Early Childhood Research Quarterly 29 (2014) 699–714

Contents lists available at ScienceDirect

Early Childhood Research Quarterly

Review

The cognitive development of young dual language learners: A critical review

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ARTICLE INFO

Article history:
Available online 4 March 2014

Keywords:
Bilingualism
Dual language learner
Cognitive development
Children
Review

ABSTRACT

Dual language exposure and bilingualism are relatively common experiences for children. The present review set out to synthesize the existing research on cognitive development in bilingual children and to identify the gaps and the methodological concerns present in the existing research. A search of major databases for research conducted with typically developing, preschool-age dual language learners between 2000 and 2013 yielded 102 peer-reviewed articles. The existing evidence points to areas of cognitive development in bilingual children where findings are robust or inconclusive, and reveals variables that influence performance. The present review also identifies areas for future research and methodological limitations.

Contents

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http://dx.doi.org/10.1016/j.ecresq.2014.02.003

1. Introduction

The study of cognitive consequences of bilingualism has a relatively long history that dates back to the beginning of the 20th century, but the effects of bilingualism on executive functions and other non-verbal abilities has only recently become a topic of research. From the beginning, bilingual research with children was concerned with the domains of intelligence and linguistic and metalinguistic performance, just as it is now. This trend reflects an intuitive understanding that bilingualism, essentially a linguistic experience, must affect linguistic performance and also an unfounded fear that managing two languages is a demanding task that may exceed children's cognitive resources and thus could potentially lead to intellectual impairment. With a few exceptions that remained largely ignored (Arsenian, 1937; Hill, 1936; Pintner & Arsenian, 1937; Stark, 1940), the majority of early studies on bilingualism in children reported superior performance in monolingual children (review in Barac & Bialystok, 2011). This monolingual advantage was found on a range of tasks such as IQ tests (Graham, 1925; Jones & Stewart, 1951; Lewis, 1959; Saer, 1923; Wang, 1926), verbal intelligence (Darcy, 1953) arithmetic and reading achievement (Macnamara, 1966; Manuel, 1935).

One of these early studies (Saer, 1923) compared the performance on the Stanford-Binet Scale of Intelligence in over one thousand English monolingual and Welsh-English bilingual school-aged children from rural and urban backgrounds in Wales. The findings showed lower intelligence scores in bilingual children from rural areas at all ages tested (i.e., 7–11 years), with the gap in performance between the two language groups becoming larger with age. The author interpreted this finding as a sign of "mental confusion" encountered by the bilingual child. Later analyses of this study pointed out several methodological flaws that essentially applied to most early research on bilingualism: (a) the groups of comparison were not properly matched on variables such as age, gender, and socio-economic status, (b) the testing was typically conducted solely in one language (L2), and bilingual children varied in the degree to which they comprehended and produced the language of testing, and (c) bilingualism was not properly defined and quantified, and sometimes bilingualism was simply assumed in children based on parents' names and country of birth (Darcy, 1953; Peal & Lambert, 1962). Interestingly, two extensive reviews (Darcy, 1953, 1963) clearly blamed early negative outcomes to methodological flaws and pointed out an important dissociation in the results: typically bilingualism was found to produce costs in verbal intelligence tests but there were no differences between monolingual and bilingual children in non-verbal intelligence. This observation set the stage for finding cognitive benefits of bilingualism or at least for distancing from the early notion of pervasive bilingual cognitive disadvantages.

A landmark study that contributed significantly to the change in attitude from believing that bilingualism was a negative experience for children to one in which it is now seen as a positive boost to cognitive functioning was conducted by Peal and Lambert in 1962. They gave a battery of intelligence tests to 10-year-old French-speaking children in Montreal, some of whom were also fluent English speakers. The authors carefully measured language experience and proficiency, quantified the degree of bilingualism and matched the groups on gender, age and socio-economic class. This resulted in a sample of 75 French monolinguals with about half a year of English experience and 89 French-English bilinguals with an average of six years of English language experience.

Peal and Lambert (1962) hypothesized that there would be no differences between the groups on measures of nonverbal intelligence but there would be a monolingual advantage in verbal intelligence. Contrary to these predictions, bilingual children outperformed monolinguals on two measures of nonverbal intelligence (Raven Progressive Matrices and the Lavoie-Laurendeau Nonverbal IQ), as well as on measures of verbal intelligence (Lavoie-Laurendeau Verbal IQ). More detailed analyses of children's performance on each subtest revealed that bilingual children generally had higher scores than monolinguals on subtests that required symbolic manipulations and reorganization but not on measures with high spatial-perceptual demands. In contrast, monolinguals did not surpass bilinguals on any of the subtests. On the basis of these findings, Peal and Lambert suggested that bilingual children may actually show *enhanced* cognitive ability, especially on tests of concept formation and symbolic flexibility. The authors further speculated that bilingual children's early and sustained experience with two linguistic symbols standing for every one thing in the world coupled with the exercise of switching between the two languages might be at the root of their advantage in nonverbal intelligence. This was the first evidence that not only was bilingualism not damaging to children's cognitive growth but also it might be a positive experience that led to cognitive benefits.

Although Peal and Lambert identified and controlled many of the methodological issues from past research, the study was not flawless. The authors used strict selection criteria to assign children in the monolingual and bilingual groups and to ensure that the bilingual children formed a homogeneous group with equal proficiency in French and English (i.e., "balanced bilinguals"). However, it is possible that applying these strict criteria might have led to the selection of a special subset of the bilingual population in that the authors excluded more than half of the original sample: 200 children out of 364 were classified as having ambiguous language experience. Thus, it is possible that the bilingual children in the study were a particularly high achieving group who may not be completely representative of the bilingual population in general whose proficiency in two languages is more average.

After 1962, bilingualism research focused on linguistic and metalinguistic performance for a few more decades, generally showing lower linguistic proficiency and more precocious metalinguistic development in bilingual children (review in Bialystok, 2001). A key advance in bilingualism research which contributed significantly to the active interest in the nonverbal cognitive effects of bilingualism from the last two decades was the development of a framework for understanding metalinguistic development. Bialystok (1986, 1993) proposed a distinction between *representation of linguistic knowledge* and *control of attentional resources*. Analysis of linguistic knowledge is the process by which implicit mental representations are reorganized and refined so that they become more explicit. Children learning to write, for instance, require more explicit knowledge (or higher levels of analysis) of the same rules that can be successfully used in an implicit way when engaging in a conversation. Control of processing refers to focusing attention selectively on different representations or different aspects of representations (focus just on form, or just on meaning) and switching back and forth as needed. Bialystok (1986, 1993) further argued that the bilingual advantage on metalinguistic tasks was in fact due to children's enhanced control skills. This is why bilingual children surpassed monolingual peers when judging the grammaticality of sentences that contained semantic errors, thus having the added demand of ignoring the unusual meaning, but did not differ from monolinguals when the sentences were semantically intact.

Research with metalinguistic tasks led to the hypothesis that the effect of bilingualism was to enhance the performance of the executive function system, not just for linguistic processing, but for nonverbal processing as well (Bialystok, 2001). This proposal represents a new conceptualization of the effects of speaking two languages and over the past two decades has been empirically supported by a growing number of studies with both children

(Bialystok & Martin, 2004; Mezzacappa, 2004) and adults (Costa, Hernández, & Sebastián-Gallés, 2008). These studies have demonstrated that the experience of speaking two languages on a daily basis has consequences for the way in which higher cognitive processes operate and results in more precocious development of inhibition and attentional abilities. However there are limits to the extent to which bilingualism boosts cognitive functioning, and some research finds no difference in performance between monolingual and bilingual children on some measures (Carlson & Meltzoff, 2008). This suggests that bilingualism effects are selective and specific to certain cognitive abilities. But which abilities are these? At present, it is unclear what cognitive abilities are affected by bilingualism, if these effects are further influenced by specific language combinations, and the extent to which other factors such as language proficiency, language of instruction and age of acquisition come into play. Thus, the present review set out to synthesize the existing research on cognitive development in bilingual children of preschool age and to identify the gaps and the methodological concerns present in the existing research. Although reviews and meta-analyses already exist in the literature (Adesope, Lavin, Thompson, & Ungerleider, 2010; Branum-Martin, Tao, Garnaat, Bunta, & Francis, 2012), the present review is unique in its focus on preschool children and the comprehensive range of cognitive processes reviewed. Given that dual language exposure and bilingualism are relatively common experiences for children, identifying the abilities that are affected by bilingualism has important implications for theoretical understanding of cognitive architecture and plasticity and for more practical application in the design of better educational programs for dual language learners.

2. Method

The working definition for dual language learners (DLLs) used in the present review includes all children exposed to two languages during early childhood (Bialystok, 2001). Because of its breadth, this definition allows us to include a large number of studies that examined the consequences of learning two languages under different circumstances and in different communities. Thus, the present review has the potential to capture some of the variability that comes with the bilingualism experience and will lead to more generalizable conclusions than would the investigation of a single community of learners. In the present review, the terms "dual language learner" and "bilingual" will be used interchangeably. To our mind, all dual language learners are potentially "bilingual," and since there is no absolute standard for bilingualism at any age, we consider all the children in these situations to be bilingual to some extent.

