UNIVERSITY OF CALIFORNIA, MERCED

The bilingual advantage debate: are we getting warmer?

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in

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By

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To Ana, Eduardo, Eddie, and Julian

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Castillo, A. Gilger, J., Khislavsky., A., & Altman., M. (2020). Executive function developmental trajectories kindergarten to first grade: Monolingual, bilingual, and English language learners. *International Journal of Bilingualism and Education,* 1-19.

Castillo, A., Cohen, S., Miguel., J., Warstadt., M. (2020). Short Report: Exploring Perceptions of Autism Spectrum Disorder in the U.S. *Research in Autism Spectrum Disorders, 70,* 92-102.

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Abstract

There is a long-standing debate about whether bilinguals have enhanced executive function abilities due to regularly managing two languages and thus constantly activating brain regions responsible for executive control. This dissertation presents four studies investigating the impact of bilingualism on executive function abilities. Chapter 1 provides an argument towards an integration of hotter executive function measures regarding the bilingual advantage debate. Chapter 2 used secondary data to analyze the development of bilingual children's executive function overtime in a longitudinal study across several time points from ages five to seven. Findings indicate that bilingual and monolingual children are different in some ways, such as their rate of change on cognitive control. Additionally, teachers rated bilingual children as having better inhibitory control and attention skills at the start of kindergarten in comparison to monolingual children, which may be reflective of hot executive function skills. Chapter 3 expands upon the results of Chapter 2 by examining how the teachers rated eight-year-old children's hot executive function skills, internalizing and externalizing problems and interpersonal skills. The results paralleled those found in Chapter 2. Next, Chapter 4 follows up and expands the prior studies through investigating hot executive function skills among bilingual undergraduates via a computerized executive function task that implements affective stimuli. Chapter 5 examines whether bilingual and monolingual children differ on hot and cool executive function tasks that differ on their interpersonal level (2 tasks that are interpersonal and 2 tasks that are intrapersonal) and furthermore how these tasks relate to a novel ecological hot executive function task. Our novel child friendly computerized executive function task with affective stimuli directly contrasts neutral stimuli of a pre-existing executive function task. Additionally, Chapter 5 includes extensive information regarding the child's background, language experience and exposure. This collection of studies aims to provide evidence for how bilingualism relates to executive function using a holistic multimethod approach including, a longitudinal design, non-affective and affective executive function tasks, teacher reports and parent reports. Theoretical and methodological implications, as well as limitations of the studies in this dissertation are discussed.

Chapter 1: General Introduction

The ability to plan our goals, inhibit temptations or distractions that may impede our goals and ability to keep our goals in mind and manage more than one goal encompasses the term 'executive function' (Denckla, 1996; Morris, 1996). So, what 'isn't' executive function and when is it not activated? Some theorists argue that executive function is not activated during simple or routinized tasks as these tasks are performed instinctively (Shallice, 1990), but some argue that all cognitive tests involve at least some executive functioning (Alexander & Stuss, 2000; Denckla, 1996). As for what it is, executive function was originally considered to be part of three functional units in the brain (Luria 1973; 1980). The first two were an arousal-motivation unit and a unit that receives, processes, and stores information. The third unit has an executive role to program, control, and to verify activity that is dependent on the activity of the prefrontal cortex (Ardila, 2008). Overtime, it seems theoretical models have converged to define executive function as a composition of three distinct components: inhibitory control, cognitive flexibility and working memory (Carlson, 2005; Diamond, 2013; Zelazo, Carter, Reznick, & Frye, 1997; Welsh, Pennington, & Groisser, 1991; Miyake et al., 2000). Nonetheless, we cannot ignore the influential origin of this term which comes from early clinical investigations of frontal pathology. To this day psychology classes never fail to mention the classical case of Phineas Gage who had a rod projected through his frontal lobes in an accident. Based on Harlow's (1869) reports, Gage had a significant change in his personality, "began to behave as an animal" (Ardila, 2008, p. 93), and showed executive function impairments.

Executive Function Historically

Executive function historically has served as a construct used to characterize various processes impaired by prefrontal cortex damage (Stuss & Benson, 1986; Zelazo, Carter, Reznick, & Frye, 1997). Studies range from adults with frontal lobe damage (Luria, 1973; Shallice, 1982; Stuss & Benson, 1986) to experimental brain lesion studies among nonhuman primates (Welsh, Pennington, & Groisser, 1991; Goldman-Rakic, 1983). These studies support the notion of a prefrontal function involving goal-directed behavior, also known as executive function (Bianchi, 1922; Luria, 1973; Shallice, 1982; Welsh & Pennington, 1988), by allowing for planning, cognitive flexibility, and inhibitory control (Welsh, Pennington, & Groisser, 1991). While early work on executive function focused on adults with frontal lobe damage, executive function research in children also focused on atypical populations (Carlson, 2005). Specifically, children with traumatic head injuries were studied (Dennis, Barnes, Donnelly, Wilkinson, & Humphreys, 1996; Levin et al., 1995), as well as children with attention deficit hyperactivity disorder (Barkley, 1997; Denckla, 1996), premature birth (Espy et al., 2002) and autism (Zelazo, Jacques, Burack & Frye, 2002; Carlson, 2005). Work on atypical populations within adults and children supports the relationship between executive function and the prefrontal cortex.

Additionally, neuroimaging studies find significant activation within the prefrontal cortex when participants are engaged in executive function tasks (Baker et al., 1996; Anderson, 2002). Of course, the prefrontal cortex neural systems underpinnings of executive function are not working in isolation as they depend on efferent and afferent

Anderson, 2002). Some even argue that a normally functioning prefrontal cortex is necessary but not a sufficient condition for intact executive functioning (Sala, Gray, Spinnler, & Trivelli, 1998; Anderson, 2002).

Executive Function as a Current Construct

As of now, most agree that executive function refers to a broad collection of cognitive processes that are interrelated and responsible for making goal-directed behavior (Anderson, 2002; Diamond, 2013). While cognitive processes associated with executive functions are plentiful, the core components include inhibitory control, working memory and cognitive flexibility (Carlson, 2005; Diamond, 2013; Zelazo, Carter, Reznick, & Frye, 1997; Welsh, Pennington, & Groisser, 1991; Miyake et al., 2000). More specifically based on the Miyake and Friedman model (2000), inhibitory control or inhibition is the ability to suppress dominant/salient responses. For example, suppressing a response to name a card with a sun, 'day' when instructed to name it 'night' (Day-Night; Gerstadt et al., 1994) or inhibiting the urge to point to a larger number of treats and instead pointing to the smaller number of treats (Less is More; Carlson, Davis, & Leach, 2005). Working memory or updating is considered the ability to update information in working memory. For example, a commonly used task that engages working memory is the backward digit span task (also known as numbers reversed, n-back) where participants must repeat a sequence of numbers in reverse order (Snyder, Miyake, & Hankin, 2015; Kirchner, 1958). Finally, cognitive flexibility or switching is considered the capacity and ease of one's transition between tasks (Miyake et al., 2000). A frequently used measure of cognitive flexibility is the Dimensional Change Card Sort (DCCS) task, which requires children to switch between two rules (Zelazo, 2006).

The traditional conceptualization of executive function was proposed as a single construct, central for multi-modal processing and high-level cognitive skills (Anderson, 2002; Shallice, 1990). More aligned with current research, executive function conceptualization began to consider an inter-related, inter-dependent multiple process related system that functions together as an executive system (Anderson, 2002; Stuss & Alexander, 2000). These components appear to be interrelated and have meaningful contributions to the construct of executive function but are also considered separate entities as they contribute to behavior in distinctive ways (Miyake et al., 2000). For instance, inhibitory control is believed to play a central role in the development of self-regulation since it creates a delay in responding that facilitates behavioral flexibility and permits the selection of strategic alternative behaviors (Miyake et al., 2000; Barkley, 2001). More specifically, the general methods that we use in self-regulation are considered executive functions (Barkley, 2001).

Development of Executive Function

challenge because the components of executive function may develop in their own trajectories, these components are difficult to isolate so what may be measured at one time point may be a different cognitive process at another, and these skills appear to develop rapidly over childhood. For instance, studies using the AB (A not B; Piaget, 1954) task suggest that by 12 months of age infants are capable of inhibiting certain behaviors that they couldn't at a prior age, such as inhibiting a desire to reach to an incorrect place (A), when they are supposed to reach somewhere else (B) (Diamond, 1985; Diamond & Goldman-Rakic, 1989). This developmental phenomenon also seems to suggest that infants are updating their working memory as they need to hold the representation of the toy as it is hidden/covered (Diamond, 2006). Some work has found associations between motor control and executive functioning among 18-month-olds and has suggested an embodied account for early executive-function development (Gottwald et al., 2016). Between 20 and 21 months, infants succeed at a delayed non matching (DNMS) to sample task where infants must show a novel object in order to be rewarded and trials follow where a new 'sample' and another novel object is shown (Diamond, Towle, & Boyer, 1994). There is also an increase in the delay once the infant passes the training delays successfully (Diamond, 2006). The idea here is that infants are inhibiting an already learned response and forming a new goal as they update to successfully complete the trail at hand. While studies use creative ways to capture what seems to be early indicators of some sort of executive functions in infancy, there doesn't appear to be standardized measurements of executive function prior to age 3.

Between the ages 3 and 5 children's executive control skills show a rapid growth. These skills appear to enable them to organize their thinking and behavior with more flexibility and they are able to decrease reactive responding to stimuli (Barkley, 2001; Bierman et al., 2008). For instance, if the DCCS task is simplified by not changing mental states so abruptly then children can pass it at 3 years of age (Diamond et al., 2005; Kloo & Perner, 2005). It seems that by age 4, children can demonstrate simple planning skills and seem to be capable of generating new concepts (Welsh et al., 1991; Jacques & Zelazo, 2001; Anderson, 2002). Planning skills and strategic behavior continue to develop rapidly between ages 7 and 11 and these abilities become more efficient over time (Anderson, 2002). Overall, converging evidence suggests that executive function development follows an inverted U-shaped curve across the life span (Zelazo, Craik, & Booth, 2004), as there are improvements in executive function during childhood into adolescence and a sharp decline during aging (Zelazo Craik, & Booth, 2004; Zelazo & Müller, 2002).

Executive Function Implications

Despite the broadness of the construct, executive function has clear implications to several (some argue every) aspects of life (See Table 1 in Diamond, 2013). For instance, some studies have found that poorer executive functions are related to overeating, substance abuse and poor treatment adherence (Miller et al., 2011, Riggs et al., 2010). Riggs and colleagues (2010) found that among nine-year-old children an executive function self-report measure was significantly negativity related to snack food intake suggesting that children with greater executive function ate fewer snack foods. Potential explanations offered by authors suggest that children with enhanced inhibitory and emotional control skills may be better at inhibiting the reward that accompanies snack foods and can also keep in mind their healthy goals to avoid snack foods (Riggs et al., 2010). In support, adult self-control is related to health outcomes. A nationally represented study among adults found that those with a higher likelihood of being diagnosed with health outcomes also had significantly lower levels of self-control (Miller, Barnes, & Beaver, 2011).

The effects of executive function on school readiness, school success, and job success have also been well documented (Blair & Razza, 2007; Blair & Diamond, 2008). Indeed, Fitzpatrick and colleagues (2014) found that among four-year-old children executive function predicted school readiness beyond socioeconomic status (SES) and other cognitive skills. In their study the association between SES and academic ability was partially mediated via executive functions. Authors pose the possibility that executive function skills support the mechanisms of learning and help children stay focused on relevant information despite distractions in a classroom setting (Fitzpatrick et al., 2014). Another study found that specific components of executive function relate to academic readiness. Mann and colleagues (2017) found that working memory and inhibitory control among 3–5-year-old children directly predicted academic readiness.

Besides physical health and school readiness, executive function has also been associated with socio-emotional development (see Riggs et al., 2006 for a review). Executive function has been associated with socio-emotional development among atypical populations that seem to show deficits in executive function and social-emotional functions, such as understanding mental states (Barkley, 1997; Lopez et al., 2005). Additionally, studies have linked executive function and socio-emotional development among typical developing children. For instance, studies have found that children with lower executive function also exhibit more negative expressions, aggressive coping strategies and impulsive behaviors suggesting a link between executive function and emotion regulation (Jahromi & Stifter, 2008). In further support of the relationship between socio-emotional development and executive function, several studies have found that executive function predicts performance on false belief tasks (Carlson & Moses, 2001; Devine & Hughes, 2014 for reviews). False belief tasks are used to measure whether children can infer that another person does not have the same knowledge they have. For instance, children could be shown a candy box that contains pennies rather than candy and then are asked what someone else might expect to find in the box.

Hot and Cool Executive Function

Given the term 'executive function' originated with atypical populations (i.e., frontal lobectomies, etc.) it is not surprising that is has traditionally been viewed under decontextualized and diagnostic testing conditions. Recently however, there has been an interest in understanding how executive function operates under emotionally motivated contexts, also known as 'hot' executive function (Zelazo & Müller, 2002). Hot executive functions operate under situations that generate emotion and motivation "because they involve meaningful, self-relevant rewards or punishes" (Zelazo, Qu, & Kesek, 2010, p. 97), including but not limited to delaying gratification or affective decision making (Zelazo and Müller, 2002; Zelazo and Carlson, 2012). If emotions are action dispositions (Frijda & Mesquita, 1998) and functional processes that seek to deal with relevant events (Campos, Mumme, Kermoian, & Campos, 1994; Frijda, 1986; Oatley, 1993), then hot executive function processes are the cognitive processes that modulate action (or inaction).

Another context where hot executive functions are elicited is in social interpersonal interactions, as social interpersonal interactions can be inherently rewarding to the self and can elicit emotional motivated responses. In extension of this notion, I argue that in our everyday lives, most of what we find emotionally meaningful and are subsequently motivated by, is inherently social. In fact, recently the field of emotion has acknowledged that emotions are intrinsically social (see van Kleef, Cheshin, Fisher, and Schneider, 2016). Of course, social interpersonal interactions may not be necessary to recruit hot executive function processes but they can be sufficient. For instance, the appearance of a 'happy face' on a computer screen or walking through the grocery store aisles around strangers may not sufficiently mediate hot executive processes. However, hot executive function is operating under the context of a happy face indicating that "you have won $100" during the Iowa Gambling Task. Further and secondly, we all can understand the emotional motivation and affective strategy planning that is involved in dodging *someone* (or attempting to) at the grocery store or witnessing a parent emotionally motivated to cease the stares from others as their child is wailing about. My point in the latter examples is that social interactions can provide "one of the most rewarding stimuli for humans" (Krach et al., 2010, p. 22). In further support of this notion, neuroimaging studies find that we exhibit striatal activations when we encounter rewarding social stimuli (Krach et al., 2010; Izuma et al., 2008; Bartels and Zeki, 2004; Spreckelmeyer et al., 2009). For instance, Izuma and colleagues (2008) specifically compared neuroimaging activations of monetary and social rewards and found that social rewards robustly stimulated reward-related brain areas, overlapping with areas activated for monetary rewards.

Imaging and lesion studies reveal that cool executive functions rely more on the lateral prefrontal cortex, whereas hot executive functions rely more on ventral and medial prefrontal cortex regions (Meuwissen & Zelazo, 2014; Zelazo & Carlson, 2012; Bechara, Damasio, Damasio, & Anderson, 1994). Thus insight from these studies support the continuum of hot and cool executive functions. Cool executive function is thought to be active during emotionally neutral, abstract, mechanistic problems and can be viewed as purely cognitive executive functions, the affective properties of these cognitive skills that are activated under motivationally and emotionally meaningful contexts are viewed as hot executive functions (Zelazo & Müller, 2002; Zelazo & Cunningham, 2007; Hongwanishkul et al., 2005). A classic example that helps differentiate between cool and hot processes is one of a 3-year-old being asked to help a graduate student solve a problem. The problem is that the graduate student can eat a candy now or wait until he's done playing games; if he waits he'll get four candies later instead of one now. The 3-year-old pragmatically believes that the graduate student should wait, so he can get more candies later. While this scenario involves candy (which may be meaningful to the child), the child is not personally implicated in this scenario. The child is merely helping someone else make their decision. Choosing for someone else (especially for a 3-year-old) is not necessarily as emotional as it would be to choose for herself. When the 3-year-old is faced with the same dilemma, she chooses to have one candy immediately. The latter is an example of hot executive function being involved because stakes are high (candy) and this decision is personally meaningful ("candy now"). Hot executive function skills help us achieve goals when it is difficult to manage emotions and control our tendencies to either approach or avoid meaningful things (Meuwissen & Zelazo, 2014). Thus, it seems reasonable that hot executive functions may be useful in explaining the link between executive function and socio-emotional functions. While the field largely has a grasp on tasks that tap into cool executive functions (DCCS, Day/Night, etc.), there is a need for more measures of hot executive functions. Cool tasks, such as the DCCS, illicit little affective significance to the task properties or to the child's performance (e.g., successful performance does not equate rewards or loss of rewards). On the other hand, the Children's Gambling Task (Kerr & Zelazo, 2004) or Less is More (Carlson, Davis, & Leach, 2005) require children to make decisions based on stimuli that is more affective, such as candy (or stimuli that resembles candy) and children are rewarded based on their performance (with candy!). Candy (rewards) is extremely personally meaningful to most children. Current measures of hot executive function involve tasks such as children's gambling task, delay of gratification tasks (Hongwanishkul et al., 2005) and Less is More (Carlson, Davis, & Leach, 2005). Further, findings support hot and cool dimensionality of executive functions (Montroy et al., 2019). Hot and cool executive functions are proposed to work together, thus it is best to view these functions as two ends of a functional continuum brought about by separate but related environmental contexts rather than two completely separate systems (Zelazo & Cunningham, 2007). For instance, Meuwissen & Zelazo (2014) make note that in everyday life, most encounters involve hot *and* cool executive functions. As an example of this they reference the game "Red Light, Green Light" which recruits cool executive function demands when a child is needed to remember and follow the appropriate rules (stop when child hears "red" and move when child hears "green") and hot executive function demands because of the desire to get to the finish line (reward) before one's peers, children must also inhibit moving forward abruptly (even though they want to get to the finish line) or start over and move behind their peers if they fail to inhibit their response (further from reward). Nonetheless, highlighting the contrast of in-lab tasks that measure executive functions demonstrate that tasks can emphasize more cool aspects of executive functions (i.e., DCCS) or more hot aspects of executive functions (i.e., Children's Gambling Task; Less is More).

Evolutionary Perspectives on Executive Function

An evolutionary account of the ontology of executive function also seems to support a continuum of executive functions that can handle both hot and cool situations as these accounts are rooted in ideas regarding social groups, communication, and interpersonal accounts of self-regulation. The collection of these evolutionary accounts of executive functions reviewed below are based on neurological organizations of language and/or executive functions, individuals with language disorders, individuals with traumatic brain injuries, and the organization of the prefrontal cortex in other species (Ardila, 2008; Adornetti, 2016; Barkley, 2001). These accounts offer a perspective as to why and how executive functions have become so specialized in humans.

Barkley (2001) speculates that for most species with a nervous system that learn from contingencies of reinforcement, impulsivity is not viewed as a "problem", but rather that this impulsiveness "problem" appears to be unique to humans. Therefore, we've developed adaptive neuropsychological mechanisms to solve problems posed by impulsivity. Furthermore, he speculates about the "social problem impulsiveness created for which inhibition and self-regulation evolved to solve" (p. 5). Some activities proposed that might require inhibition include, reciprocal altruism (formation of social coalitions), imitation, tool use, and mimetic skill and communication (Barkley, 2001). Specific to the latter, communication necessitates some level of executive function abilities to engage in reciprocal exchanges of information that include varying pragmatic elements. While Barkley (2001) does not make a distinction between hot and cool executive functions, the general point of his paper focuses on possible social pressures that gave rise to executive functioning more generally.

However, Ardila (2008) seems to have a more nuanced approach that seems to break down executive function into two continuums, instead of viewing it more holistically and general as Barkley (2001). Ardila's (2008) argument consists of two executive functions that resemble hot and cool executive functions, metacognitive (problem solving, working memory, etc.) and emotional/motivational executive functions (coordinating cognition and emotion/motivation). It is argued that metacognitive executive functions may be unique to humans and may depend on culture and culture instruments as other species have emotional/motivational executive functions (Ardila, 2008). The latter is reflective of the social pressures Barkley (2001) mentions in his paper and the impulsivity 'problem' he mentions may be the equivalent to Ardila's (2008) emotional/motivational executive functions. Thus, taking into account both perspectives, the adaptive neuropsychological mechanisms that help us solve problems posed by impulsivity, would be what Ardila (2008) calls metacognitive executive functions.

Moreover, Ardila (2008) argues that specifically language as an instrument of "internal representation of the world and thinking (Vygotsky, 1978, p. 97)" may have developed and evolved metacognitive executive functions. In favor of language and executive functions evolutionary relationship, Adornetti (2016) also connects executive functions with language functioning via the role that executive functions have in language processing. In this sense, abilities such as abiding by turn taking and coordination of narratives between individuals necessitates the activation of executive function abilities. Thus, according to Adornetti (2016) execute functions helped scaffold the modern conception of human language. In sum, while these theorical approaches regarding the evolution of executive function abilities do not all make a distinction between cool and hot executive function processes, they do all highlight the relevancy of social interactions as a catalyst for our problem-solving abilities. Additionally, it is important to note that hot executive function is a relatively new term in the field, but seems to be synonymous to what Luria (1973;1980) and others have previously described as an 'arousal-motivation' unit, with cool reflecting a 'program control unit'. Nonetheless, future research is needed to provide a more concise definition of what constitutes hot and cool executive function processes and how these processes are implicated in language processing.

Bilingualism

Another place where the relationship between executive functions and language have received considerable attention is in the discussion of potential bilingual advantages in cognition. There is a long withstanding debate about whether bilinguals have enhanced executive function abilities due to regularly managing two languages and thus constantly activating brain regions responsible for executive control (Green, 1986). Before Peal and Lambert's (1962) study on bilingualism which found findings favoring bilinguals on cognitive measures, there was an emphasis on the negative effects of bilingualism on children's cognitive development. The past two decades have explored differences among bilinguals and monolinguals in regards to their linguistic and cognitive abilities. More recently, the study of bilingualism and executive function has led to some strife in the field because of contradictory findings. While one body of research finds notable dissimilarities that favor bilinguals in comparison to monolinguals (Bialystok, 2017; Grundy, Anderson, & Bialystok, 2017), others report null results or find that monolinguals outperform bilinguals in their investigation of executive function and bilingualism (Anton et al., 2014; Dunabeitia et al., 2014). While some large metanalytic reviews find no evidence to support the idea that bilingualism is associated with enhanced executive function (Lehtonen et al., 2018), others do find an advantage (Grundy & Timmer, 2017). These discrepancies in results are not necessarily surprising given the various complexities one needs to account for when investigating bilingualism and executive function.

