults. Young children in the present research may have not had sufficient exposure and experience with snakes for them to self-report how they may actually respond to live snakes. For example, only 23% of the moderate to high snake fear group reported that they had seen a live snake. As such, children may not have enough experience to assess their own specific fear toward snakes.

Previous research investigating the effect of children's specific fear of spiders on emotional Stroop (1935) performance also reported issues with child self-report (Klein et al., 2012; Klein, Becker, & Rinck, 2011). Participants' self-reported fear failed to correlate with the measure of attention and inhibition. However, an assessment of children's behaviour when confronted with a live spider (Behavioral Assessment Test; Kindt, Brosschot, & Muris, 1996) was correlated with performance on the emotional Stroop measure. Klein et al. (2012) suggest that self-report and behavioural assessments of fear may measure various underlying processes. Specifically, Klein et al. (2011) note that automatic fear and self-reported fear levels are not as closely related to each other as previously suggested.

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In addition, fearful children are described as cautious toward novel objects/events (Rothbart et al., 1994); therefore, a negative association between parent-reported child fearfulness and cognitive flexibility under conditions of threat was predicted. Although an association was found between child self-reported specific fear toward snakes (SNAQ-C) and parent ratings of their child's general propensity toward fearfulness, child fearfulness did not correlate with performance on different conditions on the ECFT. One possible explanation is that this sample of children was not unusually fearful, and therefore, findings from this study are expected to differ from those that emerge in studies of adults with phobias or anxiety disorders.

Overall, a lack of association between child fearfulness and performance on EFs tasks in response to threat is well supported in literature. For example, a study that investigated fear conditioning in children reported that behaviour inhibition was a weak predictor of acquisition of fearfulness to novel animals (Reynolds, Field, & Askew, 2014). Further, insight can be gained from research on child anxiety, which is a risk factor for young children with fearful temperament (Rapee & Coplan, 2010). Previous research findings demonstrate that clinically anxious children do not differ from non-anxious children in their performance on a selective attention task that also involved responding to pictorial threat stimuli (e.g., snakes, spiders, viscous dogs; Waters, Lipp, & Spence, 2004a). Children with a general propensity to fearfulness may not differ from less fearful children in their sensitivity to stimuli depicting threat. The lack of association found between child fearfulness and emotional cognitive flexibility confirms Mogg and Bradley's (1998) assertion that hypervigilance to objectively threatening stimuli is functionally adaptive for all individuals, regardless of their general propensity to fear.

In summary, the present study found evidence in support of the bidirectional model of EFs (Blair & Ursache, 2011). By finding differences in children's responses to threat and neutral stimuli under conditions of low conflict, current findings confirm that that the executive system is influenced by lower order processes. As this is the first study of cognitive flexibility and arousal in young children, the present findings demonstrate that this transactional activity between emotion and the executive system is present early on in children's development. At the same time, the findings in the study also provide evidence to support the long-standing understanding of the EFs as an

emotion and behaviour regulation system. When faced with novelty, the executive system serves a top-down role and allocates cognitive resources such as attention, equally to novel stimuli, irrespective of level of inherent threat.

Enhanced accuracy in response to threat stimuli confirms the notion that mild emotional arousal enhances children's performance on EFs tasks. However, it must be noted that the speed-accuracy trade off found in the low conflict condition of the ECFT demonstrates that performance on complex executive function tasks is multifaceted, and as such may not perfectly adhere to the curvilinear pattern predicted by the bidirectional model of EFs and the Yerkes-Dodson law. Additionally, the lack of statistical differences in reaction time to responses to neutral- and mild threat stimuli in the Habituation phase or under conditions of high conflict in the Conflict phase of the ECFT highlights the complexity of relations between emotional arousal and cognitive flexibility. As proposed by Kagan and Snidman (2009), exposure to unfamiliar stimuli may invoke emotional arousal. Differences in the effects of different sources of emotional arousal and their differential effects on children's performance is a factor not previously considered in the bidirectional model of executive functions or the Yerkes-Dodson law.

