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Word Mapping and Executive Functioning in Young Monolingual and Bilingual Children

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Abstract

The effect of bilingualism on the cognitive skills of young children was investigated by comparing performance of 162 children who belonged to one of two age groups (approximately 3- and 4½-year-olds) and one of three language groups on a series of tasks examining executive control and word mapping. The children were monolingual English speakers, monolingual French speakers, or bilinguals who spoke English and one of a large number of other languages. Monolinguals obtained higher scores than bilinguals on a receptive vocabulary test and were more likely to demonstrate the mutual exclusivity constraint, especially at the younger ages. However, bilinguals obtained higher scores than both groups of monolinguals on three tests of executive functioning: Luria's tapping task measuring response inhibition, the Opposite Worlds task requiring children to assign incongruent labels to a sequence of animal pictures, and reverse categorization in which children needed to reclassify a set of objects into incongruent categories after an initial classification. There were no differences between the groups in the ANT flanker task requiring executive control to ignore a misleading cue. This evidence for a bilingual advantage in aspects of executive functioning at an earlier age than previously reported is discussed in terms of the possibility that bilingual language production may not be the only source of these developmental effects.

One of the most crucial cognitive developments in early childhood is the emergence of the executive function system (Diamond, 2002). These executive processes are the basis for all higher thought, including control of attention (needed for selection and inhibition of the variety of environmental cues), working memory (needed for planning and maintaining set), and switching (needed for multitasking). Research with preschool children has shown that bilingual children develop control over these executive processes earlier than monolingual children (Bialystok, 2001). Importantly, these bilingual advantages are found not only on verbal tasks where executive control to resolve conflict between form and meaning gives bilinguals an advantage on metalinguistic tasks (Bialystok, 1988; Cromdal, 1999; Galambos & Goldin-Meadow, 1990) but also on nonverbal tasks where no explicit linguistic processing is involved (reviewed below).

The basis for the bilingual advantage is commonly assumed to be in the constant need for bilinguals to control attention to two language systems, a process that boosts those attentional processes for all tasks including nonverbal ones. But how much experience in attending to two languages is necessary for these generalized effects to appear? If these advantages to the executive control system build up as a function of their use in language management, then it may be that very young bilinguals do not show the same degree of cognitive effect because their experience with bilingual language use is more limited. In this case, few differences between monolinguals and bilinguals would be found in very young children, but greater differences would be expected at around 4 years old, the age investigated in much of the previous literature.

In contrast to this prediction, studies have shown diverging developmental patterns in speech perception and word learning for infants raised in bilingual homes even in the first year of life. In terms of speech perception, Catalan-Spanish bilingual infants showed a delayed reorganization for vowels, occurring around 12 months of age, which is about four months later than in their monolingual peers (Bosch & Sebastian-Galles, 2003). Additionally, bilingual infants appear to differ from monolingual infants in the way they acquire a lexicon. Fennell, Byers-Heinlein, and Werker (2007) showed that bilingual infants postpone the use of phonetic details to guide their word acquisition until 20 months of age, whereas their monolingual peers succeed in this task three months earlier. More dramatically, Kovacs and Mehler (2009) reported differences between monolingual and bilingual 7-month-olds in their ability to switch their attention to a novel cue for a visual reward. These findings suggest that cognitive and linguistic networks are organized differently for monolingual and bilingual children from the first year of life.

There are three purposes for the present study. The first is to examine the possibility that there is a bilingual advantage for executive control in preschool children who are younger than those studied in previous research. The second is to determine whether potential differences in executive control are associated with different word mapping strategies for young monolingual and bilingual children. The third is to examine the generality of such effects by including two groups of monolinguals from different cultures and languages as the point of comparison for the bilingual children. The results will help to understand the origin of cognitive and language differences that can be attributed to bilingualism by identifying potential effects early and examining the generality of these effects across different groups. Such information would constrain interpretations of the mechanism responsible for the reported cognitive consequences of bilingualism.

A growing number of studies converges on the conclusion that bilingualism affects children's development of executive control. Bilingual children are more successful than monolinguals on the dimensional change card sort task (Bialystok, 1999; Bialystok & Martin, 2004) developed by Zelazo, Frye, and Rapus (1996), a written version (Pascual-Leone, 1969) of Piaget and Inhelder's (1956) water-level task (Bialystok & Majumder, 1998), the attentional networks test (ANT: Mezzacappa, 2004; Yang, Shih, & Lust, 2005) developed by Rueda, Fan, McCandliss, Halparin, Gruber, Lercari, & Posner (2004), and theory of mind tasks (Bialystok & Senman, 2004; Goetz, 2003; Kovacs, 2009). The children in these studies ranged between about 4 and 8 years of age. The common feature is that responses are based on conflict between competing options. For example, in the Simon task used by Martin-Rhee and Bialystok (2008) with 5-year-old children, a stimulus associated with a left or right key press is presented on the left or right side of the display, creating congruent and incongruent trials determined by the relation between the presentation and response sides. Bilinguals performed this task more rapidly than monolinguals, showing faster response times for both congruent and incongruent trials if they were presented in a

mixed block. Conditions in which the stimuli were presented in the center of the screen so there was no conflict were performed similarly by monolinguals and bilinguals.

