INHIBITORY CONTROL, WORKING MEMORY, AND VOCABULARY IN PRESCHOOL PREDICTING ELEMENTARY SCHOOL ACADEMIC COMPETENCE

A Thesis

by

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ABSTRACT

Lower executive functioning is associated with poor social and academic outcomes, such as academic competence. Using a family study design, the current study investigated maternal variables influence on preschool executive functioning skills, and executive functioning skills predicting elementary school academic competence. Families with two children between the ages of 2.5 and 5.5 were recruited from the Dallas/Fort-Worth Metroplex and participated in a lab visit at The University of Arlington. The current study included 196 children (mean age = 3.88, *SD*= 1.04). The follow-up for these families was conducted at elementary school. Early executive functioning, specifically inhibitory control, predicted elementary school academic competence. In addition, maternal depression symptoms influenced both working memory and vocabulary not maternal anxiety problems. Future research should examine the positive impact of increasing children's early inhibitory control on improving their academic competence at elementary school.

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NOMENCLATURE

PPVT-IV	Peabody Picture Vocabulary Test Fourth Edition
CES-D	Center for Epidemiological Studies Depression Scale
STAI	Spielberger State-Trait Anxiety Inventory
HBQ	Health and Behavior Questionnaire
MLM	Multilevel Modeling
REML	Restricted Multilevel Estimation
SES	Socioeconomic Status

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1. INTRODUCTION

Executive functions are a group of mental processes which help a person to remain focused on a task (Diamond, 2006, 2013; Hughes, 2005; Jacques & Marcovitch, 2010; Miller & Cohen, 2001). These processes are mostly associated with the prefrontal cortex area of the brain (Carlson, Faja, & Beck, 2016), which continues to develop throughout childhood and into early adulthood (Casey, Galvan, & Hare, 2005; Diamond, 2002; Huttenlocher, 1979, 1990; Sowell et al., 1999). Due to advancements in neural imaging, we now have a better understanding of when executive functioning skills occur in childhood. This research suggests that inhibitory control and working memory begin to develop during the first year of life (Baird et al., 2002; Diamond, 2002; Diamond, et al., 2007; Garon et al., 2008; Wolfe & Belle, 2007) and the remaining executive functioning skill of cognitive flexibility emerges sometime between the ages of 3 and 4 (Moriguchi & Hiraki, 2011).

There have been several studies that have suggested that executive functions may be important in aspects of cognitive and social development including theory of mind, pretend play, emotion regulation, moral conduct, and school readiness (Blair & Razza, 2007; Carlson, Mandell, & Williams, 2004; Carlson & Wang, 2007; Carlson & White, 2013; Shoda, Mischel, & Peake, 1990). Poor executive function has been associated with many childhood disorders along with poor social and academic adjustment (Casey, Tottenham, & Fossella, 2002; Hughes & Ensor, 2011; Rodriguez, Mischel, & Shoda, 1989). There is also research that suggests executive functioning is predictive of college completion (McClelland, Acock, Piccinin, Rhea, & Stallings, 2013). Researchers are in general agreement that executive functions initially consist of the two

main components of inhibitory control and working memory (Diamond, 2013; Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003, Logue & Gould, 2014; Miyake et al., 2000). These components help to make higher-order executive functions possible, such as reasoning, problem-solving, and planning (Collins & Koechlin, 2012; Lunt et al., 2012). These two initial executive functioning components are separable to an extent, but they do overlap in having a common purpose. Research describes this common purpose as the allocation of attention and control over behavior to meet a goal (Friedman & Miyake, 2017; Miyake & Friedman, 2012; Miyake et al., 2000).

1.1 Inhibitory Control

Inhibitory control is defined as the ability to control one's thinking, behavior, and/or emotion thus concentrating attention (Diamond, 2013). This aspect of executive functioning helps to make it possible for attention and goal-oriented behavior. Without inhibitory control, people would follow whatever impulses they had at any given time (Diamond, 2014). The development of inhibitory control comes about rapidly in early childhood with stark contrasts in performance on tasks within just a few years (Petersen, Hoynial, McQuillian, Bates, & Staples, 2016). Changes in neurobiology and structure in the prefrontal cortex during the preschool years contribute to the large growth in executive functioning during this period (Zelazo, Blair, & Willoughby, 2016; Zelazo & Müller, 2010). Inhibitory control is generally assessed using similar tasks such as Stroop (MacLeod, 1991), go/no-go (Cragg & Nation, 2008), and Flanker tasks (Eriksen & Eriksen, 1974, Mullane et al., 2009). These tasks are used to understand a child's ability to utilize executive control.

The early development of inhibitory control is a critical domain of interest for developmental researchers because effective inhibitory control is associated with academic

achievement, social-emotional competence, and reduced behavior problems (Espy et al., 2004; Nigg et al., 2006; Raaijmakers et al., 2008; St. Clair-Thompson & Gathercole, 2006). Additionally, poor outcomes are associated with the opposite. Children with low inhibitory control are at greater risks for problems in these major areas including externalizing behavior problems and attention deficit hyperactivity disorder (ADHD; Eisenberg et al., 2001; Eisenberg, Spinard, & Smith, 2004; Gagne, Saudino, & Asherson, 2011; Goos, Crosbie, Payne, & Shachar, 2009). Behavior problems in early childhood are predictive of maladjustment across development into adulthood including poor health and education outcomes (Denham et al., 2000; Saudino, Carter, Purper-Quakil, & Gorwood, 2008). According to Diamond (2014), "inhibitory control seems to be the executive function most predictive of long-term outcomes."