Measurement Impurity. As noted earlier, executive function is a broad construct with components that are viewed as separate entities that are interrelated. Not only are these components difficult to measure as one aspect of executive function may be influencing another, but we also know executive function is associated with several factors, such as musical training, active video gaming, education level, and SES (Valian, 2015; Urasche & Noble, 2016). Also, other work stresses the importance of early childhood environment on the development of executive function. For instance, Cuevas and colleagues (2014) found that a home environment that is low in negative caregiving behaviors will help the promotion of optimal executive function development. The fact that various factors may influence executive function makes the study of bilingualism and executive function all the more difficult to study as it becomes difficult to disentangle 'other experiences' that may train executive function and 'bilingual experiences' that may also train executive functions (Valian, 2015). Any experience that broadly influences executive function, also influences the other specific components of executive function (Morales, Calvo & Bialystok, 2013).

While measuring executive function may seem difficult, measuring bilingualism also has its share of issues. It would seem irresponsible to assume all bilingual individuals share the same experiences. For instance, I am not as proficient in the first language I acquired (L1) as I am in the second language I acquired (L2). This was not always the case as there was a time when I was more proficient in my L1 than my L2. Additionally, I never explicitly learned to read or write in my L1 but I can do it at a mediocre level. To go on further, I do not 'switch' between both languages on a daily basis as I did as a child. However, I consider myself bilingual despite my lack of L1 usage and my unequal proficiency in both languages. Thus, it should be without stating that not all other bilinguals share the same experiences. Despite these variabilities, few studies investigating the relationship between executive function and bilingualism take into account immigration status, culture, age of language acquisition, language usage, how the language was acquired, and language proficiency (Paap, Johnson, & Sawi, 2015). There has been a call for more rigorous theory supporting the idea that bilingualism has direct influences on executive function. Paap and colleagues (2015) suggest starting with a theory of how two or more languages are managed and specifying which critical experience of the bilingual experience may enhance a specific component of executive function. Per Paap and colleagues (2015) suggestion ,it seems relevant to approach this question of whether bilingualism influences executive function by starting with the fundamentals of language learning.

A Social Cognitive Perspective. An evolutionary account of why executive functions evolved in the first place seems to support the idea of bringing language learning into the picture. Learning language is inherently interpersonal as monolingual and bilingual children learning language must learn to monitor and integrate many sources of information to communicate successfully, for example interpreting other's communicative gestures (linguistic and nonlinguistic), the pragmatics of the situation, and intonation (Liberman et al., 2017; Liebal, Behne, Carpenter, & Tomasello, 2009; Liszkowski, Carpenter, & Tomasello, 2008; Martin, Onishi, & Vouloumanos, 2012; Matthews, Lieven, & Tomasello, 2010; Moll & Tomasello, 2007; Yow & Markman, 2011; Hollich, Hirsh-Pasek, & Golinkoff, 2000; Tomasello, 2003). So if both monolingual and bilingual children learn language similarly, what makes the bilingual experience unique? Bilingual children may experience more communicative challenges due to being exposed to more than one language (Yow & Markman, 2011), so they may have to do more monitoring and integrating of many sources. Evidence suggests that they are doing just that. For instance, a study exploring the possible link between bilingual and monolingual children's use of referential cues found that young bilingual children exhibit a heightened sensitivity to referential cues, such as eye gaze (Yow & Markman, 2011). In this study monolingual children are less able at using a speaker's referential intent as useful information about where a toy is hidden. Additionally, bilingual children appear to be more likely to integrate multiple cues, such as context, eye gaze, and semantics to understand a speaker's referential intent (Yow & Markman, 2015). Also, infants as young as 14 months that are exposed to a multilingual environment are better than monolinguals at using a speaker's visual perspective to understand intended meaning (Liberman, Woodward, Keysar, & Kinzler, 2017). Bilingual children seem better able to understand speaker's referential intent and use paralinguistic cues. A study exploring whether bilingual children would be better able than monolingual children to use paralinguistic cues when interpreting a speaker's emotion found that while monolingual and bilingual children are equally capable of identifying emotion using affective information, bilingual children are more adult-like in that they use intonation of speech to interpret emotion of a speaker when it is conflicting with lexical content (Yow & Markman, 2011). These studies seem to support the notion that a multilingual environment may promote effective communication abilities based on unique experiences with interpersonal communication (Yow & Markman 2011, 2015; Fan, Liberman, Keysar & Kinzler, 2015; Liberman, Woodward, Keysar, and Kinzler, 2017; Wermelinger, Gampe, & Daum, 2017; Schroeder, 2018). In further support, Genessee, Tucker, and Lambert (1975) matched monolingual children and children exposed to more than one language on IQ to explore communication skills among these two groups of children. In this study children had to explain rules of a game to two listeners, one blindfolded and one not blindfolded. In addition, the children could not point or use gestures. Children exposed to more than one language were better able at responding to the needs of another based on that individual's communicational difficulties (i.e., blindfold). Similarly, support for a relationship between bilingualism and social cognition comes from studies finding a bilingual advantage on false belief tasks (Schroeder, 2018). In sum, the overarching theme of these results suggest that a multilingual environment may foster attention to social cues among early language learners.

Executive functions and language are highly complex cognitive processes that may have been driven by the need to function in large social groups. Evidence supporting enhanced communicative intent in bilinguals might suggest a link between executive function and bilingualism with a focus on hot and cool executive functions. As noted earlier, hot executive functions are active under emotionally meaningful contexts that are typically interpersonal and social in nature, as is language learning. Thus, based on the findings discussed above that highlight the socio-cognitive differences exhibited in bilingual children, we may expect to see bilingual advantages on hot executive function tasks. According to Gunnerud and colleagues' (2020) systematic review and meta-analysis regarding executive function and bilingualism, there is not enough studies yet available to draw conclusions regarding the relationship between bilingualism and hot executive function. Specifically, there were only 4 out of 143 studies that directly assessed bilinguals' performance on hot executive function tasks. Of those studies, 3 did not find any hot executive function advantages on delay tasks (Carlson & Metlzoff, 2008; Crivello et al., 2016; Poulin-Dubois et al., 2011). While Verhagen, Mulder, and Leseman (2017) also did not find any hot executive function advantage on delay tasks between monolingual and bilingual children, they did find that bilingual children whose parents spoke different languages outperformed bilingual children with parents that spoke the same language. The latter is reminiscent of a study that examined repair of communication failures between monolingual and two groups of bilingual children. In this study, Wermelinger, Gampe, and Daum, (2017) define one bilingual group of children as acquiring two highly similar languages and the other bilingual group as acquiring two less similar languages. They found that bilingual children whose parents spoke different languages were four times more likely to repair misunderstandings in comparison to monolingual children and bilingual children with exposure to similar languages. Moreover, a recent study that included monolingual and bilingual children from three countries (U.S., Argentina, and Vietnam) found that bilinguals outperformed monolinguals on a hot executive function delay task (Tran, Arredondo, & Yoshida, 2019), though the effect was small. The latter three studies remind us that bilingual groups are not homogenous in their language experiences and they highlight the importance of investigating diverse bilingual experiences.

Relatedly, some studies have explored whether bilinguals' performance on communicative intent tasks is related to executive function abilities. However, most studies only include one cool executive function measure and find that it is not a predictor of children's performance in socio-communicative tasks (Siegal, Lozzi, & Surian, 2009; Fan, Liberman, Keysara, & Kinzleraa, 2016). Thus, future research may benefit from including a hot executive function task because of the potential link between hot executive function processes and social skills. More research is needed in order to further define hot executive function and understand whether it is related to bilingualism.

Current Set of Studies

Executive function as a field has greatly benefited and advanced from taking what we know about cool aspects of executive function to begin examining executive function under 'hot' contexts. I believe the bilingual advantage debate can greatly benefit from taking what we know about cool aspects of executive function and turning up the 'heat' on this debate. In sum, the relatively new push to understand executive functions in a variety of contexts will hopefully lead to more ecological tasks of executive functions in general and validation of previous tasks, as well a better understanding of the construct. Additionally, concerning the development of executive functions, more longitudinal studies are needed because a lot of what we know about the development of executive functions is reliant on cross-sectional studies or studies at only one time point. Furthermore, the shortcomings of executive functions research listed above directly apply to the bilingual advantage debate. Most studies regarding the ‘bilingual advantage debate’ focus on cool aspects of executive function. Yet, the hot aspects of executive function remain understudied.

Thus, in the subsequent chapters I examine the relationship between bilingualism and executive function with the hopes of transitioning the bilingual advantage debate to a more social lens. Specifically, my first study focuses on the development of bilingual children’s executive function over time in a longitudinal study across several time points. My second study explores whether teachers’ ratings of children’s ‘hot’ executive functions in the classroom relate to bilingualism. My third study seeks to understand how bilingual adults will perform on a hot executive function task. Finally, my last study examines whether bilingual and monolingual children will differ on hot and cool executive function tasks that differ on their interpersonal level and furthermore how these tasks relate to a more ecological hot executive function task.

Finally, this collection of studies aims to provide evidence for how bilingualism relates to executive function using a holistic multimethod approach including, a longitudinal design, cool executive function tasks, teacher reports, and hot executive function tasks. Additionally, the inclusion of a young adult study will provide a glimpse to how young bilingual adults preform on a relatively hot executive function task. Finally, this dissertation aims to understand executive function under hot contexts.

Chapter 2: Executive Function: A Developmental Trajectory Among Bilingual and Monolingual Children

Ongoing research with bilingual populations has yielded meaningful advances in what we know about the 50% of the world population who speak more than one language (Crystal, 1997). Prior popular belief was that learning two languages could be confusing and would result in cognitive disadvantages (Smith, 1923; Darcy, 1953) until a study by Peal and Lambert (1962) began to cast doubt on this notion through the discovery of cognitive advantages favoring bilingual participants over monolinguals. Additionally, measurable group differences among bilinguals and monolinguals are reported on biopsychological variables (e.g., brain volumes, neural activation patterns, etc.) and on behavioral tasks of linguistic and cognitive ability (Bialystok et al., 2004; Bialystok, Craik & Luk, 2012). Such findings are often attributed to the presence of the bilinguals enhanced executive function abilities. While there is not a consensus on a mechanism that underpins the bilingual advantage (Antoniou, 2019), it is generally hypothesized that individuals who regularly use two languages constantly activate brain regions responsible for executive control (Green, 1986). In bilinguals, the executive system provides immediate access to both language lexicons, while managing and inhibiting conflicting linguistic stimuli (Bialystok, Craik, & Luk, 2008; Prior & Gollan, 2011). And because bilinguals engage this language-related system more frequently, it is argued that they develop more robust executive skills as a consequence (Bialystok, 2011, 2017; Grundy et al., 2017; Kroll & Biaylstok, 2013).

Continued study of bilingualism has also given rise to some contradictory findings. For instance, one body of data demonstrates notable dissimilarities when comparing bilingual and monolingual groups (Bialystok, 2017; Grundy, Anderson, & Bialystok, 2017). Studies also report inconsistent or null results in their investigation of executive function differences among bilinguals and monolinguals (Anton et al., 2014; Dunabeitia et al., 2014). Publications by Bialystok & Grundy (2018) and Paap, Johnson, & Sawi, (2016) outline key examples of contradictory findings among adult samples. Similar contradictory findings exist among child samples (Anton et al., 2014; Dunabeitia et al., 2014; Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011; Santillán & Khurana, 2017). Systematic reviews point to several methodological issues in studies that show bilinguals outperforming monolinguals, such as small sample sizes (Paap et al., 2015). Also, comparison of un-matched samples is seen as a common shortcoming (Lehtonen et al., 2018). Several reviews have tried to address this problem by using statistical methods to control for known covariates and moderators [e.g., age, age of L2 acquisition (AoA), first (L1) or second (L2) formats of experimental tasks, and socio-demographics]. These attempts to integrate studies with positive and null findings show that cumulative executive-advantage effects for bilinguals are either small but moderated, not present, or largely diminished by statistical controls (Grundy & Timmer, 2017; Hartanto & Yang, 2018; Paap et al., 2015).

Another long-acknowledged challenge has been the issue of temporal confounding (Woumans & Duyck, 2015). The majority of research examining differences among bilinguals and monolinguals has been cross-sectional in design (Woumans, Surmont, Struys, & Duyck, 2016), or utilizes one-time concurrent measurement of executive skill. The shortage of longitudinal studies weakens assertions claiming that bilingual experiences, over time, cause augmentation of executive neural networks (Luk, Bialystok, Craik, & Grady, 2011; Sullivan, Janus, Moreno, Astheimer, & Bialystok, 2014). Additional prospective or retrospective work can help qualify the boundaries of how bilinguals differ from monolinguals on executive function abilities (Paap et al., 2016; Woumans & Duyck, 2015). More longitudinal research is needed to further examine how bilinguals and monolinguals differ in their executive function abilities.

For the purposes of this study, I have chosen to focus on behavioral measures of switching and updating. Switching can be understood as cognitive flexibility as it is measured with the ease of one's transition to a new task-set or rules (Miyake and Friedman, 2012; Valian, 2015). A rule-switching task that is widely used to measure cognitive flexibility among children is the Dimensional Change Card Sort (DCCS) task (Zelazo, 2006). Given that bilinguals switch from one language to another, it is believed that they would be better at switching between rules or tasks demands. Indeed, Bialystok (1999) found that bilingual children outperformed monolingual children in a nonverbal sorting task.

Miyake and Friedman (2012) refer to updating as "constant monitoring and rapid addition/deletion of working memory contents" (p. 2). Their example of an updating task is a letter memory task where participants are presented letters one at a time and participants must report the last three letters after the presentation of the letter sequence finishes (Miyake & Friedman, 2012). Another similar updating task is the n-back (Kirchner, 1958). A task that requires working memory manipulation is the backward digit span task (also known as numbers reserved) where participants must repeat sequence of numbers in reverse order (Snyder, Miyake, & Hankin, 2015). Several studies have examined children's working memory using the digit span backwards tasks (Chen & Stevenson, 1988; Klingberg, Forssberg, & Westerberg, 2002). Working memory involves the ability to hold information in the mind and mentally manipulate it (Baddeley & Hitch, 1994; Smith & Jonides, 1999). For instance, you must hold your goal in mind to know what to inhibit to (Diamond, 2013). Thus, many believe that working memory and inhibitory control support one another and will rarely be used exclusively (Diamond, 2013). Miyake and Friedman's (2012) model describes executive function as being illustrated by "unity and diversity" and research regarding executive function seems to support the notion of a common underlying mechanism (Morales, Calvo & Bialystok, 2013; Best & Miller, 2010; Garon et al., 2008; Lehto et al., 2003). With regards to this view, any experience that broadly influences executive function, also influences working memory (Morales, Calvo & Bialystok, 2013). Prior research supports the notion of bilingual advantages with regards to inhibition and shifting, so based on the "unity" perspective of the Miyake and Friedman's (2012) model we should also expect an advantage in working memory (Morales, Calvo & Bialystok, 2013).

Study Rationale

This article describes the longitudinal analysis of an archival dataset. It demonstrates how advanced statistical methods can be used to test effect-related hypotheses, while simultaneously accounting for the methodological and sampling problems that currently cloud our understanding of the phenomenon. Psychology has increasingly recognized quantitative examination of large data archives as a promising research methodology (Harlow & Oswald, 2016). It provides greater access to diverse samples and amplifies researchers' capacity to see naturally developing patterns of behavior (Kosinski, Wang, Lakkaraju, & Leskovec, 2016). Longitudinal analysis of a trusted data archive is well suited for testing relationships between bilingualism and executive skill over time (Santillán & Khurana, 2017). It also allows sufficient power and control over known covariates [e.g., socio-demographics, L2 proficiency, etc.]. The present study leverages data collected by the Early Childhood Longitudinal Study (ECLS-K:2011; Tourangeau et al., 2015). The ECLS collects nationally-representative samples for long-term research on development, early learning, and academic progress. This large inclusive sample allows the current study to examine how bilinguals and monolinguals may differ in their growth trajectories of executive function overtime while statistically controlling for possible socio-demographic confounds using latent growth curve modeling (LGCM).

LGCM can be considered an extension of latent variable models that are used to evaluate change over time (Felt, Depaoli, & Tiemensma, 2017). Specifically, LGCM examines change over time by the means of specifying latent growth factors. The specification of such latent growth factors comes from the estimation of a latent intercept and latent slopes (Felt, Depaoli, & Tiemensma, 2017). There are many benefits of implementing LGCM versus more traditional methods (e.g. repeated analysis of variance; repeated ANOVA). Assumptions that underlie repeated ANOVA include assumptions of sphericity, which concerns equal variances between time points/levels and independence assumption. Given the complexities of social sciences research, both assumptions are rarely met (Hancock & Muller, 2013). LGCM helps overcome such limitations. For instance, LGCM uses more information than traditional methods (Hancock & Muller, 2013). Additionally, within the SEM framework, construct's measurement errors are taken into account (Kline, 2016).

Recommendations for testing for an effect of bilingual advantage in executive functions based on the Friedman and Miyake (2004) model suggest implementing multiple measures of executive function to ensure that potential effects are not due to task impurity. Thus, our investigation includes two cognitive measures of executive function and three behavioral measures of executive function based on teacher reports. Dekker and colleagues (2017) recently found that cognitive measures of executive function and teacher reports of executive function were correlated and related to school achievement among elementary aged children. Their study provides support for the ecological validity of cognitive and behavioral measures of executive function (Dekker et al., 2017). As explained above, previous work suggests a link between cognitive measures of executive function and bilingualism. Thus, I hope to replicate this link with this sample and further explore whether there is a link between bilingualism and rating measures of executive function.

Summary and Hypotheses. Given previous literature that has found that children aged 4 to 5 still acquiring their second language show lower inhibitory control compared to bilinguals (Choi, Jeon, & Lippard, 2018; Santillán & Khurana, 2017), the current study hypothesizes that first assessments will find weaker executive skills in monolinguals and ELLs when compared to bilinguals. Also, given studies that have found that bilingual children show higher inhibitory control compared to monolingual children (Bialystok, 1999; Choi, Jeon, & Lippard, 2018; Santillán & Khurana, 2017; Carlson & Meltzoff, 2008), I hypothesized that bilinguals and English language Learners (ELLs) will show significantly steeper trajectories in executive skill development, when compared to trajectories of monolingual samples.

Study 1

Methods

This study utilized the publicly accessible ECLS-K:2011 archive from the U.S. Department of Education's National Center for Educational Statistics website (NCES, 2017). The ECLS-K:2011 archive contains data directly collected from children, families, and teachers from over 1,300 schools, from all 50 states (Tourangeau et al., 2015). Volunteers were first enrolled in the study as they entered kindergarten in fall of 2010. Parent interviews, self-administered teacher questionnaires, and one-on-one child assessments were administered to collect information regarding cognitive, social, emotional, and physical development. Included were measures of reading, math, science, and cognitive/executive skill.

All children received an English language screener that included the Preschool Language Assessment Scale (preLAS; Duncan & DeAvila, 1998) in kindergarten. If the child spoke a language other than English at home and passed the language screener (16 or higher on preLAS) than the child continued with the assessments in English. However, if the child did not pass the language screener and spoke Spanish then the child continued the assessments in Spanish. If the child spoke a language other than Spanish and did not pass the language screener then the child did not take the assessments. Furthermore, in first grade the language screener depended on whether the child's home language was not English. If the child's home language was English the child continued with assessments in English. If the child's home language was a language other than English and the child passed the screener in a previous round the child continued with assessments in English. However, if the child spoke a language other than English at home and did not pass the screener in a previous round then the child completed the English language screener and if the child passed the screener then test administrators proceeded with the assessments in English. If the child did not pass the screener and spoke Spanish then the child proceeded with the assessments in Spanish.

Participants

Information from four ECLS-K:2011 time-points was used: fall 2010 (kindergarten start), spring 2011, fall 2011, and spring 2012 (end of first grade). Children's data were excluded if their socio-demographic or language background was not reported. Additionally, having a disability was an additional exclusion criterion. Parent interview questions asked about the child's ability to pay attention, learn, communicate, relate to adults and children and overall activity and behavior level, emotional or psychological difficulties, difficulties hearing or understanding speech, and eyesight. If the parent indicated any difficulties of the above categories, then follow-up questions probed about whether the child obtained a diagnosis. A child was excluded for having any disability (which includes conditions such as developmental disabilities but not limited to conditions such as cerebral palsy). Out of approximately 18,000, N = 7,846 volunteers was retained for analysis.

Children's language background and performance on the preLAS English proficiency measure was used to assign them to one of three groups. The 'Monolingual' sub-sample (*n* = 7,095) comprised of children whose parents reported 'English' as the primary and only language used at home. Children also had to score above an accepted cut-off score (16) recommended by the preLAS. The ECLS-K:2011 bi-annually tested all children with the preLAS to determine oral and pre-literacy English skill by assessing their receptive and expressive language. To be placed in the monolingual group, children starting kindergarten needed a preLAS score of 16 or higher upon enrollment in kindergarten. The 'Bilingual' sub-sample (*n* = 522) comprised of children whose parents reported non-English as the primary language spoken in the home. Per Han's (2012) standard, both parents also had to agree that they spoke non-English to their child 'often' or 'very often' and that their child 'often' or 'very often' spoke non-English back to them. Additionally, assignment to the bilingual condition required a preLAS score above the 16-point cut-off upon enrollment in kindergarten. The English Language Learner sub-sample (*n* = 229) included children whose households reported using non-English to the same degree as the bilingual group. These children did not however, show similar levels of English (L2) proficiency. Children placed in the ELL condition, similar to Santillán and Khurana (2017), received a preLAS score below the accepted standard at the start of kindergarten but scored above the 16-point cut-off in subsequent preLAS assessments, indicating they achieved L2 proficiency in English.

Socioeconomic status (SES) was classified similarly to Hartanto, Toh, and Yang's (2018) measures of SES, which was computed through five variables: household income, maternal education, paternal education, maternal occupation prestige score, and paternal occupation prestige score (see Hartanto, Toh, and Yang, 2018 for variable computation and variable details).

Measures

The study uses direct cognitive assessments of child's executive function and teacher parent reports of child's executive function obtained from the ECLS-K 2011 dataset. The cognitive assessments and teacher report on child's self-control was administered by trained staff across all four time points. Teacher reports on child's attention level and inhibitory control were given in Fall and Spring of kindergarten and Fall of first grade.

Dimensional Change Card Sort (DCCS). Cognitive flexibility was measured via the DCCS task (Zelazo, 2006), which is a standard task for examining executive function early in development. In this task, children are asked to sort a series of 22 pictures based on different rules (color, shape, and border of card). For instance, each card had a picture of a red rabbit or blue boat and the child had to sort the cards by color (i.e., red or blue). Then, the child was asked to sort by shape (i.e., rabbit or boat). The composite score used is made up of the post-switch score (after they are required to switch rules between color to shape), which is the number of correctly sorted cards by shape and the border game score, which is the number of cards the child correctly sorted when the sorting rule was determined by the presence or absence of a border around the card. There is missing data that may be due to a child not correctly sorting at least four of the six cards in the shape game, this indicates that they were not administered the border game, hence not having a composite score. Scores ranged from 0 to 18. Please see Zelazo (2006) for further details regarding administration procedures and scoring details.

