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Examining an Executive Functioning and Bilingual Advantage Among Latino DLL Children in Head Start: A Strength-Based Approach

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UNIVERSITY OF MIAMI

EXAMINING AN EXECUTIVE FUNCTIONING AND BILINGUAL ADVANTAGE
AMONG LATINO DLL CHILDREN IN HEAD START: A STRENGTH-BASED
APPROACH

By

Lisa J. White

A DISSERTATION

Submitted to the Faculty
of the University of Miami
in partial fulfillment of the requirements for
the degree of Doctor of Philosophy

Coral Gables, Florida

August 2017

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APPROACH

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Examining an Executive Functioning and Bilingual
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Head Start: A Strength-Based Approach

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Young Spanish-speaking Latinos in the U.S., most of whom are from low-income backgrounds, perform below their English-speaking peers at kindergarten entry. This achievement gap is concerning considering the rising number of Latino children in the U.S. living in poverty. Despite this risk, a large body of research highlights the positive effects of learning two languages. Latino DLLs attending Head Start, compared to their monolingual peers, were recently found to have higher executive functioning (EF), a set of domain-general cognitive skills that robustly predict academic achievement. This emerging evidence is encouraging, however, there is still a lack of research on how this bilingual-EF advantage contributes to young DLLs' school readiness in the context of early education classrooms.

To better understand these factors, this study examined bilingual language, EF, and science achievement across the year in a sample of 424 Latino preschool DLLs across 38 Head Start classrooms. Children were assessed in the fall and spring on all measures, and observations of Spanish and English support in the classroom were conducted in the winter. Results from a cross-lag model demonstrated a significant bidirectional relationship between bilingual ability and EF across the year, and also indicated positive effects of both constructs on children's science at the end of the year. Spanish and English support in the classroom did not influence the cross-lag paths

between bilingual ability and EF across the year, however, English support appeared to moderate children's EF from fall to spring, and Spanish support predicted both bilingual ability and EF at the end of the year. Results from this study help inform the mechanisms behind the bilingual-EF relationship and demonstrate positive effects on achievement. Additionally, findings highlight the importance of supporting English and Spanish for DLLs in the early childhood classroom.

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CHAPTER ONE

INTRODUCTION

Recent estimates suggest that one third of children served by Head Start are dual language learners (DLLs), with the vast majority coming from Spanish-speaking homes (Administration for Children and Families [ACF], 2008, 2013). Latino DLLs from low-income backgrounds consistently score below the national average in math and reading at kindergarten entry (Espinosa, 2013a), and this gap widens during formal schooling (Rumberger & Tran, 2010). However, emerging evidence suggests that this group of children demonstrate unique strengths that are associated with learning two languages (Espinosa, 2013b; White & Greenfield, 2017; Barac, Bialystok, Castro, & Sanchez, 2014). Evidence also suggests that attending early education programs can be particularly beneficial for young Latino children, and potentially buffer against the negative risk factors of living in poverty (Gormley, Gayer, Phillips, & Dawson, 2005). A critical policy-relevant issue is the extent to which early education programs understand and support the learning trajectories of DLLs. Research now suggests using both the native and English language for DLLs, demonstrating a shift from traditional classroom practices that focused exclusively on English development (Castro, Espinosa, & Paez, 2011).

This shift is a direct result of research that highlights the positive effects of bilingualism on children's cognitive, language, and social and emotional development (Espinosa, 2013a). The most compelling findings from this research are those related to executive functioning (EF), a set of crucial domain-general cognitive skills that robustly predict academic achievement in preschool and beyond (Blair & Razza, 2007). Many studies show that bilingual children, compared to monolinguals, have higher EF (e.g.

Bialystok & Viswanathan, 2009; Carlson & Meltzoff, 2008; Riggs, Shin, Unger, Spruijt-Metz, & Pentz, 2013). We recently replicated these findings in a sample of 300 predominantly Latino preschoolers attending Head Start; Spanish- and English-speaking bilingual children outperformed their monolingual peers on EF tasks (White & Greenfield, 2017), and science achievement (White, 2015). This encouraging evidence indicates that young Latino DLLs from low-income backgrounds, who are often considered at-risk, demonstrate strengths in fundamental cognitive skills, which can promote learning.

Despite this evidence to suggest that these DLL children have higher EF, there is much about this relationship that remains unknown, particularly among Spanish and English-speaking DLL preschoolers attending Head Start. Specifically, it is unclear 1) how EF and bilingual language development influence each other *over time*, 2) how this impacts school readiness, specifically science, across the year, and 3) how classroom support for English and the home language may influence these relationships. To address this gap, this study explored the bidirectional relationship between bilingualism and EF development across the year in a large sample of Spanish and English-speaking DLLs attending Head Start, and examined how these potential bidirectional relationships related to science achievement at the end of the year. Furthermore, the role of teacher support in English and Spanish on children's bilingual and EF development across the year was examined.

Theoretical Framework

Early childhood learning and development has been largely informed by the Ecological and Dynamic Effects Model, which builds on contextual and bioecological

frameworks (Bronfenbrenner and Morris, 1998; Pianta and Walsh, 1996) to assert that individual characteristics and environmental contexts transactionally interact to shape a child's school readiness and transition to kindergarten (Rimm-Kaufman & Pianta, 2000). In line with this theory, this study examined both child characteristics (language and cognitive development and their bidirectional associations, in addition to science achievement) and environmental context variables (support for Spanish and English in the classroom) to help understand the dynamic experiences specific to DLLs.

On the child level, DLLs are unique in that they receive input from two different languages. Information processing theory explains how individuals manipulate incoming information from the environment using executive function skills (e.g. attention, inhibitory control and cognitive flexibility), which leads to greater cognitive efficiency over time (Klahr & MacWhinney, 1998; Munakata, 2006). These executive processes are largely influenced by environmental factors, especially in the early years (Diamond & Lee, 2011; Phillips & Shonkoff, 2000). In bilingual environments, executive functions are consistently activated in a manner unique to bilinguals, as they are exposed to two languages and must attempt to resolve competing stimuli from both languages (Bialystok, 2001). This framework provides support for the hypothesis that greater levels of bilingualism leads to greater EF. Extended to second language learning, information processing theory not only suggests that cognitive efficiency becomes more automatic over time (for bilinguals, as for monolinguals), but also that a substantial amount of these executive processes are needed to effectively learn a second language (McLaughlin, Rossman, & McLeod, 1983). This idea provides theoretical support for the alternative hypothesis in this study that earlier EF may promote bilingual development.

These theoretical assertions stemming from information processing theory are in line with a recent conceptual model proposed by Snow (2007) that describes an integrative view of children's school readiness. Language, EF, and science are all core components of school readiness, as recognized by Head Start (ACF, 2015). Snow's theoretical model asserts that while children's capacities across domains are unique, they dynamically influence each other over time. Therefore, researchers and practitioners should examine the interrelations among key components of school readiness, particularly in diverse populations of children (Snow, 2007). The current study, informed by these theories, used cross-lag and mediation analyses to explore the novel hypothesis that EF and bilingual development is bidirectional, and examine how they interact over time to promote science readiness.

It is critical to examine child-level outcomes in the context of proximal environments, considering the dynamic interactions between children, families, and teachers that promote children's learning and development (Rimm-Kaufman & Pianta, 2000). Ecological theories suggest that children's development is fostered through high-quality interactions in proximal environments, including schools (Pianta, Cox, & Snow, 2007). In turn, interactions between children and teachers in the classroom have the potential to dynamically influence children's school readiness across domains. Applied to the theories linking EF and bilingual development, it could be that the extent to which teachers expose DLL children to high-quality interactions in one or both languages affects both the bilingual language development and the elicitation of EF processes, thus influencing the potential bidirectional relationship. This is a novel hypothesis that has not yet been explored, but is supported by the multiple theories detailed above, in addition to

research documenting positive effects of classroom interactions in the preschool classroom on children's learning and development (e.g. Burchinal, Field, Lopez, Howes, & Pianta, 2012; Mashburn et al., 2008). This study used a unique observation measure of support for bilinguals in the early childhood classroom to examine how the classroom context interacted with DLL children's EF and bilingual development across the year.

Executive Functioning and Bilingualism

Executive functioning is a set of domain-general cognitive skills that span multiple core domains of Head Start's school readiness framework, including self-regulation, cognition, and approaches to learning (National Center on Quality Teaching and Learning [NCQTL], 2013). The core executive functions include inhibition, cognitive flexibility, and working memory (Miyake, Friedman, Emerson, Witzki, Howerter, & Wager, 2000). EF is robustly related to academic achievement in language (e.g. Blair & Razza, 2007; Ponitz, McClelland, Matthews, & Morrison, 2009), math (e.g. Bull, Espy, & Wiebe, 2008), and science (e.g. Nayfeld, Fuccillo, & Greenfield, 2013) during preschool, both concurrently and longitudinally, and also more broadly to favorable health and socioemotional outcomes (Bridgett, Oddi, Laake, Murdock, & Bachmann, 2013; Kochanska, Murray, & Harlan, 2000; Moffitt et al., 2011; Shonkoff et al., 2012). These skills allow children to actively manipulate and consolidate information, especially in problem-solving situations that require flexible thinking. It is suggested that bilingual children, due to the unique cognitive demands of learning two languages that elicit such skills, have higher EF than their monolingual peers (e.g. Carlson & Meltzoff, 2008). This relationship is evident already in infancy (Kovacs & Mehler, 2009), across childhood (e.g. Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011; Riggs et al., 2013) and

extends into adulthood (Bialystok, Craik, Klein, & Viswanathan, 2004). Although existing research on this topic has mostly been conducted with groups from middle- or high-income backgrounds (Bialystok & Majumder, 1998; Bialystok & Viswanathan, 2009; Poulin-Dubois et al., 2011), we were the first to document this EF advantage in a sample of bilingual Latinos from low-income backgrounds attending Head Start (White & Greenfield, 2017). These findings are encouraging, indicating strengths in a population most often considered at-risk for low achievement (Espinosa, 2013b).

In a comprehensive review on the connection between bilingualism and executive control processes (another term for EF), Bialystok (2001) describes how bilingual individuals constantly need to hold in mind the relevant language and inhibit the non-relevant language, depending on the environment. For example, a bilingual child who comes from a primarily Spanish-speaking household, but learns English in school, may often be required to flexibly switch between languages and inhibit a particular language to effectively navigate diverse classroom contexts that involve monolingual (in either English or Spanish) and other bilingual peers.

The current conceptualization of the relationship between bilingualism and EF suggests a *single* direction, that is, the bilingual experience drives higher EF (Bialystok, Craik, & Luk, 2012). These conclusions have been drawn as a result of previous research designs that are cross-sectional and do not examine how EF and bilingual development occur together over time. Typically, in these studies children of a particular age group are most often classified as bilingual or monolingual, and subsequently measured on EF at one timepoint (e.g. Bialystok & Martin, 2004). Others have attempted to examine these relationships over time – one study found that “early bilinguals” (who became bilingual

before age ten) were more efficient than “late bilinguals” (who became bilingual after age ten) on a task of cognitive control (Luk, de Sa, & Bialystok, 2011). The researchers concluded that individuals with earlier and continued experience in both languages experienced greater cognitive benefits.

A few studies have emerged recently that examine the relationship longitudinally, and found that already in early childhood, bilingualism promotes the development of EF (e.g. Blom, Küntay, Messer, Verhagen, & Leseman, 2014; Crivello, et al, 2016). Despite the longitudinal nature of the studies cited above, existing methodological approaches on this topic are problematic for understanding the possible bidirectional influence of bilingualism and EF for two reasons: First, most often, studies on the EF-bilingual relationship create gross groupings of bilinguals and monolinguals, ignoring the wide range of variability that is inherent to the bilingual experience (Hoff, 2012). Secondly, most studies do not examine EF and bilingual development *together* over time, and thus cannot make claims about leading indicators. Taken together, the literature is inundated with studies suggesting a unidirectional relationship, such that the bilingual experience drives higher EF, ignoring the potential role of EF in promoting bilingual language development. Identifying early predictors that promote bilingual language development is needed considering the positive outcomes associated with bilingualism, including theory of mind (e.g. Goetz, 2003), metalinguistic awareness (e.g. Cromdal, 1999), spatial reasoning (e.g., Bialystok & Majumder, 1998), and creativity (e.g. Kessler & Quinn, 1987). If in fact higher levels of EF early on assist a child in becoming bilingual, this could be particularly important to know when supporting the overall language and cognitive development of the bilingual child.

A growing body of evidence has started to examine the factors that contribute to DLL children's growth in English (and Spanish) in the early years to understand the competencies that promote learning in bilingual children over time, particularly among young Spanish and English-speakers (Bohlman, Maier, & Palacios, 2015; Kim, Curby, & Winsler, 2014; Maier, Bohlman, & Palacios, 2015; Winsler, Kim, & Richard, 2014). For example, Spanish-speaking preschoolers who were more cognitively advanced and socially competent at age 4, attained greater English proficiency in kindergarten (Winsler et al., 2014). Another study demonstrated a bidirectional relationship between self-regulation, which is closely related to EF, and English expressive vocabulary for Latino DLLs across the school year (Bohlman et al., 2015). This evidence provides some suggestion for a bidirectional relationship between bilingual children's cognitive and language development, at least in English. However, few have examined children's language development in *Spanish* in the context of these studies, and none have empirically tested whether there is a bidirectional relationship between *bilingualism* and EF in Latino preschoolers.

This is the first study to assess the hypothesis that the relationship between bilingualism and EF is bidirectional in *any* population. To address additional limitations of previous research, this study used a *within-group* approach (targeting developmental processes specifically in a sample of Spanish and English-speaking DLLs attending Head Start) and assessed the same participants over the course of a school year, in both English and Spanish. This approach afforded the examination of language and cognitive development over time, adding vital information to the emerging literature on the learning trajectories of young Latino DLLs.

Relationships to Science Readiness

The development of bilingual ability and EF among Spanish and English-speaking DLLs in early childhood is important, not only to inform developmental trajectories, but also to understand how these trajectories relate to children's achievement/school readiness. However, the relationship between bilingualism and EF is rarely extended to examine the impact on bilingual children's academic achievement, which is unfortunate given the robust associations between EF and academic achievement, and some findings that bilingualism relates to higher achievement for linguistically diverse children (Han, 2012; Lindholm-Leary and Hernandez, 2011). In a review on the cognitive benefits of young bilinguals, Barac and colleagues highlight the need to determine how these relationships impact academic achievement (Barac et al., 2014), which can ultimately help inform education efforts to promote school readiness for young DLLs.