This review is part of a series of critical reviews of the literature conducted by the Center for Early Care and Education Research: Dual Language Learners (CECER-DLL), a federally funded national research center in the United States. The inclusion criteria for the present cognitive review were determined by the CECER-DLL team and included: published peer-reviewed journal articles from 2000 to 2013; a focus on typically developing DLLs from birth through age six; a measurement plan that included at least one assessment point occurring during this age span; analyses that focused on DLLs either exclusively or as a subgroup; and research designs that included cross-sectional and longitudinal approaches. There were no restrictions regarding the language pairs to which the children were exposed or the country in which the research was conducted. By including research that has looked at bilingual children who speak English and a non-English language or two non-English languages, it is possible to obtain a clear and comprehensive picture of the consequences of speaking two languages on children's cognitive development. At the same time, this breadth introduces another variable in the discussion, namely, the specific language combinations and whether they change cognitive development in unique ways.

The team further developed a list of specific search terms to be used for the databases selected. The search terms were grouped into three main superordinate categories: language experience (which included 21 subordinate terms such as "dual language learners," "bilingual," "second language learners"), age (which included 12 subordinate terms such as "infant," "toddler," "preschool"), and cognitive function (which included 43 subordinate terms such as "executive function," "theory of mind," "metalinguistic awareness," "brain development," "frontal lobe," "abstract reasoning"). A library scientist assisted the team for the initial electronic database and website searches. The following electronic databases were searched: Medline, PubMed, PsychINFO, PsycArticles, ERIC, Google Scholar, Applied Social Science Index and Abstract. The search strategy, which aimed to find both studies conducted in the United States and internationally, was limited to the English language. The electronic searches were supplemented by checking the reference lists of included articles, existing systematic reviews and meta-analyses (Adesope et al., 2010; Branum-Martin et al., 2012) and hand searching online databases of research. In addition, contact was made with study authors in order to retrieve the full text of some references.

This combined search strategy generated 2738 references related to cognitive development in DLLs. After 81 duplicates were removed, 2657 references remained for the initial review of titles and abstracts by the first author and marked for inclusion or exclusion. Following title and abstract review, 187 articles were deemed potentially relevant and were included for full text review by the rest of the team. Conflicting inclusion or exclusion decisions were resolved through discussion and as a result of this process the team decided that 102 articles met all criteria and were included for the present review. The most common reasons for the title, abstract or full text to be considered irrelevant were related to the age of the study participants (i.e., school-age children as opposed to children ages 0–6 years), to the topic of interest and outcome measures (i.e., language or socio-emotional development as opposed to cognitive development) and to the specific focus on a clinical sample (i.e., children with specific language impairment or at risk for reading disabilities as opposed to typically developing children).

During the data extraction step, information from each article was coded and entered into a table. Information extracted from the articles included: the purpose and design of the study, characteristics of the study participants and setting (including languages studied, sample size, ages), outcome measures, and results. Data were extracted by two graduate students at University of North Carolina, one researcher (Marta Sánchez) and the first author. Two of the team members had been extensively involved in a similar review conducted by the CECER-DLL. In order to ensure consistency of data extraction, the team had phone and email exchanges to resolve questions arising in the process and the first author checked all entries completed by the other team members. Finally, the results were synthesized narratively based on the detailed tabular information extracted for each of the 102 studies included. The summary table is provided as online supplementary material to this manuscript.

3. Results

3.1. General description of the samples in the articles reviewed

The studies included in the present review varied greatly in terms of socio-economic status, languages spoken by children, and children's proficiency in the two languages. There were 38 studies conducted in the United States and 64 international studies.

Research conducted in the United States focused predominantly on Spanish-speaking children learners of English ($n = 30$) who came from relatively low socio-economic background and in many cases attended a Head Start program. Other languages spoken by children from the United States samples were Urdu, Chinese, Cherokee, Korean, and Hmong, for a total of eight studies.

The greatest source of variability among the studies was related to how bilingualism was defined, measured, categorized, and labeled. A variety of terms have been used such as English language learners, dual language users, learners of English as a second language, Spanish-speaking children learners of English, sequential bilinguals, L1 Spanish speakers with minimal L2 English skills, native Chinese and English as a second language, non-native language exposure, early bilingualism, early childhood bilingualism, and early sequential bilingualism. These were considered equivalent for the purpose of the present review and subsumed under the general label of dual language learners. In addition to the variety of definitions and labels used to identify bilingual groups, there was a variety of bilingualism assessments. In order to categorize children as belonging to different language groups, information about children's production and comprehension of language(s) was collected in various ways that included questionnaires filled out by parents and teachers, confirmation from teachers about children's language experience at school and at home, amount of instruction in each language offered to children at school, the language specifications of the school curriculum, and bilingual assessors. Thus, the amount of detail on children's language experience that was gathered by researchers varied from a confirmation from teachers and parents that either English or a non-English language was being used by children at school or at home (Berguno & Bowler, 2004) to elaborate questionnaires that asked for extensive information about quality and quantity of children's language use as a function of context, speaker, age, parents' country of origin, engagement in extra-curricular activities, and language dominance (Rosselli, Ardila, Navarrete, & Matute, 2010). Some studies included specific criteria for children to be categorized as bilinguals: for instance, for children to have (a) parents of different mother tongues who each address the child in their native language, and (b) daily exposure to both languages (Kovacs, 2009).

Most measures used to assess bilingualism were developed by the researchers to serve the needs of their specific studies: The Virtual Linguistics Lab (VLL) Child Multilingualism Questionnaire (Yang, Blumé, & Lust, 2007), Language and Social Background Questionnaire (Luk & Bialystok, 2013), and other brief questionnaires that included a few questions assessing language competence, typically with a 5-point scale for instance (1 = no proficiency to 5 = native-like proficiency). On rare occasions, researchers also included existing measures for examining bilingualism, such as the Language Dominance Survey, EOWPVT-SBE (Brownell, 2001 in Foy & Mann, 2013). Importantly, in the cases where information about children's language use and competence was collected from independent sources such as teachers, parents and bilingual assessors, it was largely consistent across these sources (Dickinson et al., 2004).

Information about socio-economic background was not always reported; when socio-economic status was included it was measured by using parents' education and/or income as a proxy (Yoshida, Tran, Benitez, & Kuwabara, 2011), based on student eligibility for free or reduced price lunch (Betts et al., 2008; Lindsey, Manis, & Bailey, 2003), children's attendance of a Head Start program (Atwill, Blanchard, Gorin, & Burstein, 2007; López & Greenfield, 2010) or characteristics of the home neighborhood (Bialystok, Barac, Blaye, & Poulin-Dubois, 2010). In some cases, parents' education level and income were combined to provide a composite estimate of the socio-economic status (Morton & Harper, 2007). In the majority of studies including information about socio-economic status, bilinguals and monolinguals were either matched on this variable or came from similarly high or low socio-economic backgrounds (Bialystok et al., 2010; Foy & Mann, 2013). In these studies, socio-economic status was not further considered in the statistical analyses because groups were equivalent on this variable. More rarely, when bilingual and monolingual children differed significantly in terms of socio-economic background (Carlson & Meltzoff, 2008), this effect was accounted for in the statistical analyses by covarying out differences in socio-economic status between the groups.

3.2. Research questions addressed by the studies included in the review

The studies identified for this review used either a between-subject design to compare children from different language groups (monolinguals vs. bilinguals, children learning English as a second language, or children attending an immersion program) or a within-subject design to examine performance in two languages with a group of dual language learners. Few studies were found that used a longitudinal design to trace development, specifically metalinguistic awareness, over time in the same children. The purpose of these studies was to identify cognitive skills that are shaped by the experience of speaking two languages, to identify the mechanism underlying the bilingual effects on cognition, to determine how early bilingualism effects on cognition can be documented, and to examine the issue of cross-language transfer and factors associated with bilingualism such as language proficiency and language dominance that impact performance.

3.3. Findings about development

3.3.1. Children's executive function development

An active area of bilingualism research over the last decade has been the study of a set of processes known as the executive function or executive control. These processes include attention, selection, inhibition, monitoring, and flexibility and they develop in parallel with the maturation of the prefrontal cortex. Three main abilities are typically proposed to constitute its core (Diamond, 2006; Miyake et al., 2000): inhibitory control (ability to resist a habitual response or information that is not relevant), working memory or updating (ability to hold information in mind and mentally manipulate it), and cognitive flexibility (ability to adjust to changes in demands or priorities and switch between goals).

About one-quarter of the studies included in the present review ($n = 26$) examined executive function development in children as a function of dual language experience. The majority of studies were conducted in the United States ($n = 9$) and Canada ($n = 10$), with the remaining seven studies being run in Italy ($n = 2$), Israel, Luxembourg, United Kingdom, Germany, and Japan (for each, $n = 1$). For the studies conducted in the United States, Spanish and English were typically the languages spoken by the DLLs ($n = 7$). With very few exceptions (Foy & Mann, 2013; Jia, Kohnert, Collado, & Aquino-Garcia, 2006; Kohnert & Bates, 2002), research on executive function development in children younger than six years of age has focused on non-verbal tasks using mostly visual stimuli.

These studies on the development of the executive function typically employ a between-subject design and compare performance by monolinguals and bilinguals on tasks that are superficially similar but include one condition that additionally requires some aspect of executive control. An example of a task that illustrates these processes in children's cognitive performance is the dimensional change card sort task (DCCS) developed by Zelazo, Frye, and Rapus (1996). The task is presented as a game in which images that vary on two dimensions, usually shape and color, need to be sorted according to one of them. For example, cards containing either red circles or blue squares are sorted into containers marked by an image of either a red square or a blue circle. Children are asked to first sort the cards by one dimension – blues in this box and reds in this box – and then to switch to the other – circles in this box and squares in this box. Thus, this problem places two types of rules in conflict because the same images need to be re-interpreted for the second run and children need to pay attention to the relevant dimension and ignore the previously relevant one. The ability to do this involves several aspects of the executive function – inhibit attending to the irrelevant rule, shift between rules when the game changes, and hold the current rule in mind. The dramatic finding is that young children can easily state the new rule when it changes but continue to sort by the first rule; they have great difficulty overriding the habit set up in the first phase. When this experiment was repeated with bilingual and monolingual children aged between 4 and 5 years, the bilingual children were markedly better at switching to the new rule (Bialystok & Martin, 2004; Okanda, Moriguchi, & Itakura, 2010). Importantly, this result was obtained despite there being no difference in pre-switch performance.