Numbers Reversed. Measures of working memory (WM). WM included the Numbers Reversed (NR; Woodcock, McGrew, & Mather, 2001). The NR task asks children to recall orally presented sequence of numbers and repeat the sequences, accurately, in reverse order (i.e., 3..5 would be 5..3). If the child does not fail, he or she is administered five three number sequences. The sequences become longer but do not exceed eight numbers. I used the W score, which was a type of standardized score that is derived from a transformation of the Rasch ability scale and gives a common scale of equal-intervals that are representative of the child's ability and the difficulty of the task (Tourangeau et al., 2015). The W score does not include how many of each length number sequence the child answered correctly. More information on publisher scores can be found in the Woodcock-Johnson III Tests of Achievement Examiner's Manual: Standard and Extended Batteries (Mather and Woodcock, 2001).

Teacher Report on Self Control (TR:SC). Self-control was classified based on the teacher's response on four items that were measuring the child's self-control. This measure is comprised of the Social Skills Rating System (SSRS; Gresham, & Elliott, 1990). Teachers rated the child's behavior on a frequency scale ranging from "never" to "very often" but also had the option of indicating that they had not had an opportunity to observe the described behavior for the child being asked about. The TR:SC score was computed for any child whose teacher provided a rating on a minimum 3 out of 4 items that made up the scale because that was the minimum numbers required to compute a score. Higher scores indicate the child exhibited the behavior represented by the scale more often. A high score of self-control would indicate that the child exhibited self-control often, whereas a lower score would indicate the opposite.

Teacher Report on Attention Level (TR:AL). Attention level was classified based on the teacher's response on 6 items from the Attentional Focusing subscale of the Children's Behavioral Questionnaire (CBQ; Putnam & Rothbart, 2006). Teachers would be asked to rate an item such as, "The child can wait before entering into new activities if he/she is asked to" on a 7-point scale ranging from "extremely untrue" to "extremely true". A score was computed when the teacher provided a rating of at least 4 out of 6 items because that was the minimum numbers required to compute a score. Higher scale scores indicate the child exhibited behaviors that demonstrate the ability to focus attention on cues in the environment that are relevant to the task in hand.

Teacher Report on Inhibitory Control (TR: IC). Inhibitory control was classified based on the teacher's response on 6 items from the Inhibitory Focusing subscale of the CBQ (Putnam & Rothbart, 2006). Teachers would be asked to rate a statement such as, "When building or putting something together, the child becomes very involved in what he/she is doing, and works for long periods" on a 7-point scale ranging from "extremely untrue" to "extremely true. A score was computed when the teacher provided a rating of at least 4 out of 6 items because that was the minimum numbers required to compute a score. Higher scale scores indicate the child exhibited behaviors that demonstrate the ability to resist a strong inclination to do one thing and instead do what is most appropriate.

Data Analysis

All analyses were performed with Mplus version 7.4 (Muthén & Muthén, 2017). Latent growth curve models were estimated for each measure of executive function for monolinguals and bilinguals and subsequently for monolinguals and ELLs. Time invariant covariates were included in all analysis: SES and gender (0 = Female, 1= Male). Given that a total of 10 models were generated, I chose a path diagram for one of the models to illustrate in Figure 1. The Wald test (Wald, 1943, Bollen, 1989) was used to test for group differences at the intercept and slope in each model. Currently there is not an option to run three groups simultaneously, thus one group of analyses compares monolinguals versus bilinguals and another group compares monolinguals versus ELLs. Also, while there is a difference in sample size, this is not a problem given our method of analyses (Hox, & Maas, 2001).

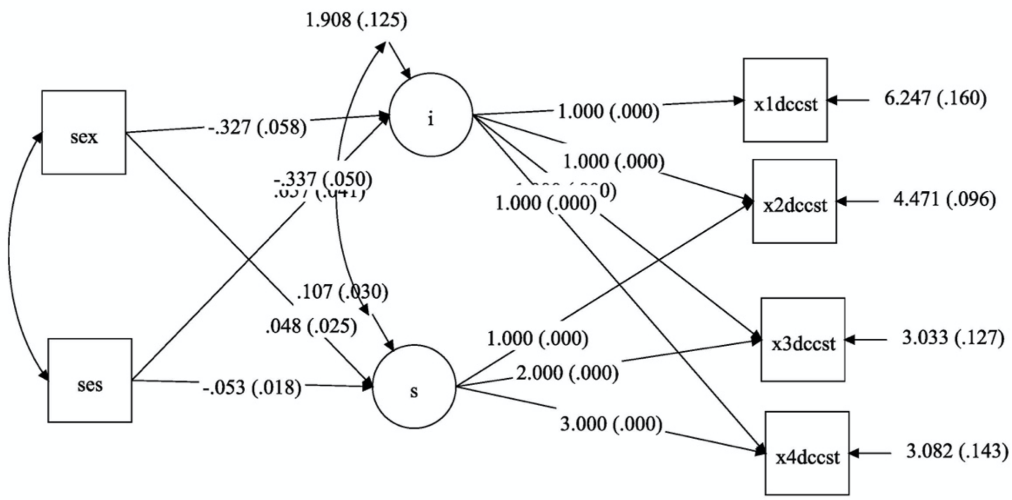

Figure 1. Path model from Chapter 2. SES and Sex are covariates and I is intercept, S is slope, dccst is dimensional change card sort task. The boxes on the far right represent the time points, hence, X1, X2, etc.

Results

First, I conducted bivariate correlations to assess the DCCS and NR tasks association with teacher reported attention, self-control and inhibitory control. I found that both the DCCS and NR tasks significantly correlated with teacher rated attention and inhibitory and self-control at all time points (*r*s > .06, *p*s < .009; see Table 1. Next, I compared differences between monolinguals and bilingual and ELL participants on these tasks and teacher reports.

Table 1

Correlations on Cognitive Tasks and Behavioral Reports Based on Teacher Reports Across All Time Points

Variables	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1. T1 NR	–																	
2. T2 NR	.55**	–																
3. T3 NR	.44**	.50**	–															
4. T4 NR	.39**	.45**	.45**	–														
5. T1 DCCS	.26**	.24**	.18**	.21**	–													
6. T2 DCCS	.24**	.25**	.20**	.21**	.26**	–												
7. T3 DCCS	.22**	.25**	.24*	.18**	.19**	.21**	–											
8. T4 DCCS	.21**	.24**	.18**	.24**	.20**	.21**	.21**	–										
9. T1 TR:SC	.17**	.15**	.11**	.16**	.13**	.10**	.07**	.09*	–									
10. T2 TR: SC	.15**	.16**	.10**	.16**	.11**	.10**	.09**	.10**	.62**	-								
11. T3 TR: SC	.16**	.16**	.15*	.14**	.08**	.06**	.13**	.68**	.36**	.41**	-							
12. T4 TR:SC	.16**	.16**	.14**	.15**	.10**	.07**	.09**	.08**	.37**	.44**	.63**	-						
13. T1 TR:IC	.23**	.23**	.21**	.22**	.15**	.14**	.11**	.12**	.55**	.39**	.39**	.40**	-					
14. T2 TR:IC	.21**	.23**	.21**	.22**	.15**	.14**	.11**	.12**	.55**	.69**	.43**	.43**	.70**	-				
15. T4: TR: IC	.23**	.21**	.21*	.22**	.13**	.11**	.15**	.13**	.36**	.42**	.55**	.66**	.47**	.51**	-			
16. T1: TR: AL	.31**	.28**	.24**	.26**	.18**	.14**	.14**	.16**	.54*·	.45**	.31**	.33**	.78**	.60**	.43**	-		
17. T2 TR:AL	.28**	.29**	.27**	.26**	.17**	.16**	.13**	.14**	.44**	.56**	.35**	.37**	.61**	.78**	.44**	.14**	-	
18. T4: TR:AL	.28**	.26**	.25**	.27**	.15**	.14**	.16**	.14**	.30**	.34**	.42**	.52**	.41**	.41**	.33**	.30**	.14**	-

Note: T = Time point; NR = Numbers Reversed; DCCS = Dimensional Change Card Sort task; TR = Teacher Reports; SC = Self Control; IC = Inhibitory Control; AL = Attention Level. ** = correlation is significant at the 0.01 level (2-tailed).

Monolingual and Bilingual Comparisons

Below is a breakdown of Wald results of the unstandardized intercept (model 1) and slope (model 2) for group comparisons between monolinguals and bilinguals. See Table 2 for slope and intercept coefficients and covariate results for monolinguals, bilinguals and ELLs. To reiterate, because I could not run three groups simultaneously in one model, one group of analyses compares monolinguals versus bilinguals slopes and intercepts and another group compares monolinguals versus ELLs slopes and intercepts.

Table 2

Latent Growth Model Findings: Monolingual vs Bilingual and Monolingual vs English Language Learners Slope and Intercept Coefficients and Standard Errors from Chapter 2

		NR		DCCS	
Language Group	**Parameter**	**Coefficient (SE)**	***p*-value**	**Coefficient (SE)**	***p*-value**
	Intercept(SE)	441.130(0.445)	***	14.981 (.440)	***
	Slope(SE)	11.353 (0.166)	***	0.491(0.017)	***
Monolingual	Gender Initial(SE)	-1.849(0.635)	***	-0.327(0.058)	***
	Gender Growth(SE)	0.049(0.237)	n.s.	0.048(0.025)	n.s.
	SES Initial(SE)	12.873(0.449)	***	0.657(0.041)	***
	SES Growth(SE)	-1.988(0.169)	***	-0.053(0.018)	***
	Intercept(SE)	442.095(1.729)	***	14.807 (0.158)	***
	Slope(SE)	10.897(0.655)	***	0.550 (0.066)	***
Bilingual	Gender Initial(SE)	-8.344(2.453)	***	-0.196(0.224)	n.s.
	Gender Growth(SE)	1.836(0.92)	**	0.017(0.093)	n.s.
	SES Initial(SE)	15.328(1.63)	***	0.663(0.149)	***
	SES Growth(SE)	-2.448(0.623)	***	-0.066(0.063)	n.s
	Intercept(SE)	419.615(2.504)	***	13.347 (0.342)	***
	Slope(SE)	15.941(1.085)	***	0.829 (0.153)	***
ELL	Gender Initial(SE)	11.153(3.002)	***	-.246 (0.447)	n.s.
	Gender Growth(SE)	-1.652(1.386)	n.s.	-0.010 (0.190)	n.s.
	SES Initial(SE)	11.153(3.002)	n.s.	0.158(0.422)	n.s.
	SES Growth(SE)	-0.868(1.292)	n.s.	-0.062 (0.180)	n.s.

		TR:AL		TR:IC	
Language Group	**Parameter**	**Coefficient (SE)**	***p*-value**	**Coefficient (SE)**	***p*-value**
	Intercept(SE)	5.149(0.026)	***	5.346(0.020)	***
	Slope(SE)	0.026(0.008)	***	0.039(0.008)	***
Monolingual	Gender Initial(SE)	-0.514(0.03)	***	-0.543(0.030)	***
	Gender Growth(SE)	0.006(0.01)	n.s.	-0.024(0.010)	n.s.
	SES Initial(SE)	0.412(0.020)	***	0.308(0.020)	***
	SES Growth(SE)	0.004(0.010)	n.s.	0.023(0.010)	***
	Intercept(SE)	5.450(0.073)	***	5.571(0.069)	***
	Slope(SE)	0.026(0.030)	***	0.031(0.028)	***
Bilingual	Gender Initial(SE)	-0.678(0.100)	***	-0.608(0.010)	***
	Gender Growth(SE)	-0.008(0.030)	n.s.	0.01(0.040)	n.s.
	SES Initial(SE)	0.192(0.070)	***	0.012(0.070)	n.s.
	SES Growth(SE)	-0.008(0.030)	n.s.	0.02(0.030)	n.s.
	Intercept(SE)	4.960(0.143)	***	5.272(0.130)	***
	Slope(SE)	0.165(0.056)	***	0.091(0.047)	***
ELL	Gender Initial(SE)	-0.317(0.180)	n.s.	-0.407(0.170)	**
	Gender Growth(SE)	-0.151(0.07)	**	-0.123(0.060)	**
	SES Initial(SE)	-0.008(0.170)	n.s.	-0.069(0.160)	n.s.
	SES Growth(SE)	0.103(0.070)	n.s.	0.052(0.060)	n.s.

		TR:SC	
	Intercept(SE)	3.243(0.010)	***
	Slope(SE)	0.031(0.001)	***
Monolingual	Gender Initial(SE)	-0.194(0.014)	***
	Gender Growth(SE)	0.005(0.006)	n.s.
	SES Initial(SE)	0.126(0.01)	***
	SES Growth(SE)	0.014(0.004)	***
	Intercept(SE)	3.287(0.037)	***
	Slope(SE)	0.052(0.016)	***
Bilingual	Gender Initial(SE)	-0.135(0.052)	**
	Gender Growth(SE)	-0.039(0.022)	n.s.
	SES Initial(SE)	-0.046(0.034)	n.s.
	SES Growth(SE)	0.017(0.015)	n.s.
	Intercept(SE)	3.163(0.068)	***
	Slope(SE)	0.077(0.027)	***
ELL	Gender Initial(SE)	-0.245(0.088)	***
	Gender Growth(SE)	0.012(0.036)	n.s.
	SES Initial(SE)	-0.168(0.081)	n.s.
	SES Growth(SE)	0.069(0.033)	**

Note: **p< 0.05, ***p< 0.01, gender DV coded '0' - Male and.'1' - Female, bilingual DV coded '0' - Monolingual, '1' - Bilingual, and '2' – ELL, NR = numbers reversed, DCCS = dimensional change card sort, TR:AL = teacher report: attentional level; TR:IC = teacher report: inhibitory control; TR:SC = teacher report: self-control

Dimensional Change Card Sort: Cognitive Control. Model 1 Wald reveals that (1, $N = 7{,}617$) = 1.132, $p = 0.2872$, the monolingual intercept is not significantly different from the bilingual intercept. Model 2 revealed significant differences (1, $N = 7{,}617$) = 4403.130, $p < 0.001$, between the monolingual and bilingual slope showing that bilinguals exhibit a steeper rate of incline in cognitive control.

Numbers Reversed: Working Memory. Model 1 Wald reveals that (1, $N = 7{,}617$) = 0.292, $p = 0.5889$, the monolingual intercept is not significantly different from the bilingual intercept. Model 2 revealed no significant differences (1, $N = 7{,}617$) = 0.456, $p = 0.4997$, between the monolingual and bilingual slope.

Teacher Perceived Self-Control. Model 1 Wald reveals that (1, $N = 7{,}407$) = 1.361, $p = 0.2434$, the monolingual intercept is not significantly different from the bilingual intercept. Model 2 revealed no significant differences (1, $N = 7{,}407$) = 2.113, $p = 0.1460$, between the monolingual and the bilingual slope.

Teacher Perception Attention Level. Model 1 Wald reveals that (1, $N = 7{,}429$) = 15.963, $p = 0.0001$, the monolingual intercept is significantly different from bilingual intercept showing that bilinguals exhibit a higher initial status of perceived attention level. Model 2 revealed no significant differences (1, $N = 7{,}429$) = 0.001, $p = 0.9819$, between the monolingual and the bilingual slope.

Teacher Perception Inhibitory Control. Model 1 Wald reveals that (1, $N = 7{,}431$) = 9.724, $p = 0.0018$, the monolingual intercept is significantly different from the bilingual intercept showing that bilinguals exhibit a higher initial status of perceived inhibitory control. Model 2 revealed no significant differences (1, $N = 7{,}431$) = 0.069, $p = 0.7927$, between the monolingual and bilingual slope.

Monolingual and English Language Learners Comparisons

Below is a breakdown of Wald results for group comparisons of the unstandardized slope and intercept. See Table 1 above for monolinguals, bilinguals and ELLs slope and intercept coefficients and standard errors. Additionally, Table 1 provides slope and intercept coefficients and standard errors for covariates.

Dimensional Change Card Sort: Cognitive Control. Given a negative residual variance in the ELL group slope, I ran the model with the variance of ELL's slope fixed at 0. Model 1 Wald reveals that (1, $N = 7{,}324$) = 22.412, $p < 0.001$, the monolingual intercept is significantly different from the ELLs intercept showing that ELLs intercept is initially lower with regards to their performance on the DCCS. Model 2 revealed significant differences (1, $N = 7{,}324$) = 4.429, $p < 0.05$, between the monolingual and ELLs slope showing that ELLs exhibit a steeper rate of incline with regards to their performance on the DCCS. It should be noted that the negative residual variance involving ELL's slope could be an indication that a nonlinear trajectory might fit this particular group best. Unfortunately, the smaller size of this group does not lend itself to comparing between other nonlinear trajectories. Additionally, this is beyond the scope of this chapter.

Numbers Reversed: Working Memory. Model 1 Wald reveals that (1, $N = 7{,}324$) = 71.580, $p < 0.001$, the monolingual intercept is significantly different from the ELLs intercept showing that ELLs intercept exhibits a lower initial status of WM. Model 2 revealed significant differences (1, $N = 7{,}324$) = 17.475, $p < 0.001$, between the monolingual and ELLs slope showing that ELLs exhibit a steeper rate of incline in WM.

Teacher Perceived Self-Control. Teacher perceived self-control. Model 1 Wald reveals that (1, $N = 7{,}131$) = 1.375, $p = 0.2410$, the monolingual intercept is not significantly different from the ELLs intercept. Model 2 revealed no significant differences (1, $N = 7{,}131$) = 3.086, $p = 0.0790$, between the monolingual and ELLs slope.

Teacher Perception Attention Level. Model 1 Wald reveals that (1, $N = 7{,}150$) = 1.711, $p = 0.1908$ the monolingual intercept is not significantly different from ELLs. Model 2 revealed significant differences (1, $N = 7{,}150$) = 6.044, $p = 0.0140$, between the monolingual and ELLs slope showing that ELLs exhibit a steeper rate of incline in perceived attention level.

Teacher Perception Inhibitory Control. Model 1 Wald reveals that (1, $N = 7{,}153$) = 0.320, $p = 0.5714$, the monolingual intercept is not significantly different from the ELLs intercept. Model 2 revealed no significant differences (1, $N = 7{,}153$) = 1.212, $p = 0.2709$, between the monolingual and the ELLs slope.

Bilingual and English Language Learners Comparisons

In addition to comparisons between monolinguals and bilinguals and monolinguals and ELLs, we have also conducted comparisons between bilinguals and ELLs. Table 3 contains bilingual and ELLs unstandardized slope and intercept coefficients and standard errors. Additionally, Table 3 lists the coefficients and standard errors for the covariates.

Table 3

Latent Growth Model Findings: Bilingual vs English Language Learners (ELL) Slope and Intercept Coefficients and Standard Errors from Chapter 2

		NR		DCCS	
Language Group	**Parameter**	**Coefficient (SE)**	***p*-value**	**Coefficient (SE)**	***p*-value**
	Intercept(SE)	441.258(1.910)	***	14.773 (0.171)	***
	Slope(SE)	11.051(0.716)	***	0.558 (0.074)	***
Bilingual	Gender Initial(SE)	-7.776(2.722)	***	-0.058(0.243)	n.s
	Gender Growth(SE)	1.836(1.017)	n.s.	-0.014(0.104)	n.s
	SES Initial(SE)	3.700(0.416)	***	0.138(0.037)	***
	SES Growth(SE)	-0.605(0.158)	***	-0.012(0.016)	n.s
	Intercept(SE)	421.462(2.670)	***	13.265(0.359)	***
	Slope(SE)	15.079(1.085)	***	0.782(0.155)	***
ELL	Gender Initial(SE)	1.619(3.533)	n.s.	0.053(0.106)	n.s.
	Gender Growth(SE)	-1.373 (1.563)	n.s.	-0.023(0.203)	n.s.
	SES Initial(SE)	3.316(0.795)	***	0.053(0.106)	n.s.
	SES Growth(SE)	-0.434(0.347)	n.s.	-0.029(0.045)	n.s.
		TR:AL		**TR:IC**	
Language Group	**Parameter**	**Coefficient (SE)**	***p*-value**	**Coefficient (SE)**	***p*-value**
	Intercept(SE)	5.448(0.079)	***	5.561(0.075)	***
	Slope(SE)	0.025(0.033)	***	0.045(0.030)	***
Bilingual	Gender Initial(SE)	-0.651(0.112)	***	-0.585(0.107)	***
	Gender Growth(SE)	0.056(0.046)	n.s.	-0.015(0.044)	n.s.
	SES Initial(SE)	0.035(0.017)	**	0.000(0.016)	n.s.
	SES Growth(SE)	0.002(0.007)	n.s.	0.004(0.007)	n.s.
	Intercept(SE)	4.926(0.138)	***	5.266(0.130)	***
	Slope(SE)	0.174(0.056)	***	0.092(0.049)	n.s.
ELL	Gender Initial(SE)	-0.197(0.188)	n.s.	-0.379(0.177)	**
	Gender Growth(SE)	-0.188(0.078)	**	-0.118(0.069)	n.s.
	SES Initial(SE)	-0.003(0.042)	n.s.	-0.014(0.040)	n.s.
	SES Growth(SE)	0.024(0.017)	n.s.	0.012(0.015)	n.s.
		TR:SC			
	Intercept(SE)	3.301(0.040)	***		
	Slope(SE)	0.052(0.017)	***		
Bilingual	Gender Initial(SE)	-0.147(0.058)	**		
	Gender Growth(SE)	-0.039(0.024)	n.s.		
	SES Initial(SE)	-0.012(0.009)	n.s.		
	SES Growth(SE)	0.005(0.004)	n.s.		
	Intercept(SE)	3.148(0.071)	***		
	Slope(SE)	0.079(0.029)	***		
ELL	Gender Initial(SE)	-0.247(0.099)	**		
	Gender Growth(SE)	0.028(0.041)	n.s.		
	SES Initial(SE)	-0.042(0.022)	n.s.		
	SES Growth(SE)	0.021(0.009)	**		

Note: $^{**}p< 0.05$, $^{***}p< 0.01$, gender DV coded '0' - Male and '1' - Female, DV coded '0' - Bilingual, and '1'– ELL, NR = numbers reversed, DCCS = dimensional change card sort, TR:AL = teacher report: attentional level, TR:IC = teacher report: inhibitory control, TR:SC = teacher report: self-control.

Dimensional Change Card Sort: Cognitive Control. Consistent with the models above regarding comparisons between monolinguals and ELLs, I ran the model with the variance of ELL's slope fixed at 0 because of the negative residual variance associated with ELLs slope on this task. Model 1 Wald reveals that (1, *N* = 613*)* = 14.397, *p* < 0.001, the bilingual intercept is significantly different from the ELLs intercept showing that ELLs intercept exhibits a lower initial status of cognitive control. Model 2 revealed no significant differences (1, *N* = 613*)* = 1.690, *p* = 0.1936, between the bilingual and ELLs slope in cognitive control. Again, it should be noted that ELL's show a negative residual variance which suggests that a linear model may not fit the data within this group well.