Science is a particularly important school readiness skill to measure, considering its crosscutting nature and applications to learning for other domains (Greenfield et al., 2009). Science includes not only content knowledge (e.g. facts about the life cycle), but also crosscutting skills (e.g. understanding cause and effect), and scientific practices (e.g. asking questions, documenting evidence, and interpreting data). These skills are critical for learning across multiple content areas (Next Generation Science Standards [NGSS], 2012), and thus are of particular importance to assess (Greenfield, 2015). A growing body of evidence also suggests that science is a particularly useful school readiness domain to engage DLLs (Moore & Smith, 2015). Children who are bilingual excel in scientific problem-solving when compared to monolingual children (Kessler & Quinn,

1980). Existing interventions capitalize on the use of science for bilingual children by focusing on building inquiry and science practices in the context of a dual language approach, with the idea that engaging young DLLs in hands-on opportunities allows them to learn and construct knowledge, while continuing to develop their language (Hampton & Rodriguez, 2001; Lee, Deaktor, Hart, Cuevas, & Enders, 2005). Science is particularly useful for young DLLs attending early education centers, in that it encourages language and cognitive development *in context*, which can facilitate academic readiness across domains (Brenneman, 2014). It may be that DLL children who experience the cognitive benefits of being bilingual, bring these strengths to science learning, which leverages their ability to think critically about complex phenomena, flexibly approach problem-solving situations, and engage in inhibitory processes to test and revise hypotheses, which are core components of effective science learning.

Unique relationships have also been found between science, EF, and bilingualism. Specifically, EF predicts the strongest gains in science for Head Start preschoolers across the school year, compared to math and language (Nayfeld et al., 2013). Considering the link between EF and science (and EF and bilingualism), which has been found in Head Start samples, it is not surprising that Latino bilingual preschoolers attending Head Start had higher science achievement than their monolingual peers, which was mediated by enhanced EF (White, 2015). This study, however, used gross groupings (monolingual vs. bilingual) and did not assess children in their dominant language, thus not accounting for varying levels of bilingualism and EF in these relationships. The present study used a measure of science achievement (in English or Spanish) across varying levels of

bilingualism to determine how the bidirectional relationship between EF and bilingualism influenced science achievement at the end of the school year.

Measuring School Readiness for DLLs

Many of the widely-used direct assessments of children's school readiness do not tap into domain-general skills such as EF, but rather focus on content-specific skills, such as knowing letters and numbers (e.g. Florida Voluntary Prekindergarten Assessment, 2011). As a result, advantages for DLLs in the higher-order thinking skills of EF and potential strengths in science, which are not typically assessed, may go unnoticed. In addition, DLL children are almost always assessed in English (e.g. Layzer & Maree, 2011), which may obscure potential knowledge they have in their home language. Researchers now advocate for measuring school readiness among Latino DLLs in Spanish, to obtain a comprehensive view of children's competency (Castro, 2014; Vitiello, Downer, & Williford, 2011).

It is often hard to assess DLL children in their native language because of a lack of reliable and valid assessments normed for diverse children (Snow & Van Hemel, 2008). However, new culturally and linguistically sensitive assessment tools in Spanish now make it possible to assess Latino children's school readiness. A promising new computerized measure of children's science knowledge in preschool, provides a useful and valid tool for measuring Spanish-speaking children's science achievement. An IES funded grant (Grant # R305A130612 "*Enfoque en Ciencia: Extending the Cultural and Linguistic Validity of a Computer Adaptive Assessment of Science Readiness for Use with Young Latino Children;*" Daryl Greenfield, P.I.) recently translated a validated computer-adaptive measure of children's science knowledge from English to Spanish, using an

extensive development process that accounted for bias across Spanish dialects and the semantic and content equivalence of the translations.

This study capitalized on this new measure of children's school readiness by assessing Latino DLLs on science in their dominant language at two timepoints. Science was examined as an outcome (by specifying two mediational effects in the cross-lag model between EF and bilingual ability) to help determine if EF and bilingual ability for DLLs promotes achievement.

Classroom Practices for DLLs

In addition to understanding how the associations between EF and bilingualism relate to children's science readiness, it is crucial to take into account environmental influences on DLL children's language and cognitive development, specifically classroom practices (Howes, Downer, & Pianta, 2011). Classroom practices and interactions may differ depending on children's language learning status, and thus may have variable effects on their learning and development. Literature suggests, for example, that DLLs benefit from emphasis on developing oral language skills in both English and the home language, through rich and engaging classroom language interactions (Buysse, Peisner-Feinberg, Paez, Hammer, & Knowles, 2014). In addition, it is important for young DLLs to be in early childhood classrooms where the child's first language is respected and culturally relevant materials are accessible, creating cultural and linguistic continuity between home and school (Castro et al., 2011; National Association for the Education of Young Children [NAEYC], 1995). It may be that these qualities influence the extent to which young Spanish and English-speaking DLLs experience and benefit

from the cognitive advantages associated with bilingualism, particularly in classroom contexts, however these associations remain unexamined in the literature.

There is empirical evidence to suggest that Latino DLL children in early childhood classrooms that use the home language show enhanced English and Spanish development (Burchinal, Field, Lopez, Howes, & Pianta; 2012; Collier & Thomas, 2004; Collins, 2014; Farver, Lonigan, & Eppe, 2009; Mendez, Crais, Castro, & Kainz, 2015), and demonstrate improved literacy scores in both languages in first grade (Tong, Lara-Alecio, Irby, & Mathes, 2011). These findings highlight both concurrent and longitudinal associations between classroom language use and first and second language development. In addition, DLLs in classrooms where both languages are spoken demonstrate fewer behavior problems (Halle et al., 2014) and increased self-regulation (Chang et al., 2007), compared to DLLs in monolingual English classrooms, providing additional support for a dual language approach and the influence of classroom practices on DLL children's early language and socioemotional development.

Although early education classroom practices have been linked to first and second language skills and socioemotional development for young DLLs, little is known about how these classroom practices affect their early EF development (and the potential bidirectional relationship with bilingual ability; Barac et al., 2014). In general, studies that measure the relationship between EF and bilingual development do not account for classroom context, and when they do, classroom-level variables are only used to create groupings of bilinguals based on amount of language exposure (e.g. Carlson & Meltzoff, 2008), but not examining differential effects on children's trajectories. One recent study did examine how language of instruction influenced English language and cognitive

skills in various groups of bilinguals, finding no effect of language of instruction on cognitive outcomes for bilinguals (Barac & Bialystok, 2012). However, this study used gross groupings for language of instruction (strictly English or French), only examined children's achievement in English, thus not examining these relationships over time and leaving warrant for future study on these relationships.

Without a clear understanding of the effect of early education practices on DLLs' language and cognitive trajectories, it has been difficult to design, implement, and evaluate effective instructional practices for DLLs (Zepeda, Castro, & Cronin, 2010). Researchers and early educators need an understanding of the language learning processes specific to DLLs to be able to teach them effectively (Castro et al., 2011). Given positive classroom effects for DLLs and beneficial outcomes associated with bilingualism and EF, it is important to examine how support for both languages in the classroom relates to the potential bidirectional relationship between bilingual and EF development.

Measuring Classroom Quality for DLLs

Previous research evaluating classroom quality has been limited due to a lack of valid and reliable methods that measure learning experiences for DLLs in the classroom (Garcia, 2011; Peisner-Feinberg et al., 2014). Too often, researchers and practitioners use existing measures of classroom quality (originally intended for use in monolingual classrooms), to observe classrooms with a high percentage of DLLs where the home language may be used in daily routines (Solari, Landry, Zucker, & Crawford, 2011). In addition, classrooms that do measure the language context of preschool classrooms typically rely on gross measures of language use in the classroom (e.g. percentage of

language use or instructional model as a proxy for this; e.g. Collins, 2014), which does not account for the nature or quality of the interactions in a given language. Given the unique developmental and learning needs of DLLs (Espinosa, 2013a), measuring classroom quality for DLLs may require distinct assessments than the traditional measures used in primarily monolingual classrooms (Garcia, 2011).

The Classroom Assessment of Supports for Emergent Bilingual Acquisition (CASEBA) is a recently-developed measure that assesses support for language and literacy in both the home language and English (Freedson, Figueras-Daniel, Frede, Jung, & Sideris, 2011). Contrary to previous tools that either examine the use of one language only (e.g. Supports for English Language Learners Classroom Assessment [SELLCA]; National Institute for Early Education Research, 2005), or do not take into account language of instruction in assessment of quality (e.g. Classroom Assessment Scoring System [CLASS]; Pianta, Le Paro, & Hamre, 2008), the CASEBA assesses the amount of support for both languages, in addition to the *quality* of these interactions. The measure was normed and developed in state-funded classrooms with a large percentage of Spanish-English DLLs, making it particularly relevant for use in the current population. Considering the promise of this measure, which is gaining attention by researchers across the country (Freedson, et al., 2011), the tool offers a way to examine how teachers may influence the bilingual language and cognitive development of Spanish and English-speaking preschoolers across the year.

Although these questions remain largely unexplored in the literature, it is expected that greater support for English and Spanish in the classroom, will strengthen the relationship between bilingualism and EF across the school year. This is informed by

theoretical and empirical evidence to suggest that 1) domains of development interact and are affected by proximal environments, such as classroom interactions (Rimm-Kaufman & Pianta, 2000), 2) classroom practices can directly promote DLL children's outcomes (e.g. Burchinal et al., 2012), and 3) the bilingual-EF relationship is affected by input and language experiences in both languages (Bialystok et al., 2012; Luk et al., 2011). This study attempts to clarify these developmental processes for DLLs to ultimately help inform intervention efforts that are sensitive to this population's unique trajectories.

The Current Study

The Office of Head Start has made clear that it is a priority to highlight and promote the linguistic assets of young children and families who speak languages other than English, with the ultimate goal of promoting school readiness for all children (ACF, 2013). In this endeavor, it is crucial to understand the developmental trajectories of school readiness skills particular to DLLs, in order to inform policy makers and educators on how to devise and implement instructional strategies that will adequately meet the needs of young DLLs. In the pursuit of meeting this goal, this study will extend previous research in three ways: 1) by examining the bidirectional relationship between bilingualism and EF across the school year in Latino DLLs attending Head Start; 2) assessing how bilingualism and EF impact children's academic readiness in science; and 3) determining how classroom support for DLLs in English and Spanish moderates the relationship between bilingualism and EF development across the year.

Aim 1. Determine if there is a bidirectional relationship between bilingual ability and EF across the school year in a sample of Latino DLL preschoolers in Head Start. Bilingual and EF ability were assessed in the fall and spring of the school

year to examine if fall bilingual ability predicted spring EF, and if fall EF predicted spring bilingual ability in the spring, accounting for initial correlations between EF and bilingual ability. It was hypothesized that there would be a bidirectional relationship, such that bilingual ability in the fall would predict EF at the end of the year, and EF in the fall would predict bilingual ability at the end of the year.

Aim 2. Evaluate if bilingualism and EF predict science readiness, controlling for baseline levels of children's ability across all outcomes. Science was assessed in the fall and spring to examine effects of bilingual ability and EF across the year on end of the year science achievement (controlling for fall science). Specifically, it was of interest if 1) EF mediated the relationship between initial levels of bilingual ability and science readiness at the end of the year and 2) bilingual ability mediated the relationship between EF and science at the end of the year. It was hypothesized that bilingualism and EF in the spring would directly predict higher science achievement, and that the cross-lag paths between bilingualism and EF across the year would mediate these relationships.

Aim 3. Assess the moderating role of classroom support for DLLs on bilingualism and EF over the school year. Classroom observations were conducted in the winter to determine if Spanish and English support in the classroom moderated the relationship between bilingual ability and EF (in both directions). It was hypothesized that classroom support in Spanish and English, respectively, would moderate the relationship between a) fall bilingual ability and spring EF, and b) fall EF and spring bilingual ability (controlling for initial levels of spring outcomes).

CHAPTER TWO

METHOD

This study was conducted in the context of a larger partnership project, “*Enfoque en Ciencia*,” between the University of Miami (UM) and Miami-Dade Head Start, to develop a computer-based adaptive science assessment for Spanish-speaking DLLs. The broader project, which was approved by the University of Miami’s Institutional Review Board (IRB), currently has over 1000 Latino children enrolled across 90 classrooms in various Miami-Dade Head Start centers. Consent was obtained from directors, teachers, teacher assistants, and parents at the beginning of each school year for participation in the larger project.

Participants

In the fall of 2015, a subset of classrooms (N=38) was randomly selected for participation in the current study, given their large proportion of Spanish- and English-speaking children. All children in each classroom were screened in English and Spanish to ensure a minimum level of proficiency in each language (i.e. DLL status). Those unable to pass the screener in Spanish, English, or both were excluded from the study. The final sample yielded 424 Latino children (52% female, M = 4.46, SD = 0.52 age in years; see Table 1) across the 38 classrooms.

Procedure

Data collection occurred across the 2015-16 academic year. Teachers and teacher assistants from all 38 classrooms in this study were re-consented in the fall of the school year, given the use of additional classroom and teacher measures collected for this study (i.e. classroom observations and demographic data). Parents also received a letter detailing the study and were able to decline their child’s participation if they chose. All

additional measures were approved by the IRB prior to consent and data collection procedures.

Following consenting procedures, child demographic information was obtained through center records (name, gender, date of birth, classroom). Children across the 38 classrooms were then assessed on a language screener to determine the final sample for this study, using two subtests from the PreLAS2000 (Duncan & De Avila, 1998), which are typically used to screen Spanish-speaking preschool children (Burchinal et al, 2012; Rainelli, Bulotsky-Shearer, Fernandez, Greenfield, & Lopez, 2017). Children who obtained a minimum score of 6 on Spanish and 2 on English were included in the sample (out of a total score calculated from two subtests of the measure). Given that there is no standard approach for the use of cutoff scores for English or Spanish PreLAS scores when used as a screener (Rainelli et al., 2017), these two cutoff scores were intentionally chosen for use in this study for the following reasons. For the Spanish subtest, children were required to obtain a minimum of 6 to ensure that they had at least some minimal level of Spanish that was beyond the ability to understand and respond to a few basic phrases (e.g. stand up, sit down). The cutoff for the English screener was lower (a score of 2), given that many of the DLL children assessed in the current sample came from primarily Spanish-speaking environments, and were learning English for the first time in their Head Start classrooms. Therefore, the lower cutoff score in English ensured that these children already had some minimal level of English ability early in the Head Start school year, which yielded a greater range of bilingual ability for this study. Given that there is not absolute standard for measuring bilingualism at any age (Barac et al., 2014; Genesee, Lindholm-Leary, Saunders, & Christian, 2006; Treffers-Daller, 2012), the

criteria above helped ensure that the children included in this study were to some extent bilingual.