Moffitt et al., (2011) found similar results in a longitudinal study that children with higher levels of inhibitory control were less apt to participate in risky behaviors like smoking, dropping out of school, and experienced fewer unplanned pregnancies at adolescence. These children were followed into adulthood and were also seen to have better health, higher income, better jobs, and had less involvement with the law compared to children with lower levels of inhibitory control. Being that inhibitory control is associated with both academic and social outcomes and many long-term positive outcomes, the importance of studying inhibitory control as an executive functioning skill is evident. These higher-risk outcomes make it important to identify those children with low inhibitory control to provide intervention opportunities before they reach critical ages for these risky behaviors and potentially negative outcomes in adulthood.

1.2 Working Memory

Baddeley (1992) defined working memory as the limited capacity cognitive system which maintains short-term storage and manipulation of information. Thus, this system is important for learning new concepts over time, utilizing directions, and remembering past events to plan for the future. This aspect of executive functioning comes about by the end of the first year of life (Baddeley & Hitch, 1994). Research on working memory typically involves some kind of memory task such as working memory components of the NIH Toolbox Cognitive Battery (Mungas et al., 2013; Zelazo et al., 2013), the Listening Recall task from the AWMA battery test (Alloway, 2007), and digit recall from the Working Memory Test battery (Gathercole & Pickering, 2001).

The capacity of this cognitive system is predictive of some influential cognitive abilities for children entering school such as reading (Baddeley, 1992; Daneman & Carpenter, 1980), writing (McCutchen, 1996; Swanson & Berninger, 1996), and arithmetic (De Smedt et al., 2009; Destefano & Lefevre, 2004; Gathercole et al., 2004). Working memory predicts math and reading competence even into young adulthood (Alloway & Alloway, 2010; Bull & Scerif, 2001; Dumontheil & Klingberg, 2012; Gathercole, Pickering, Knight, & Stegmann, 2004). Research with the A-not-B task from Piaget's work (1954) indicates that around 8 months some spatial working memory has been developed to understand where the hidden object used in this task is located. Around 1 year of age infants manage to hold the placement of the object in mind for longer, which Diamond (2002) suggests is the beginning of an integration of working memory with the other developing executive functioning skills.

Working memory is a critical component of inhibitory control functioning because each provides support for the operation of the other (Diamond, 2013). For example, a child must keep rules or expectations in mind (working memory) to understand what counterintuitive impulses must be inhibited (inhibitory control) to complete a task or goal. The reverse may also be true, as a child must inhibit other noises and distractions (inhibitory control) in order to hear and retain the instructions (working memory). Otherwise, they will not remember the directions. These two cognitive functions are important to one another. Research also suggests their combined importance, as working memory and inhibitory control have a stronger association with school readiness when compared with IQ, math, or reading skills (Blair & Razza, 2007; Espy et al., 2004; McClelland et al., 2007; Morrison, Ponitz, & McClelland, 2010).

1.3 Executive Functions and Their Relation to Vocabulary

Receptive vocabulary is especially important for communication, and it has been continually found to be associated with later reading outcomes (Scarborough, 2001). In addition, several studies indicate significant correlations (*r*'s range from .44 to .96) between executive functioning and language skills (Carlson et al, 2005; Gooch et al., 2014). This association could be indicative of executive functions supporting the development of language skills (Weiland, Barata, & Yoshikawa, 2014). Several researchers have found that higher executive functioning skills are positively associated with higher language skills for preschool and elementary school children (Gathercole & Pickering, 2000; Gathercole, Pickering, Knight, & Stegmann, 2004; Howse et al., 2003; Lehto, 1995; McClelland et al., 2000; McClelland, Cameron,, Connor, Farris, Jewkes, & Morrison, 2007; Ponitz, McClelland, Matthews, & Morrison, 2009). These findings correspond with Gremillion, Smith, and Martel's (2018) suggestion that verbal working

memory and vocabulary skills are intertwined in early development. The other pathway that has been explored is that language skills may provide support for the development of executive functioning including working memory and inhibitory control. This is indicative of a predictive relationship that was found by Schmitt, Purpura, and Elicker (2019). Their results showed that vocabulary at preschool entry was a significant predictor of executive functioning in the spring of preschool. Another study found that the role of executive functioning was supportive of gains in language skills for preschoolers also (Weiland, Barata, & Yoshikawa, 2014). However, at least one study reported no support for executive functioning influencing preschool verbal ability (Fuhs & Day, 2011). Thus, more research on the pathway between executive function and vocabulary needs to be done.

1.4 Inhibitory Control, Working Memory, and Vocabulary Gender Differences

Previous literature has noted some gender differences in cognitive performance during early childhood (Berlin & Bohlin, 2002; Carlson & Moses, 2001; Vuontela et al., 2003) These differences suggest that girls outperform boys on inhibitory control and working memory tasks, which were suggested by the number of errors on Go/NoGo working memory tasks in a longitudinal study (Mileva-Seitz, et al., 2015). In adulthood, these differences persist in both spatial and verbal working memory (Huster, Westerhausen, & Herrmann, 2011; Kaufman, 2007; Murre, Janssen, Rouw, & Meeter, 2013; Speck et al., 2000).

In vocabulary, gender differences are also prominent. Within the first years of language development, girls on average speak more and seem to have more expressive vocabulary than boys (Berglund et al., 2005). However, effect sizes for gender differences in vocabulary are usually found to be small (Driessen & van Langen, 2007). Research later in preschool (ages 2.5

to 4) does not seem to show these gender differences (van Druten-Frietman, Denessen, Gijsel, & Verhoeven, 2015; Jiang, Logan, & Jia, 2018). In addition, the results of a meta-analysis of preschool through early adolescence found that the vocabulary differences between genders is much smaller than expected (Hyde & Linn, 1988).