Numbers Reversed: Working Memory. Model 1 Wald reveals that (1, $N = 613$) = 36.368, $p < 0.001$, the bilingual intercept is significantly different from the ELLs intercept showing that ELLs exhibit a lower initial status of WM. Model 2 revealed significant differences (1, $N = 613$) = 8.617, $p < 0.001$, between the bilingual and ELLs slope showing that ELLs exhibit a steeper rate of incline in WM.

Teacher Perceived Self-Control. Model 1 Wald reveals that (1, $N = 586$) = 3.510, $p = 0.0610$, the bilingual intercept is not significantly different from the ELLs intercept. Model 2 revealed no significant differences (1, $N = 586$) = 0.682, $p = 0.4090$ between the bilingual and ELLs slope on teacher reports of self-control.

Teacher Perception Attention Level. Model 1 Wald reveals that (1, $N = 586$) = 10.716, $p < 0.001$ the bilingual intercept is greater than the ELLs intercept on teacher reports of attention level. Model 2 revealed significant differences (1, $N = 586$) = 5.299, $p = 0.0213$, between the bilingual and ELLs slope on teacher reports of attention level, showing that ELLs exhibit a steeper rate of incline in attention level.

Teacher Perception Inhibitory Control. Model 1 Wald reveals that (1, $N = 587$) = 3.887, $p = 0.0487$, the bilingual intercept is not significantly different from the ELLs intercept. Model 2 revealed no significant differences (1, $N = 587$) = 0.688, $p = 0.4069$, between the bilingual and the ELLs slope.

Study 2

Study 1 finds that monolingual, bilingual and ELL children differ in their developmental trajectories of executive function from kindergarten through first grade. For instance, ELL children consistently scored lower on DCCS and NR tasks at the start of kindergarten yet demonstrated steeper slopes with regards to these tasks throughout kindergarten and first grade. Bilinguals and monolinguals demonstrated no apparent differences on the NR task at the start of kindergarten or throughout kindergarten and first grade. While bilinguals and monolinguals also did not differ at the start of kindergarten on the DCCS task, bilinguals did demonstrate a steeper slope in comparison to monolinguals throughout kindergarten and first grade. While these results are informative, it would be useful to know how these groups of children continue to develop their executive function skills throughout elementary school. Thus, in the hopes of gathering a more comprehensive understanding of how monolingual, bilingual and ELL children may differ in their performance on executive function tasks I have conducted analyses with the same children in Study 1 at four later time points: fall of second grade, spring of second grade, spring of third grade and finally, spring of fourth grade.

These additional timepoints were not included in Study 1 because executive function performance was measured differently beyond first grade and the models I used above assume that assessments are all measured in the same way. For instance, the data collected via the DCCS task was collected with the physical version of the task which would have been too easy for children after first grade. Beginning second grade, an age-appropriate computerized version of the DCCS was administered to children. In the computerized version of the DCCS task children are still presented the cards as in the physical version of the task but the cards are presented on a computer screen and children sort them into piles using keyboards on the computer. The computerized task was also not administered during kindergarten and first grade rounds because it had been under development and was only made available in time for the second grade data collection. Details regarding how the mode of tasks affected the scoring is discussed below. Moreover, in fourth grade children also completed the Flanker task, in addition to the computerized version of the DCCS task. Finally, the fourth grade data was not made available to the public when Study 1 was conducted.

Methods

This study is an extension of Study 2 in that it follows the same participants over four additional time points. As mentioned above, a language screener was administrated for children in the kindergarten and first grade rounds. The language screener was not administered beyond spring of first grade because all children appeared to have passed the language screener by spring of first grade. Information from four ECLS-K:2011 time-points was used: fall (second grade), spring (second grade), spring (third grade), and spring (fourth grade). These are the same children previously examined in Study 1.

Measures

The study uses direct cognitive assessments of child's executive function obtained from the ECLS-K 2011 dataset. The cognitive assessments on child's self-control were administered by trained staff across all four time points. Below are descriptions of the DCCS, WM and Flanker Tasks. During both time points (e.g., fall and spring) in second grade children completed the DCCS and WM tasks. In spring of third grade children completed the DCCS and WM tasks. In spring of fourth grade children completed the DCCS, WM and Flanker tasks.

Dimensional Change Card Sort: Cognitive Control. The DCCS task (Zelazo, 2006) is a standard task for examining cognitive control early in development. Similar to the physical version of the task, children are required to sort cards by shape or color. In the standard physical task described in Study 1 the rules are consistent, first cards are sorted only by color, then by shape and finally depending on whether the card had a black border the cards are sorted by color or shape. In the computerized version of this task (Zelazo et al., 2013) the sorting rules are intermixed across 30 trails of the task. Furthermore, one rule is more common than the other in order to build a response tendency. According to the ECLS-K:2011 user manual, this was done because it is harder for children as it requires more time to inhibit a response tendency and switch the response. Also, the performance on this task takes into account accuracy and reaction time whereas the DCCS task in Study 1 does not take into account reaction time because it was not possible to accurately measure reaction time precisely in the physical version. Reaction time is measured based on the reaction time for trials using the sorting rule and only if the child responded correctly. The formula that takes into account both accuracy and reaction time is in Zelazo and colleagues (2013). The reaction time component within the overall computed score was computed using the child's median reaction time to correct responses on trials with the less frequently used sorting rule. For more information on details of the calculation of the computed score please see NIH Toolbox Scoring and Interpretation Guide (Slotkin, Nowinski, et al., 2012). Scores range from 0 to 10 and there is a weight accuracy, which is 0 to 5 units and reaction time, also 0 to 5 units in the calculation of the overall computed score.

Numbers Reversed: Working Memory. WM included the Numbers Reversed (NR; Woodcock, McGrew, & Mather, 2001). The NR task asks children to recall orally presented sequence of numbers and repeat the sequences, accurately, in reverse order (i.e., 3..5 would be 5..3). If the child does not fail, he or she is administered five three number sequences. The sequences become longer but do not exceed eight numbers. We used the W score which was a type of standardized score that is derived from a transformation of the Rasch ability scale and gives use a common scale of equal-intervals that are representative of the child's ability and the difficulty of the task (Tourangeau et al., 2015). The W score does not include how many of each length number sequence the child answered correctly. More information on publisher scores can be found in the Woodcock-Johnson III Tests of Achievement Examiner's Manual: Standard and Extended Batteries (Mather and Woodcock, 2001).

Flanker Task. The flanker task is a computerized task that measures inhibitory control and attention (Zelazo et al., 2013). Children are asked to direct their attention to a central stimulus (arrow) while ignoring distractor items (surrounding flanking arrows) and press a button on the computer that indicates the direction of the central stimulus. For instance, if the central stimulus is pointing left, the child should press the keyboard that corresponds with left, regardless of the flanking distractor items. If the central stimulus is pointing right, then the child should press the keyboard that corresponds with right regardless of the flanking distractor items. The flanking distractor items are sometimes pointing the same direction as the central stimulus (congruent trials) or pointing the opposite direction of the central stimulus (incongruent trials). The congruent and incongruent trials are intermixed. This task contains 20 trails. The final score takes into account accuracy and reaction time (please see Slotkin, Nowinski, et al., 2012 for further details regarding scoring). The performance on the trails where the child is getting opposite directions to the central stimulus are the incongruent trails that are used to derive the inhibitory control score.

Results

Data Analysis

Given that for LGCM all measures (assessments) need to be measured the same and the DCCS task went from a standard version to a computerized version I was not able to examine children's growth trajectories from second to fourth grade. However, I did use hierarchical linear regressions with the same covariates as Study 1 at each time point to further examine whether I would see differences on these executive function measures among monolingual, bilingual and ELL children, from second to fourth grade. Specifically, SES and gender were entered in Step 1 and in Step 2 I have dummy coded variables for language experience variables with the monolinguals as the referent group.

Dimensional Change Card Sort: Cognitive Control

On the DCCS task, using monolinguals as a referent group, bilinguals and ELLs performed lower. Bilinguals were not significantly lower (b = -.133, n.s.) but ELLs did perform significantly lower (b = -.383, p = .003.) at second grade. Similar results were found for second grade with bilinguals performing lower (b = -.123, n.s.), but not significantly and ELLs performing significantly lower (b = -.239, p = .024.). At third grade there were no significant differences. However, at fourth grade bilinguals outperformed monolinguals $b = .165$, $p = .026$.). but ELLs were still significantly lower $b = -.302$, $p = .001$.).

Numbers Reversed: Working Memory

There were no significant differences between groups at any of the time points from second to fourth grade.

Flanker Task

There were no significant differences between groups at any of the time points from second to fourth grade.

Discussion

Most studies that have investigated how bilingualism might relate to executive function have done so cross-sectionally or at one time point. I aimed to examine executive function across four time points, over a period of time that is often not as studied. I examined the executive function growth trajectories among bilinguals, monolinguals, and ELLs through a multi-method approach while controlling for SES and gender. In doing so, I included standardized measures of executive function skills as well as surveys of teacher perceptions. Miyake and colleagues' (2000) model of executive function identifies three distinct components of executive function: updating, switching, and inhibition (Miyake et al., 2000; Friedman & Miyake, 2004; Friedman et al., 2008; Miyake and Friedman, 2012). I was particularly interested in the ability to update and switch among children. Specifically, I looked at working memory (updating) via the NR task (Woodcock, McGrew, & Mather, 2001) and cognitive control (switching) via the DCCS task (Zelazo, 2006). While Study 1 implemented LGCM to examine growth trajectories from kindergarten to the end of first grade, Study 2 looked at each time point from second grade to fourth grade. Additionally, Study 2 included the flanker task in addition to the DCCS and NR.

Children in the bilingual group demonstrated similar cognitive control to the monolingual group at kindergarten entry but had a steeper cognitive control growth over the end of kindergarten and through first grade. However, ELL children showed lower cognitive control performance at the beginning of kindergarten but also showed faster cognitive control development during the time in which they were learning their second language. Children who are not yet proficient in English have the lowest performance at the first time point in cognitive control, but once they are proficient in their second language they improve faster, along with bilinguals. Yet, I found that bilinguals in our sample did not outperform monolinguals at the first time point. Studies have found that bilinguals outperform monolinguals prior to beginning kindergarten (Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011; Santillán & Khurana, 2017), therefore a processing advantage may become harder to detect at older ages (beyond the start of preschool) due to task differentiation and other experiences that might enhance executive functions (Valian, 2014). Other longitudinal work has found that culture plays an important role in the development of the alerting and executive control networks among bilinguals (Tran et al., 2015). A more recent longitudinal study found that bilinguals performed similarly to monolinguals at age nine but outperformed monolinguals at age ten on assessments of inhibition skills, suggesting executive function differences between the groups may only be present at certain developmental time points (Park, Weismer, & Kaushanskaya, 2018). That these differences do not emerge until the second or last time point seems to be consistent across recent developmental longitudinal studies (Santillán & Khurana, 2017; Choi, Jeon, & Lippard, 2018; Blom et al., 2014; Park, Weismer, & Kaushanskaya, 2018) Still, other work finds that bilingual children outperform monolingual children on overall accuracy across five time points on the Attention Network Test (ANT; Fan et al., 2002) from ages three to five (Tran et al., 2015). The discrepancies among developmental longitudinal studies may be reflective of specific executive function skills that can be enhanced with bilingual experience. Some studies find that bilingual experiences may modulate only certain aspects of executive function (Crivello et al., 2016).

Furthermore, previous work has found that bilingual children outperform monolingual children on the DCCS task (Bialystok, 1999; Carlson & Meltzoff, 2008; Hartanto, Toh, & Yang, 2018). Specifically, Carlson and Meltzoff (2008) found differences favoring bilingual children in the advanced version of the DCCS task. A possible reason we did not find differences at the initial start of kindergarten between bilingual and monolingual children may be a difference in task demands. Other work has found that bilingual children outperformed monolingual children only in conditions that involved executive control in a version of an anti-saccade task (Bialystok & Viswanathan, 2009). Some have argued that some reasons for inconsistencies in bilingualism research pertaining to executive function may be task impurity and the broadness of the construct (Valian, 2015). It has been proposed that in order to examine executive function the task must be novel, multifaceted and involve the integration of information (Anderson, 2002). The findings from this chapter are consistent with previous studies that find that bilingual and ELL children show faster cognitive control development (Santillán & Khurana, 2017; Ladas, Carroll, & Vivas, 2015; Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011). Thus, while it could be that the task used in these studies was not complex enough to reveal differences between bilingual and monolingual children at the initial start of kindergarten, it could also be that the children's bilingual experience and degree of balanced proficiency increased overtime resulting in a faster cognitive control growth. Given that this is secondary data I cannot further investigate this possibility. However, other work has investigated bilingualism and executive function with a variety of executive function tasks and information of the actual environment a child has and has found that bilingual children outperform monolingual children on conflict tasks but not on delay tasks (Carlson & Meltzoff, 2008).

I also found that bilingual and monolingual children appear to have equivalent working memory as they performed similarly to one another on the NR task. However, monolinguals seem to have better working memory than ELLs at the start of kindergarten. Also, despite having lower working memory at the start of kindergarten, ELL's have a steeper working memory growth over their second time point of kindergarten through first grade. Some prior research supports the notion that bilingual children would outperform monolinguals at the start of kindergarten and overtime (Bialystok, 2011, 2017; Grundy, Anderson, & Bialystok, 2017; Kroll & Biaylstok, 2013). For instance, based on the "unity and diversity" perspective of executive function (Miyake & Friedman, 2000), Morales, Calvo, and Bialystok (2013) tested whether bilingual children's working memory was enhanced compared to monolingual children. They hypothesized that among bilinguals, the core components of executive function system are all involved and modified as a consequence of bilingualism (Morales, Calvo,

& Bialystok, 2013). Indeed, they found that bilingual children outperformed monolingual children on Simon-type working memory tasks (Morales, Calvo, & Bialystok, 2013). However, with regards to WM I found no differences in between monolingual and bilingual children, yet ELLs had a lower WM score at the start of kindergarten but improved faster overtime. This study suggests that despite the lower initial status and significant growth rate, bilingual and monolingual children seem to perform similarly on the WM task. Blom and colleagues (2014) examined verbal and nonverbal WM abilities in monolingual and bilingual children and similarly found no significant differences among bilingual and monolingual children on WM tasks at time point one (age five). Our findings differ from Blom and colleagues (2014) which found differences on visuospatial WM and verbal WM differences among bilinguals and monolinguals at age six. There are several possible explanations for this difference. For instance, bilingual children in the Blom and colleagues (2014) study had the option of choosing the language in which the stimuli would be presented in whereas with our data the presentation of stimuli depended on the child's performance on an English proficiency assessment. A recent meta-analysis on bilingualism and WM capacity found that whether performance on WM task was in L1 or L2 moderated the effect size of the bilingual advantage (Grundy & Timmer, 2017). Another possibility for differences was that the presentation of stimuli (digits) varied. Blom and colleagues (2014) presented the stimuli on a laptop and the task started with a block of one digit. On the contrary, the ECLS-K:2011 WM task is administered by a person and begins with 5 two-number sequences. It is possible that the difference in presentation of stimuli affected the task demands. Other work suggests that when task demands are increased, bilingual children outperform monolinguals in nonverbal WM tasks (Feng, Diamond & Bialystok, 2007).

That children did not show differences on the DCCS task at second grade or third grade is interesting because at fourth grade we see that bilingual children are performing significantly better compared to monolinguals. This difference may be due to the fact that the score of the DCCS task is calculated with the reaction time and this contribution may be what is helping bilingual children outperform their monolingual counterparts. ELLs are still performing significantly lower compared to their monolingual peers but no differences emerge on the NR or flanker task. I also did not find any differences on the flanker task among any of the groups. So, there appears to be something unique about the DCCS task because the flanker task did incorporate reaction time too but we don't see any differences on this task. Therefore, it might be that the DCCS task is involving a different type of inhibitory control than the flanker task. Future work should specifically disentangle the differences between these tasks. It may be that the flanker task relies on more selective attention and the DCCS task is more deliberate switching between rules and this is what bilingual children are showing advantages in.

In contrast to the cognitive assessment data, teachers rated bilingual children as having better inhibitory control and attention skills at the start of kindergarten in comparison to monolingual children and there were no changes in these differences between groups across time. Further, with regards to attention skills, ELLs demonstrated favorable differences initially and overtime in comparison to bilinguals. Moreover, ELLs demonstrated favorable differences overtime in comparison to monolinguals with regards to attention skills. The fact that teacher reports on child self-control do not directly mirror the result from cognitive measures is intriguing. It is plausible that teacher's observations of children's self-control may be tapping into another form of executive function skills that cognitive assessments do not capture. These skills may be conducive for social interactions and the social development of children (Fan, Liberman, Keysar, & Kinzler, 2015; Liberman, Woodward, Keysar, & Kinzler, 2017). In addition, since learning language is an inherently interpersonal process there have been known associations between bilingualism and social skills. Specifically, there is a strong association between executive function and emotion regulation skills (Ferrier, Bassett, & Denham, 2014) and studies support the notion that bilingual children show enhanced social cognition compared to monolinguals on a variety of tasks (Liberman, Woodward, Keysar, & Kinzler, 2017; Yow & Markman, 2011; Yow & Markman, 2015; Wermelinger, Gampe, & Daum, 2017). Of course, given the nature of the data described in this chapter, teacher ratings may be subject to personal values, biases, and other perceiver characteristics, and this may have contributed to these results as well.

There were several strengths of these studies, inclusion of children with a variety of language experiences and the incorporation of perceived executive function skills as well as cognitive measures. While other recent studies with large sample sizes yielded null results (Anton et al., 2014; Dunabeitia et al., 2014), our study suggests that bilingual and monolingual children are different in some ways, such as their rate of change on cognitive control. Yet, results remain difficult to disentangle because bilingual children outperform monolinguals on the DCCS task at our final time point, but not on the Flanker task. ELLs offer a unique perspective in the examination of bilingualism and executive function. As one would expect as ELL's become more English proficient they are more bilingual and thus would perform similarly to bilinguals. However, these findings deviate from this hypotheses. ELLs were consistently lower in WM and cognitive control and once they were proficient in their second language they improved significantly, but still lower than monolinguals and bilinguals. This finding warrants future research, as there may be other factors such as acculturation (Santillán & Khurana, 2017) and/or input quantity or quality of L2 (Paradis & Jia, 2017) that may help explain findings. Provided that our only measure of English proficiency was the preLAS, it is possible that ELLs in our study were not necessarily English proficient enough to perform at par with their bilingual and monolingual peers. L2 proficiency is important in laying the foundation for academic success (Cummins et al., 2012; Paradis & Jia, 2017) and bilingualism has been shown to narrow socioeconomic disparities in executive function during early childhood (Hartanto, Toh, & Yang, 2018). Thus, it is imperative that future work continues to explore what variables shape ELL's language abilities and how these variables contribute to the development of high levels of language proficiency and literacy in both L1 and L2.

Chapter 3: Classroom Behavior: Hot Executive Function Among Bilingual and Monolingual Children

The relationship between executive function and language experience may not exhibit a linear trajectory over time. Chapter 2 demonstrated differences between monolinguals and bilinguals at some time points but not others. However, intriguingly teachers rated bilingual children as having better inhibitory and attention skills at the start of kindergarten. As mentioned in Chapter 2, it may be that the teacher reports are tapping into 'hot' executive function skills. The items under attention and inhibitory skills ask about the child's ability to switch to a new task and ability to stay focused during a task. These questions are relating to the child's attention and inhibitory abilities in a social setting (i.e., classroom), whereas the cognitive tasks in Chapter 2 take place in an isolated context. Classroom behavior may be more indicative of hot executive functions as the child is required to pay attention and exercise inhibitory skills in a social setting where rewards/punishments are more often considered social. Some examples are having the teacher call your parent, sending child to principal's office (punishment) or praising the child for good behavior (reward). Of course, children's sensitivity towards these external rewards/punishments may differ and temperament may play an important role. Nonetheless, that teachers' ratings favored bilinguals is intriguing, especially when considering possible bilingualism executive function advantages under hot contexts.

Research suggests that cool aspects of executive function are related to academic skills, such as math ability or other academic measures (Hongwanishkul et al., 2005; Willoughby et al., 2011), whereas hot aspects of executive function have been related to emotion regulation and externalizing behaviors (Zelazo & Carlson, 2012). Similarly other work has linked executive function with social cognition (Wade et al., 2018). The integration of hot contexts in the study of executive function is relatively new, however there appears to be clear implications for a continuum of executive function where one side is cool and another hot (Zelazo & Cunningham, 2007). As mentioned in Chapter 1, an evolutionary account supports the development of such continuum and such continuum lends itself to practicality. Specifically, it seems that what may be indicative of self-control or how one may respond under 'hot' contexts is not necessarily related to one's cool executive functions (Nęcka et al., 2018). Moreover, it makes intuitive sense that one's ability and the cognitive resources one is recruiting to succeed on a go/no go task is different than retrospectively reporting how successful one is at completing a diet program, etc. While these scenarios are obviously different via their context, it is still not well understood the role of executive function in the scenario that seems more practical (i.e., diet program).

However neuroimaging studies have suggested underlying brain mechanisms that are important in meditating cool and hot executive function components. It appears that the dorsolateral prefrontal cortex is important in mediating the cool functions, such as mechanistic planning, verbal reasoning and problem solving and the ventromedial or orbitofrontal prefrontal cortex may mediate the hot, such as interpersonal and social behavior, or the interpretation of complex emotions during social interaction (Chan et al., 2008). While these neuroimaging studies are enlightening more work is needed to further validate how hot executive functions are actually different than cool and to what extent. Moreover, there is a need to understand executive function skills within a social context.

Given the relationship between bilingualism and executive functions as mentioned in Chapter 1 and Chapter 2, this study aims to further understand the relationship between monolingual and bilingual children's hot executive functions. Specifically, this study will examine the relationship between children's executive function skills in the classroom as reported by their teachers. Chapter 2 focused on children from ages five to seven. Within this chapter I have examined children's social, attentional and emotion regulation behaviors as reported by their teachers when the children are eight years old. The questionnaires regarding children's emotion regulation tendencies in the classroom were only made available during the spring second grade round. These questionnaires were relevant to this study because of the proposed connection between emotion regulation and hot executive function (Zelazo & Cunningham, 2007). Thus, this chapter focuses on children's attentional focus, inhibitory control, internalizing problems, externalizing problems, and interpersonal skills spring of second grade.