Once the final sample was obtained, participating children were assessed on direct assessments of English and Spanish language, EF, and science (in this order), in the fall and spring. Both EF and science ability were conducted in the child's dominant language, as determined by the higher score on the language assessment in the fall. Staff were trained on the child assessments prior to data collection. Given that all direct assessments were computer-based, in which data were automatically retrieved, training was efficient and no extensive data verification was necessary. A team leader monitored staff in the field and ensured adequate administration (e.g. assessment, correct child ID entered, protocol). The graduate student actively participated in the data collection, worked closely with staff, and communicated with teachers and directors across the data collection cycle to ensure that all project goals were met.

Classroom observations were conducted in the winter of 2016 (January-March). The primary graduate student (who is fluent in Spanish) and three additional Spanish-English bilingual graduate students were trained on the CASEBA measure prior to the observations. One of the authors of the measure travelled to Miami in January of 2016 to conduct the training, which consisted of one full day of introduction to the measure (i.e. content, scoring, procedures) and three days of reliability visits, which were conducted in three randomly sampled classrooms from this study. All observers reached an interrater reliability of 90%. During the winter months, demographic information was also obtained from all teachers, including information on ethnicity, education level, language

proficiency in Spanish and English, and classroom language use. Teachers were given \$20 gift cards for their participation.

Measures

Language Screener. Children were screened in English and Spanish for inclusion in the study using the *PreLAS2000* in English and Spanish (Duncan & De Avila, 1998). The PreLAS is a brief assessment that measures both receptive and expressive abilities for preschool-aged children. Two subtests were administered in each language: Simon Says, measuring receptive language, and Art Show, measuring expressive language. In Simon Says, the child is asked to perform basic commands (e.g. “stand up”). In the Art Show subtest, children are shown a variety of simple pictures (e.g. apple, pencil) and asked to name the pictures and in some items, describe their function. The PreLAS has demonstrated strong internal consistency across subtests ($\alpha=.88$ for Simon Says and $\alpha=.90$ for Art Show).

Language. Children’s language ability in Spanish and English was assessed using the *Quick Interactive Language Screener – Spanish-English Bilingual Version* (QUILS-SE; Iglesias, Golinkoff, De Villiers, Hirsh-Pasek, & Sweig Wilson, 2017). The QUILS is a computerized 45-item direct assessment designed to measure language development in 3- to 6-year-old Spanish- and English-speaking children. Vocabulary, grammar, and syntax are assessed by measuring both language product (i.e. knowledge at the time of testing) and the ability to use language process (i.e. strategies for learning new language). It takes 15-20 minutes to complete in each language. Items were developed by experts in child language development under a 4-year grant from IES (Grant # R305A110284 “Using Developmental Science to Create a Computerized Preschool Language

Assessment;” Roberta Golinkoff, P.I.), and have undergone extensive item analyses using Rasch calibration techniques for final publication of the measure. The measure was normed and validated on a nationally representative sample of preschool-aged children, many of whom were served by Head Start. The QUILS-SE displays strong internal reliability for subtests in both languages ($\alpha_{Eng} = .89$ and $\alpha_{Span} = .85$). Both English and Spanish subtests demonstrate significant convergent validity with total scores on the Preschool Language Scale in English and Spanish (PLS-5; Zimmerman, Steiner, & Pond, 2011; $r_{Eng}=.693, p<.001$; $r_{Span}=.449, p<.05$) and the English subtest demonstrates significant convergent validity with the Picture Peabody Vocabulary Test (PPVT-4; Dunn & Dunn, 2007; $r=.735, p<.001$).

Executive Functioning. EF was assessed using the *Executive Functioning Early Childhood Computer Task* (EFECCT), a computerized measure of children’s attention, inhibition, and flexibility recently developed by the graduate student and her colleagues for use with preschool children (Alexander, White, Greenfield, & Penfield, in prep). EFECCT is administered on a touch-screen tablet and takes 10-15 minutes to complete. The measure includes 48 items in which the child is presented with a premise item, followed by three answer choices, and asked to sort by one of two dimensions, color or form. Half of the items are congruent and half are incongruent. On congruent items, the premise item matches the correct answer choice on both dimensions. The two incorrect answer choices do not match the premise item on either dimension. For example, the child is shown a green circle and asked to touch something else that is a circle. The correct answer choice is another *green* circle. On incongruent items, the premise item differs from the correct answer choice on one of the two dimensions (e.g. color). One of

the incorrect answer choices serves as a distractor, and matches the premise image on the other dimension (e.g. form). The other incorrect choice does not match the premise item on either dimension. For example, the child is shown a green circle, and asked to touch something else that is a circle. The correct answer choice is a *yellow* circle, and the distractor answer choice is a green shape (e.g. a green *rectangle*). Incongruent items elicit flexibility (switch the dimension they are sorting on based on a specified sorting rule) and inhibition (the impulse to attend to either color or form). Internal consistency is high ($\alpha=.90$) and a recent validity study (Alexander, White, & Greenfield, 2016) demonstrated significant correlations ($r = .423, p<.01$) with the Dimensional Change Card Sort (DCCS) task (Zelazo, 2006).

Science. Children's science knowledge was assessed using the *Lens on Science* and *Enfoque en Ciencia* computerized assessments (Greenfield, 2015). The *Lens on Science* (LENS) assessment is an Item Response Theory (IRT)-based direct assessment of science knowledge and content skills (Greenfield, 2015). Items were created based on a review of preschool and kindergarten state and national standards (including NGSS), as well as current preschool science curricula. The assessment covers a range of difficulty appropriate for Head Start preschoolers by assessing science practice skills (e.g. asking questions, making observations, making predictions, analyzing data), crosscutting concepts (e.g. recognizing patterns, cause and effect, structure and function), and science content (i.e. life science, earth and space science, physical science, and engineering and technology). Lens demonstrates sensitivity to growth over time (mean growth between two time points 4-5 months apart was 0.35 standard deviations), and significant validity with IRT estimates of vocabulary ($r = .55$) and mathematics ($r = .53$), as measured by the

Learning Express. (McDermott, et., al., 2009; *The Learning Express*). A second IES funded grant (# R305A130612) was funded to translate the measure into Spanish. An extensive Spanish translation process ensued, in which a team of bilingual experts decided upon a consensus translation from five different dialectal translations that were professionally translated (Mexican, Cuban, South American, Central American, and Caribbean). Rasch equating analyses occurred in the winter of 2017 to provide equated ability estimates for the Spanish version of the assessment.

Classroom Support for DLLs. The *Classroom Assessment of Supports for Emergent Bilingual Acquisition* (CASEBA) is an observational measure that assesses support for language and literacy development in both the home language and English in classrooms with a high number of DLLs (Freedson, Figueras-Daniel, & Frede, 2014). A validity study of the measure was conducted in 100 state-funded Abbott preschool classrooms in New Jersey with a large percentage of Spanish bilingual children. It is made up of 27 research-based items that cluster around five factors: 1) Supports for English Acquisition, 2) Supports for English Print Literacy, 3) Supports for Home Language, 4) Culturally Responsive Environment, and 5) Knowledge of Child Background. Correlations ranged from low to high between the factors because of the variability in classroom practices across dimensions (.12-.72). The CASEBA factors demonstrate adequate concurrent validity with Activities and Materials subtest from the Early Childhood Environment Rating Scale- Revised (ECERS-R), with correlations between .44-.70.

Data Analytic Plan

All analyses were conducted in Mplus Version 7 (Muthén & Muthén, 1998-2012) to allow for the construction of path models and account for the nested structure of the data. For Aims 1 and 2 (child-level questions), Type = Complex was used, with classroom entered as the cluster variable, to account for non-independence of the child level data (Muthen & Muthen, 1998-2012). Aim 3 was run in a two level framework, using Type = Two Level Random to allow for estimation of random effects (i.e. slopes and intercepts) at levels one (child level) and two (classroom level).

First, bilingual ability scores were created, taking into account both the child's *degree of balance* between the two languages and their *bilingual proficiency* across the two languages. Given that there is no general consensus on the best way to obtain a score of bilingualism (Bedore et al., 2012; Treffers-Daller, 2012), a combination of approaches was used to obtain an adequate bilingual score for purposes of this study, which included referencing previous approaches in the literature and consulting national experts in the field on the question of bilingual measurement. Consistent with other studies measuring bilingualism by creating a *degree of balance* (e.g. Bialystok & Barac, 2012; Gollan, Weissberger, Runnqvist, Montoya, & Cera, 2012), this portion of the bilingual ability score was obtained by creating a ratio of the child's lower score in English or Spanish to their higher score in English or Spanish at a given timepoint (i.e. low/high). Alone, however, this technique yields only a measure of *balance*, and does not account for language *proficiency* in both languages, which has also been implicated in the relationship between bilingual ability and executive control (Bialystok, Craik, & Luk, 2008; Bogulski, Rakoczy, Goodman, & Bialystok, 2015; Singh & Mishra, 2013). In other

words, simply using a *degree of balance* score does not discriminate children on the continuum of bilingual *proficiency* (i.e. a child who is high on both languages obtains the same score as a child who is low on both), while a score of *proficiency* in both languages does not account for *degree of balance* (representing more a measure of total language across both, rather than a measure of bilingualism). To account for this, the *degree of balance* score was then multiplied by overall *bilingual proficiency*, as measured by the child's percentage of total correct in both languages (i.e. low+high/total possible) to yield the final bilingual score, which ranged from 0-1.

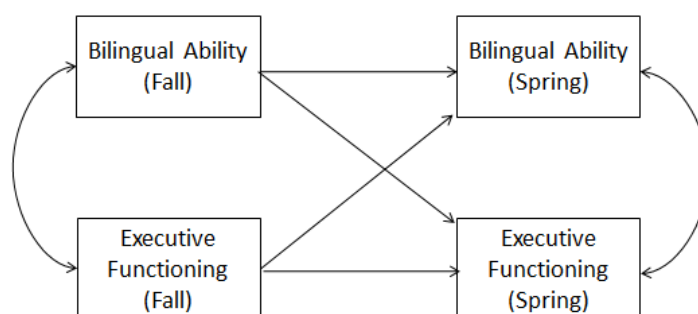
To examine if there was a bidirectional relationship between bilingual ability and EF across the school year (Aim 1), an autoregressive cross-lag model was constructed in which fall and spring levels of bilingualism and EF, respectively, were entered into one model, thereby estimating four direct paths. This model allowed for the calculation of autoregressive effects (the extent to which each construct develops independently over time) and cross-lagged effects (the extent to which initial levels of one outcome predict later levels of the other).

A strength of this model is that the cross-lagged effects represent associations between X_1 and Y_2 , for example, above and beyond the correlations between the two variables at time one (X_1 and X_2) and the effect of X_2 on Y_2 , allowing one to rule out the possibility that the cross-lagged effect is simply due to the fact that X_1 and X_2 are correlated at time one (Selig & Little, 2012). The following four paths were estimated in one model: 1) fall bilingual ability predicting spring bilingual ability, 2) fall EF predicting spring EF, 3) fall bilingual ability predicting spring EF (controlling for fall levels of EF), and 4) fall EF predicting bilingual ability in the spring (controlling for fall

levels of bilingual ability). Age, gender (0 = female; 1 = male), and dominant language (0=Spanish, 1=English) were entered as covariates on both spring outcomes. A visual model of the cross-lag analysis is included below. The single headed arrows represent the direct paths, and the double-headed arrows represent covariances, following common practices in constructing autoregressive cross-lag models (Martens & Haase, 2006).

Demographics were not in the figure for purposes of visual parsimony.

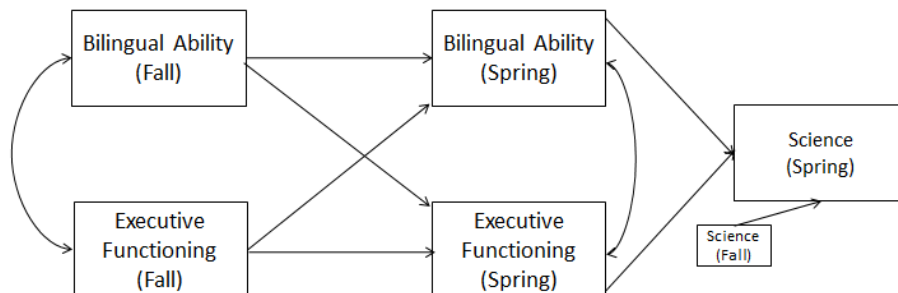
Figure 1. *Autoregressive Cross-lag Model Between Bilingual Ability and EF*



To examine if these relationships influenced science achievement at the end of the year (Aim 2), spring science achievement was added to the cross-lag model as an outcome (controlling for fall science ability), and two mediational effects were examined. Conducting mediation analyses in Mplus allows for an estimation of indirect effects in the context of complex path models (Muthen, 1998-2012). Although ideally longitudinal mediation is conducted with three time points, research designs with two time points on all variables still allows for an estimation of indirect effects (Cole & Maxwell, 2003). Direct paths between spring bilingual ability and spring EF (respectively) and science achievement in the spring were added to the model. In the same model, two indirect effects were estimated to examine whether a) EF mediated the relationship between fall bilingual ability and spring science (i.e. indirect path from fall bilingual ability to spring EF to spring science) and b) bilingual ability mediated the relationship between fall EF

and spring science (i.e. indirect bath between fall EF, spring bilingual ability, and spring science). Spring science was assessed as the last outcome across the academic year, providing the temporal sequence required to test mediation (Cole & Maxwell, 2003).

Figure 2. *Autoregressive Cross-Lag Model of Bilingual Ability and EF Predicting Science Readiness in the Spring, Controlling for Fall.*



To examine the effect of classroom support for English and Spanish, respectively, on DLLs' bilingual ability and EF across the school year (Aim 3), a sequence of two level models were conducted, estimating the effect of classroom support on 1) fall bilingual ability predicting spring EF and 2) fall EF predicting spring bilingual ability. First, a baseline model was run with the fall and spring levels of the outcome to determine the distribution of variance in residualized change in either bilingual ability or EF attributable to Level 1 (L1; variability due to differences between children *within* classroom) and Level 2 (L2; variability due to differences *between* classrooms), as indicated by the Intraclass Correlation Coefficients (ICCs). Subsequently, Level 1 and 2 predictors were added to examine the effects of child and classroom level variables.