This study also aimed to investigate the relationship between child fearfulness and cognitive flexibility under conditions of mild threat. In contrast to previous findings with adults, no differences emerged between children who self-reported moderate to high level of specific fear toward the threat stimuli and those reported low level of specific fear toward threat stimuli. As children in the study had little experience and exposure to snakes, their self-reported feelings of fearfulness towards snakes may not translate to how they will behave in the presence of snakes. Moreover, the present study also demonstrated a lack of association between children's general propensity to fear and cognitive flexibility under conditions of mild threat, confirming findings from previous research that has investigated these relations with other cognitive measures. As objectively threatening stimuli is functionally adaptive for all individuals, temperament may have little effect on the executive system under such conditions.

This study has a number of implications. Firstly, it adds to the growing literature on the effects of emotion on cognitive flexibility in early childhood. As informed by the

bidirectional model of EFs, lower order and higher order processes both play a role in explaining these effects reported in this study. Another implication of this research is the effects of novelty must be considered when designing cognitive flexibility tasks for young children. Finally, this study contributed to research that aims to link children's general fearfulness with other aspects of cognition.   Findings reported here suggest that children's temperament, specifically their propensity to fearfulness, is not associated with their ability to flexibly attend to rules under conditions of emotional arousal to threat.

There were several limitations to the present study. First, the picture stimuli served as only a mild threat, and as such may not have elicited significant levels of arousal to affect performance on the ECFT across all conditions. Second, a behavioural measure of child fearfulness may have produced different effects than those found when parent- and child- report measures were used. Third, the study could be interpreted as having low ecological validity because performance on the ECFT was not associated with parent-report of child behaviour in real world settings. Further research that associates ECFT performance with direct measures of child behaviour is needed.

References

Archibald, S. J., & Kerns, K. A. (1999). Identification and description of new tests of executive functioning in children. *Child Neuropsychology, 5*(2), 115-129. doi:10.1076/chin.5.2.115.3167

Arnsten, A. F. T. (2009). Stress signalling pathways that impair prefrontal cortex structure and function. *Nature Review Neuroscience, 10*(6), 410-422. Retrieved from http://dx.doi.org/10.1038/nrn2648

Arnsten, A. F. T., & Goldman-Rakic, P. S. (1985). Alpha-2 adrenergic mechanisms in prefrontal cortex associated with cognitive decline in aged nonhuman primates. *Science, 230*(4731), 1273–1276. Retrieved from http://www.jstor.org.proxy.lib.sfu.ca/stable/1695635

Arnsten, A. F. T., & Goldman-Rakic, P. S. (1998). Noise stress impairs prefrontal cortical cognitive function in monkeys: Evidence for a hyperdopaminergic mechanism. *Archives of General Psychiatry, 55*(4), 362-368. doi:10.1001/archpsyc.55.4.362

Baker, S. T., Friedman, O., & Leslie, A. M. (2010). The opposites task: Using general rules to test cognitive flexibility in preschoolers. *Journal of Cognition and Development*, *11*(2), 240-254. doi:10.1080/15248371003699944

Bialystok, E., & Feng, X. (2009). Language proficiency and executive control in proactive interference: Evidence from monolingual and bilingual children and adults. *Brain and Language, 109*(2-3), 93-100. doi:10.1016/j.bandl.2008.09.001

Bialystok, E., & Martin, M. M. (2004). Attention and inhibition in bilingual children: Evidence from the dimensional change card sort task. *Developmental science, 7*(3), 325-339. doi:10.1111/j.1467-7687.2004.00351.x

Blair, C., & Ursache, A. (2011). A bidirectional model of executive functions and self-regulation. In K. D. Vohs, & R. F. Baumeister (Eds.), *Handbook of self-regulation: Research, theory, and applications* (2nd ed., pp. 300-320). New York, NY: Guilford Press.