3.3.1.1. What executive control abilities are altered by bilingualism?. From all the executive function abilities, inhibition has been most extensively studied, typically using the child Attention Network Test (ANT). The child ANT is a child-friendly version of the classic flanker task designed by Rueda and colleagues to measure attentional processes in children (Rueda et al., 2004). In the classic flanker paradigm, the target is an arrow pointing to the left or to the right and is surrounded by flankers, stimuli that point in the same (congruent trials) or opposite direction (incongruent trials) as the target (Eriksen & Eriksen, 1974). The typical finding is that participants are slowed down in incongruent trials, when the flankers and the target indicate different responses compared to congruent trials in which both the flankers and the target require the same response. Rueda and colleagues adapted this task and replaced the arrows by colored fish that pointed either to the left or to the right (Rueda et al., 2004). Comparisons of monolingual and bilingual children's performance on this task have shown smaller costs (Mezzacappa, 2004; Yoshida et al., 2011) or more accurate and faster performance (Yang, Yang, & Lust, 2011) for bilinguals on the incongruent trials.

In an important refinement to the research showing a bilingual advantage in executive function, Carlson and Meltzoff (2008) administered nine different executive function tasks to 50 kindergarten children who were English-speaking monolinguals, English-Spanish bilinguals, or children who were in a language immersion elementary school. The major finding was that the English-Spanish bilingual children performed better on the executive function battery than both other groups, once differences in age, vocabulary, and parents' education and income levels were statistically controlled. The effects were specific to only some aspects of control: there were no bilingual advantages in the control of impulses (response inhibition) but significant advantages on conditions requiring memory and inhibition of attention to a prepotent response (interference suppression). In other words, on tasks that required children to refrain from peeking at or opening a nicely wrapped gift, bilingual children did not differ from monolinguals. However, on tasks that required children to focus on selected information such as the middle fish in an array of five fish, and ignore the distractors (i.e., the four fish flanking the middle fish), bilingual children surpassed monolinguals. Therefore, the bilingual advantage in executive functioning tasks reflects precocious development in only specific components of executive control. Similarly, Martin-Rhee and Bialystok (2008) found that bilingual children (speakers of English plus French, Chinese or Spanish) showed an advantage over English-speaking monolinguals, but only on the Simon task that measured interference suppression; in contrast, on a response inhibition task, monolinguals and bilinguals performed equivalently. However, the equivalent performance on response inhibition tasks is not a consistent finding. For instance, a recent study showed that the bilingual enhancement of executive control was found in a nonverbal auditory response inhibition task (Foy & Mann, 2013). In the study by Foy and Mann (2013), 5-year-old Spanish-English bilingual and monolingual children performed two auditory tasks: verbal and nonverbal. The nonverbal task used a go/no-go experimental design and children were asked to respond to a target sound (barking dog) and ignore a distractor (ringing bell). The verbal task had a similar design but the target and distractor verbal stimuli were the syllables/ba/and/pa/. As hypothesized and consistent with previous research, bilingual children had higher accuracy and shorter reaction times than monolinguals only on the nonverbal task. The authors argue that the findings provide indirect support for a domain-general processing advantage in bilinguals.

Although early research on executive control focused predominantly on inhibitory tasks, it is important to note that bilingual enhancements in executive function are not limited to inhibition. In one study, Bialystok (2010) found a bilingual advantage in processing complex stimuli in tasks that require executive processing components for conflict resolution, including switching and updating, even when no inhibition appears to be involved. Additionally, other evidence has shown that these effects of bilingualism extend to working memory tasks (Morales, Calvo, & Bialystok, 2013), and cognitive flexibility (Adi-Japha, Berberich-Artzi, & Libnawi, 2010). However, in the area of working memory, the bilingual advantage has not been consistently found. For instance, Engel de Abreau (2011) compared the performance of 6-year-old monolingual and bilingual children in Luxembourg on simple and complex working memory tasks and found no difference between the two language groups after controlling for verbal abilities. In contrast, in the study by Morales and colleagues (Morales et al., 2013), 5-year-old bilingual children in Canada outperformed monolinguals on tasks of working memory that posed additional executive control demands. Although, at present, there is too little research on working memory in bilingual children to draw firm conclusions, the existing evidence suggests that a bilingual advantage in working memory is especially evident when the task contains high levels of executive function demands (Morales et al., 2013).

In addition to the research investigating bilingual effects on nonverbal executive function tasks, a minority of studies has examined cognitive control involved in verbal processing (Foy & Mann, 2013; Jia et al., 2006; Kohnert & Bates, 2002). In one of these studies, early sequential Spanish-English bilingual children had to name action pictures in two experimental conditions: single-language (Spanish or English) and mixed-language (alternating between Spanish and English). In the mixed-language condition, children showed slower reaction times and lower accuracy than in the single-language condition (Jia et al., 2006). Similarly, in the study by Kohnert and Bates (2002), there were differences between mixed and single-language conditions in language production tasks, suggesting potential inter-language interference. These findings from experimental tasks with bilinguals parallel the switch cost previously documented in non-linguistic tasks in studies comparing monolinguals and bilinguals (Barac & Bialystok, 2012). Interestingly, in the Jia et al.'s study (2006) this switch cost was found in bilingual children between 5 and 13 years of age, but not in the oldest group (14–16 years). The authors attributed the better management of competition in the mixed language condition in the oldest bilinguals to a combination of typical cognitive development and a boost of executive control processing associated with the prolonged and systematic experience of speaking two languages.

3.3.1.2. How early can the bilingual advantage be detected?. The benefits of the bilingual experience on children's cognitive development have been documented at various ages ranging from 2 to 6 years. Recently, Kovacs and Mehler (2009a) extended this pattern to infants. They presented 7-month-old infants with a verbal cue followed by a visual reward. The verbal cue consisted of a meaningless trisyllabic auditory stimulus and the visual reward was a toy that always appeared on the same side of the screen. Infants quickly learned that the verbal cue predicted the location of the toy reward and made anticipatory looks toward the location where the reward was going to appear when they heard the auditory cue. Monolingual and bilingual infants were equally good at learning this relation. However, in the second part of the task, the rule was changed so that the toy reward appeared on the opposite side of the screen. Thus, again, infants had to learn that the cues predicted the location of the toy, but to do so they needed to overcome the old response, the tendency to look to the side of the screen that was previously rewarded. In this sense, infants needed to rely on executive functions in order to be able to switch to the new location. Kovacs and Mehler (2009a) found that 7-month-old infants raised in bilingual households were better able to switch responses after a rule shift than were their peers raised in monolingual households. These results suggest that the experience with two languages changes the cognitive system from very early on.

Related to the question of how early the bilingual advantage can be documented is the question of how much dual language experience is necessary to distinguish the performance of monolingual and bilingual children. In the study by Carlson and Meltzoff (2008), three groups of kindergarten children performed a set of executive function tasks: English-speaking monolinguals, native Spanish-English bilinguals and children attending a second language immersion program in which half of the instruction in English and the other half in Japanese or Spanish. At the time of testing, children in the immersion group had received about six months of exposure to a second language. After controlling for verbal abilities, age and parental socio-economic status, the native bilingual children outperformed the other two language groups which did not differ from each other. These findings suggest that early, systematic dual language exposure leads to enhancements of executive control processing and six months of second language immersion for half of the instruction day might not be sufficient to confer such an advantage in executive control.

3.3.1.3. But is it really bilingualism that is responsible for this advantage in executive function performance or it is something else?. Bilingualism is often correlated with other types of experience that may themselves influence performance, so it is difficult to be sure that the performance differences between monolinguals and bilinguals are caused by bilingualism per se. For example, Morton and Harper (2007) claimed that the reported bilingual advantage was due to socio-economic differences between monolingual and bilingual children that favor the bilingual children. There is no doubt that socio-economic status is a powerful influence on executive control, but it does not undermine the body of literature for which bilingual advantages have been recorded (Bialystok, 2009). Similarly, claims for cultural effects favoring Asian children on tests of executive control (Sabbagh, Xu, Carlson, Moses, & Lee, 2006) must be separated from the role of bilingualism in shaping this performance. Several studies have addressed this issue and demonstrated that bilingualism affects cognitive performance independent of other factors. For instance, Bialystok et al. (2010) examined the role of culture and immigration history on the cognitive outcomes of bilingualism. Bialystok and colleagues (2010) compared a group of bilinguals to two monolingual groups – an English-speaking group in Canada and a French-speaking group in France. Results showed no difference between the two monolingual groups and better performance by the bilinguals on all the executive control tasks that involved conflict resolution. Similarly, Yang et al. (2011) examined bilingualism and cultural effects on executive function performance by comparing 4-year-old U.S. Korean-English bilingual children to three monolingual groups – English and Korean monolinguals in the U.S. and another Korean monolingual group, in Korea. Bilingual children had the fastest and most accurate performance compared to all three monolingual groups demonstrating that bilingualism is advantageous to executive attention development. Finally, in the study by Barac and Bialystok (2012), three groups of bilingual children (Chinese-English bilinguals, French-English bilinguals, Spanish-English bilinguals) who differed from each other in terms of the relationship between the two languages, cultural background, and language of schooling, all showed better executive control than English monolinguals. In this study, all children were 6-years-old and all except the French bilingual children were being educated in English. This is in line with findings of studies with slightly older children (i.e., 8-year-old children; Bialystok and Viswanathan, 2009) showing that bilingualism acts independently of variables such as cultural background and immigration history in influencing nonverbal executive function outcomes. Thus, these studies endorse the conclusion that bilingualism itself is responsible for the increased levels of executive control reported in the literature.