1.5 Maternal Depression and Anxiety's Link to Executive Functions

Children exposed to maternal depression are at higher risk of developing both externalizing (Leschied, Chiodo, Whitehead, & Hurley, 2005; Ashman, Dawson, & Panagiotides, 2008) and internalizing problems (Hammen & Brennan, 2003; Murray et al., 2011; Garstein et al., 2010). Depression symptoms are common and often chronic (Field, 2011); there are reports of up to 24% of 17-month-olds exposed to these symptoms (Mclennan, Kotelchuck, & Cho, 2001) which can hinder parenting processes contributing to greater risk for negative child outcomes (Hughes, Roman, Hart, & Ensor, 2013). Researchers found similar results with maternal depression symptoms having a predictive relationship with children's executive functioning longitudinally (Hughes, Roman, Hart, & Ensor, 2013). Maternal depression poses a concern for developing young children's executive functioning skills.

Maternal anxiety also has an influence on executive functions, as maternal anxiety during gestation predicted impaired executive function among 6- to 9-year-old offspring (Buss, Davis, Hobel, & Sandman, 2011). In Pearson et al., (2016), postnatal maternal anxiety and depression were risk factors for impairments in attentional control, and prenatal anxiety was associated with impairments in working memory. Postnatal anxiety was also associated with higher risk in failing at poor math and language. However, these findings were confounded by maternal education and socioeconomic status. Both maternal depression and anxiety early in life can have

potentially negative outcomes for children, which suggests that executive functioning is subject to environmental influences.

1.6 Executive Functions and Vocabulary and Their Relation to Academic Competence

As previously reviewed, researchers have established relationships amongst the executive function variables, vocabulary, and academic skills. Findings include working memory capacity predicting reading (Baddeley, 1992; Daneman & Carpenter, 1980), writing (McCutchen, 1996; Swanson & Berninger, 1996) and arithmetic (De Smedt et al., 2009; Destefano & Lefevre, 2004; Gathercole et al., 2004), associations between higher inhibitory control and higher academic achievement (Espy et al., 2004), and vocabulary being important for communication and later reading achievement (Scarborough, 2001). Inhibitory control and working memory are also significantly associated with emergent literacy when adjusting for child gender, child age, and maternal education (Becker, Miao, Duncan, & McClelland, 2014). They also found that inhibitory control was partially related to math and that vocabulary was significantly related to both inhibitory control and working memory. Working memory is therefore necessary for understanding written and oral language along with mentally calculating math (Diamond, 2013). Lastly, vocabulary is strongly linked with children's listening and reading comprehension skills (Cain, Oakhill, & Bryant, 2004; Cromley & Azevedo, 2007; Language and Reading Research Consortium, Currie & Muijselaar, 2019). Thus, inhibitory control, working memory, and vocabulary contribute heavily to children's academic competence.

In this particular study of academic competence, the measure is perceived by parents through survey data. Studies have shown that parent's perceptions of their child's competence are important in predicting children's performance in school (Phillipson & Phillipson, 2007;

Pomerantz & Dong, 2006). Those students with parents that hold higher competence perceptions for their children tend to receive higher grades, achieve higher scores on standardized tests, and stay longer in school than those children whose parents hold lower perceptions (Peet, Powell, & O'Donnel, 1997; Phillipson, 2010; Pomerantz & Dong, 2006; Yamamoto & Holloway, 2010 as cited in Gut, Reimann, & Grob, 2013). Given this information, the variable perceived academic competence should be taken into consideration for the current study.

2. THE CURRENT STUDY

There is a wide range of research regarding inhibitory control, working memory, and vocabulary as predictors of academic competence. However, few extant studies take maternal depression and anxiety symptoms into consideration. Using a family study design, the current study sought to identify child-level variables to predict academic competence. The primary focus for child-level factors was on child gender, vocabulary, and executive functions. The focus for parent-level variables included maternal depression and anxiety symptoms as predictors of executive functioning and vocabulary. The family design allows for assessing within sibling pairs to create a broader picture of home life and relatedness among sibling outcomes.
The present study has three specific aims.

To evaluate relations between preschooler variables including inhibitory control, working memory, and vocabulary. Gender will also be considered. I will test the model presented in the literature for how inhibitory control predicts vocabulary by multilevel linear regression (MLM) analysis. I will also test working memory in predicting vocabulary. I hypothesize that higher inhibitory control and higher working memory will predict higher vocabulary, as much more research suggests this pathway than the latter.

To determine whether maternal anxiety symptoms influence preschool executive functioning and vocabulary knowledge using MLM regression analysis. I will also determine whether maternal depression symptoms predict children's executive functioning and vocabulary. I predict that higher maternal anxiety and depression will be associated with lower inhibitory control, working memory, and vocabulary.

To test whether preschool inhibitory control predicts higher academic competence in elementary school using a multiple linear regression model. I will also test whether working memory at preschool will predict academic competence and vocabulary at preschool will predict academic competence. I expect that all three variables will predict elementary school academic competence.

First, I will calculate descriptive statistics, gender differences and check skewness and kurtosis on all variables. If necessary, I will transform skewed variables in the appropriate manner. I will then examine all correlations between variables. I expect that the cognitive variables will be highly correlated with each other and slightly less so with academic competence at elementary school, as it is parent-reported rather than a lab measure. I also expect that maternal depression and anxiety will be less correlated with the cognitive variables, but it will still be significant. Maternal depression is predicted to be positively correlated with maternal anxiety.

Next, I hypothesize that higher executive function skills and vocabulary will predict higher academic competence. Therefore, children that perform better on vocabulary and executive functioning tasks will have higher elementary school academic competence. I also hypothesize that higher maternal depression and anxiety will predict lower executive functioning. Children with mothers that have higher depression and anxiety symptoms will have lower executive functioning skills and vocabulary.