Blanchard, D. C., & Blanchard, R. J. (1988). Ethoexperimental approaches to the biology of emotion. *Annual Review of Psychology*, 39, 43 – 68. doi:10.1146/annurev.ps.39.020188.000355

Chen, D., Katdare, A., & Lucas, N. (2006). Chemosignals of fear enhance cognitive performance in humans. *Chemical senses*, *31*(5), 415-423. doi:10.1093/chemse/bjj046

Constantine, R., McNally, R. J., & Hornig, C. D. (2001). Snake Fear and the Pictorial Emotional Stroop Paradigm. *Cognitive Therapy and Research, 25*(6), 757-764. doi:10.1023/A:1012923507617

Davidson, M.C., Amso, D., Anderson, L.C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*(11), 2037–2078. doi:10.1016/j.neuropsychologia.2006.02.006

Deutch, A. Y. & Roth, R. H. (1990). The determinants of stress-induced activation of the prefrontal cortical dopamine system. *Progress in Brain Research, 85*, 367–403. doi:10.1016/S0079-6123(08)62691-6

Diamond, A., & Kirkham, N. Z. (2005). Not quite as grown-up as we like to think: Parallels between cognition in childhood and adulthood. *Psychological Science*, *16*(4), 291–297. doi:10.1111/j.0956-7976.2005.01530.x

Edwards, W. (1961). Costs and payoffs are instructions. *Psychological Review*, *68*(4), p. 275–284. Retrieved from http://dx.doi.org/10.1037/h0044699

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & Psychophysics, 16*(1), 143-149. doi:10.3758/BF03203267

Fisher, A. V. (2011). Automatic shifts of attention in the dimensional change card sort task: subtle changes in task materials lead to flexible switching. *Journal of experimental child psychology, 108*(1), 211-219. doi:10.1016/j.jecp.2010.07.001

Frings, C., Englert, J., Wentura, D., & Bermeitinger, C. (2010). Decomposing the emotional Stroop effect. *The Quarterly Journal of Experimental Psychology, 63*(1), 42-49. doi:10.1080/17470210903156594

Flykt, A., Esteves, F., & Ohman, A. (2007). Skin conductance responses to masked conditioned stimuli: Phylogenetic/ontogenetic factors versus direction of threat? *Biological Psychology, 74*(3), 328-336. doi:10.1016/j.biopsycho.2006.08.004

Funahashi, S., Bruce, C. J. & Goldman-Rakic, P. S. (1989) Mnemonic coding of visual space in the monkey's dorsolateral prefrontal cortex. *Journal of Neurophysiology, 61*(2), 331–349. Retrieved from https://web.stanford.edu/group/brainsinsilicon/documents/FunahashiEtAl1989.pdf

Goldstein, S., Naglieri, J. A., Princiotta, D., & Otero, T, M. (2014). Introduction: A History of Executive Functioning as a Theoretical and Clinical Construct. In S. Goldstein, & J. A. Naglieri (Eds.), *Handbook of Executive Functioning* (pp. 3-12). New York, NY: Springer Science & Business Media.

Gray, J. R. (1999). A Bias Toward Short-Term Thinking in Threat-Related Negative Emotional States. *Personality and Social Psychology Bulletin, 25*(1), 65-75. doi:10.1177/0146167299025001006

Gray, J. R. (2001). Emotional modulation of cognitive control: Approach–withdrawal states double-dissociate spatial from verbal two-back task performance. *Journal Of Experimental Psychology: General, 130*(3), 436-452. doi:10.1037/0096-3445.130.3.436

Gray, J. R. (2004). Integration of emotion and cognitive control. *Current Directions in Psychological Science, 13*(2), 46-48. doi:10.1111/j.0963-7214.2004.00272.x

Ionescu, T. (2012). Exploring the nature of cognitive flexibility. *New ideas in psychology, 30*(2), 190-200. doi:10.1016/j.newideapsych.2011.11.001

Jacques, S., Zelazo, P.D., Kirkham, N.Z., & Semcesen, T.K. (1999). Rule selection versus rule execution in preschoolers: an error-detection approach. *Developmental Psychology, 35*(3), 770–780. doi:10.1037/0012-1649.35.3.770

Jacques, S., & Zelazo, P. D. (2005). On the possible roots of cognitive flexibility. In B. Homer and C. Tamis-LeMonda (Eds.). *The development of social cognition and communication* (pp. 53-81). Mahwah, NJ: Lawrence Erlbaum.