To sum up, these findings demonstrate a robust bilingual advantage in executive control that is apparent as early as the first year of life, holds across various language pairs, and is distinct from the effects of culture, immigration history, and language of instruction. Although bilingual children outperformed monolinguals on a variety of executive control tasks assessing different executive function components, this advantage is relatively more robust for inhibitory control and cognitive flexibility, and less so for working memory, which has been explored to a lesser extent.

3.3.2. DLLs' metalinguistic development

Another important aspect of metacognitive development during the preschool years is metalinguistic awareness. Metalinguistic ability allows children to see through the meaning of language to its underlying structure. With metalinguistic ability, children can analyze linguistic representations to extract general grammatical rules and state them explicitly, and control attention to different aspects of a sentence or a word such as its form or its meaning. Tests of metalinguistic awareness, therefore, typically include conflicting information about form and meaning to determine children's understanding that they are separate and their ability to attend to them individually.

Compared to the other cognitive abilities, metalinguistic awareness has a longer history and has been more extensively researched in the bilingual population. About half of the studies included in the present review focused on metalinguistic abilities. The majority of studies were conducted in the United States ($n = 21$), Canada ($n = 8$), Hong Kong ($n = 6$), Singapore ($n = 5$) and China ($n = 4$), with the remaining coming from Israel, India, Korea, Taiwan, United Kingdom, Finland, and Holland. For the United States samples, Spanish and English were typically the languages spoken by children, with a few exceptions that included Cherokee (Hirata-Edds, 2011), Urdu (Davidson, Raschke, & Pervez, 2010), Korean (Kim, 2009), and Hmong (Roberts, 2005). In addition, children from the United States samples typically came from families with a low socio-economic status.

Of the different metalinguistic abilities, phonological awareness has received most attention. Phonological awareness is the ability to recognize and manipulate linguistic sounds separate from their meanings and has been shown to have a significant contribution to children learning to read. Standard phonological awareness tasks include rhyming, blending, and sound deletion ("Say mat without the/t/"). Far less studied in this 0–6 age group within the last 13 years were syntactic awareness (Davidson et al.,

2010) and morphological awareness (Cheung, Chung, et al., 2010; Deacon, Wade-Woolley, & Kirby, 2007; Hirata-Edds, 2011). In syntactic awareness tests, children are usually required to identify correct and incorrect grammatical constructions (i.e., grammatical judgment measures). Morphological awareness is the recognition of and ability to manipulate the meaning structure of language such as identification of variations in the form of the word that are related to plural formation, grammatical gender or verb tense (Cheung, Chung, et al., 2010). The research on the sub-components of metalinguistic abilities is reviewed below, beginning with morphological and syntactic awareness followed by phonological awareness.

3.3.2.1. Morphological and syntactic awareness. Research on metalinguistic awareness has used both between-subject designs to compare monolingual and bilingual children's abilities and within-subjects designs to examine cross-linguistic transfer in dual language learners. In terms of morphological and syntactic awareness, research comparing monolingual and bilingual children has typically reported a bilingual advantage (Davidson et al., 2010; Hirata-Edds, 2011). For instance, in the study by Davidson and colleagues (2010), Urdu-English bilingual children and English-speaking monolinguals in two age groups – three to four years of age in experiment 2 and five to six years of age in experiment 1 – were asked to identify grammatically correct and incorrect sentences. The older children were tested in English only, whereas the younger children performed the syntactic awareness test in both English and Urdu. Bilingual children of both ages were better at identifying grammatically incorrect sentences than monolinguals and had equivalent performance in judging the grammatically correct sentences. Younger children, who were tested in both languages, showed this advantage in processing grammatically incorrect sentences only in Urdu and not in English. This pattern of results was found despite the fact that bilingual children showed similar receptive vocabulary in the two languages. The authors proposed that this selective advantage in Urdu might be related to Urdu being the first language and the language of the home for this group of bilingual children. In addition, consistent with previous research, children's receptive vocabulary was correlated with their ability to identify grammatically incorrect sentences in the same language (experiment 2), thus showing no evidence for cross-linguistic transfer.

A study by Hirata-Edds (2011) produced similar results. In that study, 4.5- to 6-year-old children attending a Cherokee immersion program showed better or comparable performance to English monolinguals on measures of morphological awareness that required identifying correct past tense forms for various categories of English verbs. It is important to note that children learning Cherokee in this study had attended the immersion program for only one year and so they had limited exposure to a second language. The author attributed the lack of a generalized advantage across all types of morphological awareness tasks in the immersion group to children being in process of acquiring a second language and thus perhaps not having reached a threshold of fluency that translates into metalinguistic advantages, as well as the limited nature of the L2 experience (i.e., possibly L2 needs to be used not just in conversation but also in more complex activities such as literacy). Additionally, this study showed that learning a second language is not detrimental to performance in the first language. Notably, children in this study were speakers of a majority language and learned another language after the first one was relatively consolidated.

A different study by Barac and Bialystok (2012, described above) highlighted additional variables that influence morphological awareness performance. In this study, three groups of bilinguals (Spanish-English, French-English, Chinese-English) and a group of English monolingual children were given the Wugs test, which is a measure of morphological awareness, in addition to a non-verbal executive control task. In the Wugs test (Berko, 1958), children are presented with pictures of novel objects, animals, plants, or actions, and hear a text that introduces a pseudo-word such as "wug" and "kazh." Children need to complete the sentence using the target word by applying English morphology rules for noun plural, past tense and other aspects of grammar to the new words. The Chinese-English bilingual and the French-English bilinguals did not differ from each other (or from the monolinguals), and the best performance, significantly different from the former, was achieved by the Spanish-English bilingual children. For the latter, two factors combined to produce their superior performance: the language of instruction was the same as the language of testing and their two languages had considerable structural overlap. It is interesting to note that cultural background, language pairs, and language of instruction did not matter for executive function performance (i.e., the three bilingual groups were not different from each other and outperformed monolinguals), but they shaped performance on a language task.

Although many questions still remain, the small body of research investigating syntactic and morphological awareness in children learning a second language has shown no costs for bilingual children relative to monolinguals and, in fact, better or equivalent performance by dual language learners. This conclusion is consistent with research conducted prior to 2000 (Cromdal, 1999; Galambos & Goldin-Meadow, 1990). This research also highlighted variables associated with bilingualism that possibly contribute to or condition this pattern of findings: status of the language, namely if it is the first or second language, or if it is the language of the majority or not, where, when how much the language is being used, fluency and experience with the language.

3.3.2.2. Phonological awareness. Most of the research on metalinguistic awareness has targeted phonological awareness skills in dual language learners, presumably because it is one of the key components of emergent literacy. Similar to the studies on syntactic and morphological awareness, research on phonological awareness uses both between- and within-subject designs. Results generally show that multiple variables related to the bilingual experience come into play and shape the development of phonological awareness skills in each language and demonstrate how these skills further relate to other literacy developments. As a consequence of multiple variables influencing phonological awareness performance, research investigating phonological awareness skills in DLLs has shown mixed results, with bilingual children performing better, the same or even worse than monolingual peers. For instance, in two studies, Bialystok et al. (2003) found no differences between monolinguals and French-English bilinguals on a phoneme substitution task ("Take away the first sound from the word cat, and put in the first sound from the word mop") and language of instruction effects (i.e., performance on the phonological awareness task was higher if testing was done in the language of school instruction). In addition, a third study conducted with 6- and 7-year-olds showed a boost in performance on a phoneme segmentation task in Spanish-English bilinguals and a decrease in performance in Chinese-English bilinguals relative to monolingual children. The phoneme segmentation task required children to "spread out" and count the sounds of a given word using poker chips. The authors attributed the Spanish-English advantage to the increased similarity between Spanish and English relative to Chinese and English and to the regularity of the phonetic structure of Spanish which facilitates access to phonological awareness in children. Similarly, Dodd, So, and Lam (2008) found evidence for a specific language effect on phonological awareness as demonstrated by their finding that Cantonese-Putonghua bilingual children had better syllable awareness than monolingual

Cantonese-speaking control group whereas the Cantonese-English bilinguals showed no overall advantage over the monolingual Cantonese-speaking children.

Other research comparing monolingual and bilingual children's phonological awareness skills has also reported mixed results. Specifically, there is evidence for a bilingual advantage in Russian-Hebrew bilinguals relative to Hebrew monolinguals (Eviatar & Ibrahim, 2000; Ibrahim, Eviatar, & Aharon-Peretz, 2007), Korean-English bilinguals relative to Korean monolinguals (Kang, 2012), English-Greek bilinguals relative to English monolinguals (Loizou & Stuart, 2003) and Putonghua-Cantonese bilinguals relative to speakers of Putonghua and Cantonese (Dodd et al., 2008). Similarly, Chen and colleagues showed that English instruction enhanced the development of phonological awareness skills in Chinese as revealed by performance of Chinese speakers who received English instruction or not (Chen, Xu, Nguyen, Hong, & Wang, 2010). However, there is also evidence for equivalent performance on phonological awareness tasks in Greek-English bilinguals and Greek monolinguals (Loizou & Stuart, 2003), in Russian-Finnish bilinguals and Finnish monolinguals (Silvén & Rubinov, 2010), and in Cantonese-English bilinguals and Cantonese monolinguals (Dodd et al., 2008). Furthermore, in one of the studies by Dodd and colleagues, monolingual Putonghua speakers outperformed bilinguals on the phoneme detection task (Dodd et al., 2008). Thus, overall, these studies have shown an inconsistent profile of findings in which bilingualism facilitates, hinders, or does not make any difference to the development of phonological awareness skills in preschool children.