3. METHODS

3.1 Participants

The sample for the preschool phase of the study consisted of 99 families with two typically developing children (*N*=198) between 2.5 and 5.5 years of age (*M*= 3.88, *SD*= 1.04) and their mothers (mean age = 34.14, *SD* =5.13) in the Dallas Fort-Worth area. The sample included 102 boys (mean age= 3.79, *SD*=0.99) and 96 girls (mean age=3.97, *SD*= 1.08). Participants included 57 full sibling pairs, 10 identical twin pairs, and 32 fraternal twin pairs. The racial distributions was predominantly Caucasian (84% of children, 88% of mothers, and 87% of fathers). Other races included were Hispanic or Latino (13% of children; 7% of mothers; 8% of fathers), multiracial (11% of children; 5% of mothers; 4% of fathers), and African American individuals (4% of children; 4% of mothers; 7% of fathers). Less than 3% were reported as Asian American, Pacific Islander, and other races. The mean household income was approximately $70,000 (Range from $20,000 to over $200,000) and mean parental years of education was 15.83 years for mothers and 15.2 years for fathers (ranging from 8 to 22 years). A follow-up survey was conducted for these participants during the elementary school phase of the study. The participants included 128 of the original children ages 5 to 11 (mean age= 7.5, *SD*= 1.26) with a total of 70 families participating from the original 99. The primary parent was asked to report on the surveys. For both phases of the study, data was de-identified to ensure anonymity and securely stored.

3.2 Procedure

This sample is derived from the initial TEXAS Family Study which assessed preschooler temperament, executive functioning, and other family variables at the University of Texas at Arlington under Dr. Gagne, the primary investigator. Families were recruited beginning in late 2012 in the Dallas-Fort Worth Metroplex through fliers on the University of Texas at Arlington campus and in pediatricians' offices and at daycares. Interested families were asked to complete online screening. After qualifying, online surveys were completed through SurveyMonkey predominantly by mothers. A total of 126 families participated in the preschool phase online portion. Of these families, only 99 participated in a laboratory visit. These visits consisted of different behavioral and cognitive assessments described as "fun games" for the children. There were also additional questionnaires for the parents to fill out during the laboratory visit. There were no differences seen in demographic variables for families in parental age, years of education, and family income that only completed the surveys and those that participated in the laboratory visit with child age being the only exception. The mean child age for the survey-only participants was lower because some parents completed surveys for children that were not in the specific age range of the study which made them ineligible for the laboratory visits. Participants received a $25 gift card for completing the surveys, and the participants that completed the laboratory visits received an additional $50 gift card.

The elementary school follow-up surveys were also completed through SurveyMonkey. Previous participants were emailed with the link to participate. After emailing three times, the participants were called for recruitment. The surveys consisted of four separate invitations based on family variables, parent variables, child one, and lastly child two. Upon completion, a $50 gift

card was emailed to the family. Elementary school data were only used if accurate birthdates for each child were confirmed. If another date of birth was given that did not match, then the family was not used in data analysis.

3.3 Measures

3.3.1 Executive Functioning Tasks: Preschool

Given previous literature studying executive functioning variables separately and the low correlation from previous literature and this study's low correlation (r= -.04 to .33** for spatial and verbal working memory respectively; Brocki, Nyberg, Thorell, & Bohlin, 2007; Table 1), inhibitory control and working memory were examined separately in analyses.

To obtain measures of inhibitory control, we utilized a modified Stroop task. This measure took place during the preschool phase. These tasks required children to suppress their automatic response to provide a correct response. This task was modified for the different age ranges that participated. The younger age range (2.5-3.5 years) participated in a baby game Stroop task (Hughes & Ensor, 2005). This task required two cups. One was small and referred to as "baby" cup and a regular sized cup which referenced a "mommy" cup. The child was directed to post to the baby cup and mommy cup to check for understanding of both stimuli. Then, the experimenter informed the child that they were playing an "opposites game," and the child would have to respond the opposite of which cup was presented. Therefore, if the "baby" cup was presented, then the child would need to respond, "mommy cup" and vice versa for the "mommy cup" being presented. The cups were presented in a pseudorandom order. There is no psychometric data available for this task.

For children age range of 3.5-4.5, they participated in the hand game (Hughes, 1996). The hand game includes either a fist or a pointer finger that the experimenter presents to the child. The child then must imitate the gesture. Once the child understands the hand gestures for the game, the experimenter gave instructions to present the opposite of the hand gesture. If the gesture was a fist, then the child needed to present their pointer finger and vice versa. A Cronbach's alpha of 0.88 was reported for the hand game (Chasiotis, Kiessling, Hofer, & Compos, 2006).

Participants that were 4.5-5.5 years of age participated in the day-night Stroop task (Gerstadt, Hong, & Diamond, 1994). The experimenter displayed a card with either a moon with stars or the sun depicted on it. The child was instructed to say the either day for when a moon was displayed or night when a sun was displayed in keeping with the opposites of the other tasks. There has been internal reliability reported for this Stroop task with a range from 0.79 to 0.93 by Chasiotis et al. (2006), Rhoades, Greenberg, and Domitrovich, 2009, and von Stauffenberg & Campbell (2007).

All three Stroop tasks were given a total of 12 trials and number correct was recorded out of 12. More correct answers reflected higher levels of inhibitory control. The combination of these three types of Stroop tasks have been used in previous published articles (Hughes, Ensor, & Marks, 2011; Hughes & Ensor, 2008).