In the final two level models, age and dominant language were entered as covariates (fixed effects) at Level 1. Additionally, the L1 predictor of interest (i.e. fall bilingual or fall EF) and the fall level of the outcome were entered as random effects at Level 1, to allow for the estimation of random intercepts and slopes by classroom. All

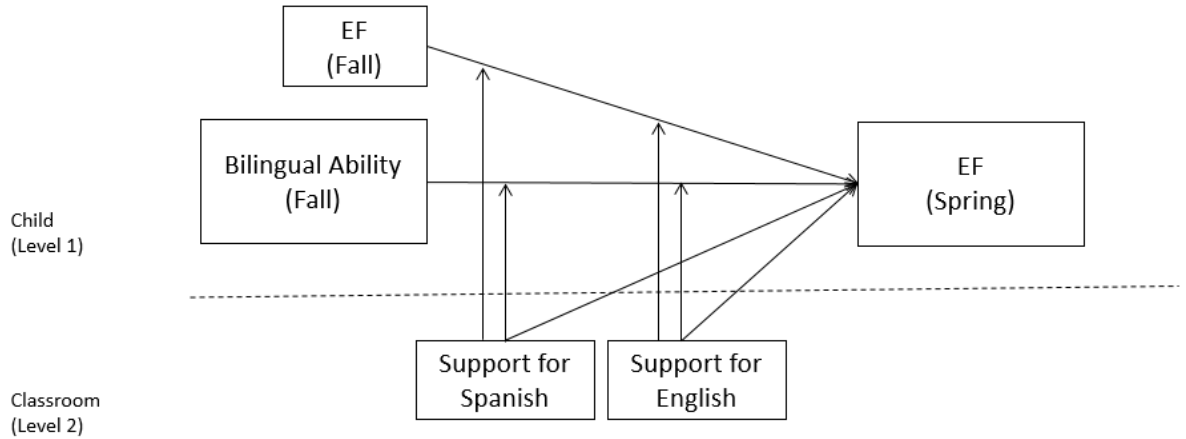
Level 1 predictors were group mean centered and Level 2 predictors were grand mean centered, as recommended (Enders & Tofighi, 2007). English and Spanish support scores (L2 predictors) were obtained from the CASEBA observation measure by summing the relevant items for English and Spanish support, respectively. Factor analyses were conducted to establish which items should be retained for inclusion in the score¹. The final scores consisted of 5 items for the Spanish support factor and 6 items for the English support factor. Given the difference in number of items by factor, total sum scores for both factors were converted to standardized z-scores for analyses.

Bilingual ability predicting EF. To test the moderating role of support for Spanish and English on bilingual ability in the fall predicting EF in the spring, child-level variables were entered as Level 1 predictors (age, dominant language, fall EF, and fall bilingual ability) of spring EF. Classroom level variables (support for Spanish, support for English) were entered as Level 2 predictors to examine the potential effects of English and Spanish classroom support on spring EF. Cross-level interactions between classroom-level variables and the path between fall bilingual ability and spring EF were analyzed to determine if classroom support for DLLs moderated the predictive relationship between fall bilingual ability and spring EF. In addition, entering fall EF as a random effect allowed for the examination of the cross-level interaction between

¹Two confirmatory factor analyses were conducted in this sample to generate factors for Spanish and English support, respectively, both of which demonstrated good model fit: Spanish factor: $\chi^2(5)=3.247$, $p=.6619$; RMSEA = 0.000; CFI = 1.000; SRMR = 0.037; English factor: $\chi^2(8)=8.569$, $p=.380$; RMSEA = 0.043; CFI = .991; SRMR = 0.070. Slight modifications were made to the published factor structure for both theoretical and empirical reasons, and based on conversations with the publishers of the measure. The final items included in the English and Spanish support scores in this study are presented in Table 4, and were used to create sum scores, for each language. The sum score approach was preferred over the extraction of factor scores, given that extracting factor scores are very sample dependent and tend to be biased (Muthen & Hsu, 1993), thus the sum score approach allowed each item to be weighted equally, promoting appropriate interpretation of results.

classroom support and the path between fall EF and spring EF. A visual model (see figure 3) and equations of the final model are presented below.

Figure 3. *Multilevel Model of Spanish and English Support as Moderators of Fall Bilingual Ability Predicting Spring EF.*



$$\text{Level 1: } \text{Spring } EF_{ij} = \beta_{0j} + \beta_{1j} (\text{Fall Bilingual}) + \beta_{2j} (\text{Fall EF}) + \beta_{3j} (\text{Age}) + \beta_{4j} (\text{DomLang}) + r_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + \gamma_{01} (\text{Support for Spanish}) + \gamma_{02} (\text{Support for English}) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11} (\text{Support for Spanish}) + \gamma_{12} (\text{Support for English}) + u_{1j}$$

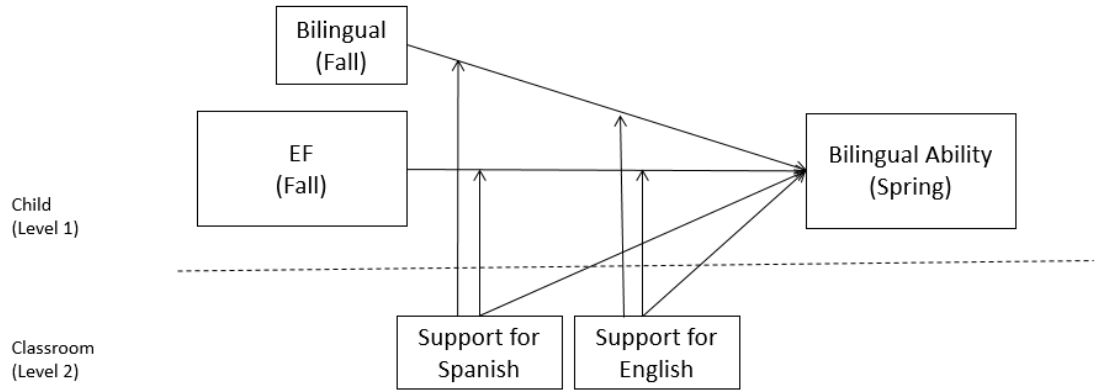
$$\beta_{2j} = \gamma_{20} + \gamma_{21} (\text{Support for Spanish}) + \gamma_{22} (\text{Support for English}) + u_{2j}$$

$$\beta_{3j} = \gamma_{30}$$

$$\beta_{4j} = \gamma_{40}$$

EF predicting bilingual ability. A parallel model following the steps above was analyzed to determine the moderating role of support for Spanish and English on EF predicting bilingual ability in the spring. Data analytic steps are identical to those presented above, but testing the alternative direction between EF and bilingual ability. A visual model (see figure 4) and equations of the final model are presented below.

Figure 4. Multilevel Model of Spanish and English Support as Moderators of Fall EF predicting Spring Bilingual Ability.



$$\text{Level 1: } \text{Spring Bilingual}_{ij} = \beta_{0j} + \beta_{1j}(\text{Fall EF}) + \beta_{2j}(\text{Fall Biling}) + \beta_{3j}(\text{Age}) + \beta_{4j}(\text{DomLang}) + r_{ij}$$

$$\text{Level 2: } \beta_{0j} = \gamma_{00} + \gamma_{01}(\text{Support for Spanish}) + \gamma_{02}(\text{Support for English}) + u_{0j}$$

$$\beta_{1j} = \gamma_{10} + \gamma_{11}(\text{Support for Spanish}) + \gamma_{12}(\text{Support for English}) + u_{1j}$$

$$\beta_{2j} = \gamma_{20} + \gamma_{21}(\text{Support for Spanish}) + \gamma_{22}(\text{Support for English}) + u_{2j}$$

$$\beta_{3j} = \gamma_{30}$$

$$\beta_{4j} = \gamma_{40}$$

Missing Data

Fifteen percent of children were missing data at the fall timepoint (on bilingual ability, EF, and/or science) and 20% were missing data at the spring timepoint. Missing data at either of these timepoints were due to absence on assessment date or computer malfunction (e.g. data not recorded or able to be retrieved from laptop). Missing data on child outcomes were determined to be missing completely at random (MCAR) by conducting the Little's MCAR Test ($p=.107$). Regarding classroom data, one of the classrooms in the study only had one teacher present on the date of observation (two

teachers are needed to accurately score some of the items in the measure). Thus, the score obtained for this classroom was not valid, and Aim 3 analyses did not include classroom scores or children (N=13) for that classroom.

Given that all models in this study were run in a two level framework in MPlus (using Type = Complex for Aims 1 and 2 and Type = Two Level Random for Aim 3), full information maximum likelihood (FIML) estimation was used with estimates of robust standard errors (MLR), as recommended by the authors of the statistics package (Muthen & Muthen, 1998-2012).

CHAPTER THREE

RESULTS

Descriptive statistics for all child-level variables are reported in Tables 1 (demographics) and 2 (outcomes). Teacher-level variables are reported in Tables 3-6 (including demographics and language use). Correlations for all variables included in analyses are presented in Table 7. All variables were assessed for skewness and kurtosis and found to be sufficiently normal in distribution.

Aim 1: Cross-lag Model Between Bilingual and EF Ability

A cross-lag model was constructed to examine the potential bidirectional relationship between bilingual ability and EF across the year. The final model was saturated, demonstrating perfect fit to the data, and allowing for the interpretation of relevant paths. Both autoregressive and cross-lag paths were interpreted (see Figure 5). Results demonstrated that both autoregressive paths were significant, such that bilingual ability in the fall significantly predicted bilingual ability in the spring ($\beta = .545, p < .001$), and executive functioning in the fall significantly predicted executive functioning in the spring ($\beta = .396, p < .001$), controlling for age, gender, dominant language, and fall levels of the other construct (i.e. fall bilingual ability or fall EF). Findings also demonstrated significant cross-lagged paths in both directions, such that bilingual ability in the fall significantly predicted higher EF in the spring ($\beta = .193, p < .001$), and EF in the fall significantly predicted higher bilingual ability in the spring ($\beta = .221, p < .001$), accounting for initial correlations between fall bilingual ability and EF, and autoregressive paths for each construct. Age was a significant covariate on both spring outcomes ($\beta_{BIS} = .127, p < .001$; $\beta_{EFS} = .120, p < .01$), such that older children had higher bilingual ability and EF in the spring. Dominant language was a significant covariate only

on spring EF as an outcome, such that children who were English dominant scored higher on EF ($\beta_{EFS} = .191, p < .001$), but not on spring bilingual ability ($\beta_{BIS} = .035, p = .313$). Gender was not a significant covariate on either outcome ($\beta_{BIS} = -.048, p = .216$; $\beta_{EFS} = -.012, p = .783$). These results confirm the hypothesis of a bidirectional relationship between EF and bilingual ability across the year in a large sample of Spanish and English-speaking DLLs attending Head Start.

Aim 2: Mediation Model with Science Achievement

Once the cross-lag model was established, science achievement was added as an outcome to examine if spring bilingual ability and spring EF acted as mediators of science at the end of the year, controlling for fall levels of science (see Figure 6). Two direct effects were estimated (i.e. spring bilingual ability and EF each predicting science at the end of the year), in addition to two indirect effects (i.e. spring EF mediating the relationship between fall bilingual ability and science at the end of the year; spring bilingual ability mediating the relationship between fall EF and science at the end of the year). First, the direct effects were interpreted. Science in the fall significantly predicted science achievement at the end of the year ($\beta = .404, p < .001$). EF in the spring significantly predicted science achievement at the end of the year ($\beta = .241, p < .001$), controlling for fall EF and fall science (and all other variables in the cross-lag model). Spring bilingual ability also significantly predicted science achievement at the end of the year ($\beta = .215, p < .001$), controlling for fall bilingual ability, fall science, and the previously stated covariates.²

²In order to remain consistent with the cross-lag model in Aim 1, covariates were retained on spring bilingual ability and EF, respectively, rather than added to science, as the outcome. A model was run in which the covariates were moved to spring science, and results did not change. Thus, for parsimony, we retained the model in which the covariates were on the same outcomes, as the cross-lag only model.

Subsequently, the two indirect effects were interpreted. First, the indirect effect testing spring EF ability as a mediator between fall bilingual ability and spring science was examined. There was a significant positive association ($\beta = .039, p < .05$), such that EF mediated the relationship between fall bilingual ability and science at the end of the year. Second, the indirect effect testing spring bilingual ability as a mediator between fall EF and spring science was examined. This path was also significant ($\beta = .027, p \leq .01$), such that higher EF in the fall predicted higher science in the spring, which was mediated by fall EF predicting spring bilingual ability, also in the positive direction. Thus, the indirect effects demonstrated that EF and bilingual ability in the spring independently mediated relationships between fall levels of the other construct and science achievement at the end of the year.

Aim 3: Moderating Role of Classroom Support

Lastly, a series of two level models were run to examine the effect of classroom support in English and Spanish on children's trajectories across the year (see Figures 7 and 8 for visual diagram of models). Results described are for the final two level models. Given that all Level 1 predictors were group mean centered, estimates at Level 1 were interpreted in relation to the average levels of a given variable for children within a particular classroom. Age and dominant language were entered as controls in Level 1 in both final models, thus all effects can be interpreted as controlling for these as covariates. All Level 2 effects were interpreted for children in classrooms with "average" levels of Spanish and English support, respectively.

Fall Bilingual ability predicting spring EF. Results from the baseline model indicated that 7.4% of the variability in residualized change in EF was attributed to

classroom level (as indicated by the ICC), leaving 92.6% of the variability attributable to the child level. This allowed for an examination of the effect of L1 and L2 predictors on spring EF. Results from the final model testing the main effects of the L1 predictors of interest (i.e. fall bilingual ability, and fall EF ability) demonstrated that fall bilingual ability significantly predicted spring EF ($\gamma_{10} = .274, p < .001$) and fall levels of EF significantly predicted spring EF ($\gamma_{20} = .412, p < .001$; see Table 8). These results indicate that children with higher EF and bilingual ability in the fall, respectively, demonstrated higher EF in the spring (consistent with results from the cross-lag model). Subsequently, the main effects for the L2 predictors were interpreted. Results showed a significant effect of Spanish support on spring EF ability ($\gamma_{01SpanSup} = .032, p < .01$), such that for every unit increase in Spanish support, spring EF was expected to increase by .032 units. There was no main effect for English support on children's spring EF ($\gamma_{02EngSup} = -.007, p = .472$).

Finally, the cross-level interaction testing the effect of Spanish and English support, respectively on the path between children's fall bilingual ability and spring EF was interpreted. Results demonstrated that neither Spanish nor English support moderated the path between fall bilingual ability and spring EF ($\gamma_{11SpanSup} = .042, p = .477$; $\gamma_{12EngSup} = -.080, p = .284$), indicating no differences in how English and Spanish support by classroom influenced the relationship between children's fall bilingual ability and spring EF. Although not a primary research question of this study, the cross-level interaction between Spanish and English support, respectively, and the slope between fall EF and spring EF was also examined, given that this relationship was a random effect allowed to vary by classroom. The cross-level interaction testing the effect of Spanish

support on the association between children's fall and spring EF across the year indicated no significant effect ($\gamma_{21\text{SpanSup}} = -.071, p = .141$). However, there was a significant cross-level interaction of English support on children's EF from fall to spring, demonstrating a moderating effect ($\gamma_{22\text{EngSup}} = .123, p < .01$), such that the relationship between children's fall and spring EF differed based on the level of English support they received in their given classroom.