Methods

Researchers retrieved the publicly accessible ECLS-K:2011 archive from the U.S. Department of Education's National Center for Educational Statistics website (NCES, 2017). The ECLS-K:2011 archive contains data directly collected from children, families, and teachers from over 1,300 schools, from all 50 states (Tourangeau et al., 2015). Volunteers were first enrolled in the study as they entered kindergarten in fall of 2010. Parent interviews, self-administered teacher questionnaires, and one-on-one child assessments were administered to collect information regarding cognitive, social, emotional, and physical development. Included were measures of reading, math, science, and cognitive/executive skill. This study examines teacher reports regarding children's attentional focus, inhibitory control, internalizing problems, externalizing problems, and interpersonal behaviors in the classroom. Moreover, this study utilized children's language exposure to parse children into a monolingual group and bilingual group. ELL children were not included in this study because at this time point ELL children should technically be considered bilingual because they have passed the English screener mentioned in Chapter 2, however they are objectively different from bilinguals that began kindergarten English proficient. Future work should consider including ELLs given that in Chapter 2 ELLs also appear to have higher rates of teacher reported attention skills in comparison to monolinguals and bilinguals, despite their lower scores on DCCS and WM tasks. However, for the purposes of this study they are excluded because I did not have a fully developed a priori hypothesis as to how teachers would rate this group of children in comparison to bilinguals that started kindergarten English proficient and monolinguals.

Participants

Participants were collected from the ECLS-K:2011 dataset. We were particularly interested in the end of second grade (spring 2013) when most children are eight years old in the American school system. As mentioned above, children considered ELL were not included in this study because of the lack of a clear hypothesis with regards to how this group of children would differ in comparison to monolingual and bilingual children. Children's data was excluded if their socio-demographic or language background was not reported. Having a disability was an additional exclusion criterion. Parent interview questions asked about the child's ability to pay attention, learn, communicate, relate to adults and children and overall activity and behavior level, emotional or psychological difficulties, difficulties hearing or understanding speech, and eyesight. If the parent indicated any difficulties of the above categories, then follow-up questions probed about whether the child obtained a diagnosis. Child was excluded for having any disability (which includes conditions such as developmental disabilities but not limited to conditions such as cerebral palsy). Further, children were excluded if teachers did not report on the child's attentional focus, inhibitory control, internalizing problems, externalizing problems, or interpersonal skills. In total, ECLS-K:2011 data from *N* = 1,222 volunteers was retained for analysis.

Children's language background and performance on an English proficiency measure (preLAS; Duncan & DeAvila, 1998) was used to assign them to one of two groups. The 'Monolingual' sub-sample (*n* = 700) comprised of children whose parents reported 'English' as the primary and only language used at home. Children also had to score above an accepted cut-off score (16) recommended by the preLAS. The ECLS-K:2011 bi-annually tested all children with the preLAS to determine oral and pre-literacy English skill by assessing their receptive and expressive language. To be placed in the monolingual group, children starting kindergarten needed a preLAS score of 16 or higher upon enrollment in kindergarten. The 'Bilingual' sub-sample (*n* = 522) comprised of children whose parents reported non-English as the primary language spoken in the home. Per Han's (2012) standard, both parents also had to agree that they spoke non-English to their child 'often' or 'very often' and that their child 'often' or 'very often' spoke non-English back to them. Additionally, assignment to the bilingual condition required a preLAS score above the 16-point cut-off upon enrollment in kindergarten.

As in chapter 2, socioeconomic status was classified similarly to Hartanto, Toh, and Yang, (2018) measures of SES which was computed through five variables: household income, maternal education, paternal education, maternal occupation prestige score, and paternal occupation prestige score (see Hartanto, Toh, and Yang, 2018 for variable computation and variable details).

Measures

The study uses teacher reports of child's executive function obtained from the ECLS-K 2011 dataset. Teacher reports on children's social skills were also used.

Attentional Focus. Teachers rated children's attentional focus on the Attentional Focusing subscale from the Temperament in Middle Childhood Questionnaire (TMCQ; Simonds & Rothbart, 2004). Items ranged from "Gets distracted when trying to pay attention in class", "Needs to be told to pay attention", to "Can tell if another person is sad or angry by the look on their face". A score was computed if the teacher rated at least 4 out of 6 items. Some items were reverse coded. Higher scores on the Attentional Focus scale indicate that the child exhibited more behaviors that showed his/her ability to focus attention on cues in the environment that are relevant to the task at hand. The Attentional Focus scale has an internal consistency reliability of .96.

Inhibitory Control. Teachers rated children's inhibitory control on the Inhibitory Control scale from the Temperament in Middle Childhood Questionnaire (TMCQ; Simonds & Rothbart, 2004). Some items included, "Has a hard time waiting his/her turn to talk when excited", Has an easy time waiting to open a present", to "can stop him/herself from doing things too quickly". Some items were reversed coded. Higher scores indicated that the child demonstrated more behaviors that show the ability to hold back or suppress a behavior as necessary for a particular situation. The Inhibitory Control scale has an internal consistency reliability of .87.

Interpersonal Skills. Interpersonal Skills was classified based on the teacher's response on 5 items from a subscale of the SSRS (Gresham, & Elliott, 1990). Teachers rated the child's behavior on a frequency scale ranging from "never" to "very often" but also had the option of indicating that they had not had an opportunity to observe the described behavior for the child being asked about. The score was computed for any child whose teacher provided a rating on a minimum 4 out of 5 items that made up the scale because that was the minimum numbers required to compute a score. Higher scores indicate the child exhibited the behavior represented by the scale more often. A high score of Interpersonal Skills would indicate that the child interacted with others in a positive way more often, whereas a lower score would indicate the opposite. The scale has an internal consistency reliability of .86.

Externalizing Problem Behaviors. Externalizing Problem Behaviors were classified based on the teacher's response on 6 items from a subscale of the SSRS (Gresham, & Elliott, 1990). Teachers rated the child's behavior on a frequency scale ranging from "never" to "very often" but also had the option of indicating that they had not had an opportunity to observe the described behavior for the child being asked about. The score was computed for any child whose teacher provided a rating on a minimum 4 out of 6 items that made up the scale because that was the minimum numbers required to compute a score. Higher scores indicate the child exhibited the behavior represented by the scale more often. A high score of Externalizing Problem Behaviors would indicate that the child exhibited behaviors indicative of externalizing problems more often, whereas a lower score would indicate the opposite. The scale has an internal consistency reliability of .87.

Internalizing Problem Behaviors. Internalizing Problem Behaviors were classified based on the teacher's response on 4 items from a subscale of the SSRS (Gresham, & Elliott, 1990). Teachers rated the child's behavior on a frequency scale ranging from "never" to "very often" but also had the option of indicating that they had not had an opportunity to observe the described behavior for the child being asked about. The score was computed for any child whose teacher provided a rating on a minimum 3 out of 4 items that made up the scale because that was the minimum numbers required to compute a score. Higher scores indicate the child exhibited the behavior represented by the scale more often. A high score of Internalizing Problem Behaviors would indicate that the child exhibited behaviors indicative of internalizing problems more often, whereas a lower score would indicate the opposite. The scale has an internal consistency reliability of .78.

Results

Data Analysis

We implemented hierarchical linear regressions, with the same covariates as Study 1 at each time point to further examine whether we will see differences in how teachers report social skill behaviors among monolingual and bilingual children at the end of second grade. First, we ran correlations among the attentional variables and social skill behaviors (See Table 4) to explore the relationship between these variables. Next, we ran hierarchical linear regressions to evaluate the relationship between children's language experience and attentional and social behaviors as reported by their teachers. We controlled for SES because of the profound influence SES has on executive function skills (Hartanto, Toh, & Yang, 2018). We also controlled for gender because previous work has found that girls are universally rated by teachers as having greater behavioral regulation (Wanless et al., 2013). In step 1, our control variables SES and gender were entered. In step two, we entered a binary variable of language experience (0 = monolingual, 1 = bilingual).

Table 4

Correlations of Teacher Rated Social and Attention Behaviors from Chapter 3

Variables	1.	2.	3.	4.	5.
1.Internalizing Problems	-				
2.Externalizing Problems	.30**	-			
3.Interpersonal Skills	.20**	.13**	-		
4.Inhibitory Control	-	-.20**	.30**	-	
5.Attentional Focus	-	-.19**	.21**	-.75**	-

Note: **. Correlation is significant at the 0.01 level (2-tailed).

Attentional Focus

Gender (*b* = -.462, *p* = .000) was a significant predictor of attentional focus as rated by teachers but not SES (*b* = .030, *p* = .067). With regards to language status, bilingual children (*M* = 3.78, *SD* = 1.19) were rated as having more attentional focus by their teachers (*b* = .425, *p* = .000) than monolingual children (*M* = 3.32, *SD* = 1.26).

Inhibitory Control

Gender (*b* = -.479, *p* = .000) was a significant predictor of inhibitory control as rated by teachers but not SES (*b* = .015, *p* = .230). With regards to language status, bilingual children (*M* = 3.87, *SD* = .98) were rated as having more inhibitory control by their teachers (*b* = .277, *p* = .000) than monolingual children (*M* = 3.58, *SD* = .94).

Interpersonal Skills

Gender (*b* = .003, *p* = .974) and SES (*b* = -.023, *p* = .143) were not significant predictors of interpersonal skills as rated by teachers. With regards to language status, bilingual children (*M* = 2.86, *SD* = 2.19) were rated as having less interpersonal skills by their teachers (*b* = .186, *p* = .034) than monolingual children (*M* = 3.01, *SD* = 1.06).

Externalizing Problem Behaviors.

SES (*b* = -.055, *p* = .000) and gender (*b* = .292, *p* = .000) were significant predictors of externalizing problem behaviors as rated by teachers. With regards to language status, monolingual children (*M* = 1.76, *SD* = .89). were rated as having more externalizing problem behaviors by their teachers (*b* = -.281, *p* = .000) than bilingual children (*M* = 1.44, *SD* = 1.03).

Internalizing Problem Behaviors

SES (*b* = -.023, *p* = .143) and gender (*b* = .003, *p* = .974) were not significant predictors of internalizing problem behaviors as rated by teachers. With regards to language status, monolingual children (*M* = 1.49, *SD* = 1.15). were rated as having more internalizing problem behaviors by their teachers (*b* = -.186, *p* = .034) than bilingual children (*M* = 1.26, *SD* = 1.45).

Discussion

Chapter 2 mainly focused on cool executive function in childhood, this chapter was intended to examine hot executive function among children. We explored whether teachers would rate bilingual and monolingual children differently on what we consider hot executive function skills. Classroom behaviors are useful in studying hot executive function systems because of the activities children encounter. For instance, children exercise hotter executive function skills when waiting for a turn or inhibiting impulses to play with friends while they should be focusing on their teacher (Brock et al., 2009).

In support of our theoretical framework in Chapter 1, which postulates a hot executive function bilingual advantage, teachers did indeed rate bilingual children as having better attentional focus and inhibitory control within social settings compared to their monolingual counterparts. Specially, teachers rated bilingual children as being more able to pay attention in class and pay attention to their peers' social cues (facial expressions) in comparison to monolinguals. Also, bilingual children were rated as being able to wait their turn to talk when excited, wait to open a present, and have the ability to stop themselves from doing things too quickly more often than monolinguals. This finding contradicts previous research that does not find a bilingual advantage on delay tasks (Carlson & Meltzoff, 2008). A possible explanation for this is that the delay tasks used in other work is not inherently social. The child is inhibiting impulses but on an intrapersonal level and these questionnaires tap into how the child is inhibiting impulses socially. Our findings suggest that 1) questionnaires regarding attention and inhibitory control may be tapping into hot executive function processes and 2) bilingual children may possess an executive function advantage that extends to hot executive function measures.

We also found that teachers rated monolingual children as having more internalizing and externalizing problems. Teachers rated monolingual children as experiencing more tantrums, arguing with others, more and disrupting ongoing activities more in comparison to bilingual children. Also, monolingual children were rated as appearing more lonely, showing more anxiety with peers and feeling more rejected compared to bilingual children. Some work supports the relationship between bilingualism and socioemotional well-being. For instance, Alqarni and Deweale (2018) found that bilingual adults scored higher on Trait Emotional Intelligence and bilinguals outperformed English monolinguals on an emotion perception task. However, the work here is limited thus it is overreaching to suggest that bilinguals have 'better' emotion regulation strategies. First, these studies warrant replication because they are fairly new and scarce. If these studies are replicated it would give claims that bilinguals are different in their socioemotional abilities in comparison to monolinguals more validity. Moreover, extensions with behavioral paradigms should be considered because the addition of behavioral paradigms could serve as objective measures of how bilinguals regulate their emotions in comparison to monolinguals. Nonetheless, while it may be the case that bilingualism is related to hot executive function, there is still a need to understand how hot executive function processes are implicated in emotion regulation strategies.

Despite the findings above favoring bilinguals, teachers did rate monolingual children as having better interpersonal skills. Monolingual children were viewed as volunteering more, making friends easily, initiating conversations, and attempting tasks on their own more often than bilingual children. These items seem to be reflective of the child's initiating behavior and do seem different than the items in the other subscales. The subscales regarding children's attentional behaviors in the classroom seem to be more indictive of hot executive function in comparison to these interpersonal skills items. The interpersonal skills subscale may be tapping into a different construct that may be more related to social confidence. However, future research should explore whether interpersonal skills are related to hot executive function skills.

Limitations

A limitation of this study is that we solely relied on teacher reports. Teacher reports may be subject to biases that we cannot control for that may have influenced some teachers' responses. Additionally, we only controlled for SES and gender but we did not have measures that speak to the child's social environment at home, culture, or behavioral tendencies at home that may affect our results.

Future directions

Despite these limitations, this study is a contribution to the limited work regarding socioemotional development and bilingualism. Future studies should incorporate behavioral measures that may capture the nuances described in this study. For instance, an observational classroom study may be a good first step in further understanding our findings. Additionally, child's language environment at home should be taken into account, such as culture, rules at home and behavior at home in general.

Chapter 4: Young Adults Performance on a Hot Executive Function Task

Chapters 2 and 3 find that a bilingual environment sometimes leads to differences on executive function measures. However, there is variability in when this difference emerges and which measures show this difference. For instance, in Chapter 2, we found that bilinguals outperformed monolinguals on the Flanker task in fourth grade but not the DCCS task in third grade. Again, that in Chapter 2 and 3 teachers rate bilingual children as having better socially self-regulated abilities compared to monolingual children might be indictive of bilingual children's enhanced hot executive function. While most standard executive function tasks may seem more cool, as mentioned in Chapter 1, executive function tasks under hot contexts evoke motivation that is tied to social behaviors because of the interpersonal function of emotions. Work with younger children shows that children growing up hearing more than one language indeed outperform their monolingual counterparts on tasks that measure communicative intent interpersonally (Yow & Markman 2011, 2015; Fan, Liberman, Keysar & Kinzler, 2015; Liberman, Woodward, Keysar, & Kinzler, 2017; Wermelinger, Gampe, & Daum, 2017; Schroeder, 2018). However, there is still not a clear link between being raised in a multilingual environment and enhanced communitive intent abilities.

Nonetheless, it appears that differences between monolingual and bilingual children's communicative intent abilities reaches an equilibrium around age 5 (Yow & Markman, 2011). However, we might see enhanced communicative intent abilities if task demands are increased within communitive intent tasks or if we use different measuring strategies. In further support of this notion, studies with adults do find differences in how bilinguals navigate their social environment. For instance, Ikizer and Ramirez-Esparza (2018) found that bilinguals report more social flexibility than monolinguals. This finding was still present when controlling for socio-demographic factors. Bilinguals may be able to cope with change and attend to others' perspectives and adapt to new environments as a result of switching between two languages (Ikizer & Ramirez-Esparza, 2018). Others have similarly found that cognitive empathy, cultural empathy, open-mindedness, understanding and attributing other people's mental states has been related to bilingualism (Dewaele & Wei, 2012; Dewaele & Stavans, 2014; Rubio-Fernandez & Gluckberg, 2012). These studies cite bilinguals' cognitive flexibility advantages as a process that gives rise to enhanced social abilities. This research is relatively new and scarce, thus it warrants further investigation as most of the research among adults is based on survey data. Survey measures are capturing individuals' perceptions of their social interactions. It remains unknown whether proposed differences among bilinguals and monolinguals are reflected in cognitive assessments.

Study Aims

Thus, the current study investigated how bilingual adults' cognitive abilities relate to emotional stimuli in a hot executive function task. More specifically, a modified version of the Connors Continuous Performance Test 3rd Edition (CPT 3; Conners at al., 2003) was administrated to adults. The CPT 3 measures impulsivity, sustained attention, and inattentiveness. In the standard version, adults must respond to any letter, except X that appears on the computer screen but we have substituted the presentation of letters to presentation of emotional stimuli (emoticons). Some participants were asked to inhibit responses to negative faces (Condition 1) and others were asked to inhibit responses to positive faces (Condition 2). First, it should be noted that this task is considered hot in comparison to its classic counterpart (e.g., inhibit response to 'X'). The stimuli of positive or negative emoticons constitutes this task as 'hotter' given the motivational effect of happy faces. For instance, approach reactions are faster to happy faces (Nikitin & Freund, 2019), happy faces are motivating (Yang & Urminsky, 2015) and rewarding (Tsukiura & Cabeza, 2008). Thus, taking our definition of hot executive function in Chapter 1 this task is hotter than its counterpart.

In both conditions 1 and 2, I predicted that bilingual adults would show more sustained attention, less impulsivity and inattentiveness because of bilinguals proposed enhanced inhibitory control and proposed enhanced attention to nonverbal communicative cues. It has been proposed that non-verbal emotion regulation draws upon executive control (Barker & Bialystok, 2019). A study conducted by Barker and Bialystok (2019) found that given an emotion *n*-back test, bilingual adults were not as impacted by the emotional stimuli as were monolinguals. Bilinguals were also more accurate. Consequently, given the nature of this task, I predicted that bilinguals would outperform monolinguals.

Methods

Participants

Adult college students were recruited (N = 76) as part of an ongoing study. Ten participants were excluded due to extreme data. Six of these participants demonstrated an extremely high rate of missed targets (60 or more). A target is considered missed when the participant did not press the spacebar for stimuli they were instructed to press the spacebar for. Four of the ten participants were excluded due to demonstrating an extremely high rate of false alarms meaning they pressed the spacebar to stimuli they were not instructed to press the spacebar for fifty or more times. Twenty participants failed to provide information regarding their native language. Consequently, our final sample consisted of forty-six participants. Adults (N = 46) were between 18 to 27 years of age (M = 20, SD = 3.06) with an average college grade point average of 3.069 (SD = .54). The majority of participants self-identified as female (63%), Latino/Hispanic (45%) and indicated being of bilingual status (78%). This study contained 2 conditions with participants randomly assigned to one of the two conditions. Specifically, half of the participants received the negative target image and the other received the positive target image.

Measures

Language Experience. The Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld, & Kaushanskaya, 2007) was used to measure participants language experience through a variety of questions. For instance, participants are asked about the order of language dominance, order of acquisition, language usage, language proficiency, and the contexts in which the languages are used (e.g., around family or friends). Additionally, participants are asked how they learned their language (e.g., self-taught, family, friends etc.).

Attention and Inhibitory Control. A modified version of the Connors Continuous Performance Test 3rd Edition (CPT 3) was used. Where the CPT 3 asks participants to pay attention to and inhibit to letters, participants were required to pay attention to and inhibit to emotional stimuli in this task. In one condition participants are required 1) to press a spacebar every time a positive emoticon (target) appeared on the screen and 2) not press the spacebar when a negative emoticon (non-target) appeared on the screen. In the other condition participants are required 1) to press a spacebar every time a negative emoticon (target) appeared on the screen and 2) not press the spacebar when a positive emoticon (non-target) appeared on the screen (see Figure 2 for illustration of emoticons). This task consists of 6 blocks, with 60 trials each. Each sub-block consisted of 20 trails but varied in its inter-stimulus intervals (ISIs; 1,2, and 4 seconds). The varying ISIs allows for the assessment of vigilance because task demands need to be adjusted to the changing tempo (Conners, 2000). The order of sub-blocks is randomized so the ISI's are randomized throughout the experiment. The task takes approximately 14 minutes to complete and is a total of 360 trials.

Scoring. In the standard CPT (see Conners, 2000) measures are made up of a variety of scores. For the purposes of this study I focus on detectability and omission scores as a measure of inattentiveness. Detectability scores are a participant's ability to discriminate between targets and non-targets. The measure is scored by subtracting the proportion of hits (e.g., correct responses to a target) and proportion of false-alarms (e.g., incorrect responses to a non-target). Omission scores are a participant's proportion of missed targets. The measure is scored by the total amount of times a participant did not press the spacebar to targets (e.g., stimuli they were required to press the spacebar for). Impulsivity in this study is measured by commission scores and perseveration scores. Commission scores are a participant's proportion of responses given to non-targets (e.g., stimuli participants were told not to press the spacebar for). The measure is scored by the total amount of times a participant incorrectly responded to non-targets. Perseverations are a participant's total amount of random or anticipatory responses. The measure is scored by the total amount of times any stimuli (targets and non-targets) appeared on the screen and the participate pressed the spacebar more than once after the stimuli was not on the screen. Finally, sustained attention in this study is measured by the total amount of correct rejections. The measure is scored by the total amount of times a participant correctly did not press the spacebar for non-targets.

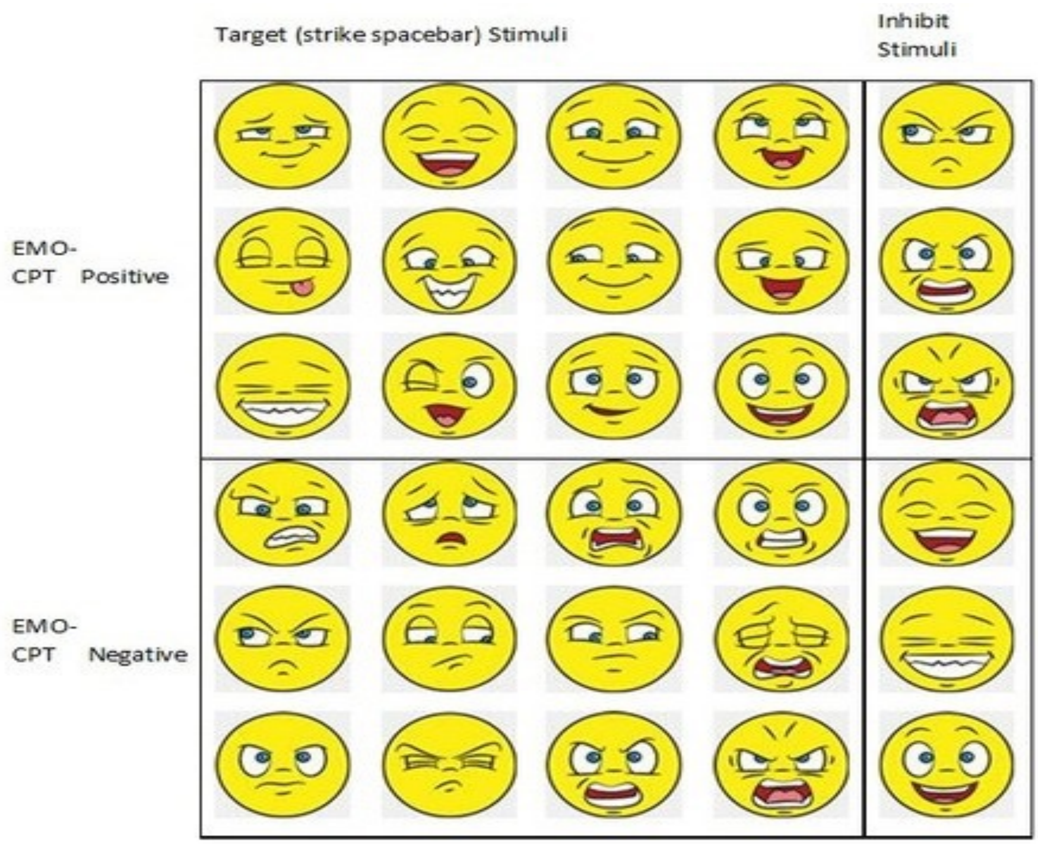

Figure 2.
Illustration of emoticons used in both conditions, top part of figure represents the positive condition and the bottom part represents the negative condition in the modified CPT3 used in Chapter 4.