Spin-the-Pots was a multi-location search task used to measure working memory (Hughes & Ensor, 2005). The child was asked to place stickers in whatever colored box they wished on a turn table. There were many visually distinct boxes to choose from. The number of boxes the children had to choose from differed according to age. For children aged 2.5-3.5, 8

boxes were used. For children 3.5-4.5, 10 boxes were used. Lastly, children 4.5-5.5 were given 12 boxes to choose from. Once the child finished placing the stickers with only two boxes remaining empty, the boxes were all closed, and a cloth was placed over the boxes to hide them from view. The Lazy Susan was then turned one time around. It was then uncovered, and the child was asked to locate one of the stickers that he/she placed. The task would continue until all the stickers were retrieved or the maximum number of spins were met (12 spins for the youngest group, 16 spins for the middle-aged group, and 20 spins for the oldest group). Scores were reported based on the number of stickers to number of spins. Thus, scores ranged from 0 to 1 with 1 representing the highest score. Test-retest reliability for this task was r=0.59, p=0.002 (Lalonde & Holt, 2014). ().

3.3.2 Vocabulary: Preschool

The Peabody Picture Vocabulary Test (4th ed.; PPVT-IV; Dunn & Dunn, 2017) was used to assess vocabulary. The experimenter would state a word from the standardized list, and the child would be required to point to the picture that corresponds with the word stated. There is four pictures to choose from when responding. If eight items were missed from a block of 12, then the experimenter would stop the test. Otherwise, the PPVT-IV would continue through until the end of the test. Children's results were compared with standardized scores. The internal consistency coefficient of the PPVT is.97 and researchers have found a significant relationship between PPVT scores and reading comprehension (Dunn & Dunn, 2007).

3.3.3 Assessment of Maternal Affect & Mental Health

For the anxiety measure, the Spielberger State-Trait Anxiety (STAI) was used. It is a questionnaire that asks questions regarding current states of anxiety and general anxiety

tendencies. This questionnaire has items that distinguish anxiety symptom from depressive symptoms. For example, one item states “I am a steady person.” Then a person would need to answer by rating the item on a scale of 1 (almost never) to 4 (almost always). There are a total of 40 items. The sum of the total items are then taken as a measure of anxiety symptoms. A score of 43 or higher indicates risk for an anxiety disorder (Spielberger, 1983). The reliability estimate for the STAI is .86, and there has been satisfactory validity established as well (Spielberger, 1983). The internal consistency for the A-trait scale on the STAI for this sample was 0.90.

Maternal depression symptoms were measured using the Center for Epidemiological Studies Depression Scale (CES-D; Radloff, 1977). This questionnaire includes 20 items that reference feelings and behaviors of the past week. This questionnaire was also rated on a scale by the participant including 0 (Rarely or less than one day) to 3 (Most or 5-7 days). The items on the CES-D were summed with a possible range of 0 to 60 with 60 indicating the presence of the greatest symptoms. This questionnaire also has satisfactory validity along with a reliability estimate of .88 (Orme, Reis, & Herz, 1986). Cronbach’s alpha was calculated for the CES-D, and it was .84.

3.3.4 Academic Competence: Elementary School

The Health and Behavior Questionnaire (HBQ) was included in the online survey follow-up. Parents rated their children’s academic functioning, social functioning, and health. For this questionnaire, the academic competence scale will be used. This scale uses children’s abilities in both math and reading to report on academic competence (Armstrong, Goldstein, & The MacArthur Working Group on Outcome Assessment, 2003). The HBQ has been shown to have

high test-retest stability (Essex, et al., 2002). For our data, the Cronbach's Alpha was calculated as 0.90.

4. RESULTS

4.1 Data Analysis

Preliminary analyses involved calculating the descriptive statistics for measures of central tendency and differences in gender. Next, Pearson's R correlations were calculated for the study variables.

My first aim was to assess the relationship between preschool variables of inhibitory control, working memory and preschool vocabulary. There are two different pathways for this relationship, either executive functioning influencing the development of vocabulary, or vocabulary influencing the development of executive functioning. Gender differences were taken into consideration beforehand by comparing means. These variables were screened to ensure normality, and then the relationship was assessed using a multilevel regression model to account for the nested structure of the study design. Ordinary least squares (OLS) should not be used because of the risk of increased Type I error (Cohen, Cohen, West, & Aiken, 2003), but multilevel regression models account for the individual level predictors on dependent variable(s). This model did require the restriction to only allow fixed effects based upon individual predictors of the outcome (Kenny et al., 2006).

The second aim was to determine whether maternal anxiety and depression influences preschool executive functioning and vocabulary. A multilevel linear regression model was also used for this aim. It was predicted that higher maternal depression and anxiety symptoms would predict lower executive functioning skills and lower vocabulary in children.

The third and final aim was to determine if preschool inhibitory control, working memory and vocabulary would predict academic competence in elementary school. The prediction for

this aim was that higher cognitive variables would predict higher academic competence. This aim also used a multilevel linear regression model.

4.2 Data Screening

Prior to analysis, data was screened for outliers and missing values using SPSS Missing Values Analysis and minimum and maximum values. Outlier values consisted of 3.29 standard deviations above or below the mean and were treated as missing values. The variables that consisted of outliers include maternal depression symptoms, maternal trait anxiety, spin-the-pots for working memory, and academic competence. Outliers were treated as missing values. Two variables indicated a greater than 5% missing values: Stroop task (12.1%), and lastly the HBQ academic competence (37.9%). The HBQ was expected to have high levels of missing data, as it was collected in the longitudinal follow-up which had less families participate. Little's MCAR test was run and came back significant, $\chi^2(55)= 113.954$, $p=.001$. Therefore, the variables were not missing completely at random, and they were kept as is.