Given the significant cross-level interaction between English support and fall and spring EF, post-hoc analyses were conducted to examine the direction of the effects (Preacher, Curran, & Bauer, 2006). Classroom groups were split into three groups: at the mean and 1 standard deviation above and below the mean based on amount of English support (Cohen & Cohen, 1983), and subsequently plotted to compare the relationship between fall and spring EF for children in the given classrooms. As demonstrated in Figure 9, the relationship between children's fall EF and spring EF seemed to change based on their experience of English support in the classroom. It appeared that children in classrooms with high English support demonstrated a stronger relationship between their fall and spring EF. This seemed to be particularly beneficial for children who started the school year with higher EF, such that they demonstrated higher EF at the end of the year if they were in high English classrooms (compared to if they were in lower English support classrooms). However, for children who started the year with lower EF, although still a positive relationship, high English support did not seem to benefit them in the same way on their levels of spring EF.

Fall EF predicting spring bilingual ability. The baseline model indicated that 6.6% of the variability in residualized change in bilingual ability was attributed to

classroom level (as indicated by the ICC). This left 93.4% of the variability attributable to the child level, prompting further evaluation of the effect of L1 and L2 predictors on spring bilingual ability. Results from the final model testing the main effects of the L1 predictors of interest demonstrated that fall levels of EF significantly predicted spring bilingual ability ($\gamma_{10} = .180, p < .001$), and that fall levels of bilingual ability significantly predicted spring bilingual ability ($\gamma_{20} = .646, p < .001$; see Table 9). The main effects for Level 2 predictors were then interpreted, and showed a significant effect of Spanish support on spring bilingual ability ($\gamma_{01\text{SpanSup}} = .026, p \leq .001$), such that for every unit increase in Spanish support, mean scores in spring bilingual ability were expected to increase by .005 units (controlling for the other variables in the model). There was no effect of English support on mean levels of spring bilingual ability ($\gamma_{02\text{EngSup}} = -.009, p = .380$).

Lastly, the cross-level interactions were interpreted. Similar to the results from the previous model, neither Spanish nor English support moderated the relationship of the path between fall EF and spring bilingual ability ($\gamma_{11\text{SpanSup}} = -.045, p = .354$; $\gamma_{12\text{EngSup}} = .051, p = .379$), suggesting that English and Spanish did not influence the predictive relationship between fall EF and spring bilingual ability in this sample. There was also no evidence of a cross-level interaction on the relationship between fall and spring bilingual ability for either English or Spanish support ($\gamma_{21\text{SpanSup}} = -.006, p = .949$; $\gamma_{22\text{EngSup}} = -.039, p = .679$), suggesting that English and Spanish support in the classroom was not associated with children's bilingual ability from fall to spring.

CHAPTER FOUR

DISCUSSION

This was the first study to examine the relationship between bilingual language and executive functioning development across the year in a sample of Spanish and English-speaking DLLs attending Head Start, taking into account bidirectional associations, influences on science achievement, and the classroom context. By conducting this research in a large sample of Latino DLL preschoolers on the continuum of bilingual development, this study offers a within-group approach to understanding common trends within this critical population. Results supported the hypothesized bidirectional relationship between bilingual ability and EF. These findings were extended to uncover significant influences (in both directions) on children's science achievement at the end of the year, such that 1) EF mediated the relationship between bilingual ability and science, and 2) bilingual ability mediated the relationship between EF and science. Classroom support did not moderate the respective bidirectional associations between EF and bilingual ability. However, English support moderated the relationship between children's fall and spring EF across the year, and Spanish support predicted children's bilingual ability and EF at the end of the year. This study not only provides evidence for a bidirectional relationship between bilingual language and EF development in this sample of Latino DLLs attending Head Start, it also uncovered positive associations with science learning *and* found preliminary support for the benefits of Spanish and English classroom use on children's EF and bilingual ability across the year. Taken together, this novel study provides preliminary evidence for the mechanisms behind the development of the EF-bilingual advantage in this critical population of young bilingual learners.

Bidirectional Associations between Bilingual and EF development

Consistent with previous research suggesting a link between bilingualism and EF (Bialystok, Craik, & Luk, 2012; Carlson & Meltzoff, 2008; White & Greenfield, 2017), results from this study found that Latino DLL children with higher levels of bilingual ability in the fall demonstrate better EF performance in the spring. This finding is in line with the prevailing notion that the experience of bilingualism drives higher cognitive functioning (Bialystok, 2001, 2015; Thomas-Sunesson, Hakuta, & Bialystok, 2016), and with findings from emerging studies (albeit, few) that examine the influence of bilingualism on EF over time (e.g. Blom et al., 2014; Crivello et al., 2016). The current study was the first to demonstrate the longitudinal relationship between early bilingual ability and subsequent EF development across the school year in a sample of Spanish and English-speaking DLLs attending Head Start. By controlling for children's fall EF ability in the model (thus removing the variability in spring EF due to initial levels of EF) *and* the initial associations between bilingual ability and EF in the fall, findings indicate that the observed relationship is above and beyond 1) the development of EF across the school year and 2) the fact that bilingual ability and EF were correlated at the first timepoint, providing a robust approach for the documented relationship.

Additionally, this was the first study to examine the bidirectional relationship between EF and bilingual ability, to examine how EF may promote bilingual learning. Similar to the results found for the influence of bilingual development on EF, results confirmed the hypothesis that early EF ability significantly predicted bilingual ability at the end of the year, above and beyond children's gains in bilingual ability from fall to spring and the initial associations between EF and bilingual ability in the fall. These

findings suggest that EF can facilitate the development of bilingualism in Latino DLLs during the preschool years. Although this question has not been explicitly examined in existing literature, there is some research to suggest that early aspects of cognitive ability facilitate second language learning for young DLLs (Keller, Troesch, Loher, & Grob, 2016; Kim et al., 2014; Winsler et al., 2014). However, these studies have not typically measured language development in children's first language, alongside English, to determine the effect of early cognitive ability on *bilingual* language learning. Findings from this study provide support for the idea that early cognitive proclivity, specifically EF, can help promote the learning of two languages for young DLLs.

Results from the current study also support work from a larger body of research that links language and EF development in the preschool years (Bohlman, et al., 2015; Fuhs & Day, 2011; Weiland, Barata, & Yoshikawa, 2014). From a theoretical perspective, language plays an important role in helping children regulate behavior and engage in inhibitory processes (Bodrova & Leong, 2006). At the same time, theory on language development suggests that children need a certain amount of cognitive control and flexibility (i.e. EF) to effectively develop language (Samuelson & Smith, 2000; Woodward and Markman, 1998; Zosh, Brinster, & Halberda, 2013). These relationships have been empirically established, demonstrating positive concurrent associations between EF and language in preschool (e.g. Muller, Zelazo, & Imrisek, 2005), and longitudinal associations in both directions, such that verbal ability leads to greater change in EF (Fuhs & Day, 2011), and EF in the early years predicts later language achievement (Blair & Razza, 2007). There is also some emerging work that explicitly demonstrate a bidirectional relationship between language and self-regulation (which has

overlapping skills with EF), in both monolingual and bilingual populations (Bohlman et al., 2015). Findings from our study support such existing research that suggests concurrent, longitudinal, and bidirectional relationships between language and EF development, and extend these studies by using a unique measure of *bilingual language ability* to highlight such reciprocal relationships in a sample of young Spanish- and English-speaking DLLs.

The examination of such associations in linguistically diverse populations requires going beyond competency in one or both languages, to account for how these languages interact, providing a frame for *bilingual language ability* that is unique to DLLs (Castro et al., 2011; Gathercole, Thomas, Roberts, Hughes, & Hughes, 2013). In this study, the measurement of bilingualism supersedes a score of *overall* language, as typically assessed in the studies mentioned above, and accounts for two important aspects of bilingual ability: proficiency (in both languages) and degree of balance (between both languages). Both proficiency and balance have been implicated in the bilingual-EF relationship (Bialystok & Barac, 2012; Bialystok, Craik, & Luk, 2008; Bialystok & Majumder, 1998; Blom et al., 2014; Crivello et al., 2016; Keller et al., 2016; Lonigan, Lerner, Goodrich, Farrington, & Allan, 2016; Singh & Mishra, 2012; Thomas-Sunesson et al. 2016), with greater levels of proficiency (e.g. Singh & Mishra, 2012) and balance (e.g. Bialystok & Barac, 2012), respectively, associated with better performance on measures of EF. However, these components are typically not examined in conjunction to create a continuous measure of bilingualism, omitting important information (i.e. balance alone does not account for level of language ability in both languages, while proficiency alone does not account for bilingual balance), which may help elucidate the critical

factors contributing to the EF-bilingual phenomenon. Experts in the field have recently argued that measuring bilingualism on a continuum is preferred to the longstanding categorical approach (Luk & Bialystok, 2013; Bogulski et al., 2015). The bilingual score used in this study represents a unique interaction between proficiency and degree of balance in English and Spanish, such that higher proficiency *and* balance produce a better bilingual score. Subsequently, this score demonstrated significant bidirectional associations with EF across the school year, implicating both proficiency and balance as important components of the EF-bilingual relationship.

Predicting Science Achievement

Findings with science achievement added as an outcome to the cross-lag model revealed that both EF and bilingual ability related positively to children's science achievement at the end of the year. There was a significant direct relationship between EF and science for these Spanish and English-speaking DLLs, such that greater levels of EF predicted higher science achievement at the end of the year (controlling for fall levels of each). This finding is consistent with an emerging base of research that suggests that EF is particularly useful for science learning (Gropen, Clark-Chiarelli, Hoisington, and Ehrlich, 2011; St. Clair-Thompson & Gathercole, 2006). In these contexts, the cognitive processes involved in EF (e.g. flexible thinking, inhibition) are consistently activated when engaging the higher-order thinking skills (e.g. comparison, critical thinking, questioning) during science exploration. The relationship between EF and science has been documented in the preschool years for children attending Head Start, which included Latinos in the sample, but did not distinguish them based on language status (Nayfeld et al., 2013). Additionally, a recent study conducted by the primary author of

this paper found an effect of EF on Spanish- and English-speaking bilingual children's science achievement (White, 2015). DLL children's strengths in EF could promote their engagement in science learning by facilitating the use of higher-order critical thinking skills needed to engage in effective science exploration. The current study was the first to document that EF benefits children's science achievement, as assessed in their dominant language, in a large sample of Spanish and English-speaking DLLs who ranged in bilingual ability.

We also found that bilingual ability positively predicted science achievement at the end of the year in this linguistically diverse population of children. Although the evidence documenting the relationship between bilingual ability and achievement (in any domain) is limited and somewhat inconsistent, there are a range of studies suggesting that bilingual children demonstrate adequate academic achievement (and sometimes even enhanced achievement compared to monolinguals), especially when proficient and supported in both languages (Golash-Boza, 2005; Guhn, Milbrath, & Hertzman, 2016; Han, 2012; Lindholm-Leary & Hernandez, 2011; Marian, Shook, & Schroeder, 2013; Oades-Sese, Esquivel, Kaliski, & Maniatis, 2011; Portes & Hao, 2004; Slavin, Madden, Calderon, Chamberlain, & Hennessy, 2011). However, these studies tend to classify children into bilingual groups (e.g. bilingual vs. monolingual), and do not use a measure of bilingual ability to examine how this may predict academic achievement. Additionally, existing studies are conducted mostly with older children (e.g. Lindholm-Leary & Hernandez, 2011), only assess achievement in English (e.g. Han, 2012), and/or have not measured science as an academic domain (e.g. Tong et al., 2011). Therefore, this study advances the field in two important ways: 1) identifying bilingual ability as an important

predictor of young Spanish- and English-speaking DLL children's achievement, and 2) using science (assessed in the child's dominant language) as the measure of achievement.

As hypothesized, two significant mediational effects emerged in the context of these relationships. First, EF not only directly predicted children's science achievement, but also acted as a mediator in the relationship between children's fall bilingual ability and science achievement at the end of the year. In other words, children's bilingual ability in the fall promoted EF development across the year, which subsequently predicted greater science achievement (controlling for fall levels of EF and science). Although research on this topic is scant (particularly between bilingual ability, EF, and science), this effect is similar to those reported in a broader base of research examining EF as a critical mediator in predicting academic achievement for young children (e.g. Bindman, Pomerantz, & Roisman, 2015; Lawson & Farah, 2015; Nesbitt, Baker-Ward, Willoughby, 2013). This study represents one of the first to extend the bilingual-EF relationship to examine effects on academic achievement, using a within-group approach. Such studies are critical to determine if the EF-bilingual advantage for young preschool-aged DLLs promotes their school readiness (Barac et al., 2014). Our findings highlight a unique relationship between all three constructs, indicating that an EF advantage for bilingual children has the potential to promote science achievement.

The cross-lag analytical technique allowed for the examination of an effect in the opposite direction, to determine if bilingual ability mediated the relationship between EF in the fall and science achievement at the end of the year. This hypothesis was also supported, such that children's EF in the fall promoted bilingual ability across the year, which subsequently predicted higher science achievement. Given the lack of research on

EF as it promotes bilingual ability (and achievement) for DLLs, this is the first study to empirically test and demonstrate such a relationship. Theoretically, it is expected that cognitive and language competence would interact and develop together over time to promote school readiness (Rimm-Kaufman & Pianta, 2000). There is also empirical evidence to suggest that language ability mediates the relationship between certain individual factors (e.g. SES), and academic achievement for young children (Dickinson & Porche, 2011; Forget-Dubois, et al., 2009). Results from this study demonstrate that bilingual ability was a significant mediator between EF and science achievement across the year, supporting two novel ideas: 1) EF supports bilingual development (in English and Spanish) over time and 2) this enhanced bilingual ability can promote science achievement.

Taken together, these are very encouraging findings for this group of young Latino DLLs, highlighting the need to support both bilingual ability *and* EF to promote the achievement of emerging bilinguals. Although an understudied school readiness domain, science has the potential to promote learning across domains, given that it provides an engaging, hands-on context to learn language, explore mathematical concepts, and develop a greater understanding about the world (Brenneman, 2014; Bustamante, White, & Greenfield, 2016; Greenfield et al., 2009). Thus, this finding has promising implications on the bilingual-EF advantage promoting academic achievement for young DLLs, which is a very encouraging finding in this “at-risk” population of Latino DLLs from low-income backgrounds.