Jones, L. B., Rothbart, M. K., & Posner, M. I. (2003). Development of inhibitory control in preschool children. *Developmental Science, 6*(5), 498-504. Retrieved from http://www.bowdoin.edu/~sputnam/rothbart-temperament-questionnaires/pdf/2003_Dev_Exec_Atten_Preschl_Chldrn.pdf

Kagan, J. (1994). On the nature of emotion. *Monographs of the Society for Research in Child Development, 59*(2/3), 7–24. doi:10.2307/1166136

Kagan, J., & Snidman, N. (2009). *The long shadow of temperament*. Harvard University Press.

Kindt, M., Brosschot, J. F., & Muris, P. (1996). Spider phobia questionnaire for children (SPQ-C): A psychometric study and normative data. *Behaviour Research and Therapy, 34*(3), 277-282. doi:10.1016/0005-7967(95)00069-0

Klein, A. M., Becker, E. S., & Rinck, M. (2011). Direct and indirect measures of spider fear predict unique variance in children's fear-related behaviour. *Cognition & emotion, 25*(7), 1205-1213. doi:10.1080/02699931.2010.530454

Klein, A. M., Kleinherenbrink, A. V., Simons, C., de Gier, E., Klein, S., Allart, E., Bogels, S. M., Becker, E. S., & Rinck, M. (2012). Subjective fear, interference by threat, and fear associations independently predict fear-related behavior in children. *Journal of behavior therapy and experimental psychiatry, 43*(3), 952-958. doi:10.1016/j.jbtep.2012.02.005

Lipp, O. V., & Waters, A. M. (2007). When danger lurks in the background: Attentional capture by animal fear-relevant distractors is specific and selectively enhanced by animal fear. *Emotion, 7*(1), 192–200. doi:10.1037/1528-3542.7.1.192

LoBue, V., & DeLoache, J. S. (2008). Detecting the snake in the grass attention to fear-relevant stimuli by adults and young children. *Psychological science, 19*(3), 284-289. doi:10.1111/j.1467-9280.2008.02081.x

Luu, P., & Tucker, D. M. (2004). Self-regulation by the medial frontal cortex: Limbic representation of motive set-points. In M. Beauregard (Ed.), *Consciousness, emotional self-regulation and the brain* (pp. 123–161). Amsterdam: Benjamins.

McGlynn, F. D., Wheeler, S. A., Wilamowska, Z. A., & Katz, J. S. (2008). Detection of change in threat-related and innocuous scenes among snake-fearful and snake-tolerant participants: Data from the flicker task. *Journal of Anxiety Disorders, 22*(3), 515–523. doi:10.1016/j.janxdis.2007.05.002

Miller, E. K. (1999). *The prefrontal cortex: complex neural properties for complex behavior. Neuron, 22*(1), 15-17. doi:10.1016/S0896-6273(00)80673-X

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual Review of Neuroscience, 24*, 167-202. doi:10.1146/annurev.neuro.24.1.167

Mogg, K., & Bradley, B. P. (1998). A cognitive–motivational analysis of anxiety. *Behaviour Research and Therapy, 36*(9), 809–848. doi:10.1016/S0005-7967(98)00063-1

Naglieri, J., & Goldstein, S. (2013). *Comprehensive executive functioning inventory technical manual.* Toronto, ON: Multi-Health Systems.

Neuenschwander, R., Roebers, C., & Blair, C. (2014). Being Optimally Aroused Matters: Effects of a Weak Stress Manipulation on Children's Executive Functions Are Moderated by Temperament and Age. *Journal of Educational and Developmental Psychology, 4*(1), 194-208. doi:10.5539/jedp.v4n1p194

Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences, 9*(5), 242-249. doi:10.1016/j.tics.2005.03.010

Öhman, A., Flykt, A., & Esteves, F. (2001). Emotion drives attention: detecting the snake in the grass. *Journal of experimental psychology: general, 130*(3), 466-478. doi:10.1037/AXJ96-3445.130.3.466

Öhman, A., Lundqvist, D., & Esteves, F. (2001). The face in the crowd revisited: A threat advantage with schematic stimuli. *Journal Of Personality And Social Psychology, 80*(3), 381-396. doi:10.1037/0022-3514.80.3.381

Paulitzki, J. R., Risko, E. F., Oakman, J. M., & Stolz, J. A. (2008). Doing the unpleasant: How the emotional nature of a threat-relevant task affects task-switching. *Personality and Individual Differences, 45*(5)*,* 350–355. doi:10.1016/j.paid.2008.05.003