Histograms, skewness, and kurtosis statistics were used to assess the data for the assumption of normality. Stroop and maternal depression symptoms were positively skewed. Stroop was due to reverse scoring. A square root transformation was used for both. All variables then met the assumption of normality and were used in future analyses. The data did meet the assumptions of lack of multicollinearity among predictors and lack of univariate and multivariate outliers. It did not violate the assumption of homoscedasticity, and the multilevel assumption of homogeneity of level 1 variance. The predictors for the aims of the study were all grand-mean centered for the multilevel models, as opposed to group-centered because group-centering with

dyadic data removes all variance due to the dyad (Kenny et al., 2006). The zero point for all predictors was the grand mean of those variables.

4.3 Associations Amongst Variables

Correlational analyses were conducted to study the relationship between the variables of interest as noted in Table 1. Inhibitory control was significantly associated with working memory, vocabulary, and academic competence. It was predicted that the cognitive variables for executive functioning and vocabulary would be significantly correlated with one another, and they were. However, inhibitory control was not as highly correlated with working memory and vocabulary as expected. It was also predicted that they would be less highly correlated with academic competence because the executive functions and vocabulary were lab measure and the academic competence at elementary school was conducted through survey. This was not the case, as Stroop and vocabulary were just as strongly correlated with academic competence as with each other and working memory. Surprisingly, working memory was not associated with academic competence.

Maternal depression and anxiety symptoms were not associated with the executive functioning variables. Maternal depression and state anxiety symptoms are associated with vocabulary, but maternal trait anxiety is not. Maternal depression and both trait and state anxiety were highly correlated with one another, which was hypothesized.

In testing for gender differences, an independent T-test was run. The results are shown in Table 2. The inhibitory control measure of Stroop was the only variable that showed gender differences. The measure was reverse scored; lower mean is higher inhibitory control. Therefore,

girls showed higher inhibitory control on the Stroop task than boys. There were no gender differences in working memory, vocabulary, maternal variables, or academic competence.

4.4 Aims and Hypotheses

Restricted Maximum Likelihood (REML) estimation was used to test the null model in which the only predictor of vocabulary was the family effect. This was used to determine the distinction between the sibling groups. The estimates of the variance at Level 1 and Level 2 produced an intraclass correlation of .003. Thus, .3% of the variance in children's vocabulary was accounted for at the family level. Results indicated the distinguishability between siblings was not significant, the difference in $\chi^2(1)$ was .082, p=.775. Therefore, distinguishable variance was not supported. The siblings were not made alike for analysis. Multilevel modeling was still used to determine the relationship of inhibitory control and working memory with vocabulary to account for the nested data in the study by dropping the assumption of independence in favor of estimations that consider family level clustering of the data, as research suggests that any intraclass correlation above zero can produce biased standard errors in ordinary least squares regression (Cohen et al., 2003). This type of clustered data is favorable when individuals are assumed to be more similar than if the participants were randomly selected (Kenny et al., 2006). Therefore, multilevel modeling was used for all analyses including nonsignificant intraclass correlation models.

Next, the full model was tested with the inhibitory control measure of the Stroop task. Spin-the-Pots task for working memory was also added as a predictor. As predicted by my hypothesis, Stroop did predict vocabulary, b= -.15, SE=1.18, $t(95)$= -2.41, p=.018. Unexpectedly,

Spin-the-Pots working memory scores did not predict vocabulary, *b*=.10, *SE*=.47, *t*(95)= 1.54, *p*=.126. The results for this aim can be found in Table 3.

Again, REML estimation was used to test the null model of family effect as a predictor for the executive functioning measures including Stroop for inhibitory control, Spin-the-Pots for working memory, and PPVT-IV for vocabulary. The Level 1 and Level 2 variance produced an intraclass correlation of -.081, which -8.1% of the variance in Stroop was accounted for at the family level. Results indicated the distinguishability between siblings was not significant, the difference in $\chi^2(1)$ was .001, *p*=.992. Therefore, distinguishable variance was not supported. The siblings were not made alike for analysis. The null model tested for the working memory task was also not significant with the Level 1 and Level 2 variance producing an intraclass correlation of -.028, which -2.8% of the variance in Spin-the-Pots working memory task was accounted for at the family level, $\chi^2(1)$ =.111 , *p*=.739. Distinctive variance was not supported. The siblings were not made alike for analysis. The null model for PPVT-IV vocabulary measure was not significant with an intraclass correlation of .002, as previously stated. PPVT-IV had .02% variance accounted for at the family level, $\chi^2(1)$ =.19 , *p*=.665, and distinguishable variance was not supported. The siblings were not made alike for analysis.

In running the full models for these variables, the predictors of maternal depression and maternal trait anxiety were included as predictors. It was surprising to find that most model predictors did not significantly predict the executive functioning measures or vocabulary. In the Stroop inhibitory control dependent variable model, all three predictors were not significant including maternal depression *b*= -.02, *SE*=.05, *t*(93)= -.26, *p*=.798, maternal anxiety, *b*= -.02, *SE*=.01, *t*(93)=-.16==23, *p*=.819. Results are shown in Table 4.

For the Spin-the-Pots working memory task model, both maternal depression, *b*= -.16, *SE*=.13, *t*(97)= -1.93, *p*=.056, and maternal anxiety, *b*= .17, *SE*=.02, *t*(97)= 1.97, *p*=.051, were not significant in the model. However, they were both close to .05 significances. Results are shown in Table 5.

In the final model for vocabulary, maternal depression was the only significant predictor, *b*= -.25, *SE*=1.17, *t*(97)= -2.44, *p*=.017. Maternal anxiety was not significant, *b*=.06, *SE*=.20 , *t*(97)= .56, *p*=.576. Results are shown in Table 6.

The final aim also kept the REML theme from the previous aims, as dyadic data was used for the entire project. The null model was tested for the academic competence subscale of the HBQ to account for the possible family effect on reporting academic competence. The Level 1 and Level 2 variance produced an intraclass correlation of .029, which 2.9% of the variance in academic competence was accounted for at the family level. Results indicated that this was not significant, $\chi^2(1) = .004$, *p*=.950. Therefore, distinguishable variance was not supported. The siblings were not made alike for analysis.