Effect of Classroom Context (English and Spanish support)

Finally, this study examined the effect of classroom support on the two cross-lagged paths between bilingual ability and EF across the school year (i.e. fall bilingual ability predicting spring EF; fall EF predicting spring bilingual ability). Findings did not support the hypothesis that classroom support in English and Spanish would moderate these associations (in either direction). Given that this relationship remains unexplored in the literature, it is difficult to conclude if this finding is strictly due to the fact that this relationship does not exist, or to some other explanation (e.g. other contextual variables, study design, measurement).

If in fact the relationship between EF and bilingualism across the year remains unaffected by classroom support for English and Spanish, these findings would suggest that the relationship between EF and bilingual ability (in both directions) remains stable across the year. This interpretation is supported by the robust findings across Aims, including the significant cross-lagged paths in Aim 1 and the replication of these direct effects at the child level in Aim 3. In the existing literature, this explanation is also supported by the consistent findings across ages, languages, and levels of bilingualism that repeatedly support individual level associations between bilingualism and EF (e.g. Barac et al., 2014; Bialystok, 2001; Carlson & Meltzoff, 2008). Additionally, Barac & Bialystok (2012) found no effect of language of instruction on the cognitive outcomes in various groups of bilinguals (although it should be noted that they used a single measure for language of instruction, i.e. English or French). It could be that the strength of the EF-bilingual relationship at the child level leaves little room for the effect of a classroom variable on the bidirectional associations, which is supported by the notion that it can be

difficult to find effects of education practices (as measured by classroom observations) on children's outcomes (Blau, 1999; Burchinal, Kainz, & Cai, 2011). Such an explanation, however, should be interpreted with caution in concluding that the classroom context does not influence the bidirectionality between bilingual ability and EF.

It is unlikely that environmental contexts have little effect on these relationships. The development of bilingualism and EF for DLLs is largely influenced by the environment, which includes a range of contextual factors such as language input, family and community language use, and educational approaches (Bialystok, 2001; Collins, O'Conner, Suarez-Orozco, Nieto-Castañon, & Toppelberg, 2014; Gathercole & Hoff, 2007; Hammer et al., 2012, 2014; Hindman & Wasik, 2015; Hoff, 2012; Toppelberg & Collins, 2010). Across these contexts, bilingual children typically have multiple opportunities to use both languages, or, depending on who is present, may be required to inhibit one language to speak the other. These contextual factors determine the extent to which bilingual individuals' cognitive resources are activated to manage these experiences (Bialystok, 2001). The children in this study were Latino DLLs living in Miami-Dade County, a unique location where both Spanish and English are vital in economic, cultural, and familial discourse (Carter & Lynch, 2015), likely providing them with multiple opportunities *outside* of the classroom to engage in the critical processes implicated in the bilingual-EF relationship. Thus, our inability to detect an effect of Spanish and English support in the classroom on the bidirectional development of EF and bilingual ability, could be attributed to only measuring one contextual variable, and that various environmental factors, such as the quality and quantity of language use at home

and in the community, interact with school language use to affect the relationship between bilingualism and EF for DLLs.

Alternatively, it could be that the timeframe across which these constructs were measured was not long enough to detect a significant effect of the classroom on children's bilingual ability and EF (as they predict one another) over the course of the school year. Children were assessed on all measures at two timepoints (fall and spring), with 6-7 months between repeated assessments. This may not have been enough exposure within the same classroom environment to influence the reciprocal change in bilingual and EF ability across the year. A recent study on the effect of home and school language factors on DLL children's dual language development in kindergarten may help make sense of these lack of findings (Collins et al., 2014). The authors found that instruction type and classroom language practices were not related to DLL children's language profiles in kindergarten (as were home factors), but became more influential in predicting language profile membership in second grade. Thus, it could be that the DLLs in this study needed to experience longer and more sustained interactions in the same classroom for these factors to affect the bidirectional trajectories between bilingual ability and EF.

Another possible explanation for the lack of findings for this research question could be attributed to the measure used to assess classroom support in this study. The CASEBA is intended to capture support for *bilingual* acquisition, however items are distinctly separated by support for a given language, and do not reflect the interaction of both languages in the classroom. The measure has yielded distinct factors for English and Spanish (Freedson et al., 2011), indicating a discrete focus on English and Spanish language acquisition, and not on the development of overall *bilingual* ability as

conceptualized in this study. Thus, the classroom measure, although intended to capture *bilingual* support, seemed to capture support for English and Spanish independently, which may have limited the ability to find effects on the cross-lagged paths between bilingual ability and EF across the school year. However, given the lack of valid and reliable observation measures for use with DLLs, particularly those that examine classroom support for bilingual language acquisition (Castro, 2014; Howes et al., 2011; Peisner-Feinberg et al., 2014), this was the best measure available at the time. Future work should examine if Spanish and English support *interact* to influence the bidirectional relationships.

Lastly, it could be that there was a lack of power at Level 2 to detect the hypothesized effects between classroom support variables and children's outcomes. A total of 37 classrooms were included at Level 2 in a complex model estimating multiple random intercepts, slopes, and cross-level interactions. The effects found for Spanish and English support, respectively, on DLL children's outcomes were not primary research questions of this study, but emerged given the data analytical context. Significant findings from these models should thus be interpreted with caution, and additional analyses are required that test these hypotheses as the main research questions of interest.

Among these, additional findings were examined on how classroom support moderated the relationship between fall and spring levels of each construct, respectively (rather than the bidirectional relationships). An interesting result emerged, such that English support moderated the relationship between fall and spring EF. Follow-up analyses showed that children who started the year with higher EF and experienced more English support seemed to achieve greater EF in the spring (see Figure 9). It could be that

for children with higher levels of EF, greater English support in the classroom activated the processes involved in promoting EF, leading to higher levels of EF in the spring. On the other hand, for children who start the school year with lower EF, higher levels of English support did not seem to benefit their EF in the spring (and they seemed to end up lower than children who started with the same levels of EF in the fall, but were in average or low English support classrooms). As noted, these findings should be interpreted with caution. However, a preliminary interpretation may draw on theory suggesting that bilingual children need a certain level of cognitive ability to experience the cognitive benefits of being bilingual (Threshold Hypothesis; Cummins, 1976; MacSwan, 2000). If this is the case, then, perhaps the DLL children in this study with low EF at the beginning of the year had not yet reached a cognitive competency to benefit from increased English support in the classroom, particularly if they came from predominantly Spanish-speaking homes. In turn, high English support may not have been appropriate in some cases for these DLLs at-risk for lower levels of EF. This is only a preliminary finding that warrants further investigation, to understand and be able to support the learning of DLLs who come in with different levels of cognitive skills in the beginning of the year.

Results from the two level models also showed a significant main effect for Spanish support (but not English support) on children's EF, such that children who experienced greater Spanish support in the classroom demonstrated higher levels of EF in the spring (controlling for EF and bilingual ability in the fall). Once again, this question remains largely unexplored in the literature. However, a body of research demonstrates positive effects of global classroom quality on change in preschool children's cognitive ability (e.g. EF) across the year (Finch, Johnson, & Phillips, 2015; Mashburn et al., 2008;

Peisner-Feinberg et al., 2001; Rimm-Kaufman, Curby, Grimm, Nathanson, & Brock, 2009; Weiland, Ulvestad, Sachs, & Yoshikawa, 2013), positing that higher quality/better functioning classrooms provide children with consistent opportunities to practice and develop inhibitory control (Bodrova & Leong, 2006; Weiland et al., 2013). Although some of these studies included DLLs in the sample, they did not examine effects of classroom quality for DLLs in particular, nor did they measure Spanish support in the classroom. The mechanisms behind this relationship may be slightly different for DLLs given the unique trajectories of EF development in dual language contexts.

On this note, there is some evidence to show that classroom quality predicts DLL children's learning in language, math and social development (e.g. Downer et al., 2012; Hindman & Wasik, 2015), however they did not measure children's EF, nor did they account for the language being spoken during classroom interactions. Others have examined effects of language use, and found positive effects of Spanish use in the classroom on DLLs' learning and socioemotional development (e.g. Chang et al., 2007; Collins, 2014), however, these have typically assessed *quantity* of language (not *quality*), and did not measure children's EF. One study measured both global quality and percentage of language use in the classroom, and found an interesting interaction, such that DLL children in classrooms with greater quality (specifically Emotional Support) and increased Spanish use demonstrated greater achievement (Burchinal et al., 2012), suggesting benefits of using Spanish in *if* the classrooms are high quality. Additionally, it has been suggested that incorporating the home language in the classroom for DLLs creates a culturally and linguistically sensitive environment that makes them feel respected and eager to learn, which can promote learning (Castro et al., 2011; Chang et

al, 2007; Halle et al., 2014). This study provides preliminary evidence for the provision of consistent high-quality interactions in Spanish by early childhood teachers working with young Latino DLLs, which may benefit EF at the end of the year.

Similarly, Spanish support positively related to children's bilingual ability in the spring (controlling for fall levels of bilingual ability and EF). The effects of teacher practices on DLL children's bilingual development are more often examined in the literature than effects on their EF. Previous research shows that bilingual children who are taught in their native language attain higher levels of language proficiency in both languages (Barnett, Yarosz, Thomas, Jung, & Blanco, 2007; Collier & Thomas, 2004; Collins, 2014; Farver et al., 2009; Lindholm-Leary, 2001; Mendez et al., 2015; Tong, et al., 2011). These studies also typically reference cross-language transfer theory to explain their findings, asserting that development in a child's first language can facilitate the learning of a second language (August & Shanahan, 2006; Cummins, 1979; Dickinson, McCabe, Clark-Chiarelli, & Wolf, 2004; Lopez & Greenfield, 2004). Taken together, existing evidence suggests that providing children with consistent quality classroom interactions in Spanish, may not only promote Spanish development, but also English development (which would then be expected to promote overall bilingual ability). Results from this study support and extend existing research on the influence of classroom language use on DLL children's language development using a continuous measure of bilingual ability, suggesting that teacher support of Spanish in the early childhood classroom can benefit bilingual ability across the year.

Lastly, it should be noted that the CASEBA is a recently developed measure, and still requires additional validity and reliability data to demonstrate associations of the

factors with DLL children's outcomes. The support scores used in these analyses were theoretically and empirically derived, and represent both *quantity* and *quality* of English and Spanish support. Thus, speculatively, it could be that the findings of classroom support specific to language may be more representative of quality in general, rather than specific to that language. Descriptively, it seemed there was generally more Spanish happening in the classrooms (e.g. TAs spoke an average of two thirds in Spanish; see Table 6), so the main effects of *Spanish support* on children's outcomes may represent classrooms that are better functioning in general, thus serving as a proxy for overall quality. Future research should examine similar questions, but also accounting for global classroom quality to clarify effects specific to language support, and those representing general best practices in early education.

Note on Miami-Dade County Head Start Classroom Context

The Head Start classrooms included in this study did not prescribe to a purposeful dual language model. In discussions with local program administrators, there was interest and talk of moving towards an intentional dual language approach, however no formal model was implemented at the time of observations in the current study. Although both English and Spanish language use were common across classrooms, there were some interesting trends in the data (see Tables 4-6). Average percentages of classroom language use (as determined by two observers in the classroom) indicated that lead teachers used approximately equal levels of English and Spanish (49.5% English; 50.5% Spanish), while teaching assistants (TAs) spoke more Spanish than English (65.8% Spanish; 34.2% English; see Table 6). The standard deviations for these percentages were quite large, indicating a substantial range. This was probed further – almost one third

(30%) of lead teachers in the sample were observed speaking Spanish 80% or more of the time, and almost two thirds (60%) of TAs were observed speaking Spanish 80% of the time. These trends indicate that in general, there was a large amount of Spanish being spoken by teachers in the classroom. Corroborating these trends with the findings of main effects of Spanish support on children's EF and bilingual development, it could be that they were receiving more language interactions in Spanish in general (compared to English), which could explain this finding (and the lack of a main effect for English).

Thus, teachers in this study may not have been intentionally support bilingual language development as conceptualized in this study (i.e. promoting equal opportunities to develop proficiency in and balance between both languages). Anecdotally, it seemed that Spanish was used to a large extent for social interactions (e.g. free play, meal time, outside) and as an occasional scaffold during instructional time, while English use was used more formally during explicit instruction (e.g. vocabulary instruction). Teachers themselves reported more frequent use of Spanish for social interactions (84% responded yes), compared to English (63% responded yes; see Table 4). As for instruction, the majority of teachers did report using Spanish for instructional purposes (84%), but even more (94%) reported using English for instructional purposes. Thus, the focus in the classroom may have been more on second language acquisition (i.e. English), and not *bilingual* acquisition. This context may have had implications for DLL children's opportunities to engage in the EF processes implicated in the cognitive development of bilinguals, and potentially have diminished the ability to find moderating influences of the classroom on the bidirectional relationship between EF and bilingual ability.

The current focus on second language acquisition in Miami-Dade Head Start preschools is not surprising, given that the school readiness assessments in Miami-Dade County are conducted primarily in English. National bilingual education experts discuss that program models around the country vary in terms of theoretical rationale, language goals, cultural goals, academic goals, teacher qualifications, and instructional resources, among others (Garcia, 2005; Genesee, 2010; Ovando, Collier, & Combs, 2006). In turn, the development of balanced bilingualism is determined largely by state and local policies, teacher availability, and course curricula (Garcia, 2011). At the same time, one must consider the sociolinguistic context; in general, children growing up with two languages tend to shift to the dominant societal language (i.e. English), which often coincides with loss of the native language (Oller & Ellers, 2002), and this is even present in communities like Miami where Spanish is prominent and widely-used (Portes & Schauffler, 1996; Carter & Lynch, 2016). Given the variability in these approaches and the tendency for young bilinguals to shift to the majority language, studies examining the effects of the classroom on EF and bilingual development in DLLs should account for specific program models and intentional supports to prevent against language shift/loss, and consider how this may affect results.

Implications for Practice

The bidirectional relationship between EF and bilingual ability found in this study, not only provides additional information on the trajectories of young DLLs, but also promotes the idea of intentionally supporting both competencies for DLLs in the early childhood classroom. Currently, most of the early educational interventions specifically designed for DLLs target bilingual language development (Buyse et al.,

2014), and do not systematically focus on EF, which may be a missed opportunity in helping to foster this advantage. Given the overwhelming evidence that EF skills are malleable and responsive to curricular interventions in early childhood (Diamond & Lee, 2011; Diamond, Barnett, Thomas, & Munro, 2007), intentional EF skill development is increasingly recognized as a critical point of intervention for early educators. Taken together with the evidence on the effectiveness of specific language and literacy based interventions for DLLs in early childhood settings on DLL children's learning (e.g. Mendez et al., 2015), results from the current study can help inform the development and testing of interventions for DLLs that bridge the EF-bilingual relationship.