Purkis, H. M., & Lipp, O. V. (2009). Are snakes and spiders special? Acquisition of negative valence and modified attentional processing by non-fear-relevant animal stimuli. *Cognition & Emotion, 23*(3), 430–452. doi:10.1080/02699930801993973

Rapee, R. M., & Coplan, R. J. (2010). Conceptual relations between anxiety disorder and fearful temperament. In H. Gazelle & K. H. Rubin (Eds.), *Social anxiety in childhood: Bridging developmental and clinical perspectives.* San Francisco: Jossey-Bass.

Reynolds, G., Field, A. P., & Askew, C. (2014). Effect of vicarious fear learning on children's heart rate responses and attentional bias for novel animals. *Emotion, 14*(5), 995. doi:10.1037/a0037225

Rothbart, M. K. (2007). Temperament, Development, and Personality. *Current Directions in Psychological Science, 16*(4), 207-212. Retrieved from http://www.jstor.org/stable/20183198

Rothbart, M. K., Ahadi, S. A., Hershey, K. L., & Fisher, P. (2001). Investigations of temperament at three to seven years: The Children's Behavior Questionnaire. *Child Development, 72*(5), 1394-1408. doi:10.1111/1467-8624.00355

Rothbart, M. K., Derryberry, D., & Posner, M. I. (1994). A psychobiological approach to the development of temperament. In J. E. Bates & T. D. Wachs (Eds.), *Temperament: Individual differences at the interface of biology and behavior* (pp. 83-116). Washington, DC: American Psychological Association.

Rothbart, M. K., & Jones, L. B. (1998). Temperament, self-regulation, and education. *School Psychology Review, 27*(4), 479-491. Retrieved from http://proxy.lib.sfu.ca/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=aph&AN=1435149&site=ehost-live

Sawaguchi, T. & Goldman-Rakic, P. S. (1991). D1 dopamine receptors in prefrontal cortex: involvement in working memory. *Science 251*(4996), 947–950. Retrieved from http://www.jstor.org.proxy.lib.sfu.ca/stable/2874911

Schermerhorn, A. C., Bates, J. E., Goodnight, J. A., Lansford, J. E., Dodge, K. A., & Pettit, G. S. (2013). Temperament moderates associations between exposure to stress and children's externalizing problems. *Child development*, *84*(5), 1579-1593. doi:10.1111/cdev.12076

Schimmack, U. (2005). Attentional Interference Effects of Emotional Pictures: Threat, Negativity, or Arousal? *Emotion, 5*(1), 55-66. doi:10.1037/1528-3542.5.1.55

Schore, A. N. (2012). *The Science of the Art of Psychotherapy*. New York: W. W. Norton & Company.

Schmid, C., Zoelch, C., & Roebers, C. M. (2008). Das Arbeitsgedächtnis von 4-bis 5-jährigen Kindern: Theoretische und empirische Analyse seiner Funktionen [Working memory in 4- to 5-yr-olds: Theoretical and empirical analyses of its functions]. *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie, 40*(1), 2-12. doi:10.1026/0049-8637.40.1.2

Schwartz, C. E., Snidman, N., & Kagan, J. (1996). Early temperamental predictors of Stroop interference to threatening information at adolescence. *Journal of Anxiety Disorders*, *10*(2), 89-96. doi:10.1016/0887-6185(96)87623-7

Statistics Canada (2012). *Focus on Geography Series, 2011 Census.* (Catalogue number 98-310-XWE2011004). Retrieved April 3, 2015 from Statistics Canada: http://www12.statcan.gc.ca/census-recensement/2011/as-sa/fogs-spg/Facts-cma-eng.cfm?LANG=Eng&GK=CMA&GC=933

Strelau, J. (1995). Temperament and stress: Temperament as a moderator of stressors, emotional states, coping, and costs. In C. D. Spielberger, & I. G. Sarason (Eds.), *Stress and emotion: Anxiety, anger, and curiosity* (Vol. 15, pp. 215-254). Washington, DC: Hemisphere.