In the full model, inhibitory control, working memory, and vocabulary were included as predictors. The preschool inhibitory control and vocabulary measures both significantly predicted elementary school academic competence, *b*= -.27, *SE*=.15, *t*(58)= -2.71, *p*=.008, *b*=.27, *SE*=.01, *t*(58)= 2.87, *p*=.006 respectively. Surprisingly, preschool working memory, *b*=.03, *SE*=.06, *t*(58)= .28, *p*=.777, did not predict elementary school academic competence. The results are displayed in Table 7.

5. DISCUSSION AND SUMMARY

The purpose of the current study was to examine relations between vocabulary, inhibitory control, and working memory in preschool, then determine whether these variables predicted elementary school academic competence. Research shows that inhibitory control, working memory, and vocabulary influence later reading and math success (Baddeley, 1992; Daneman & Carpenter, 1980; De Smedt et al., 2009; Destefano & Lefevre, 2004; Scarborough, 2001; Becker, Miao, Duncan, & McClelland, 2014). The current study aimed to contribute to the literature by examining longitudinal predictions using a family design, including maternal variables such as depression and anxiety. The results indicate that inhibitory control influenced vocabulary and academic competence more so than working memory, and maternal depression was a significant predictor of working memory and vocabulary. Findings are discussed along with limitations and implications for future research.

5.1 The Relationship between Maternal and Preschool Child Variables, and Elementary School Academic Competence

Preliminary analyses revealed significant correlations between the executive functioning variables and vocabulary in preschool. Although these findings were consistent with the literature, effect sizes were more moderate than expected. Preschool inhibitory control and vocabulary were also significantly associated with elementary school academic competence. The maternal variables were significantly correlated amongst themselves, and they were associated with preschool vocabulary and elementary school academic competence. The only significant

gender differences were found for inhibitory control where preschool girls had higher levels than boys.

Among all the models tested, the sibling participants proved indistinguishable from one another. This was not surprising as there were many groups of twins in the study, several of whom were monozygotic pairs. The first hypothesis was only partially confirmed in that inhibitory control did predict vocabulary. Thus, Weiland, Barata, and Yoshikawa's (2014) proposed model is relevant to this study, as they suggested that the high association between executive functions and vocabulary due to executive functions supporting the development of language skills. However, working memory did not predict vocabulary. This was somewhat surprising given previous significant associations between working memory, vocabulary, and inhibitory control. These findings point toward the importance of inhibitory control in language learning.

The hypotheses about maternal depression and anxiety were also only partially confirmed. Maternal depression was the only maternal variable that predicted vocabulary. Contrary to our expectations, none of the maternal variables predicted inhibitory control or working memory, and maternal anxiety symptoms did not predict any of the preschool variables included in the study, inconsistent with the literature (Hughes, Roman, Hart, & Ensor, 2013; Buss, Davis, Hobel, & Sandman, 2011). Given that maternal depression symptoms have a negative effect on preschool vocabulary, mothers that experience high levels of symptoms may wish to seek additional support for their children.

The final set of hypotheses were partially confirmed because preschool inhibitory control and vocabulary did predict academic competence in elementary school. Contrary to my

hypothesis, working memory was not a significant predictor. The fact that preschool working memory did not predict elementary school academic competence is also inconsistent with the literature (Baddeley, 1992; Daneman & Carpenter, 1980; De Smedt et al., 2009). These findings do support the emergence of inhibitory control and vocabulary in the transition to elementary school. More preschool programs should support the growth of inhibitory control and vocabulary to improve their students' transition into the formal school system. This study also supported the long-term effects of both inhibitory control and vocabulary in early elementary school.

5.2 Limitations and Implications

As with any study, there are some limitations to take under consideration. Some notable limitations include sample size and composition, the inclusion of sibling pairs which includes a wide age range with coinciding age-related measurement issues, and lack of father and/or other partner data. The sample size of 99 pairs of siblings and their mothers is a rather moderate sample size. However, the follow-up portion only retained 70 of the original 99 families. Thus, decreasing the power with the inclusion of the elementary school variables. This reduction in the follow-up sample size was to be expected as with any longitudinal study some participants tend to drop out. The sample consisted of majority Caucasian participants with higher SES, reducing generalizability. Future studies should include a larger and more diverse sample. Also, the use of slightly different Stroop tasks across the wide preschool age range is a limitation, as lab measures were not uniform across participants, but the tasks used had been used in previous studies in much the same manner. Future researchers may benefit from a more limited age range that allows for a single measurement task. Age was not accounted for in the analyses and should be taken into consideration for future analyses.

The results indicated that working memory was not a predictor of vocabulary or academic competence. One potential explanation for this is that the task was focused on spatial working memory as opposed to verbal working memory. Given that both dependent variables were focused on reading or verbal understanding (the academic competence subscale asked questions regarding children's reading ability), spatial working memory might not have been as great an indicator as verbal working memory. Therefore, future researchers may need a different task for measuring working memory or use multiple working memory and/or executive functioning tasks. It has been reported that using six executive functioning tasks correlated higher with informant-reported measures of inhibitory control compared to using just three (Beck, Carlson, & Rothbart, 2011 as cited in Duckworth et al., 2011).

Another reason that there could be less covariance between our preschool measures and the elementary school outcome are different reporters at each age. The preschool executive functioning and vocabulary measures were all lab-based observational measures, and our elementary school academic competence measure was parent-reported. In addition, the temporal effect of the number of years between the preschool testing and the elementary school parent report could contribute lower associations. If the executive function measures and the academic competence parent ratings were collected concurrently either in preschool or elementary school, higher covariance could be expected. An additional limitation of this study is the lack of measures of effect size to determine the strength of significant relationships due to the use of MLM. This should be taken into consideration for future research in using this model.