In addition, given the positive effects of both EF and bilingual ability on children's science achievement, findings from this study provide support for science as an important learning context to provide for DLLs. Particularly for young DLLs, science is an engaging context that provides contextualized opportunities for learning (Brenneman, 2014; Moore & Smith, 2015). Most existing educational interventions that use science as a context particularly for young bilingual learners, however, have been designed for children in primary or secondary school (Moore & Smith, 2015). Findings from this study support the idea of increasing science education in the early childhood classroom for DLLs, which help leverage the bidirectional relationship between bilingual and EF development and promote learning across domains.

Lastly, results from this study provide support for the range of literature calling for the need to incorporate intentional support for both first and second language development in the classroom (Goldenberg, Hicks, & Lit, 2013). These young DLLs deserve to be in spaces where their home language is valued, supported, and encouraged,

helping them feel valued and eager to learn, which can in turn have positive benefits for cognitive and academic achievement (Castro et al., 2011). The early childhood classroom should provide opportunities for emerging bilinguals to use both of their developing languages. New approaches, such as translanguaging, provide spaces that allow for the fluidity and flexibility to engage with multiple languages (Gort, 2015). Such an approach may be particularly beneficial for promoting bilingual proficiency and balance (and EF), by allowing both languages to interact in a single space, rather than employing strict separation policies for each language (e.g. by time, subject matter, or teacher; Gort & Sembiante, 2015). Our findings provide preliminary support that both English and Spanish in the classroom can benefit DLLs' bilingual language and EF development in preschool, and should both be promoted to optimize their learning and set them on a path of academic success.

Limitations and future directions

The use of a cross-lag model to determine bidirectional associations between EF and bilingual development provides a rigorous approach that adds to the literature on the EF-bilingual advantage. Follow-up research should examine if the significant cross-lagged paths found in the current study differ in strength, to determine the leading indicators of the relationship. In addition, this study only used two timepoints to measure EF and bilingual ability. A stronger approach would be to assess children at three or more timepoints. Future research should conduct longitudinal studies and employ growth curve analyses in the context of cross-lagged models to determine the trajectories of these processes over time.

A strength of this study is the use of a within-group approach to examine these processes in a large sample of bilinguals. Despite the utility of this approach, children across the sample ranged greatly on the continuum of bilingualism, introducing variability to the sample which is inherent to diverse linguistic populations. For example, some children in this study were highly balanced and proficient in both languages, while others demonstrated less balance (but high proficiency in one language, and low on the other). Future research should examine more fine-grained questions within this population of children to determine how these processes may differ within this sample of DLLs based on other factors (e.g. language dominance, dialect/country of origin, specific language components). A future direction could be to conduct latent profile analysis of bilinguals, which could then be used to examine if the profiles differentially relate with EF and science (and other outcomes of academic achievement).

It could also be that individual children in classrooms experience the effects of English and Spanish support differently, based on their levels of bilingual and EF ability at the beginning of the school year. For example, there is some evidence to suggest that quality language interactions in the classroom are more strongly predictive of DLL children's vocabulary learning for those who start the school year with lower English skills (Hindman & Wasik, 2015). There is also theory and evidence to suggest a threshold effect, such that children may need to have a certain level of English (and Spanish, for that matter) to benefit from the cognitive advantages of bilingualism (Cummins, 1976). Alternatively, there could also be a threshold effect at the classroom level, as established in some studies examining the effect of classroom quality on children's outcomes, providing evidence to model these relationships quadratically (e.g. Burchinal et al.,

2011). Perhaps a certain amount of English or Spanish support is needed to influence child outcomes across the year. Future research should examine these questions to help uncover the underlying factors that influence the complexity of DLLs' language and cognitive development.

Another strength of this study was the use an observation measure of English and Spanish support in the classroom to determine contextual influences on the bilingual-EF relationship, however findings of the effects of this support were mixed. Future research should examine other aspects of the classroom, such as percentage of language use (in both languages) and global classroom quality, and determine potential interaction effects as they relate to children's outcomes. It would also be interesting to examine classroom effects on children's English and Spanish language abilities uniquely (separate from the construct of bilingual ability), to determine the effect of classroom practices on the development of each language. Additionally, several other contextual factors would be important to measure, such as home language use and exposure for DLL children. These variables were excluded from the current study because of a lack of resources and access to parent information, however it would be useful in future research to determine how additional environmental factors may affect the bidirectional associations revealed in this study.

Lastly, the use of Spanish assessments to assess children's EF and science achievement in this study is a methodological strength that differs from previous studies that only measure DLL children's outcomes in English. It is strongly urged that DLL children should be assessed in both languages at multiple timepoints across the school year to obtain an adequate measure of their competencies across domains (Castro, 2014;

Espinosa & Garcia, 2012). Although we assessed Spanish and English language for all children in this study at two timepoints, children were only assessed on EF and science in their dominant language, due to time and resources. Future research should measure all outcomes in both languages, which would allow for examining the influence of language of assessment on observed relationships (e.g. Lonigan et al., 2015). Additionally, this would provide data to help explore the creation of conceptual scores for bilingual children across various assessments, an increasingly popular approach to obtaining a measure of total ability for multilingual learners (Peña & Halle, 2011). Future research should also include measures of general cognitive functioning (e.g. processing speed, verbal IQ) as discriminant validity evidence, to strengthen evidence for these findings, beyond general intellectual ability.

Conclusion

Findings from this study begin to highlight the mechanisms behind the EF-bilingual relationship for young Spanish and English-speaking DLLs from low-income backgrounds, and suggest potential entry points for early educators to focus on when instructing DLLs in the early childhood classroom. The discovery of a bidirectional relationship between EF and bilingual ability highlights two mutually developing processes that promote science achievement for young Latino DLLs. In addition, findings suggest positive effects of English and Spanish support in the classroom on DLL children's outcomes, add to the body of literature highlighting the utility of dual language approaches in early childhood settings.

Ultimately, children who are dual language learners deserve to experience the wide range of benefits associated with learning two languages. Research on the

advantages of bilingualism, coupled with the achievement gap among Latino DLLs, as it stands, suggests that perhaps it is not the children who are deficient, but rather a deficiency of an educational system that is not adequately supporting their needs (Castro et al., 2011). This study represents an important step within a programmatic research agenda to understand and capitalize on the strengths that young Latino DLL's demonstrate from an early age, shifting the framework from a deficiency to a strength-based model (Zambrana & Zoppi, 2002). This powerful paradigm shift for young Latino children from low-income backgrounds should inspire a framework among researchers, educators, and policymakers in which the unique strengths that develop from learning two languages are recognized and utilized to promote optimal learning and development. Ultimately, these findings should inform the design and implementation of intentional and effective classroom practices that target bilingual development *and* EF, with the goal of best meeting the needs of young DLLs in Head Start and setting them on a trajectory of continued academic success.

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TABLES

Table 1

Child Demographics

	N	%	M (SD)
Age	424	100	4.47 (.52)
Gender			
Male	202	47.6	
Female	222	52.4	
Language Screener			
Spanish	424	100	16.29 (4.05)
English	424	100	10.77 (5.71)
Dominant language			
Spanish	213	50.2	
English	211	49.8	

Note: Dominant language was determined by the higher total score obtained on the primary language measure (QUILS). There were no differences in age or gender by dominant language group.

Table 2

Child Assessments

	Fall		Spring	
	N	Mean (SD)	N	Mean (SD)
Language (QUILS)				
English (total)	407	17.54 (7.52)	403	22.86 (8.23)
Spanish (total)	411	18.27 (6.71)	398	23.46 (7.96)
Bilingual Score				
English	200	.33 (.13)	193	.44 (.18)
Spanish	195	.29 (.14)	193	.40 (.16)
Total	395	.31 (.14)	386	.42 (.17)
Executive Functioning (EFECCT)				
English	189	.63 (.19)	178	.74 (.18)
Spanish	200	.58 (.18)	198	.64 (.19)
Spanish	389	.61 (.19)	376	.69 (.19)
Total				
Science (Lens/Enfoque)				
English	194	.23 (1.03)	171	.85 (1.04)
Spanish	195	.28 (.79)	201	.09 (.87)
Total	389	.26 (.92)	372	.44 (1.02)

Note on scores: Language scores in English and Spanish are raw scores, out of a total of 45 for each language. Bilingual and Executive functioning scores are proportion scores on a 0-1 scale. Science scores are derived from Rasch ability estimates, ranging from -3 to 3.

Note on group differences: Independent t-tests indicated that there were significant differences between the English and Spanish groups on bilingual scores, such that the English dominant group scored obtained higher bilingual scores than the Spanish dominant group in both the fall and spring (Fall: $t(393) = -2.982, p < .01$; spring: $t(384) = -.2517, p < .05$). The same pattern of results was found for EF, such that the English group scored significantly higher than the Spanish group at both timepoints (Fall: $t(387) = -2.344, p < .05$; Spring: $t(374) = -5.124, p < .001$).

Table 3

Teacher Demographics

	Teacher		Teacher Assistant	
	N	%	N	%
Ethnicity				
Hispanic	33	89	33	89
Black	4	11	4	11
Education Level				
High School	1	3	3	8
CDA	0	-	22	59
Associates	2	5	2	5
Bachelors	30	81	8	22
Master's	4	11	2	5
First Language				
English	4	11	4	11
Spanish	33	89	33	89
English Language Proficiency (speaking)				
Extremely Well	4	11	5	14
Very Well	10	27	7	19
Average	19	51	12	32
Not Very Well	4	11	13	35
NA	0	-	0	-
Spanish Language Proficiency (speaking)				
Extremely Well	27	73	19	51
Very Well	3	8	11	30
Average	1	3	0	-
Not Very Well	0	-	0	-
NA	4	11	4	11
Left blank	3	8	4	11
Language use in classroom				
Spanish all the time	0		3	8
Spanish most of the time	1	3	7	19
Spanish and English equally	25	68	19	51
English most of the time	5	14	3	8
English all of the time	2	5	1	3
Left blank	4	11	4	11

Note: These represent self-reported data from 37 teachers (one classroom was missing data). Percentages were thus calculated based on all available data n(N=37), disregarding the missing classroom.

Table 4

Teacher Report of Language Use in the Classroom

	English				Spanish			
	Yes		No		Yes		No	
	N	%	N	%	N	%	N	%
Social	24	63	14	37	32	84	6	16
Procedural/Behavior Management	26	68	12	32	27	71	11	29
Instruction/Teaching	35	92	3	8	32	84	6	16

Note: Represents the number of teachers (and percentage) responding yes or no. Answers to these questions were reported by teachers to the observer on the day of the observation (N=38).

Table 5

Item Scores for Observed Spanish and English Support in the Classroom

	N	M (SD)
Spanish Support Items		
<i>The lead teacher engages in high quality talk in the home language.</i>	37	4.65 (1.77)
<i>The assistant teacher engages in high quality talk in the home language.</i>	38	4.13 (1.88)
<i>Teaching staff use effective strategies during group instruction to support ongoing development of the home language.</i>	38	2.30 (1.01)
<i>Teaching staff interact one-on-one with individual DLL children in ways that support the development of the home language.</i>	38	5.14 (1.75)
<i>Teaching staff expand children's repertoire of concepts and vocabulary in the home language.</i>	38	2.60 (1.28)
Total Spanish Support Score (out of 35)	37	18.90 (5.74)
English Support Items		
<i>The lead teacher engages in high quality talk in the home language.</i>	37	2.23 (1.53)
<i>The assistant teacher engages in high quality talk in English.</i>	38	2.04 (1.53)
<i>Teaching staff use effective strategies to scaffold children's comprehension of instructional content in English.</i>	38	4.42 (1.60)
<i>Teaching staff use effective strategies during group instruction to build children's communicative skills in English.</i>	38	3.63 (1.75)
<i>Teaching staff interact one-on-one with individual DLL children in ways that support the acquisition of English.</i>	38	4.36 (1.70)
<i>Teaching staff expand children's repertoire of concepts and vocabulary in English.</i>	38	2.60 (1.34)
Total English Support Score (out of 42)	37	19.60 (6.33)

Note: These are the raw item scores (rated on a Likert scale of 1-7).

Table 6

Observed Percentage of Classroom Language Use

	English %	Spanish %
	M (SD)	M (SD)
Teacher	49.54 (31.92)	50.46 (31.92)
Teacher Assistant	34.24 (36.67)	65.76 (36.67)

Note: These percentages were obtained by two observers who independently coded classroom interactions, and subsequently agreed on a percentage score.

Table 7

Bivariate Correlations of All Variables Included in Analyses

	1	2	3	4	5	6	7	8	9	10
1. Age										
2. Gender	.010									
3. DomLang	.007	.061								
4. Bil Fall	.421**	.016	.149**							
5. EF Fall	.266**	-.052	.118*	.460**						
6. Sci Fall	.455**	-.089	-.030	.565**	.529**					
7. Bil Spring	.421**	-.065	.127*	.712**	.516**	.635**				
8. EF Spring	.322**	-.019	.256**	.473**	.537**	.452**	.537**			
9. Sci Spring	.400**	-.066	.367**	.550**	.457**	.656**	.603**	.539**		
10. Span Support	.010	-.041	-.060	.163**	.143**	.200**	.147**	.165**	.235**	
11. Eng Support	.025	.044	.031	-.096	-.002	-.014	-.025	-.057	-.070	-.085

Note: **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

Table 8

Two-Level Model of Spanish and English Classroom Support: Fall Bilingual Ability Predicting Spring EF

		Estimate	S.E.	<i>p</i> -value
Intercepts	Spring EF (γ_{00})	0.678	0.012	<0.001
Main Effects	Slope FBil→SEF (γ_{10})	0.274	0.072	<0.001
	Slope FEF→SEF (γ_{20})	0.412	0.067	<0.001
	Spanish Support (γ_{01})	0.032	0.011	0.005
	English Support (γ_{02})	-0.007	0.010	0.472
Cross-Level Interactions	Slope FBil→SEF			
	Spanish support (γ_{11})	0.042	0.059	0.477
	English support (γ_{12})	-0.080	0.075	0.284
	Slope FEF→SEF			
	Spanish Support (γ_{21})	-0.071	0.048	0.141
	English Support (γ_{22})	0.123	0.046	0.008
L1 Covariates	Age (γ_{30})	0.040	0.023	0.080
	Dom Lang (γ_{40})	0.066	0.023	0.004
Residual Variance L1	Spring EF (r_{ij})	0.021	0.002	<0.001
Residual Variances L2	Spring EF (u_{0j})	0.003	0.001	0.045
	Slope FBil →SEF (u_{1j})	0.002	0.084	0.982
	Slope FEF→SEF (u_{2j})	0.002	0.035	0.946

Note: These are the unstandardized estimates of coefficients. FBil = fall bilingual ability; FEF = fall EF; SEF = spring EF.