In terms of the factors contributing to this mixed profile of results, as noted earlier, specific language pairs and language-specific characteristics have been found to shape metalinguistic skills in bilingual children. Interestingly, in the study by Loizou and Stuart (2003) comparing two groups of bilinguals who had either English or Greek as a first language (i.e., English-Greek and Greek-English bilinguals) and two groups of monolinguals (Greek- and English-speaking), the bilingual advantage was observed only in the English-Greek bilinguals. The authors proposed that bilingualism is facilitative of the development of phonological awareness skills as a function of the relative phonological complexity of the child's first and second language and typically a bilingual advantage is documented when the second language is phonologically simpler than the first. In the case of the Greek-speaking children learning English as a second language, the opposite pattern is found where the second language is phonologically more complex than the first and so there is no boost in the development of phonological awareness.

In the study by Ibrahim and colleagues (Ibrahim et al., 2007), the authors tested phonological awareness skills and reading performance in three groups of children (Arabic speakers, Hebrew speakers, and Hebrew-Russian bilinguals) and found that both Arabic speakers and Hebrew-Russian bilinguals showed greater phonological awareness skills than Hebrew monolinguals. These results were interpreted to suggest that language experience – including both the experience of speaking two languages and specific language characteristics – shape metalinguistic performance. Moreover, orthography was shown to play an important role as well: Hebrew speakers, regardless of whether they were monolinguals or bilinguals, showed better text reading abilities than Arabic speakers and this performance was correlated with phonological abilities, whereas for Arabic speakers, the correlation between reading performance and phonological abilities was very weak. Ibrahim and colleagues argue that the visual complexity of the Arabic language is responsible for the finding that Arabic speakers have more difficulty processing Arabic orthography compared to Hebrew monolinguals and bilinguals processing Hebrew orthography.

3.3.2.3. Cross-linguistic transfer. Many studies examining phonological awareness in DLLs have used a within-subject design and compared skills in the two languages in order to explore the notion of cross-linguistic transfer. Results typically show correlation between performance on phonological awareness measures in the two languages, consistent with the idea of cross-linguistic transfer (Anthony et al., 2009; Atwill et al., 2007; Chen et al., 2010; López & Greenfield, 2010; Verhoeven, 2007). For instance, Dickinson and colleagues (Dickinson et al., 2004) found transfer of phonological skills from L1 to L2 in a group of 4-year-old low-income Spanish-English bilingual children. Similarly, Atwill and colleagues (2007) found evidence for cross-linguistic transfer as illustrated by the correlation between English and Spanish measures – in a sample of low socio-economic status Spanish-speaking children with limited English abilities in the United States. However, when the sample of kindergarteners was divided into two sub-groups based on Spanish receptive vocabulary (i.e., children with vocabulary smaller or larger than average), the correlation in the group with low Spanish vocabulary disappeared. These results suggest that cross-linguistic transfer is conditional on proficiency in the L1, an interpretation that is in line with Cummins (1979) that the degree of competency in L1 influences the competency achieved in L2. Furthermore, Anthony et al. (2009) found that, in a group of low socio-economic status Spanish-speaking English language learners in the United States, children's competence with phonological awareness in one language transferred to their competence in phonological awareness in the other language, but these cross-linguistic influences were smaller than previously reported in other studies. This difference in the size of the cross-linguistic influence was possibly due to the fact that the researchers controlled for the effects of the classroom, in other words took into account the nesting structure of the data. When the same analyses were performed without controlling for classroom effects, the size of the cross-linguistic transfer was as large was previously documented. Thus, together these studies have shown that there is cross-linguistic of phonological awareness, but it is influenced by variables such as proficiency in the first language and requires separating the classroom effects from children effects.

In conclusion, the findings of the research on metalinguistic awareness in bilingual children paint a relatively inconsistent picture that include advantages in performance related to dual language learning, equivalent performance for monolingual and bilingual children, and sometimes bilingual costs. These inconsistencies have been found to be related to features of the languages, typological distance between languages, instructional context in which children learn and use the two languages involved, language proficiency, and task demands. In addition, the results demonstrated that metalinguistic skills transfer from one language to another, but the size of the cross-linguistic transfer is constrained by language proficiency and nesting structure of the data. Thus these results point to the importance of evaluating these variables in the investigation of the development of metalinguistic awareness in DLLs.

3.3.3. Children's brain development

Only 10 of the studies reviewed examined brain development in children as a function of dual language experience. Four of these studies were conducted in United States with infants between 6 and 20 months, all being exposed to Spanish and English (Conboy & Mills, 2006; Conboy & Kuhl, 2011; Garcia-Sierra et al., 2011; Shafer, Yu, & Garrido-Nag, 2012). The remaining six studies were conducted in Japan (Japanese and English; Hidaka et al., 2012; Takahashi et al., 2011), United Kingdom (Welsh and English; Kuipers & Thierry, 2012), Canada (English in addition to French, Spanish, Chinese; Petitto et al., 2012), Germany (German and Turkish; Rinker, Alku, Brosch, & Kiefer, 2010) and

Finland (Finnish and French; Shestakova, Huotilainen, Ceponiene, & Cheour, 2003).

These 10 studies included for the present review used two different brain measurement technologies: event-related potentials (ERPs; $n = 8$) and functional near-infrared spectroscopy (fNIRS; $n = 2$). ERPs have excellent temporal resolution and so this method provides an online measure of brain activity with a precision of milliseconds. Despite the excellent temporal resolution, ERPs have very poor spatial resolution, so it is difficult to establish the exact neural source of the voltage recorded at the scalp level. In contrast, fNIRS provides good anatomical localization and excellent temporal resolution (Petitto et al., 2012). All studies focused on how dual language experience changes brain responses to processing verbal tasks; none of the studies included measures of nonverbal cognition.

Overall, the findings from all 10 studies are consistent in demonstrating that the task of building up linguistic knowledge in two languages, in other words creating and accessing phonological, lexical, and semantic representations, induced functional brain changes in children. For instance, in one study, 19- to 22-month-old Spanish-English bilingual children were tested by recording ERPs to known and unknown words in both languages (Conboy & Mills, 2006). The results demonstrated that language experience altered the organization of language in the brain as indicated by differences in ERP responses between infants with low and high vocabularies in each language and between the patterns elicited by infants' dominant and non-dominant languages. Latency analyses showed that processing of known and unknown words occurred earlier in the dominant language than in the non-dominant language. Similarly, Rinker and colleagues found that language experience influenced the electrophysiological brain responses of 5–6-year-old German monolinguals and Turkish-German bilinguals in their study comparing ERPs to vowel contrasts unique to German or common to both German and Turkish (Rinker et al., 2010). The study focused on one ERP component, the mismatch negativity, which is particularly sensitive to differences in processing between native and non-native phonemes. The bilingual children showed a less pronounced brain response for the German-specific contrast compared to the German-speaking monolinguals, but did not differ from the monolingual children on the contrast that exists in both Turkish and German. The authors interpreted these findings to show that the Turkish-German bilingual children have not fully acquired the German phonetic system, but they have adequately acquired the phonetic contrasts that are common to both languages.

The studies summarized so far used ERPs and so their conclusions are limited to differences in timing, and not localization or topography of brain responses as a function of dual language experience. As mentioned, fNIRS has the advantage of offering a window into the spatial characteristics of brain responses. In their fNIRS study, Petitto and colleagues (2012) found that phonetic processing in bilingual and monolingual babies recruited the same language-specific brain areas as typically documented in adults, including the left superior temporal gyrus (involved in phonetic processing) and the left inferior frontal cortex (involved in meaning retrieval and processing of syntactic and phonological patterns). Monolingual and bilingual infants in this study belonged to two different age groups (4–6 months and 10–12 months) and were exposed to linguistic phonetic (native and non-native) units and non-linguistic tones. The finding that both bilingual and monolingual babies activate similar areas as adults when they process linguistic phonetic stimuli is important and suggests that this early specialization for language is likely biologically determined. However, experience matters as well: the 10–12 month-old infants exposed to two languages showed robust activation in the left inferior frontal cortex to both native and non-native contrasts, whereas the monolingual infants activated the same area in response to native contrasts only. Thus, being exposed to two languages changes the way in which the brain processes linguistic stimuli from *any* language. Petitto and colleagues interpreted these findings to show that receiving input from two languages serves as a kind of "perceptual wedge" that increases plasticity and opens the linguistic processing across language systems.

Two studies also examined the functional brain changes in children processing linguistic tasks after short-term exposure to a second language (Conboy & Kuhl, 2011; Takahashi et al., 2011). Thus, these studies did not look directly at the impact of bilingualism on linguistic processing but rather at the neural signature of short-term exposure to a second language. These studies investigated phonological or semantic performance in infants or pre-school children. Both studies showed that having limited experience with a second language changed the brain responses to verbal tasks. These results are important because they demonstrate that even very limited exposure to a second language shapes brain responses in young children.