Despite the limitations mentioned, the current study adds to the literature by examining longitudinal relations between preschool executive functioning and vocabulary and elementary

school academic competence, by assessing maternal variables and by studying siblings. The family study design allows for a better representation of the data across family members. Few studies have considered maternal variables influence on executive functioning, and even fewer have included data for both parent and sibling. The family design perspective also allows for disentangling unique effects at the family-level. The study also utilizes a longitudinal follow-up of the preschool to elementary school transition, which provides more information for this difficult time for children. These factors help to provide a broader picture of both family environment and this critical period of development for the children involved in our study as they transition to formal schooling. Overall, this study provides support for the long-term effects for inhibitory control in the school setting and sets a precedent for helping to improve this mental process before school, which can help children throughout their education.

Future studies should examine maternal variables of depression and anxiety as predictors for academic competence with executive functions mediating the relationship, as the correlations between maternal variables and academic competence may suggest a relationship and research suggests executive functions may be a potential mediator of this relationship. In addition, future studies may include other maternal variables such as maternal education level and family socioeconomic status (SES). Research on quality of home environment indicates that maternal education influences children's academic performance indirectly (Davis-Kean & Sexton, 2009; Murnane, et al., 1981). Lower-SES families have less resources which are important for the pursuit of higher education (Gut, Reiman, & Grob, 2013). Thus, this may be an important contributor to academic competence and parent's perception of their child's academic competence.

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APPENDIX A

Table 1. *Association Amongst Study Variables.*

Measure	1	2	3	4	5	6	7
1. Stroop	--	-.341**	-.182*	-.035	-.040	-.064	-.338**
2. Spin-the-Pots		--	.241**	-.069	.094	-.008	.165
3. PPVT-IV			--	-.213**	-.099	-.162*	-.310**
4. CES-D				--	.542**	.442**	-.198*
5. STAI-Trait					--	.558**	-.188*
6. STAI-State						--	-.262**
7. HBQ							--
Mean	2.142	7.530	107.660	2.5256	32.851	28.523	5.370
Standard Dev	.760	1.908	14.258	1.232	7.359	6.234	1.140

Note. Stroop represents reverse scored and square root variables. CES-D has also been square root transformed.*p<.05,**p<.01

Table 2. *Gender Differences Amongst Study Variables.*

Measure	Girls (n=96)	Boys (n=102)				
	Mean (*SD*)	Mean (*SD*)	*t*-value	df	*p*-value	Effect Size
1. Stroop	**2.02 (.78)**	**2.26 (.73)**	**2.10**	**172**	**0.037**	0.32
2. Spin-the-Pots	7.63 (1.93)	7.43 (1.89)	-0.70	189	.482	-0.10
3. PPVT-IV	107.43 (13.52)	107.89 (15.01)	0.22	191	.825	0.03
4. HBQ	5.38 (1.07)	5.36 (1.20)	-0.08	121	.936	-0.01

Note. Stroop is reverse scored and square root transformed values. CES-D is also square root transformed values.

Table 3. *Model of Executive Functioning Predictors of Vocabulary.*

Fixed Effect	*b*	*SE*	*t*-value	df	*p*-value
Intercept	108.92	1.28	84.90	95	<0.001
Stroop	**-0.15**	**1.18**	**-2.41**	**95**	**0.018**
Spin-the-Pots	0.10	0.47	1.54	95	0.126

Note. Stroop is the task for inhibitory control; Spin-the-Pots is the task for working memory.

Table 4. *Model of Maternal Predictors of Inhibitory Control.*

Fixed Effect	*b*	*SE*	*t*-value	df	*p*-value
Intercept	2.14	0.06	37.05	93	<0.001
CES-D	-0.02	0.05	-0.26	93	0.798
STAI-Trait	-0.02	0.01	-0.23	93	0.819

Note. CES-D is the maternal depression symptom scale, and STAI is the maternal anxiety scale for both trait anxiety and state anxiety.

Table 5. *Model of Maternal Predictors of Working Memory.*

Fixed Effect	*b*	*SE*	*t*-value	df	*p*-value
Intercept	7.53	0.13	57.15	97	<0.001
CES-D	-0.16	0.13	-1.93	97	0.056
STAI-Trait	0.17	0.02	1.98	97	0.051

Note. CES-D is the maternal depression symptom scale, and STAI is the maternal anxiety scale for both trait anxiety and state anxiety.

Table 6. *Model of Maternal Predictors of Vocabulary.*

Fixed Effect	*b*	*SE*	*t*-value	df	*p*-value
Intercept	107.65	1.22	87.89	97	<0.001
CES-D	**-0.24**	**1.17**	**-2.44**	**97**	**0.017**
STAI-Trait	0.06	0.20	0.56	97	0.576

Note. CES-D is the maternal depression symptom scale, and STAI is the maternal anxiety scale for both trait anxiety and state anxiety.

Table 7. *Model of Preschool Executive Functioning and Vocabulary Predictors of Elementary School Academic Competence.*

Fixed Effect	*b*	*SE*	*t*-value	df	*p*-value
Intercept	5.28	0.10	50.99	58	<0.001
Stroop	**-0.27**	**0.15**	**-2.72**	**58**	**0.008**
Spin-the-Pots	0.03	0.06	0.28	58	0.777
PPVT-IV	**0.27**	**0.01**	**2.87**	**58**	**0.006**

Note. Stroop is the task for inhibitory control; Spin-the-Pots is the task for working memory, and PPVT-IV is the task for vocabulary. All predictors were done at preschool.