Table 9

Two-Level Model of Spanish and English Classroom Support: Fall EF Predicting Spring Bilingual Ability

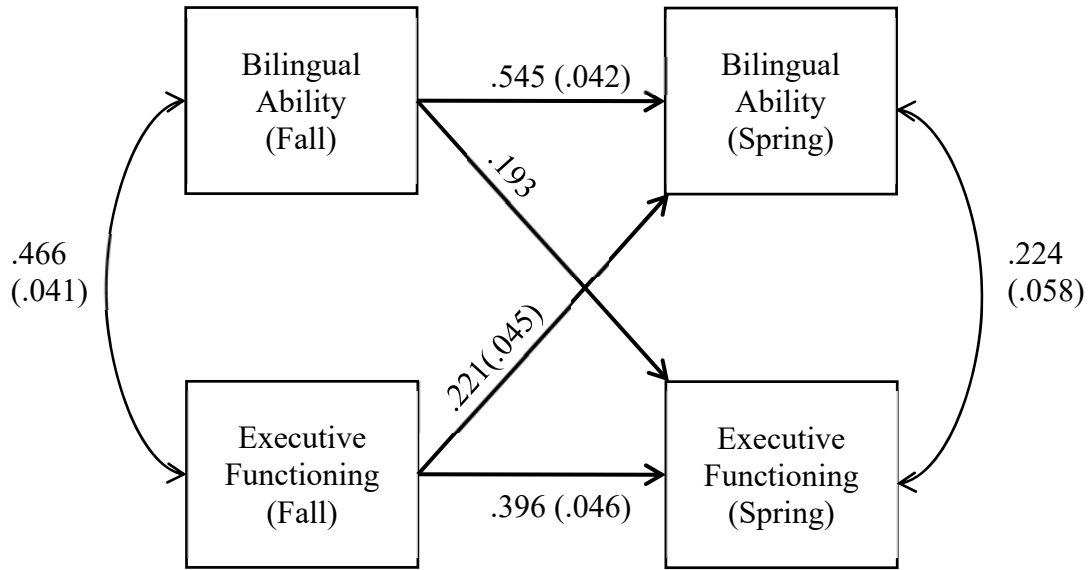
		Estimate	S.E.	<i>p</i> -value
Intercepts	Spring Bil (γ_{00})	0.412	0.011	<0.001
	<hr/>			
Main Effects	Slope FEF→SBil (γ_{10})	0.180	0.048	<0.001
	Slope FBil→SBil (γ_{20})	0.646	0.185	<0.001
	Spanish Support (γ_{01})	0.026	0.008	0.001
	English Support (γ_{02})	-0.009	0.010	0.380
<hr/>				
Cross-Level Interactions	Slope FEF→SBil			
	Spanish support (γ_{11})	-0.045	0.048	0.345
	English support (γ_{12})	0.051	0.058	0.379
	Slope FBil→SBil			
	Spanish Support (γ_{21})	-0.006	0.100	0.949
	English Support (γ_{22})	-0.039	0.096	0.689
<hr/>				
L1 Covariates	Age (γ_{30})	0.045	0.019	0.016
	Dom Lang (γ_{40})	0.005	0.014	0.705
<hr/>				
Residual Variance L1	Spring Bil (r_{ij})	0.013	0.001	<0.001
<hr/>				
Residual Variances L2	Spring Bil (u_{0j})	0.003	0.001	0.017
	Slope FEF →SBil (u_{1j})	0.000	0.028	0.987
	Slope FBil→SBil (u_{2j})	0.002	0.045	0.965

Note: These are the unstandardized estimates of coefficients. FBil = fall bilingual ability; FEF = fall EF; SBil = spring bilingual ability.

FIGURES

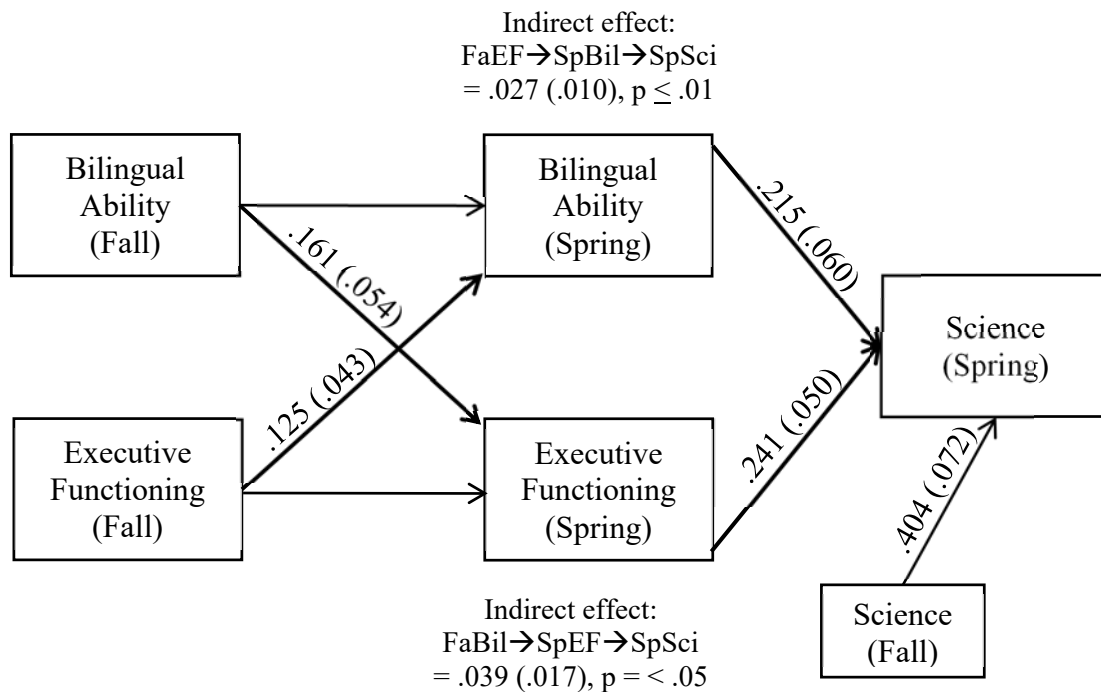
Figure 5

Cross-Lag Model with EF and Bilingual Ability



Note: Regression coefficients presented are standardized beta estimates, followed by the standard error. All paths present in this model were significant at the $p < .001$ level. The single-headed bolded arrows represent the paths of interest (autoregressive and cross-lagged paths), and the double-headed arrows represent symmetric associations (i.e. covariances), following common practices in constructing autoregressive cross-lag models (Martens & Haase, 2006). Demographics were not included in this figure for purposes of visual parsimony.

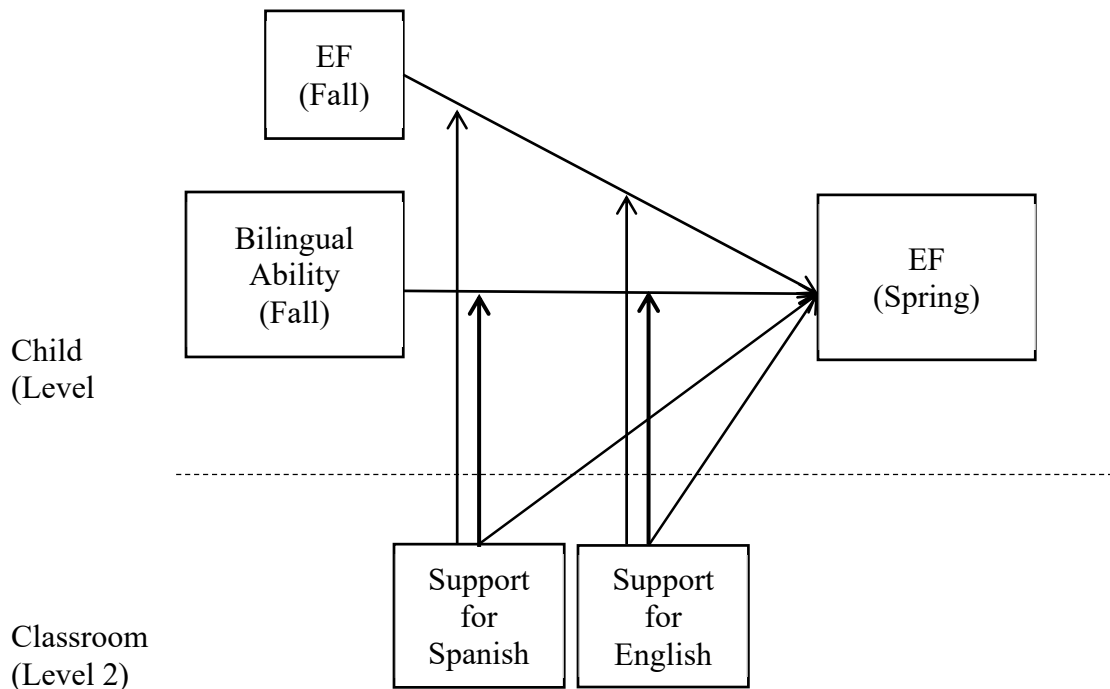
Figure 6

Cross-lag Model with Science as an Outcome

Note: The regression coefficients presented are standardized beta estimates of direct effects - all were significant at the $p \leq .001$ level. Two indirect effects (indicated by the bolded arrows) were also estimated in this model, using the cross-lagged paths between bilingual ability and EF to predict science achievement at the end of the year. Demographic control variables were not included in this figure for visual parsimony.

Figure 7

Multilevel Model of Spanish and English Support as Moderators of the Relationship between Fall Bilingual Ability and Spring EF, Controlling for Fall EF



Note: The bolded vertical arrows represent the main question of interest (the cross-level interaction between Spanish and English support and the relationship between fall bilingual ability and spring EF). The thin vertical arrows also represent cross-level interactions between fall and spring EF, and were thus interpreted (see results for description of results).

Figure 8

Multilevel Model of Spanish and English Support as Moderators of the Relationship between Fall EF and Spring Bilingual Ability, Controlling for Fall Bilingual Ability

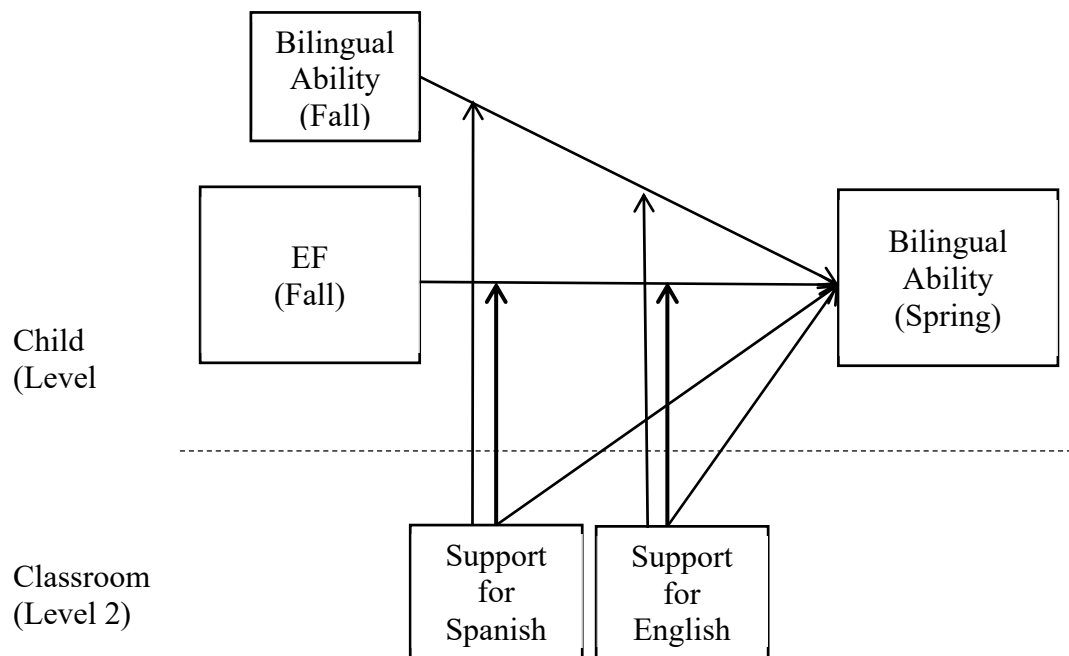
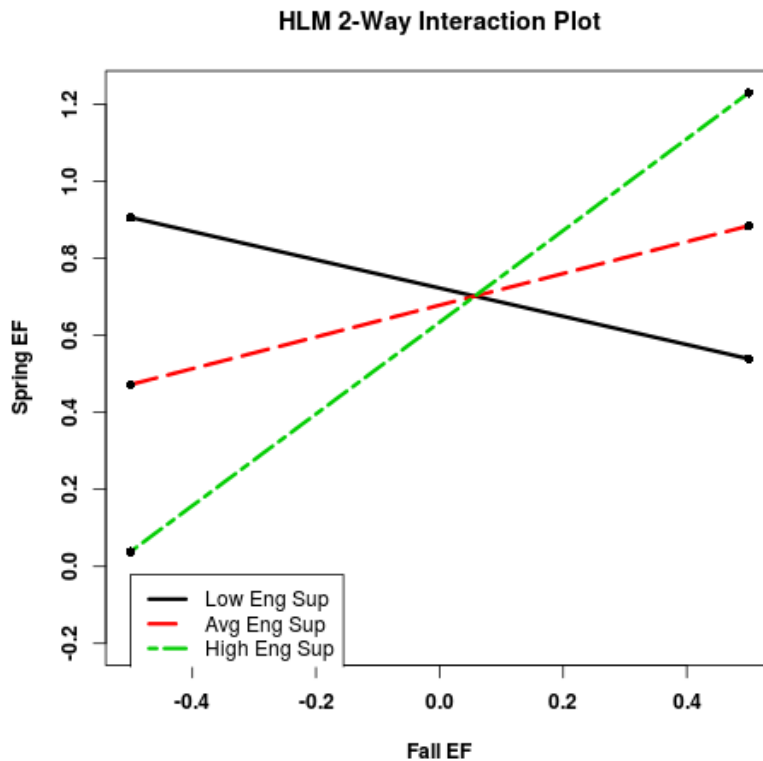


Figure 9

Cross-Level Interaction on Change in EF Across the Year



Note: The above plot was conducted using Preacher's calculator to probe significant cross-level interactions (Preacher, Curran, & Bauer, 2010-2017). English support (as the moderator) was split into 1 SD above and below the mean, and subsequently compared on fall and spring EF. The calculator provided estimates of the slopes. The slope for High English support was significant, and thus, interpreted ($\beta=1.191$ (0.299, $p<.001$)). It should be noted that Fall EF was centered at group mean and the estimates for Spring EF are projected, and thus warrant caution in interpretation (the actual scale ranged from 0.21 to 1).