Procedure

Participants completed a single lab visit that lasted approximately 45 minutes. A trained research assistant provided an overview of the procedures and participants completed consent documents, demographic questionnaires, and the LEAP-Q. Participants then sat at a computer in the lab and were given detailed instructions on the modified CPT 3. They are randomly assigned to either the target positive condition or target negative emoticon condition. They also completed a short practice session so that I could make sure they understood the instructions properly.

Results

Analytic Strategy

First, it should be noted that due to the COVID-19 pandemic recruitment for this study was halted and I did not complete data collection. The following results are preliminary and not corrected for multiple comparisons and thus should be interpreted with caution. Bilingual participants were placed into two groups: bilingual non-English native speakers ($N = 25$) and bilingual English native speakers ($N = 11$). Research suggests that whether a task is administered in native versus nonnative language may moderate task performance (Grundy & Timmer, 2017). The remaining participants were classified as monolingual. However, it should be noted that 68% of the non-English native speakers reported being English dominant and 64% indicated Spanish as their native language. All monolinguals indicated English as their primary language. I ran correlations between college grade point average, race/ethnicity, gender, condition (positive/negative) and commissions, correct rejections, omissions, detectability and perseverations. Given that there were not any significant correlations among between task measures and potential covariates (e.g., college grade point average, race/ethnicity gender or condition type), I began to explore the data visually and conducted mean group comparisons per task measure.

Connors Continuous Performance Test Results

Inattentiveness. Monolinguals demonstrated a higher detectability (d') score, which suggests that they were better at (M = 3.48, SD =. 45) discriminating between targets and non-targets compared to bilingual non-English native speakers (M = 2.75, SD = .911), $t(33)$ = -2.3, p = .008. There was no significant difference between monolinguals (M = 3.48, SD = .45) and bilingual English native speakers (M = 3.36, SD =.96), $t(19)$ = -.359, p = .106. There was no significant difference between bilingual non-English native speakers (M = 2.75, SD = .911) and bilingual English native speakers (M = 3.36, SD =.96), $t(34)$ = 1.818, p = .675. See figure 3 for a graphical description. Additionally, bilingual non-English native speakers demonstrated higher omission scores (M = 19, SD = 22), indicating that they missed more targets in comparison to Monolinguals (M = 4, SD =8), $t(33)$ = 1.96, p = .033. There was no significant difference between monolinguals (M = 4, SD =8), and bilingual English native speakers (M=4, SD=4.6), $t(19)$ = -.089, p = .281.Bilingual non-English native speakers demonstrated higher omission scores (M = 19, SD = 22), indicating that they missed more targets in comparison to bilingual English native speakers (M=4, SD=4.6), $t(33)$ = 1.96, p = .033.

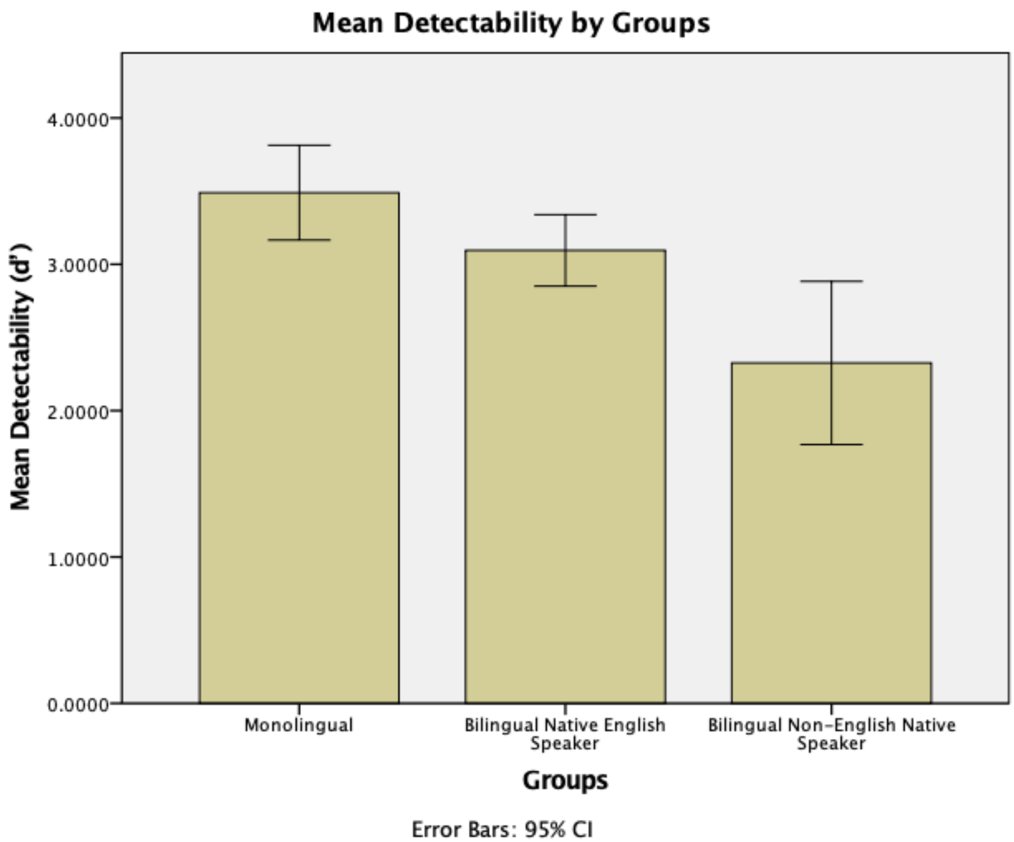

Figure 3. Mean detectability scores for participants, separately by language group. Error bars represent standard errors.

Impulsivity. Monolinguals demonstrated a lower commission score which suggests that they were less likely to incorrectly respond to non-targets (M =10.10, SD = 6.13) compared to bilingual non-English native speakers (M = 13.12, SD = 11.55), $t(33)$ = .779, p = .049. There was no significant difference between monolinguals (M=10.10, SD=6.13) and bilingual English native speakers (M = 11.45, SD =9.36), $t(19)$ = .110, p = .110. Moreover, there was no significant difference between bilingual non-English native speakers (M = 13.12, SD = 11.55) and bilingual English native speakers (M = 11.45, SD = 9.36), $t(34)$ = -.420, p = .500. Additionally, bilingual non-English native speakers demonstrated higher perseveration scores (M = 2.88, SD = 3.8), indicating more random or anticipatory responses in comparison to Monolinguals (M = 1.30, SD = 1.1), $t(33)$ = 1.26, p = .043. There was no significant difference among monolinguals (M = 1.30, SD = 1.1), and bilingual English native speakers (M = 1.36, SD = 2.2), $t(19)$ = .082, p = .222. There was also no significant difference between bilingual non-English native speakers (M = 2.88, SD = 3.8) and bilingual English native speakers (M = 1.36, SD = 2.2), $t(34)$ = -1.217, p = .170. See Figures 4-5 for a graphical description.

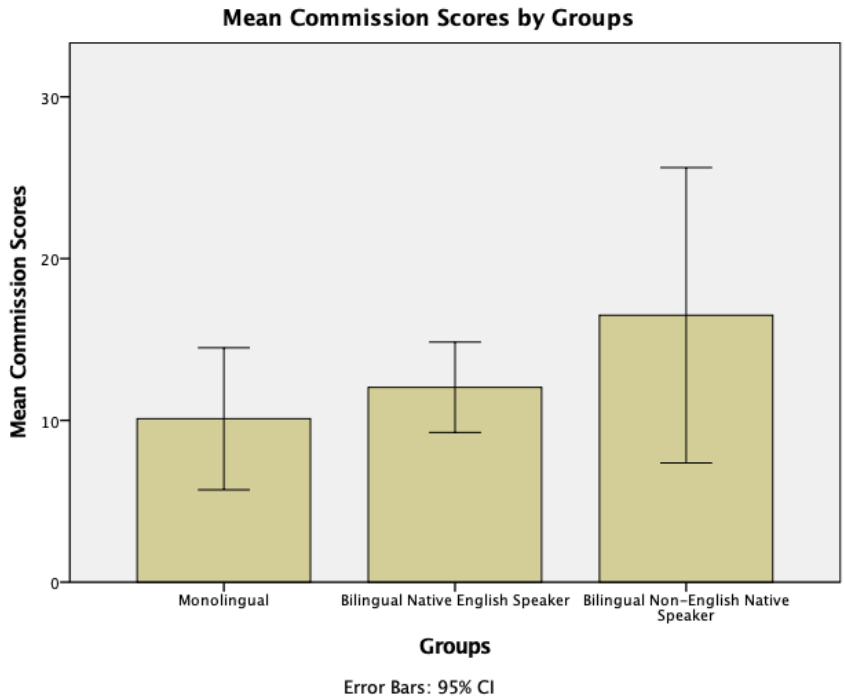

Figure 4. Mean commission scores for participants, separately by language group. Error bars represent standard errors.

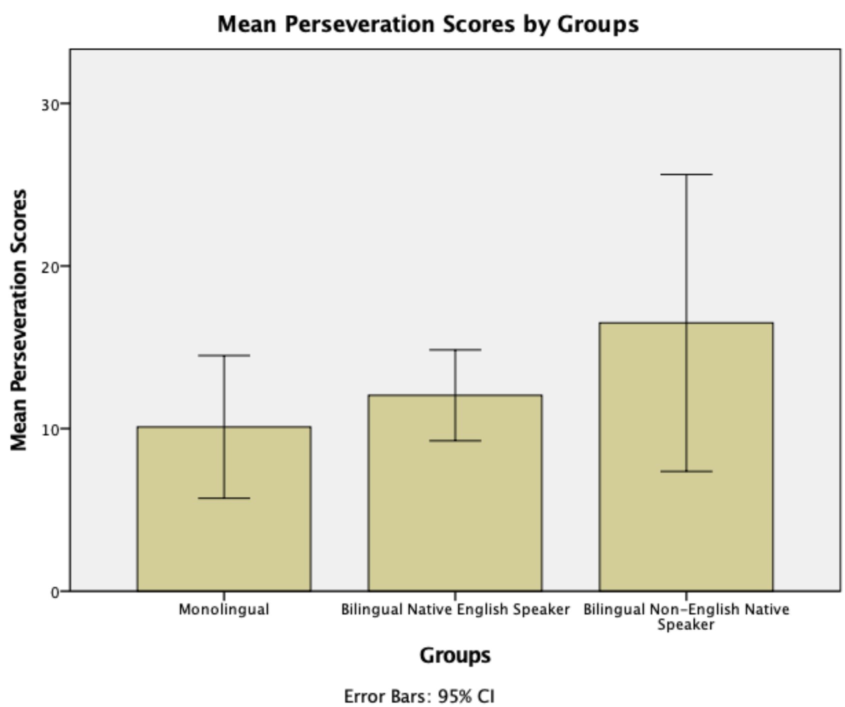

Figure 5. Mean perseveration scores for participants, separately by language group. Error bars represent standard errors.

Sustained Attention. Monolinguals demonstrated a higher correct rejection score (M = 61.50, SD = 5.85), which suggests that they were better able at correctly inhibiting a response towards non-targets compared to bilingual non-English native speakers (M = 58.40, SD = 11.83), $t(33) = -.786$, $p = .044$. There was no significant difference among monolinguals (M = 61.50, SD = 5.85) and bilingual English native speakers (M = 60.45, SD = 9.56), $t(19) = -.298$, $p = .089$. There was also no significant difference among bilingual non-English native speakers (M = 58.40, SD = 11.83) and bilingual English native speakers (M = 60.45, SD = 9.56), $t(34) = .506$, $p = .509$. See Figure 6 for a graphical description.

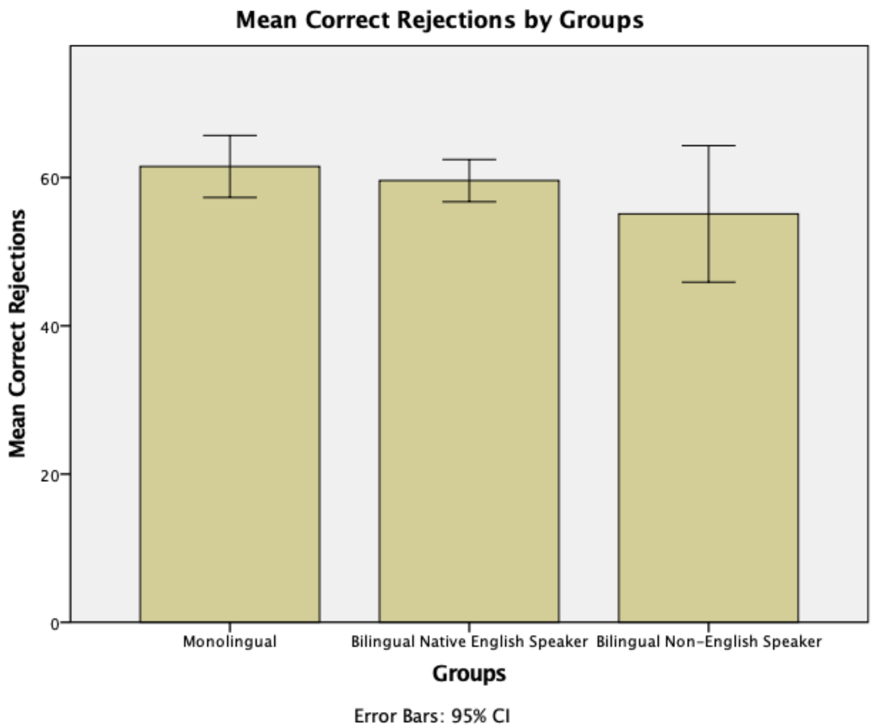

Figure 6. Mean correct rejection scores for participants. Error bars represent standard errors.

Discussion

Bilingual individuals may monitor their social surroundings differently than monolinguals, and consequently may be more adept to social cues that facilitate language learning (Chapter 1). Previous work has suggested that bilinguals show differences in their social cognitive abilities (Ikizer & Ramirez-Esparza, 2018). Specifically, findings demonstrate that bilinguals report more social flexibility in their day-to-day interactions compared to monolinguals (Ikizer & Ramirez-Esparza, 2018), more cognitive empathy (Dewaele & Stavans, 2014), and they are better at understanding and attributing other people's mental states (Rubio-Fernandez & Gluckberg, 2012). While research indicating a social adeptness among bilingual adults is interesting, these studies are relatively new and mostly rely on survey measures. Findings from Chapter 2 and 3 suggest that bilingual children may have enhanced hot executive function skills in comparison to their monolingual counterparts, as rated by their social skills in the classroom, therefore this study set out to explore whether bilingual adults would outperform monolinguals on a computerized intrapersonal hot executive function task.

Bilinguals did not outperform monolinguals in this study. Instead, it appears that monolinguals outperformed bilingual non-English native speakers. There were no consistent apparent differences between bilingual groups or between monolinguals and bilingual English native speakers. It is possible that I did not find differences in line with my hypothesis because of my small sample size and limits in study design. First, due to the COVID-19 pandemic I did not complete data collection and thus the sample size per groups for this study was uneven and small. Second, it is possible that the task used in this study could have been 'hotter' if actual faces were used over emoticons. Studies that use actual human faces and frame their task in a distance-regulation paradigm that require participants to 'approach' or 'avoid' happy versus angry faces (Nikitin & Freund, 2019) appear to hotter than the task used in this study. Thus, that we did not use actual human faces or consider framing is a limitation of the study design.

Bilingual non-English native speakers demonstrated lower attentional abilities in comparison to monolinguals. Specifically, non-English native speakers may react more impulsively to emotional stimuli compared to monolinguals, as demonstrated by their higher perseveration and commission scores. Bilingual non-English native speakers made more random or anticipatory reactions and also incorrectly responded to images they were supposed to refrain from responding to. Bilingual non-English native speakers also demonstrated higher inattentiveness scores and lower sustained attention scores. Findings from this study contradict research which suggests that bilinguals are not as impacted by emotional stimuli in executive control tasks, in comparison to monolinguals (Barker & Bialystok, 2019). In fact, findings from this study suggest that bilingual non-English native speakers may be more sensitive to emotional stimuli in comparison to bilingual English native speakers and monolinguals. However, these findings should be interpreted with caution because of our small sample sizes per group and that we did not include a 'cooler' executive function task. Consequently, we cannot rule out the possibility that bilingual non-English native speakers would have performed similarly on a task without emotional stimuli.

All groups, on average, consider themselves 'English dominant' and proficient in their native language, however it is possible that bilingual English native speakers and monolingual English speakers have more similar language experiences. In fact, Dewaele and Wei (2012) only find an association between cognitive empathy and second language frequency and proficiency. Unfortunately, we do not have access regarding the capacity in which bilingual English native speakers acquired their second language or the frequency and proficiency of their second language usage. Thus, the lack of information regarding second language acquisition is limitation of the study design.

Future Directions

Potential extensions of this study can examine whether language experience modulates performance on tasks that measure attention with emotional stimuli versus non-emotional stimuli. Our study did not find bilingual advantages in hot executive function among an adult population. As mentioned above, this may be due to my small sample size and methods. If bilinguals and monolinguals differ in executive function abilities, then we should expect to see profound differences in their performance on tasks with emotional stimuli because these tasks are more difficult than executive function tasks with neutral stimuli (Lagattuta, Sayfan, Monsour, 2011). However, whether bilinguals outperform monolinguals at these tasks is what is still up for debate. Furthermore, it is necessary to establish whether incorporating emotional stimuli to an executive function task constitutes it as a hot executive function task. For instance, this would begin a discussion that can disentangle whether action tendencies towards ‘happy faces’ versus ‘angry faces’ represent a salient enough reward to be considered *hot*.

Chapter 5: The Bilingual Advantage Debate: Implementing An Intra-Interpersonal Account of Hot and Cool Executive Function Tasks

Chapters 2-4 include a variety of executive function measurements and have shown that executive function measures may be tapping into different aspects of executive function. Across these studies, bilingual children seem to demonstrate enhanced hot function skills (Chapters 2 and 3) as measured via executive function questionnaires. However, it remains to be studied whether bilingual children outperform monolingual children on hot and cool executive function tasks. This chapter investigates whether bilingual children will outperform monolingual children on executive function tasks that vary in their hot and cool contexts. Additionally, in an attempt to replicate findings from Chapter 2 I will investigate whether bilingual children are rated as having enhanced hot executive function skills in comparison to monolingual children.

First, it should be noted that performance on cool tasks as measured via cognitive tasks has not correlated with hot executive function skills as measured with questionnaires (see Chapter 2). Other work has similarly found profound discrepancies between executive function questionnaires and tasks (Duckworth & Kern, 2011). More specifically, it seems that cognitive tasks and questionnaire may be assessing differing underlying mechanisms that both relate to efficient goal achievement in different ways (Toplak, West, & Stanovich, 2013; Gerst, Cirino, Fletcher, & Yoshida, 2017; Toplak et al., 2012). Cognitive tasks may be providing information on the efficiency of processes recruited during goal-oriented tasks in a structured environment, but questionnaires seem to provide information regarding an individual's goal pursuits in everyday life (Toplak, West, & Stanovich, 2013). For instance, a child inhibiting his urge to yell out an answer in class appears different than the type of inhibition that child is using while inhibiting a response on a go/no go task. Questionnaires seem to tell us more about the former and cognitive assessments tell us more about the latter. Furthermore, I postulate that questionnaires seem to be more indicative of hot executive function skills as individuals are evaluating their inhibitory control in the context of social settings or 'real world' scenarios versus a cool decontextualized lab environment. Being able to assess both processes under a bilingual lens allows us to further understand whether the bilingual advantage relates to both, cognitive tasks and questionnaire measures of executive function. In fact, including both task and questionnaire measures is considered the optimal measurement strategy for assessing executive function skills (Duckworth & Kern, 2011).

Considering the bilingual advantage debate, it is important to consider what 'type' of executive function is expected to show differences and *why*. Given that executive function under hot and cool contexts is proposed to be on a continuum (Zelazo & Müller, 2002; Zelazo & Cunningham, 2007), it is plausible that bilinguals may be better under both contexts, one, or neither. Findings from studies examining bilingualism and executive function are inconclusive and findings from studies examining the relationship between bilingualism and communicative intent abilities are relatively new and scarce in comparison (see Chapter 1). Thus, while the search for a link continues it is imperative to 1) properly define bilingualism and 2) choose executive function tasks mindfully. Hence, the theoretical framework of language learning discussed in Chapter 1 has led me to investigate probable differences between monolingual and bilingual children's performance on hot and cool tasks. Further, because language learning is inherently interpersonal it is important to consider the varying degrees of 'interpersonal-ness' and 'hot-ness' of executive function tasks.

Studies have failed in their attempt to link executive functions as a mechanism underlying bilingual children's enhanced communicative intent abilities (Siegal, Lozzi, & Surian, 2009; Fan, Liberman, Keysara & Kinzleraa, 2016). A possible explanation may be that the tasks used to measure executive function in these studies are not appropriate in these circumstances. For instance, if we are measuring social abilities, perhaps hot executive function measures are more appropriate because of hot executive function's social component. Additionally, these studies typically only have one assessment of executive function, which makes it difficult to disregard executive function skills as a potential mechanism underlying communicative intent abilities. In an attempt to understand the relationship between communicative intent and executive function skills among bilinguals, I examined children's performance on a variety of executive function tasks and reports. This study also included an ecological task that required children to manage conflicting attentional demands in an interpersonal setting while they participated in a delay of gratification task.

Study Aims

The current study investigated how four-year-old bilingual children performed on a series of executive function tasks varying from intrapersonal to interpersonal and differing in their hot to cool contexts (see Figure 7). In an effort to replicate previous hot-cool framing (Allan and Lonigan, 2014), children were given small prizes prior to affective 'hotter' tasks (i.e., bear/dragon; affective KCPT) and told they would lose prizes if they responded incorrectly, whereas children were presented cooler tasks (i.e., day/night, KCPT) in their traditional fashion (e.g., no prizes and neutral affect). Regarding the framing of intrapersonal versus interpersonal, intrapersonal tasks were administered via computerized executive function tasks (e.g., KCPT) and interpersonal tasks were administered via a dyadic interaction between the child and task administrator.