In the first study, Conboy and Kuhl (2011) tested English monolingual infants at 9 and 11 months, before and after a month of naturalistic exposure to Spanish. The authors collected ERPs from infants who were presented with contrasts that were phonemic either in English or in Spanish. At 9 months, before exposure to a second language, infants showed the typical mismatch negativity in response to English contrasts, but no discrimination of the Spanish contrasts. However, after only one month of exposure to Spanish, infants showed the neural signature of a second-language phonetic learning illustrated by the presence of a mismatch negativity response to the Spanish contrast. Importantly, this second language phonetic learning did not come at the cost of native language phonetic learning – in fact, post-exposure to Spanish, infants showed improved processing of the native contrast as indicated by earlier latency of the brain responses to the English phonemes.

In the other study, Takahashi and colleagues focused on semantic processing indexed by the N400 component to Japanese sentences that had congruous ("My father eats an apple") and incongruous ("My father eats a bathtub") endings. The authors tested four groups of Japanese-speaking children: 4- and 5-year-old children who were never exposed to English, 4-year-olds with about 30 h of English exposure and 5-year-olds with about 290 h of English exposure in a kindergarten setting. The results indicated that in children with longer exposure to a second language, the N400 showed an earlier onset and more distributed brain topography, suggesting again that systematic exposure to a second language alters the brain processing of the native language.

Together, these studies demonstrate that experience with two linguistic systems, no matter how short and regardless of the language pairs involved, changes the way in which language is organized in the brain. Furthermore, these functional brain changes are present very early on, after only limited bilingual experience, suggesting that setting up representations in two linguistic systems through exposure to two languages, and not only language production, drives functional plasticity in bilingual children.

It is important to emphasize that this research has focused exclusively on *brain function* in response to *linguistic tasks*. Thus, to date, no studies have investigated the neural correlates of non-verbal executive processing in bilingual children. Similarly, no studies have examined structural brain changes in preschool bilingual children, although the topic has been recently investigated with older children (Mohades et al., 2012). In their study, Mohades and colleagues (2012) reported changes in white matter microstructure in simultaneous and sequential bilingual children between 8 and 11 years of age in two of the four white matter tracts investigated (i.e., left inferior occipitofrontal fasciculus and the anterior part of the corpus callosum projecting to the orbital lobe than monolingual children). Notably, the strongest effect was found in bilingual children who learned the second language at an earlier age, that is, simultaneous bilinguals, with sequential bilinguals showing a neural profile intermediate to that of monolinguals and simultaneous bilinguals.

3.3.4. Children's theory of mind development

Theory of mind is a key metacognitive development during the preschool years and refers to children's ability to ascribe mental states to other people. Of the studies reviewed, seven examined development of theory of mind in dual language learners and only one of these studies was conducted in United States with Chinese-English bilinguals and English monolinguals (Goetz, 2003). The remaining six studies were conducted in United Kingdom (L1 English, L2 unspecified; Berguno & Bowler, 2004), Canada (heterogeneous language group; Bialystok & Senman, 2004), Hong Kong (English and Cantonese; Cheung, Mak, Luo, & Xiao, 2010), Romania (Romanian and Hungarian; Kovacs, 2009), India (English and Marathi; Tare & Gelman, 2010) and Iran (Kurdish and Persian; Farhadian et al., 2010).

Typically in these studies, children were given a false belief task – unexpected location, unexpected content, or appearance-reality conflict. Successful performance in all these tasks requires an understanding of the distinction between the state of the world and the child's or other person's belief about this state. In the case of the appearance-reality task, children are shown a sponge/rock, for instance, in which the appearance is consistent with the visual features of a rock but its compositional structure is actually a sponge (Bialystok & Senman, 2004). Children are shown the object and given the opportunity to interact with it to discover its properties. Importantly, this presentation is followed by two types of questions: what children thought the object looked like before its true identity was revealed (appearance question) and what it actually is (reality question). Performance on the reality question only was predicted by performance on inhibitory control tasks and Bialystok and Senman (2004) argue that these questions test different kinds of abilities: representational ability in the case of appearance questions and inhibitory control in the case of the reality question (i.e., the correct answer requires successfully inhibiting the perceptual characteristics of the object, for instance its "rocky" appearance to acknowledge a less apparent reality, that the object is a sponge).

Most studies used a between-subject design and compared the performance of bilingual and monolingual children. A couple of studies, however, did not include a monolingual group and instead examined the links between DLLs' pragmatic abilities to switch between languages to accommodate for the listener's needs on the one hand and theory of mind performance on the other hand. For the between-subjects studies, the results comparing monolinguals and bilinguals showed a remarkable consistency in that, across various language pairs, bilingual children outperformed monolinguals, demonstrating enhanced understanding of mental representations and false beliefs. These findings show that the experience of speaking two languages does not only impact linguistic processing, but also extends to children's understanding of other people, their mental and knowledge states.

Why would bilingualism have consequences for theory of mind development and what is the possible mechanism for this effect? Some of the studies included in the present review employed a design that allowed an exploration of possible mechanisms underlying enhanced theory of mind performance in bilingual children. In the study by Bialystok and Senman (2004), bilingual children performed better than monolinguals on the reality question after controlling for vocabulary (bilingual children typically have smaller monolingual vocabulary than monolingual children, all else being equal; Bialystok et al., 2010), but both groups performed equivalently on the appearance question. The difference between these questions is that executive control, in particular inhibition, is required for the reality question but not for the appearance question which relies on simple short-term memory. This pattern of findings supports the notion that bilingual children's advanced inhibitory processing may be responsible for superior theory of mind abilities. In a different study, Kovacs (2009) reached a similar conclusion. Kovacs (2009) included a modified theory of mind task in addition to a standard theory of mind task and a control task involving physical reasoning. The modified task mimicked a language-switch situation and included two puppets, one monolingual and one bilingual, who approach an ice-cream stand interested in buying ice-cream. As they approach, the vendor announces in the language unknown to the monolingual puppet that the stand has no more ice-cream but they can find ice-cream at the sandwich stand. The experimenter emphasized that the monolingual character does not understand the language spoken by the vendor and then asked the child participant 'Where will the monolingual puppet go to buy ice-cream?' The inclusion of this task, in addition to the standard theory of mind task, allows distinguishing between two explanations for the performance of the bilingual children: general advantage in inhibitory control or a specific advantage in understanding other people's mental states related to language knowledge. If the inhibitory account is correct, bilingual children should outperform monolinguals on both theory of mind tasks, as they have similar inhibitory demands. Alternatively, if bilingual children's performance on theory of mind tasks is boosted by their understanding that people differ in their language knowledge, then bilingual children should outperform monolinguals only in the modified theory of mind task. Results from Kovacs (2009) study supported the inhibitory control account as the 3-year-old bilingual children performed better than monolinguals on both theory of mind tasks, but not on the control task.

In addition to the evidence that differences in inhibitory processing account for superior theory of mind in bilingual children, other research has explored the links between sociolinguistic awareness and theory of mind in bilingual children. In a study conducted by Cheung and colleagues (Cheung, Mak, et al., 2010), sociolinguistic awareness was operationalized as the child's ability to adjust his or her language use as a function of the experimenter's language knowledge. Their sociolinguistic awareness task captured the child's ability to switch between Cantonese and English in order to match the language spoken by the experimenter. In addition, children received a standard theory of mind task. The results showed second-language learners and bilingual children differed from each other in terms of sociolinguistic awareness and theory of mind, with bilingual children having superior performance on both tasks. However, for both second-language learners and more balanced bilingual children, sociolinguistic awareness predicted performance on the false-belief task. The authors argued that the more precocious understanding of other people's mental representations in dual language learners is related to children's practice and adjustments required in the process of communicating with speakers of different languages, in other words by their sociolinguistic awareness. It is important to note that since inhibitory control was not examined in this study, it cannot be ruled out as a contributor to children's performance on the false belief tasks and in fact it is possible that it is responsible for the better theory of mind performance in the balanced bilingual group. Similarly, Tare and Gelman (2010) showed that bilingual children's pragmatic abilities to differentiate and use Marathi and English across different contexts were correlated with children's theory of mind.

In sum, although there is relatively little research examining development of theory of mind in DLLs, the findings consistently demonstrate more advanced theory of mind understanding in bilingual children. This precocious development in bilingual children has been documented regardless of the languages spoken by children and has been linked to both enhanced inhibitory processing and better sociolinguistic awareness in bilingual children.

3.3.5. Children's memory development

In contrast to executive function and metalinguistic awareness, little research has investigated memory development in dual language learners. Some of the research has focused on working memory and these findings have been reviewed in the previous section, as part of the executive control system. In some cases, memory tasks have been used as control measures – and not as main experimental tasks – to ensure that different language groups are comparable in terms of different aspects of cognitive development (Bialystok, 2010; Bialystok & Senman, 2004; Bialystok & Martin, 2004; Foy & Mann, 2013). Typically these studies used simple digit span measures and found no differences between monolingual and bilingual children.