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*, 643-662. Retrieved from http://psychclassics.yorku.ca/Stroop

Talge, N. M., Donzella, B., & Gunnar, M. R. (2008). Fearful temperament and stress reactivity among preschool-aged children. *Infant and Child Development*, *17*(4), 427-445. doi:10.1002/icd.585

Waters, A. M., & Lipp, O. V. (2008). The influence of animal fear on attentional capture by fear-relevant animal stimuli in children. *Behaviour research and therapy*, *46*(1), 114-121. doi:10.1016/j.brat.2007.11.002

Waters, A. M., Lipp, O. V., & Spence, S. H. (2004a). Attentional bias toward fear-related stimuli: An investigation with nonselected children and adults and children with

anxiety disorders. *Journal of Experimental Child Psychology, 89*(4), 320-337. doi:10.1016/j.jecp.2004.06.003

Waters, A. M., Lipp, O. V., & Spence, S. H. (2004b). *Finding the snake in the garden: Automatic for adults but not for children.* Unpublished manuscript, Griffith University.

Watters, P. A., Martin F., & Schreter, Z. (1997). Caffeine and Cognitive Performance: The Nonlinear Yerkes-Dodson Law. *Human Psychopharmacology, 12*(3), 249-257. doi:10.1002/(SICI)1099-1077(199705/06)12:3<249::AID-HUP865>3.0.CO;2J

Watts, F. N., McKenna, F. P., Sharrock, R., & Trezise, L. (1986). Colour naming of phobia-related words. *British Journal of Psychology, 77*(1), 97–108. Retrieved from http://web.b.ebscohost.com/ehost/pdfviewer/pdfviewer?sid=e7c6074c-2d7d-473c-bd8d-08145f32c01d%40sessionmgr198&vid=1&hid=118

Wiebe, S. (2014). A case study of the DCCS task. *Monographs of the Society for Research in Child Development, 79*(2), 12-25. doi:10.1002/mono.12097

Williams, J. M. G., Mathews, A., & MacLeod, C. (1996). The emotional Stroop task and psychopathology. *Psychological Bulletin, 120*(1), 3–24. doi:10.1037/0033-2909.120.1.3

Yerkes R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit-formation. *Journal of Comparative Neurology and Psychology*, 18, 459–482. doi:10.1002/cne.920180503.

Zelazo, P. D. (2006). The dimensional change card sort (DCCS): A method of assessing executive function in children. *Nature Protocols, 1*(1), 297-301. doi:10.1038/nprot.2006.46

Appendix.

Children's Snake Anxiety Questionnaire (SNAQ-C)

Name: ID :   S ex: Date:

SNAQ-C

1	Would you play at a park if there were snakes nearby?	Yes	No
2	Are you afraid to hold a toy snake in your hand?	Yes	No
3	If a movie showed a live snake, would you look at the snake?	Yes	No
4	Do you like to look at pictures of snakes in books?	Yes	No
5	Are you afraid to look at a live snake?	Yes	No
6	Would you like to see a snake hide in the rocks?	Yes	No
7	Would you be scared to touch a snake?	Yes	No
8	If someone told you that a snake was at Science World, would you be afraid?	Yes	No
9	Would you walk on a path if snakes are around?	Yes	No
10	Do you think all children should watch out for snakes?	Yes	No
11	If you saw a live snake, would you feel scared?	Yes	No
12	Do you like to listen to stories about snakes?	Yes	No
13	Do snakes make you feel worried?	Yes	No
14	Do you think snakes are good for the environment?	Yes	No
15	Would you be frightened if you saw a snake?	Yes	No
16	Would you hold a snake if an adult helped you?	Yes	No
17	Do you think some snakes are beautiful?	Yes	No
18	Do you think most children are afraid of snakes?	Yes	No
19	Do you like the way snakes move?	Yes	No
20	Are you afraid to touch a dead snake with a stick?	Yes	No
21	If children see a snake in the grass, should they run away?	Yes	No
22	Would you visit a zoo that has a lot of snakes?	Yes	No
23	Do you think some children like snakes?	Yes	No
24	Have you seen a live snake?	Yes	No
25	Have you touched a snake?	Yes	No
26	Is anyone in your family afraid of snakes?	Yes	No
27	If yes, who?		