Children in this study were approximately four years of age because previous work has suggested that differences among bilingual and monolingual children may be more prevalent in younger children (Carlson & Meltzoff, 2008). Furthermore, communicative intent studies that demonstrate favoring results towards bilinguals in comparison to monolinguals also reveal more consistent findings among younger children. For instance, compared to their monolingual counterparts, bilinguals aged 3 to 5 show an advantage in detecting conversational violations (Siegal, Lozzi, & Surian, 2009), adjusting to speaker needs (Genesse, Tucker, & Lambert, 1975; Gampe, Wermelinger, & Daum, 2019), and using referential cues from others to achieve a goal (Yow & Markman, 2011; Fan, Liberman, Keysara, & Kinzler, 2016). Finally, in order to assure an accurate depiction of children's language environment and abilities I collected extensive information regarding children's language experiences via parent surveys and I also tested children's English receptive vocabulary.

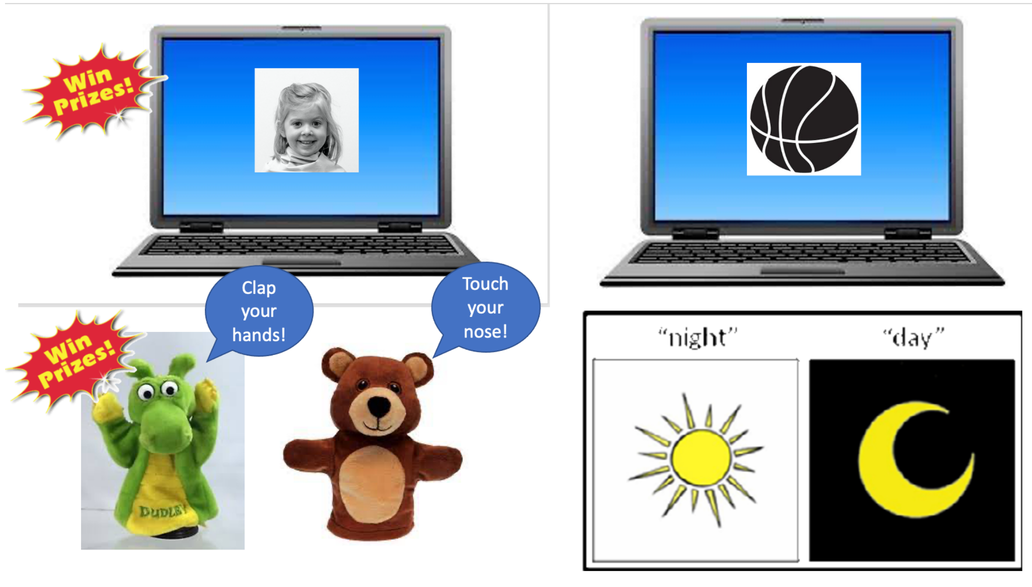

Figure 7. Illustration of intrapersonal tasks (top two images) and interpersonal tasks (bottom two images). Tasks on the left received prizes (hot) and tasks on the right did not receive prizes (cool).

Methods

Participants

Nineteen (*N* = 19) four-year-old's (*M* = 4.76, *SD* = .44) completed this preliminary study. Participants were recruited from the California San Joaquin Valley through community events or word-of-mouth. The COVID-19 pandemic prevented us from recruiting the remainder of our sample. Thus, preliminary results will be described. A little over half of the children were identified as females (57%) and identified as Hispanic/Latino (58%) per their parent reports. Additionally, primary caregivers' highest level of education was a college degree (47%), with mothers indicating a mean age of 35 (*SD* = 5.45) and fathers indicating a mean age of 36 (*SD*=6.99). Household income revealed a normal distribution which ranged from 'less than $23,000' to 'more than $150,000' with a mean of $41,000 to $60,000. Specifically, *n* = 1 participant reported a family income of less than $25,000, *n* = 4 participants reported a family income of $25,000 to $40,000, *n* = 3 reported a household income of $41,000-$60,000, *n* = 3 reported a household income of $61,000 to $80,000, n = 2 reported a household income of $81,000 to $100,000, *n* = 4 reported a household of $101,000 to $120,000, *n* = 1 reported a family income of more than $121,000 to $150,000 and finally, *n* = 1 reported a family income of more than $150,000. Children had a variety of language experiences, with most speaking and being exposed to English since birth or English and Spanish but one did have French exposure, another Cantonese exposure, and finally one had Mein exposure. Children who have been diagnosed with a condition or illness that would significantly affect their performance on the tasks were excluded (*n* = 1). This may include hearing loss, visual impairment, any type of developmental disability or learning disability. Additionally, given that a primary variable of interest is language proficiency, if the child's primary language was other than Spanish or English then they were excluded (we did not have appropriate resources to accommodate a language other than

English or Spanish). No child was excluded given the latter criteria. Furthermore, given that our tasks measure attention broadly, children were excluded for fussiness that obstructed task competition (*n* = 2). Bilingual criteria were based on previous research (Kuzyk et al., 2020), with exposure to a second language at a minimum of 20% from birth constituting bilingualism (*n* =4). All bilinguals were non-English natives, indicating Spanish as their native language and English as their second language. Three bilinguals had average English receptive vocabulary and one had moderately high English receptive vocabulary. Three children were considered bilinguals based on parent reports but were not sufficiently exposed to both languages (e.g., exposed to L2 between 12 to 17%) to meet our criteria of bilingualism so they are labeled L2 exposed (*n* = 3). Finally, monolinguals were exposed to mostly English 90-100% of the time since birth (*n* = 10). Additional parent responses based on their perception of their child's language proficiency, experiences and exposure were consulted in the development of these three groups.

Procedure

Upon arrival at the lab, parents and child were consented and the child had time to get comfortable with the lab space and experimenters. An approximately 10- to 15-minute-long warm-up period took place. The experimenter played with toys with the child to ensure the child was comfortable before beginning the tasks. During the task period, parents filled out a variety of questionnaire forms. The questionnaire forms were about the child and their own parenting style, the child's behavior, environment and executive function skills as perceived by the parent and basic demographics (e.g., income, education level of parents etc.). Completion of all paperwork and questionnaires took parents approximately 30-45 minutes

This study used preexisting executive function measures: the bear/dragon task (5-10 mins), day/night task (5-10 mins), kiddie continuous performance test (K-CPT; 5 mins long) and the affective K-CPT (5 mins long). Children participated in a five-minute break after three tasks. The break consisted of children sitting at the same table they had been at during tasks. Children drew their handprint on a paper and decorated it. Following the fourth task, all children were randomly assigned (via random number generator) to one of three conditions for the final task (details provided below).

Children were also randomly assigned (via random number generator) to receive either the hot tasks first or the cold tasks first so that we could examine whether there were effects of completing either the more 'motivated (hot)' tasks first or the cooler tasks first. The bear/dragon task is a hot interpersonal task as the child is required to inhibit the response from the 'naughty dragon' and there are social cues in the voices of the 'naughty dragon' and 'nice bear'. The day/night task is a cool interpersonal task because the child is still required to be engaged with the experimenter but is not required to pay attention to any social cues, hence less affect than bear/dragon. The intrapersonal hot task is the affective KCPT because children attend to and inhibit to social stimuli (other children's faces) and the intrapersonal cool task is the standard KCPT as children were required to inhibit to a neutral object (e.g., soccer ball). Additionally, for the hot tasks (bear/dragon and KCPT faces) children picked prizes from a prize box that they either kept or lost based on their performance. This is a similar approach used in the field to make tasks 'hotter' among children (Allan & Lonigan, 2014).

In sum, children were randomly assigned to hot or cool tasks first and following all four tasks they were randomly assigned to a condition of the delay of gratification task. Finally, the child completed the Peabody Picture Vocabulary Test (PPVT). Completion of all tasks took approximately 45 to 60 minutes.

Child Measures

Language Exposure Questionnaire (LEQ) (Bosch & Sebastián-Gallés, 1997; Fennell et al., 2007). The questionnaire requires parents to provide precise estimates of their infants' exposure to both languages. An estimate is given for each major caregiver in an infant's life (e.g., parents, grandparents, child-care workers), which is critical for quantifying bilingual exposure (De Houwer, 1995). A global estimate of percentage of exposure determined each of the languages to which the child was exposed.

Peabody Picture Vocabulary Test (PPVT) (Dunn & Duncan, 2007) PPVT. We obtained each child's English receptive vocabulary scores using the Peabody Picture Vocabulary Test IV (PPVT). Each child was asked to select one picture from a set of four that depicts the word that was spoken by the experimenter. For instance, a page had four photos: a horse, a cow, a pig, a dog and the child was asked to point to 'cow'. Raw scores were converted to standard scores using normalized tables based on age.

Bear/Dragon. The Bear/Dragon (Reed et al., 1984) assesses the ability to inhibit or activate a motor response following a rule, in a similar way as in a go no-go task. The experimenter introduced children to a "nice" bear puppet and a "naughty" dragon puppet. The children were told that in this game, they are to do what the bear asks them to do (e.g., "touch your nose"), but not to do what the dragon asks. After practicing, there are 10 test trials with the bear and dragon commands in alternating order. For instance, "touch your head" and "touch your nose". The children were seated at a table throughout the task, and all actions involved hand movements. The performance on the bear and dragon trials are considered to be an index of self-control. The tasks are scored as follows: 0 indicates a movement or response when the dragon asks and no movement when the bear asks; 3 indicates no movement when the dragon asks and a movement or response when the bear asks. Also partial credits were scored: 2 indicates a partial movement or response when the bear asks, and a wrong movement when the dragon asks; 1 indicates a wrong movement when the bear asks and a partial movement or response when the dragon asks. The score ranged from 0 to 20.

Affective KCPT. The Conners Kiddie Continuous Performance Test 2nd Edition™ (Conners K–CPT 2™) assesses attention deficits in children ages 4 to 7 years old. The task measures children's inhibition and sustained attention. Our modified version of this task is 5 minutes, whereas the original task is 7.5. We also include a break in the middle of the task whereas the original task does not. Our task contains two blocks of 40 trials with a break in between the blocks and the original tasks contains five blocks with 40 trials. Children received a practice session with 20 trials and was reminded of the rules when they made a mistake and praised for their correct responses. Children were asked to respond to targets (all faces except the happy face) and refrain from responding to non-targets (happy face) that appear on the computer screen. To respond, the child presses a big blue spacebar that is on a kid friendly keyboard. The faces come from the Child Affective Facial Expression (CAFÉ) set which contains photos of children that are validated for their expressions (LoBue, Baker, & Thrasher, 2018). Boys received the task with boy faces and girls received the tasks with girl faces. This task was administrated via laptops.

Day/Night. In the original and standard administration of the day/night task (Gerstadt et al., 1994), children were instructed to say the word 'day' when viewing a card depicting a nighttime sky and to say 'night' when shown a picture of the daytime sky. Children were first instructed to the cards and asked when they see the sun and when they see the moon. The experimenter then proceeded to tell the children that they would be playing a silly game that is an opposite game. They were then explained the rules above. A practice trial began and the child was praised if they got the trial right or corrected if they got it wrong. Once the child passed the practice trials the test trials proceeded. There was a total of 16 trials. The trials were scored as follows: 0 = no response or incorrect response, 1=self-correct and 2 =correct response. The score ranged from 0 to 32.

Modified KCPT. The Conners Kiddie Continuous Performance Test 2nd Edition™ (Conners K–CPT 2™) assesses attention deficits in children ages 4 to 7 years old. This task is exactly the same as the Affective KCPT computerized task explained above in terms of time-length, trials, set-up and its presentation but instead of photos of faces children are presented photos of objects. We used pictures of objects (e.g., boat, soccer ball, train) that are familiar to young children as in the original KCPT. The child was asked to respond to targets (all objects except soccer ball) and refrain from responding to non-targets (soccer ball) that appeared on the computer screen.

Modified Forbidden Toy. Similar to the Forbidden Toy paradigm (Lewis, Stranger & Sullivan, 1998) and the delay of gratification task Carlson and Meltzoff (2008) implemented, a toy is in a shiny box that has a cloth covering one end of the box and a side window (see Appendix A Figure A1). Children were asked to wait without peeking inside the box for 5 minutes. The experimenter acted surprised to see the box and turned the toy while excited and making sure the child cannot see what is in the box. The experimenter then told the child she needed to leave the room for a while to finish up some work, and asked the child to wait and not touch the toy in the following manner: "Do you know what this is? It's a Magic Robot! But only adults can play with it. I might have time to play with it with you before you have to leave. But I have to go out of the room to do some work. So, sit here, stay seated, and wait for me to come back all right? We might get to play with it together, so before I come back, remember you can not to touch the toy, okay? It's for grown-ups." Then the box with the toy in it was placed directly in front of the child (approximately 1 foot). The experimenter then left the room.

Our modified version includes an adult at the opposite end of the room that seemed distracted. This person has been sitting here throughout all tasks appearing distracted and busy working while wearing headphones (see Appendix A Figure A2 for room setup). This procedure was the same for all 3 conditions, but the child was randomly assigned to one of the three: *No adult condition*: there was no other adult in the room during the tasks and when the experimenter leaves, the child was left alone with the box. *Subtle approval condition*: the adult was across the room looking as if they were busy but gazing at the toy and the child with slight expressions of approval every 30-40 seconds since the experimenter left the room. *Subtle disapproval condition*: the adult was across the room looking as if they are busy but gazing at the toy and the child with slight expressions of disproval gestures (see Appendix A Figure A3 for facial expressions) every 30-40 seconds since the experimenter had left the room. The adult was a trained research assistant (always female), who was instructed not to respond to the child. She also was wearing headphones so the child would assume that the research assistant could not hear them if they spoke. Regardless of each condition and what the child did, the child was able to play with the toy before leaving the lab. Demonstration for this task can be seen in Figure 8.

Coding. Scores were adapted from Carlson and Meltzoff (2008) as follows: 1= removed cover and looked inside the box; 2 = looked in the window of the box but did not remove cover; 3 = touched the box or cover without looking inside of it; 4 = looked at (but not inside) the box and did not touch box; 5 = never touched or looked at or inside the box. I also coded behavioral disengagement tendencies descriptively (e.g., singing, playing with their hand or a bracelet; putting their head down at the desk; turning away from the box). I also coded the child's overall mood when the 'magic robot' was displayed, looks towards 'other in room', and towards or away from the box.

Figure 8. Demonstration of Forbidden Toy/Delay of Gratification modified task from Chapter 5.

Parent Questionnaires

Rules Questionnaire* (*Smetana, Kochanska & Chuang, 2000; based on Gralinski & Kopp, 1993.) This 29-item questionnaire asks about household rules such as not interrupting when mother is on the phone and eating food that parents serve. The items represent categories including child safety, protection of property, interpersonal manners, obedience/order, food/mealtime routines, family routines/chores, self-care, and parental control over the child's choices in clothing, friends, etc. Item wording was modified slightly to be more appropriate for this older age group of children. Parents indicated first if the item is a 'rule' (formal or informal expectation) for their child, and second how important it is to them that their child complies, on a 5-point scale. Total scores on the rule-importance items were used in analyses.

Emotion Regulation Questionnaire (Gross & John, 2003). This scale measures two emotion regulation strategies: cognitive reappraisal and expressive suppression. Cognitive reappraisal is a cognitive strategy involving reinterpretation of a potentially emotion-eliciting situation into a situation with a different emotional impact. Expressive suppression is a way of response modulation involving inhibition of emotion-expressive behavior. Examples of this questionnaire are "I control my emotions by changing the way I think about the situation I'm in" (reappraisal), "I control my emotions by not expressing them" (suppression). The scale consists of 10 items (6 reappraisal items, 4 suppression items). Lower reappraisal and higher suppression scores indicate more problems with emotion regulation.

Berkeley Expressivity Questionnaire (BEQ) (Gross & John, 1995). This questionnaire assesses three facets of emotional expressivity: negative expressivity (NE) (6 items), positive expressivity (PE) (4 items), and impulse strength (IS) (6 items). The questionnaire measures the degree to which both positive and negative emotions are expressed behaviorally and also the general strength of the emotional impulses. Examples of items are "It is difficult for me to hide my fear" (NE), "When I'm happy, my feelings show" (PE), "My body reacts very strongly to emotional situations" (IS). Items can be rated on a scale ranging from 1 (strongly disagree) to 7 (strongly agree). Higher scores indicate higher degrees to which emotion response tendencies are expressed as manifest behavior and a higher general strength of these tendencies.

Children's Behavior Questionnaire (CBQ) (Rothbart, Ahadi, Hershey & Fischer, 2001). This questionnaire includes 95 items regarding a variety of the child's temperament. For instance, attentional focusing, sadness, shyness, fear, etc. Parents indicated how true each statement is of their child on a 7-point scale. Next, we asked parents to indicate how important they believe these skills are at their child's present age, such as, 'How important is it to you that your child can focus his/her attention and easily concentrate on a particular task?' followed by, 'How upsetting is it to you when your child does not focus his/her attention on a particular task?' for a total of eight questions (also on a scale of 1–7). Responses to these eight items indicating the importance of self-control according to the parent were summed for analyses.

Results

Analytic Strategy

Preliminary analyses included graphical visualizations of demographic variables (e.g., gender, race/ethnicity, income, etc.). Additionally, I also ran correlations between task performance, parent questionnaires and language groups. For instance, executive function measures, the BEQ, CBQ, and rules questionnaire. Given the limited sample size due to the COVID-19 pandemic my results are descriptive in nature and I will not conduct inferential statistics. These results should be interpreted with extreme caution given the extremely low sample size per group.

While it seems that those receiving hot tasks first may perform better on subsequent tasks, we do not have enough data to determine whether receiving hot tasks first indeed influenced children's performance on subsequent cool tasks or vice versa. We also do not have enough data to determine if hot tasks are more related to one another in comparison to cool tasks or how these cognitive tasks as a whole relate to a more behavioral version of a delay of gratification task (e.g., Modified Forbidden Toy).

Group Descriptive Results

Bilingual children (*M* = 109, *SD* = 6.9) obtained a higher PPVT score in comparison to children exposed to a second language (*M* = 98, *SD* = 12) and monolinguals (*M* = 103, *SD* = 14). On average, monolingual children's parents had household income on the higher side (e.g., $61,000-$80,000). There did not appear to be a difference among groups on parent emotion regulation strategies or emotional expressivity, child's behavioral questionnaire or rules implemented in the home or ratings of children's compliance towards house rules.

Task by Group Descriptive Results

Bear/Dragon. There appear to be no apparent group differences with bilingual children (*M* = 18, *SD* = 2.06), exposure children (*M* = 19, *SD* = 1.15) and monolingual children performing similarly (*M* = 18, *SD* = 1.50).

Day/Night. Bilingual (*M* = 27, *SD* = 5.6) and exposure children (*M* = 26, *SD* = 5.6) appear to have slightly better performance than monolingual children (*M* = 23, *SD* = 5.7).

Affective KCPT. Monolingual (*M* = 15, *SD* = 4) and bilingual (*M* = 14, *SD* = 3) children appear be slightly more accurate at refraining from pressing the spacebar to non-targets (e.g., the happy face) on the affective KCPT in comparison to exposure children (*M* = 11, *SD* = 7). In contrast, bilinguals (*M* = 1.50, *SD* = .707) seem to have slightly less perseverations (e.g., random or anticipatory keyboard presses compared to monolinguals (*M* = 3, *SD* = 2) and exposure children (*M* = 3, *SD* = 2). Bilinguals (*M* = 47, *SD* = 10.60) and monolinguals (*M* = 46, *SD* = 15.63) also appear to have slightly higher commission scores demonstrating that they are slightly more accurate at pressing the spacebar to targets (e.g., non-happy faces) compared to exposure groups (*M* = 38, *SD* = 3.53). The exposure group (*M* = 18, *SD* = 4.95) had higher omission scores, indicating that they missed (did not correctly press spacebar) to targets (e.g., non-happy faces) compared to monolinguals (*M* = 8, *SD* = 7.15) and bilinguals (*M* = 11, *SD* = 11).

Modified KCPT. Bilingual (*M* = 12, *SD* = 5) and exposure children (*M* = 12, *SD* = 4) appear to be slightly more accurate in refraining from pressing the spacebar to non-targets (e.g., the basketball) on the cool version of the KCPT in comparison to the monolingual children (*M* = 11, *SD* = 4). Similarly, bilinguals (*M* = 2.75, *SD* = 2.5) and exposure groups (*M* = 3.33, *SD* = 4.16) seem to have less perseverations (e.g., random or anticipatory keyboard presses) compared to monolinguals (*M* = 7.29, *SD* =7). Bilinguals (*M* = 44, *SD* = 12.76) and monolinguals (*M* = 42, *SD* = 10.19) seem to have higher commission scores demonstrating that they are slightly more accurate at pressing the spacebar to targets (e.g., non-basketball objects) compared to exposure children (*M* = 34, *SD* = 12.42). The exposure group (*M* = 22, *SD* = 8) had higher omission scores, indicating that they missed (did not correctly press spacebar) to targets (e.g., non-basketball objects), compared to bilinguals (*M* = 11, *SD* = 9) and monolinguals (*M*=10, *SD*=7).

Modified Forbidden Toy. Monolingual (*M* = 3.71, *SD* = .48) and bilingual children (*M* = 3.75, *SD* = 1.2).were slightly rated as interacting with the box with the magic robot in it less than the exposure children (*M* = 2.33, *SD* =1.5). Monolingual (*M* = 16.86, *SD* = 9.4) and bilingual children (*M* = 15.75, *SD* = 11) were slightly rated looking at the experimenter less than the exposure children (*M* = 18, *SD* = 16).

Questionnaire by Group Descriptive Results

There did not appear to be a difference among groups on impulsivity or inhibition as rated by children's parents with bilingual children (*M* = 4.80, *SD* = .76, exposure children (*M* = 4.09, *SD* = .33) and monolingual children performing similarly (*M* = 4.38, *SD* = .93) rated similarly with regards to impulsivity. Additionally, parents rated bilingual children (*M* = 5.48, *SD* = .58, exposure children (*M* = 5.41, *SD* = .82) and monolingual children performing similarly (*M* = 4.48, *SD* = .95) rated similarly with regards to inhibition.

Discussion

The current study aimed to identify whether there is a relationship between children's languages experiences and their hotter executive function skills. Hot executive function skills are proposed to be elicited within social problems that have emotional significance (see Chapter 1) because hot executive functions are evoked under motivationally significant circumstances (Zelazo & Carlson, 2012). Learning language necessitates a dyadic process, thus posing the question as to whether bilingual children who are learning two languages at once and relying more on social cues outperform monolinguals on hotter executive function tasks. Results from this study indicated no profound differences in bilingual's performance of hotter executive function tasks in comparison to two other groups of children (e.g., monolinguals and L2 exposure children). Specifically, there were no profound differences between bilinguals and monolinguals performance on tasks that differed in their *hotness* or interpersonal-ness. However, bilinguals did have slightly less perseverations on the Affective KCPT, and they were slightly more accurate at pressing the spacebar to non-happy faces. Additionally, the exposure group seemed to miss responses to non-happy faces more so than bilinguals and monolinguals. This suggests that there may be subtle differences between early language environments and tracking of affective stimuli.