Studies that set out to specifically investigate memory abilities in bilingual children have been conducted in the United States (Brito & Barr, 2012; Lanfranchi & Swanson, 2005) and the Netherlands (Messer, Leseman, Boom, & Mayo, 2010). Lanfranchi and Swanson examined short-term memory (i.e., passive storage of information) and working memory (i.e., storage plus active processing of information) capacity in English and Spanish in 6-year-old children who received formal instruction in English at school and typically spoke either Spanish or a combination of Spanish and English at home. No monolinguals were assessed and all tasks were administered in both Spanish and English. The purpose of the study was to examine whether or not short-term memory and working memory are language dependent in dual language learners. The main finding was that short-term memory is language dependent whereas working memory is language independent. In other words, children with higher English vocabulary had better performance on English short-term memory measures than those with lower vocabulary and children with higher Spanish vocabulary had better performance on Spanish short-term memory measures than those with low Spanish vocabulary. In contrast, for working memory tasks, having a high vocabulary in English or Spanish did not improve performance when testing was conducted in that specific language. The authors proposed several explanations for the difference in the language effects found for short-term memory and working memory that are possibly related to the language of instruction, control processes in the dominant language, and inhibition in English.

The study by Brito and Barr (2012) used a between-subject design and compared 18-month-old monolingual and bilingual infants. Infants were assigned to one of two conditions: the generalization condition in which the experimenter performed three target actions with a duck puppet (pull off mitten, shake mitten to ring the bell, replace mitten) and a baseline condition in which no action was demonstrated. After a 30-min delay, infants were shown a novel puppet and encouraged to interact with it. Bilingual infants outperformed monolinguals in their ability to generalize the observed actions to a new puppet. Interestingly, performance on the memory generalization task was predicted by infants' exposure to the second language and not by their vocabulary. This finding with infants is consistent with results from Bialystok and Barac (2012) study with 8-year-old children in immersion programs showing that the length of time in the immersion program was related to performance on non-verbal executive control tasks and level of proficiency in the language of testing was related to performance on metalinguistic tasks. The authors attributed the bilinguals' advantage in memory generalization to enhanced selective attention, more precocious development of the ability to form relational representations, and enhanced links between frontal lobe and hippocampus.

Given that the research on the relation between memory and bilingualism during the preschool years is limited, it is difficult to draw firm conclusions about the specifics of this interaction. The existing evidence, however, points to the interpretation that dual language learning influences the development of domain-general abilities, such as memory, even early in development, and that language effects differ for short-term memory and working memory.

3.3.6. DLLs' performance on neuropsychological assessments

Although the last decades of bilingualism research have demonstrated consistent differences between monolingual and bilingual children in cognitive, language and brain development, it is still common procedure to use normative data from monolingual children to provide neuropsychological assessment for bilingual children. Given that neuropsychological tests can be used for the purposes of classifying children, providing diagnosis or treatment, it is important to get the measurement right and consider the factors that might impact performance, such as the experience of speaking two languages. To address this issue, three of the studies included in the present review examined bilingual children's performance on neuropsychological assessments in the United States (Rosselli et al., 2010), United Kingdom (Garratt & Kelly, 2008) and Finland (Westman, Korkman, Mickos, & Byring, 2008).

Garratt and Kelly (2008) used the Developmental Neuropsychological Assessment (NEPSY), a neuropsychological assessment tool designed for children between 3 and 12 years of age, to examine differences between English-speaking monolinguals and a heterogeneous group of bilinguals. NEPSY includes 14 areas of performance falling under five main domains: attention and executive functioning, language, sensorimotor, visuospatial and memory. Monolingual children outperformed bilinguals in the domain of language, but had comparable performance on the other four broad developmental domains. However, for some of the subtests, the two language groups differed from each other: for instance, bilinguals outperformed monolinguals on the Design Copying subtest of the visuospatial domain, whereas monolinguals performed better on the visual attention subtest of the attention/executive functioning domain. In addition, monolingual and bilingual children showed similar academic achievement scores for mathematics and reading, as measured by Performance Indicators in Primary Schools. For both monolinguals and bilinguals, the NEPSY performance correlated with academic achievement scores, indicating the external validity of the NEPSY battery. This study provides preliminary evidence that NEPSY is generally not sensitive to the effects of bilingualism, with the exception of the language domain in which bilinguals are at disadvantage because they are generally tested in one of their two languages.

In the study conducted in the United States, Rosselli et al. (2010) set out to collect preliminary normative data for a bilingual population with ages between 5 and 14 years on a neuropsychological battery, Evaluación Neuropsicológica Infantil (ENI), developed for Spanish-speaking children because of the large number of Spanish speakers in United States. ENI assesses multiple cognitive domains including visuo-spatial processing, memory, perceptual abilities, oral language, metalinguistic awareness, spatial skills, attention, concept formation, and executive functions. The language of school instruction was English for all participants in the study and Spanish was predominantly the home language. Testing was conducted exclusively in Spanish. Scores were converted in percentiles in order to compare the performance of Spanish-English bilingual children to that of Spanish-speaking monolinguals. The results showed dissociation between performance on tests relying on verbal processing, in which bilinguals obtained scores below the 50th percentile (category fluency, verbal spatial abilities, verbal expressive abilities, verbal memory, story recall) and tests that contained high executive demands (letter fluency, digits backward, concept formation, metalinguistic awareness) in which bilinguals excelled. In fact, on some of the metalinguistic awareness tests bilinguals scored above the 90th percentile (i.e., phonemic blending and spelling). Thus, although bilinguals had a similar performance to the ENI normative group, the results also point to the fact that bilingualism is an important variable that needs to be considered when in doing neuropsychological assessments. Similar results were found in the Westman et al. (2008) study, in which 6-year-old Finnish-speaking monolinguals and Finnish-Swedish bilinguals were administered subtests from the Wechsler Primary and Preschool Scale of Intelligence-Revised and the NEPSY battery. Again, the findings highlighted a verbal cost for bilinguals on measures of (single-language) vocabulary and sentence repetition, with no other significant differences.

Research in the area of neuropsychological assessment is scarce but the existing evidence parallels the previously documented pattern of bilingual effects on cognitive development, with enhancements on tests that are nonverbal and contain high executive demands and costs in verbal processing.

3.3.7. DLLs' intelligence, processing speed, and academic performance

There is minimal research examining intelligence and processing speed in preschool bilingual children. Most studies identified in the present review did not focus specifically on intelligence or processing speed but rather assessed these abilities to ensure that the different language groups show similar cognitive development (i.e., background measures). In these studies, overall, the findings were that there were no differences between monolinguals and DLLs on measures on intelligence, such as Raven's Coloured Progressive Matrices which measures non-verbal reasoning (Bialystok & Martin, 2004; Cheung, Mak, et al., 2010; Engel de Abreau, 2011), C-TONI (Comprehensive Test of Nonverbal Intelligence; Carlson & Meltzoff, 2008), Kaufman Brief Intelligence Test (K-BIT; Barac & Bialystok, 2012; Morales et al., 2013) and Matrix Analogies Test (MAT; Morton & Harper, 2007). Similarly, there were no differences in processing speed between monolingual and bilingual children (Barac & Bialystok, 2012; Bialystok, 2010). In these studies (Barac & Bialystok, 2012; Bialystok, 2010), processing speed was measured by the box completion task that captures the time children take to complete a set of three-sided boxes by adding the fourth side.

In terms of school readiness and academic achievement, some research has focused predominantly on metalinguistic awareness, but in addition examined aspects of school readiness such as early literacy skills including letter, syllable and word identification, reading, and arithmetic skills (Dixon, 2010; Kang, 2012; Lesaux & Siegel, 2003; Lesaux, Rupp, & Siegel, 2007; Lindsey et al., 2003; Macaruso & Rodman, 2011; Manis, Lindsey, & Bailey, 2004; Nakamoto, Lindsey, & Manis, 2010; Paéz, Tabors, & López, 2007; Yeong & Rickard Liow, 2011). Results from metalinguistic tasks are reported in more detail in the previous section on phonological awareness. Letter and word identification are typically standardized tasks in which children are shown a series of letters and words that increase in difficulty and are asked to name them (see Woodcock battery for testing in English or Woodcock–Muñoz-Sandoval battery for testing in Spanish; Woodcock & Johnson, 1989; Woodcock & Muñoz-Sandoval, 1995). Overall, research examining these emergent literacy skills has shown mixed results. In some cases, bilingual children performed similarly to monolinguals on tasks such as letter identification and word reading in Korean (Kang, 2012), letter identification, word reading and reading comprehension in English (Lesaux & Siegel, 2003), and word identification and reading comprehension in Spanish and English (Manis et al., 2004). In other studies, bilingual children outperformed monolinguals on Korean pseudo-word reading (Kang, 2012), arithmetic, English spelling of words and non-words (Lesaux & Siegel, 2003), and reading in English (Dixon, 2010). Finally, other results from the letter-word identification and dictation tasks show that Spanish-English bilingual children obtained scores below average at the beginning of the pre-kindergarten year when compared to the monolingual norms for English- and Spanish-speaking children (Paéz et al., 2007). Similar to findings on metalinguistic awareness, variables such as language proficiency and language of instruction come into play to influence performance on emerging literacy tasks.

Two more studies can be included in the school readiness and academic achievement category: one that looked at academic achievement as a function of socio-emotional development (Oades-Sese, Esquivel, Kaliski, & Maniatis, 2011) and one that examined counting abilities in bilingual children (Rasmussen, Ho, Nicoladis, Leung, & Bisanz, 2006). Oades-Sese and colleagues (2011) used a longitudinal design and found that low socio-economic Spanish-English bilingual children who were identified as socially competent at age 4 had significantly better academic outcomes than bilingual children who were identified as socially vulnerable. Social competence meant that children had developed socio-emotional and linguistic skills that supported their academic success, as measured by performance in math and reading two years later. This has educational implications as bilingual children who were not proficient in any language at age 4 showed lower academic outcomes as well as relatively low English skills 2 years later.