The general results from this study were not consistent with the hypothesis and the subtle descriptive differences that are noted should be interpreted with grave caution because of the limited sample size. I did plan to have a larger sample size and sufficient power to run inferential analyses but due to the COVID-19 pandemic recruitment was halted. Thus, the differences described above are extremely subtle differences. It is possible that with a larger sample and continued recruitment efforts that these differences could be amplified, however it is also possible that they could diminish.

Questioning parents with solely one question as to whether their child is bilingual deviated from a more accurate depiction of their child's language experiences. For instance, simply asking parents about their child's proficiency and exposure to both L1 and L2 led to an obvious conclusion that children differ in whether they are a balanced bilingual or merely exposed to another language. The LEQ we administered further corroborated parent's ratings of their child's L1 and L2 proficiency. Moreover, parents were accurate in providing their prediction of LEQ results (e.g., percentages of language exposure). When examining potential differences between bilingual and monolingual children it is important to get a thorough evaluation of children's language skills and experiences. That there were subtle differences among these three groups of children on executive function tasks warrants future work.

Future Directions

First, this study implemented two novel tasks, one that mirrors a standard attention task but with emotional stimuli and another that aimed to extend a delay of gratification task in an attempt to make it a more social task. The implementation of these tasks in the context of the bilingual advantage debate warrants future investigations because of the scant research among bilingualism and hot executive function. Moreover, given that hot executive function is a relatively new term these tasks may be a fruitful avenue for researchers that are still in the search for defining hot executive function and cool executive function as independent constructs. It is also up for debate as to whether these hotter tasks constitute a hot executive function task and if so, how these tasks relate to socio-cognitive abilities.

Future work can also examine how parent reports of their children's impulsivity and attentional skills relate to hotter and cooler executive function tasks and whether certain parent questionnaires are actually measuring hot executive function skills more so than they are cool executive function skills. For instance, questionnaires require parents to evaluate their children's executive function skills in their everyday contexts whereas as executive function tasks are usually administrated in laboratory settings. Moreover, it is worth exploring if parents' emotion regulation strategies or expressivity tendencies relate to children's responses towards affective stimuli. Little is known about how parent's everyday emotional tendencies relate to their children's attention abilities.

The introduction of the term hot executive function is exciting in that it encompasses emotion and cognition. Understanding how to measure hot executive function and whether these novel measurements are more similar to executive function in everyday contexts is important for a validated construct. Executive function is a messy term but perhaps evaluating executive function skills on a continuum of hot and cool can lead to a less messy term.

Chapter 6: General Conclusion

While we know that executive function skills have plentiful implications, executive function as a construct is messy (see Chapter 1 for review). Moreover, the executive function bilingual advantage appears to be elusive (Chapter 2). In the hopes of identifying a clearer relationship between bilingualism and executive function I examined bilingual's performance on hotter executive functions via questionnaires and tasks (Chapter 3-5). I have presented studies that have employed a variety of methodologies across a diverse set of age groups with the aims of bridging hot executive function abilities with the bilingual advantage debate. In this final chapter, I first discuss how Chapters 2-4 relate to previous research findings and how Chapter 5 expands the previous chapters by encompassing a multimethod evaluation of hot and cool executive functions while also thoroughly categorizing children's bilingual status. Second, I discuss implications for executive function theory and the bilingual advantage debate. Lastly, I describe limitations and suggestions for future directions to examine how hot executive function can be leveraged as a tool for evaluating cognition and emotion, especially in early childhood.

I collected evidence and theoretical approaches from different camps of research that hover around early language experiences to inform the theoretical foundation of these studies (Chapter 1). I used a longitudinal approach to explore the developmental trajectories of bilingual, monolingual and English learners' executive function abilities (Chapter 2). Specifically, Chapter 2 contained questionnaire measurements of executive function and common executive function tasks. Generally, findings from Chapter 2 highlighted that bilingual advantages are only detected at certain ages and with certain executive function measurements. Additionally, findings suggested that English learners may have a non-linear executive function trajectory in comparison to their monolingual and bilingual counterparts. The motivations for Chapter 3, came from teacher reports of children's executive function abilities in social settings that were found in Chapter 2. More specifically, Chapter 3 aimed to further explore teacher ratings of children's hotter executive function abilities. That bilingual children were rated as having higher attentional focus and inhibitory control within social settings compared to their monolingual counterparts suggests that bilingual children may have higher performance within hotter executive function tasks. Chapter 4 attempted to validate findings from Chapters 2-3 by evaluating bilingual adults' performance on a hotter executive function task instead of questionnaire reports as in Chapters 2-3. While Chapter 4 did not find apparent bilingual advantages implementing a hotter executive function task, there were differences within bilingual groups (native English speakers and non-English native speakers). Together, the results emphasize the importance of 1) carefully choosing executive function measures and 2) thoroughly evaluating language experiences when categorizing bilinguals.

The studies reported in Chapters 2-4 support that idea that different executive function measurements may be tapping into different types of executive function. It seems that questionnaires of executive function are measuring executive function under 'hot' contexts (see Chapter 1) and executive function tasks are measuring executive function under 'cool' contexts. More specifically, questionnaires ask about executive function in day-to-day experiences whereas tasks are measuring abilities that one may not be as conscious of. As suggested by findings in Chapters 2-3, executive function tasks may be tapping into the underlying processes that in some ways impact our executive function skills on a day to day. These discrepancies are important because we do know that hot executive function skills are related to impulsive problem behaviors and cool executive function skills are related more with academic outcomes (Kim et al., 2013; Willoughby et al., 2011). Furthermore, it is important that researchers are cognizant of the differences between measurements of executive function as construct validity issues could lead to inaccurate interpretations.

Moreover, studies in Chapters 2-5 highlight the importance of thoroughly evaluating language experiences when comparing monolinguals and bilinguals. An abundance of research has investigated whether proficiency in two languages (or more) produces cognitive benefits, specifically better performance on executive function tasks (see Chapter 1). The most prominent notions have been that an advantage arises from both languages being active at all times and thus a need for a system that inhibits the language that is not being used at the time (Green, 1998) or more broadly, an effective attention system (Bialystok, 2017). The notion once was that a bilingual environment would hinder cognitive development via language confusion (Saer, 1923; Goodneough, 1926), we now know that bilingual infants are not delayed in their early language acquisition in comparison to their monolingual counterparts (Sebastian-Galles, 2010). In fact, to cope with the linguistic differences in their environments, it seems bilingual infants and young children are better able at differentiating languages visually (Sebastian-Galles et al., 2012), determining a speaker's communitive intent (Yow & Markman, 2011a, 2011b), and more sensitive to speaker's nonverbal communicative cues (Yow & Markman, 2016). Whether these early differences translate to a domain-general attentional mechanism for language selection is still up for debate, as is whether this mechanism is maintained overtime (Chapter 2).

However, along with previous research, our findings from Chapters 2-5 suggest that bilinguals should not be considered a homogenous group when comparing monolinguals and bilinguals because language experiences within bilinguals can differ and this can lead to important differences within bilinguals (Wermelinger, Gampe, & Daum, 2017; Tran, Arredondo, & Yoshida, 2019). While findings remain mixed regarding the bilingual advantage debate, perhaps we are getting a fuller picture of what the research is converging upon. For instance, more recently two systematic reviews seem to converge on a similar notion. Gunnerud and colleagues (2020) evaluated the bilingual advantage in executive function among children 18 years old and younger across 143 studies. Additionally, they evaluated moderating characteristics such as socioeconomic status, nonverbal IQ, etc., and different components of executive function, such as working memory, inhibition attention, switching, etc., and importantly, publication bias. Overall, they found little support for a bilingual advantage on overall executive function once controlling for publication bias but tasks involving switching did indicate a bilingual advantage (even after controlling for bias). While systematic reviews and metanalysis are powerful in that they combine a wealth of information over several years, across several studies and participants, even they are subject to controversy and inconsistencies.

Importantly, it is not a question about whether bilinguals and monolinguals are different but rather how two or more languages are coordinated in a way that would enhance executive function. Learning a language is an inherently interpersonal process yet most executive function tasks are intrapersonal. Most studies examining executive function among bilinguals and monolinguals rely on cold intrapersonal cognitive tasks such as, the Simon task (Bialystok et al., 2004), Stroop task (Bialystok, Craik & Luk, 2008), Flanker task (Costa et al., 2008) or tasks similar to the day-night task (Martin-Rhee & Bialystok, 2008). There are critical issues regarding the tasks commonly used to assess executive function and the functionality and ecology of instruments have been called into question (Chan, Shum, Toulopoulou, & Chen, 2008). For instance, some tasks are not representative of the actual environment a child has or his/her abilities (Anderson, 2002; Valian, 2014). Thus, Chapter 5 attempted to compare and contrast interpersonal and intrapersonal preexisting executive function tasks among bilingual and monolingual children.

In support, recent but limited work suggests that bilinguals may indeed excel in socio-cognitive tasks because exposure to a multilingual environment may promote effective communication (Fan, Liberman, Keysar & Kinzler, 2015; Liberman, Woodward, Keysar, and Kinzler, 2017). Bilingual infants and children appear to be better at guiding their attention to communicative intent that would lead to successful communication. For instance, infants as young as 14 months that are raised in a multilingual environment outperform monolingual infants at taking a speaker's visual perspective to understand intended meaning (Liberman, Woodward, Keysar, and Kinzler, 2017). Also, two to four-year-old bilingual children appear to be better at using nonverbal referential cues (e.g., gaze direction) in comparison to monolinguals in the face of a conflict (Yow and Markman, 2011a). Similarly, bilingual children appear to pay more attention to paralinguistic cues (e.g., tone of voice) when interpreting emotion in speech in comparison to monolingual children (Yow and Markman, 2011b). Bilingual children also appear to be better able at paying attention to multiple sources of information and being able to integrate those sources. Yow and Markman (2015), found that in comparison to monolingual children, bilingual children were also better at integrating context, eye gaze and semantics in order to understand a speaker's referential intent. It appears that bilingual children may have increased socio-cognitive benefits due to their multilingual environment. Thus, Chapter 5 attempted to combine a delay of gratification task with an emotional social referencing component.

While monolingual and bilingual children may not have parents who gesture more or less, bilingual children may have to rely more heavily on communicative cues because of their unique communicative challenges (Yow & Markman, 2011a). Given the limited work but rather strong theoretical underpinnings, Chapters 2, 3 and 5 aimed at understanding the impact of a bilingual environment on broad attention skills and how such attention skills relate to ecological contexts. Taken together these findings, it is too early to claim that there is a hot executive function bilingual advantage, nor do these findings confirm or disconfirm a bilingual cool executive function advantage.

Limitations

While careful consideration was taken during the construction of the studies described above, there are limitations to consider with regards to this line of research.

First, Chapters 2-3 were secondary data analyses, so I did not have access to firsthand information regarding children's general mood during tasks or whether English learners properly understand the instructions of tasks. Moreover, given the nature of the dataset I relied on a limited amount of parent responses and only children's English receptive vocabulary to construct bilingual, monolingual and English learner groups. While the strategies I used are validated by previous research, these limitations should still be taken into consideration when interpreting the results from these studies. Additionally, the sample sizes for these studies were relatively large which could have inflated results.

With regards to Chapter 4, we did not have access to a cooler executive function task (standard CPT) to contrast with the hotter task (modified emoticon CPT). This is a limitation in study design that makes it difficult to understand whether bilingual adults would have performed similarly on a cooler task and further how a cooler task would differ from the hotter task. Also, that I did not pair a reward with performance during the task lessens its hotness. In fact, it is possible that the task in Chapter 4 is not considered a hot executive function task, rather it may be merely a standard executive function task with emotional stimuli. Further, that the emotional stimuli were emoticons may have had a weaker impact on attentional resources, in comparison to real faces flashing on a screen. Studies do find effects on approach and avoidance related behaviors with regards to fearful, angry or facial expressions (Marsh, Ambady, Kleck, 2005; Roelofs et al., 2010; Stins et al., 2011). Thus, future work should compare emoticons with actual faces in attention tasks in order to identify whether this change in stimuli impacts attentional processes. Moreover, that the language questionnaire I employed did not gather information regarding how adults acquired both languages and how proficient they were in both languages is an unfortunate flaw of the study design. For instance, more information regarding both languages would have provided potential explanations as to why results suggested a difference between non-English native speakers and English native speakers. Finally, the same sample may not have been adequate enough to run appropriate group comparisons. Due to the COVID-19 pandemic it was not possible to recruit more participants for this study.

While Chapter 5 intended to extend Chapters 2-4, it was not without limitations. For instance, while I included a measurement of English receptive vocabulary, I did not have a measurement of Spanish receptive vocabulary. Thus, it is difficult to place the exposure group because it possible that they would have had higher Spanish receptive vocabulary and be considered Spanish monolinguals. On the other hand, that we did not measure Spanish receptive vocabulary also makes it difficult to validate bilinguals propped proficiency in both languages. Furthermore, the modified Forbidden Toy task may have been too simple for preschool children and but may be more appropriate to be tested among two- and three-year old. Additionally, children appear to be hitting ceiling with the bear/dragon task, which is common among four-year old's (see Carlson, 2005). Future research examining executive function abilities among children should examine age trends in performance and task difficulty per age groups before selecting an executive function task (Carlson, 2005). Finally, due to the COVID-19 pandemic recruitment was halted and the final sample size is not sufficient enough to draw meaningful conclusions. Future research could extend methodologies discussed in Chapter 5 to examine whether bilinguals indeed differ in their performance of hotter tasks in comparison to their monolingual counterparts.

Future Directions

Several studies have examined whether bilingualism is linked to an executive function advantage leading to several strife's in the field. Nonetheless, several strides have also been made. For instance, we now know that bilingual language experiences do not negatively affect cognitive development. Moreover, we are exploring socio-cultural influences on cognitive development with a strengths-based approach. Below I describe future areas of research inspired by the studies described in this dissertation.

Language Experiences. Chapters 2-5 found differences within bilinguals which is a promising step forward in the search for a link between bilingualism and executive function. These differences did not necessarily favor bilinguals. Nonetheless, it is important to study whether executive function advantages may be more prominent given certain linguistic experiences. For instance, learning a second language from birth, as a child is acquiring a foundation of L1 is different than acquiring a second language after already having a foundation of L1. How would these scenarios relate to the notion that executive function processes are recruited in order to manage both languages? Moreover, just as bilingual children must learn that an object can have two labels (one in Spanish and one in English), monolingual children also learn that one thing can have multiple labels. Thus, it is important to understand how learning one language over two languages differs and how executive function skills relate to both of these circumstances if it is implied that learning two languages promotes enhanced executive function abilities. Finally, a continuous measure over a categorical measure of bilingualism (Luk & Bialystok, 2013) may be a more accurate measurement of bilingualism. Future research should consider the multiple dimensions of bilingual experiences when investigating potential differences among bilinguals and monolinguals.

Socio-cognitive Approaches. While we do know that a bilingual environment promotes enhanced communitive abilities (Fan, Liberman, Keysar & Kinzler, 2015; Liberman, Woodward, Keysar, and Kinzler, 2017; Yow & Markman, 2015), it is unclear whether this advantage is extended into adulthood. The research investigating bilingual adults' socio-communicative abilities is relatively new and questionnaire based, which may be subject to biases. Future research should explore whether early communicative advantages seen in bilingual children extend into middle childhood and adulthood. Of course, the measurement strategies would differ as most older children and adults (regardless of language experience) acquire efficient communicative abilities, but it is possible that these early bilingual communicative advantages translate to tracking social stimuli or sensitivity to emotional stimuli. For instance, implementing an adult social referencing task such as the Balloon Analogue Risk Task (BART; see Parkinson, Phiri, & Simons, 2012) may be a useful measurement in exploring potential bilingual and monolingual differences regarding ability to suppress and track emotions in an interpersonal setting. Future research should consider such tasks in exploring socio-communitive differences between monolingual and bilingual older children and adults.

Hot Executive Functions. Contrary to cool tasks, hot executive function tasks require regulation in contexts where the outcomes are of greater personal significance (Kerr & Zelazo, 2004), such as completing a task to earn a prize. Interest in studying executive function within 'hot' motivational emotional contexts is gaining traction in the literature (Zelazo & Cunningham, 2007; Garon 2016). Such studies include examining the regulation of one's own social behavior or decision-making involving punishment and reward (see Bechara, Damasio, Damasio, & Lee, 1999; Damasio, 1995). For example, Zelazo and Cunningham (2007) proposed a reciprocal relationship between emotion and executive function based on the problem's motivational significance (i.e., hot or cool). In this model, emotion and executive functions are inseparable. Future research should explore how hotter executive function tasks relate to cooler tasks and how both of these measures relate to children's self-regulation strategies within their everyday experiences.

Furthermore, if executive function and attention skills are truly at the core of how one begins to control one's behavior in relation to one's goal (Cuevas et al., 2018), then these skills may inform the development of emotion regulation and the influence of emotions on self-regulatory abilities. Rhoades et al. (2009) found that a task designed to capture children's ability to inhibit a motor response was the best measure for predicting social-emotional development. Consequently, the ability to inhibit certain action tendencies of emotions (Frijda, 1986) may be important for socio-emotional development. Thus, future emotion research should consider including complementary cognitive processes in order to provide a dynamic view of emotion and cognition during child development (Bell & Wolfe, 2004). Indeed, there are a variety of standardized attention and executive function measurements that would be fruitful in this endeavor (Mahone, 2005; Carlson, 2005). Specifically, some tasks require motoric inhibition, verbal inhibition, flexibility between competing rules, or working memory demands – all processes likely related to emotion regulation. Thus, the inclusion of standardized executive function tasks into studies on emotional development would offer emotion researchers a peak at the intertwined nature of emotion and cognition in early childhood.

General Summary

The chapters within this dissertation present multiple studies using a variety of methodologies such as questionnaires, standard tasks, and novel tasks in the evaluation of executive function and bilingualism. Moreover, these studies include a broad range of ages from children to adults. As a whole these studies demonstrate that language experiences relate to executive function abilities, but not always in the way we would predict. Further, these studies consistently revealed differences within bilingual groups highlighting the importance of adequately measuring language experiences. Finally, the evaluation of hot executive function on a theoretical and empirical level poses interesting questions for future work.

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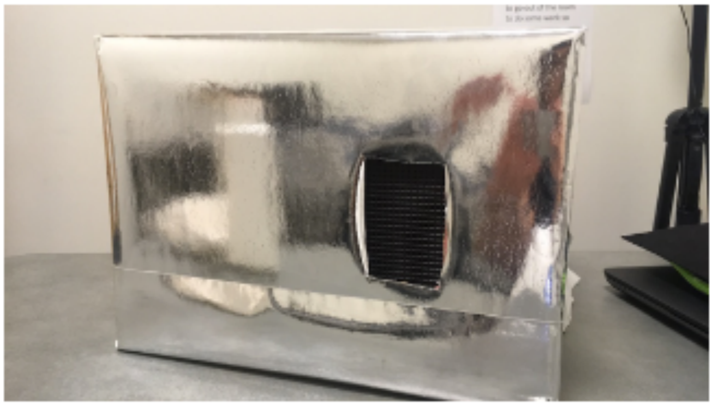
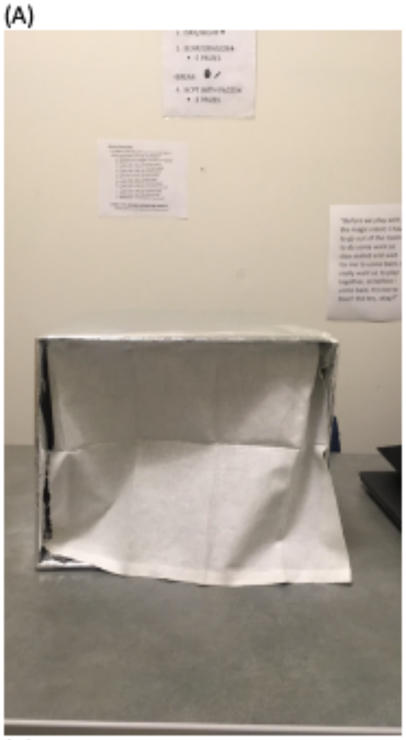
Appendix A



(A)



(B)

Figure A1. (A) is the side of the box with the window and (B) is the front of the box with the cloth from Chapter 5.

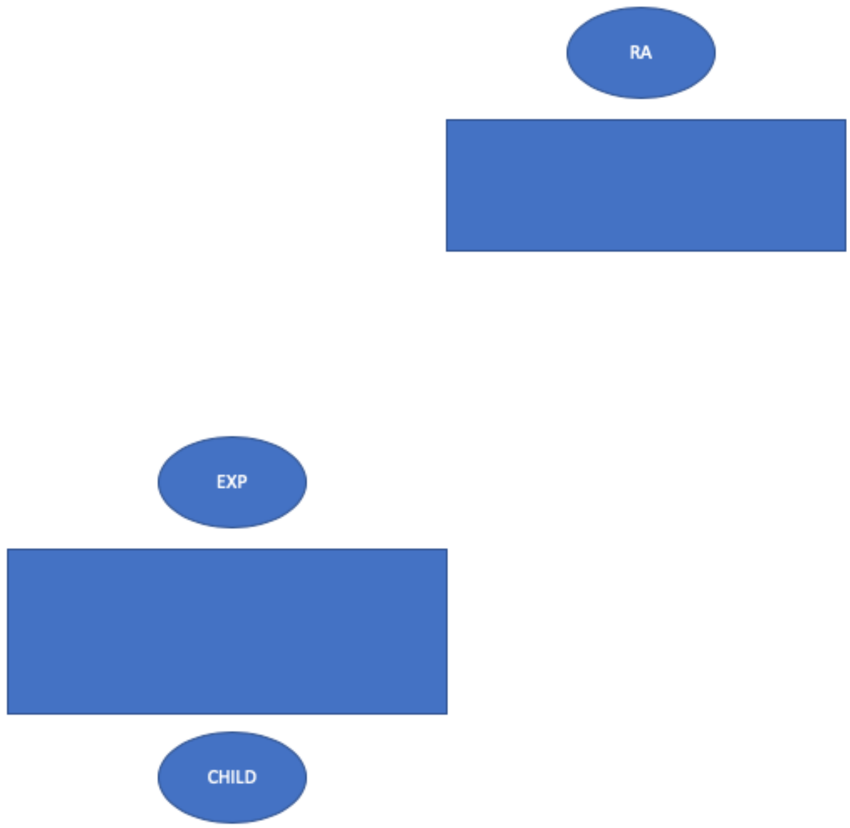


Figure A2. Experiment room layout. EXP is experimenter and RA is research assistant from Chapter 5.

If ***subtle disproval condition***, micro expression = shake head lightly side to side as eyebrows are scrunched, there should be a little scrunch between your eyebrows, lips straight.

If s***ubtle approval condition,*** micro expression = shake head lightly up and down as eyebrows are "more up" like when you're excited, keep lips slightly curved like a smile.

*Figure A3.*Description of both conditions for Chapter 5 modified Forbidden Toy.