The study by Rasmussen and colleagues (2006) set out to answer a different question: whether the counting abilities of the Chinese-English bilingual children were influenced by the transparency of the Chinese number-naming system. Chinese number-naming is transparent in that number names clearly indicate the base-10 structure, for example, "13" is named "ten-three" in Chinese. This feature is opaque in English; the name "thirteen" does not help to understand the structure of that number concept. As a consequence, past research has demonstrated that Chinese-speaking children showed more precocious development in counting and math than English-speaking children. Rasmussen and colleagues asked Chinese-English bilingual children between 3 and 5 years of age to count as high as they could without providing any physical supports and to count objects in both languages. There was no evidence of transfer between the two languages in that language proficiency in each language influenced counting skills in that language; in other words there was no correlation between children's counting performance in one language and performance in the other language. Language proficiency in this study was measured by asking parents which language their children understood better on a 3-point scale (1 = Chinese, 2 = both languages, 3 = English). Thus, the transparency of the Chinese number-naming system did not confer an advantage to the bilingual children in this study, in contrast to the advantage found in Chinese-speaking monolingual children. This conclusion is based on the finding that Chinese-English bilingual children in this study had a lower counting performance in both languages than the Chinese-speaking monolinguals in a previous study by Miller and colleagues (Miller, Smith, Zhu, & Zhang, 1995). It is possible that bilingual children have less experience counting in Chinese than Chinese monolinguals and that perhaps learning to count in English cancels out the transparency of the Chinese number-naming system.

In sum, research on intelligence and processing speed, although scarce, showed no differences between monolingual and bilingual children. Research on school readiness and academic achievement showed mixed findings, with variables such as language of instruction and language proficiency influencing performance.

4. Discussion

Both in United States and globally, a large number of children grow up learning more than one language. There is a significant body of research showing that this life experience has important consequence for children's development. The purpose of the present paper was to critically review the main findings of the research on cognitive development in bilingual children of preschool age conducted post-2000 both in United States and internationally.

4.1. Key findings on DLLs' cognitive development

Despite the variety of questions asked, measures used, and definitions of bilingualism, a relatively consistent pattern of results emerged in certain areas of cognitive development that include executive control, brain function, and theory of mind. First, across studies, non-verbal executive control skills and theory of mind abilities were changed by the experience of speaking or being exposed to two languages, and typically bilingual children showed more advanced skills than their monolingual peers. Second, the bilingual advantage was not found for all executive control skills (see response inhibition, or delay of gratification, for instance, where bilinguals perform similarly to monolinguals; Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008); the existing evidence suggests that tasks need to carry relatively high executive demands to distinguish between monolinguals and bilinguals. In addition, the bilingual advantage is not found only on tasks that have inhibitory demands, as initially proposed, but extends to switching and cognitive flexibility among others (Barac & Bialystok, 2012; Bialystok, 2010). Working memory is one executive control process that has been relatively less studied and thus the evidence is less clear. The existing findings, however, suggest that bilinguals outperform monolinguals when there are increases in the executive demands of the working memory tasks (Morales et al., 2013). Third, differences in executive control were found very early on, in the first year of life, indicating that being exposed to two languages and not necessarily speaking two languages, has consequences for cognitive processing (Kovacs & Mehler, 2009a). Fourth, bilingual children showed different pattern of brain responses to processing linguistic stimuli, adding to the extensive literature demonstrating bilingualism effects at the behavioral level (Conboy & Mills, 2006).

An important finding is that bilingualism benefits were documented in theory of mind and executive control regardless of the language combinations children were exposed to or spoke (Goetz, 2003; Kovacs, 2009). This suggests that it is the cognitive exercise of managing two linguistic systems, rather than the specific relationship or typological distance between the two languages that leads to consequences for cognitive development. Importantly, in the study by Barac and Bialystok (2012), variables related to bilingualism such as typological distance, cultural background, and language of instruction did not influence executive function performance in Chinese-English, Spanish-English, and French-English bilinguals did not differ from each other and outperformed monolinguals on a non-verbal executive function task – but the groups varied considerably on metalinguistic tasks. Children in the United States mostly spoke Spanish and English (almost 80% of the studies) but in the international studies a variety of languages were included, which sometimes did not include English and the same pattern was found, highlighting a bilingual advantage on theory of mind and executive control processing.

Memory abilities, intelligence, processing speed, and academic performance have received little attention in this literature and thus no firm conclusions can be drawn at this time (Bialystok, 2010; Engel de Abreau, 2011). Nonverbal intelligence has been included in many studies as a background measure and showed no differences between monolingual and bilingual children (Barac & Bialystok, 2012).

In contrast, metalinguistic awareness – particularly phonological awareness – is an area of cognitive development that has been extensively studied and shown inconsistent findings (Barac & Bialystok, 2012). The little research on morphological and syntactic awareness has shown a bilingual advantage (Davidson et al., 2010; Hirata-Edds, 2011) but for phonological awareness bilingual children scored either higher, lower, or the same as monolinguals (Bialystok et al., 2003; Eviatar & Ibrahim, 2000; Loizou & Stuart, 2003). At the heart of these differences among research findings appear to be variables associated with bilingualism such as language proficiency, typological distance between languages, features of the linguistic system, order in which languages were learned by the child, and task demands, etc. (Chen et al., 2010; Loizou & Stuart, 2003) Thus, in the case of metalinguitic awareness, language characteristics matter much more than in the case of executive control and theory of mind.

In sum, in contrast to executive control and theory of mind, advantages in metalinguistic awareness are more modest and inconsistent. These results contribute to understanding the mechanism by which bilingualism affects cognitive and linguistic outcomes by pointing to two aspects of bilingual experience as being responsible for developmental differences between monolingual and bilingual children. The outcomes of bilingualism depend on both the achievement of adequate linguistic proficiency and experience over a sufficient amount of time using two languages. These factors can be understood in terms of the distinction proposed by Bialystok (2001) between the representational structure of knowledge and control of attention. Cognitive development proceeds as children build more structured representations of knowledge and gain greater control over attentional procedures, a framework that applies equally to cognitive change across the lifespan (Craik & Bialystok, 2006). However, each of these processes may be promoted by different experiences. Representational structure is sensitive to increasing knowledge; metalinguistic tasks place a premium on linguistic representations, so to the extent that knowing two languages enhances knowledge of abstract linguistic structure, bilingualism improves metalinguistic performance. It is the absolute level of linguistic knowledge and not the relative degree of bilingualism that is most important in this development. Control, in contrast, is sensitive to accumulating experience; executive control tasks rely on domain-general systems that are also recruited in bilingual language processing, but it takes time for these systems to reach sufficient levels to influence non-linguistic domains.

4.2. Methodological concerns

One of the issues identified in the present review is the definition and categorization of the bilingualism experience. Bilingualism is a complex experience and a precise definition and quantification remain elusive. The wide variability in how researchers measure bilingualism and form various language groups is in part responsible for the mixed results in the areas of cognitive development. Certain aspects of cognitive development (metalinguistic awareness) seem more likely to be affected by specific language characteristics and related variables than others.

Another concern is the choice of tasks for measuring executive control abilities as it appears that tasks need to contain high executive demands in order distinguish between monolinguals and bilinguals. The executive demands of the tasks do change as a function of age as well, which makes it more difficult to find the right "dose" that makes a difference. Finally, some of the studies did not include background measures such as general cognitive development, making it difficult to interpret the findings from the experimental tasks.

4.3. Gaps in the existing research and future needs

The present review of the existing research on cognitive development in bilingual children has highlighted several areas of cognitive development that have been insufficiently investigated. Brain development in children who grow up with two languages has received very little attention and the existing studies have focused exclusively on brain function with no research on brain structure in bilingual children ages 0–6. Moreover, research on brain function in bilingual children has focused exclusively on verbal processing. Thus, at present we know little about the neurocorrelates of the executive control tasks for monolingual and bilingual children and so many questions remain unanswered: Is bilingualism an experience that has the potential to alter brain function and organization? Is bilingualism-related neuroplasticity evident early on in development, during childhood, after only limited bilingual experience? How does functional neuroplasticity relate to bilingual advantages reported in behavioral tasks?

It is important to note that most research has focused on executive control, theory of mind, and metalinguistic awareness and just a handful of studies have investigated memory, working memory processes, intelligence, processing speed, and academic achievement. Other cognitive abilities such as problem-solving, divergent and convergent thinking have not been examined at all in bilingual children of preschool age. Thus, these are all important directions for future research as numerous questions still remain. Being able to map more precisely the areas of cognitive development affected by bilingualism has important implications for understanding the mechanisms underpinning these effects.

Also lacking in the literature is research examining the links between verbal and non-verbal skills in bilingual and monolingual children. Being able to explore these correlations has the potential to contribute to our understanding of how an essentially linguistic experience leads to changes in non-verbal cognitive development. Similarly, longitudinal research has the potential to capture how increasing command of languages relates to non-verbal skills and the issue of reaching a certain threshold of language experience and/or proficiency to be able to see changes in other cognitive areas. A longitudinal design following DLLs from infancy for several years would be important because it could inform the issue of how an essentially linguistic experience leads to non-verbal advantages in cognitive development. In other words, a longitudinal study could potentially illuminate the mechanisms underlying the bilingual advantages. Finally, there is relatively little research focusing on very young children (ages 0–2). Studying the effects of bilingualism early on in development helps us to understand better what changes as a function the bilingualism experience, when it changes, and possibly how.

Acknowledgments

We thank Jackie E. Relyea and Alexandra Reyes for their help with data abstraction and creating the summary table.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.ecresq.2014.02.003.

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