This research demonstrates more efficient performance by bilinguals, but the mechanism underlying that advantage is not clear. Early speculation pointed to advanced inhibitory control as the mechanism (e.g., Bialystok, 2001), but that explanation may be too narrow. For example, inhibitory control would not explain why bilinguals perform congruent trials more rapidly than monolinguals in studies that include both congruent and incongruent trials (Bialystok, in press; Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Ryan, 2006; Costa, Hernandez, & Sebastian-Galles, 2008; Martin-Rhee & Bialystok, 2008). Another executive function component, such as cognitive flexibility, must also be involved to explain how bilinguals monitor the context and switch between changing trials and rules in order to perform more efficiently than monolinguals in congruent trials as well as incongruent ones. At the same time, inhibitory control is too broad an explanation. In a study by Carlson and Meltzoff (2008), a battery of tasks requiring various types of inhibition was presented to monolingual and bilingual children; bilingual children performed better than monolinguals on tasks that required resolving conflict between competing responses but not on tasks that required withholding a primed response, even though that too is an aspect of inhibitory control. Moreover, aspects of executive control that have little role for inhibition, such as working memory, also demonstrate some bilingual advantage (Feng, Diamond, & Bialystok, 2007). Evidence from an earlier stage in development will help us to understand these issues.

Monolingual and bilingual children also differ in aspects of lexical development. In general, both the course and rate of language development for monolingual and bilingual children are similar (Lindholm, 1980; de Houwer, 1995), but the vocabulary controlled by a bilingual child in *each* language is smaller than that of a comparable monolingual (Bialystok et al., in press; Oller & Eilers, 2002). This outcome may simply reflect the fact that their language-learning experience is divided between two languages, but it may also be that the *process* of vocabulary learning is different for bilingual children. Minimally, bilingual children have an additional referential system that could be incorporated into their word-learning experiences. Therefore, our question is whether monolingual and bilingual children use different attentional resources for mapping new words to meanings.

One influential account of word learning in young children is the mutual exclusivity (ME) hypothesis (Markman & Wachtel, 1988; Markman, 1989). Although its developmental origins and interpretation are controversial, the assumption is that ME is a natural constraint that restricts preschoolers' assumptions about word meanings and word extensions. Children believe that labels for objects are mutually exclusive, that is, a given object can only have one name (Markman, 1989; Woodward, 2000 for discussion). Moreover, the tendency for this assumption to influence children's naming behavior increases during the preschool years (Au & Glusman, 1990; Merriman & Bowman, 1989), and some have suggested that it is a heuristic that children learn to use as they get older (MacWhinney, 1991). Others have proposed that the constraint may be a default strategy that children use when other options are not available (Merriman & Bowman, 1989; Markman, 1992).

The ME strategy incorporates an element of attention and includes a small but perceptible degree of conflict: a novel word in the context of a familiar and unfamiliar object can potentially refer to either item. The ME hypothesis is one resolution for that conflict because it assigns the new word to the unfamiliar object in order to satisfy the need for each object to have one name. Because it is based in conflict, it is possible that bilingual children will resolve the relation between a novel word and two potential object referents differently from monolinguals. Specifically, bilingual children should be less constrained by ME than

monolinguals because the conflict between the novel word and the two objects is less salient. There are three possible reasons for this outcome: first, the enhanced conflict resolution processes of bilingual children will simply assign the new word to one of the objects without effort; second, the experience of knowing multiple labels for the same object will diminish the conflict at the outset because it is known that things can have two names; and third, the greater cognitive flexibility of bilingual children will allow them to override the ME bias and accept two verbal representations for a given object. In all three cases, the prediction is that there should be less evidence of ME in bilingual children.

Some research has investigated this issue but the results are contradictory. Some studies report less reliance of bilingual children on ME than matched monolinguals (Davidson, Jergovic, Imami, & Theodos, 1997; Davidson & Tell, 2005; Yow & Markman, 2007) and others find no difference (Au & Glusman, 1990; Frank & Poulin-Dubois, 2002; Merriman & Kutlesic, 1993). Although bilingual children are familiar with having two names for a particular object, it appears that the ME constraint does not apply if the words come from different languages, even for monolingual children (Au & Glusman, 1990). Thus, there may be no difference between monolingual and bilingual children in adopting this strategy for words in the same language. However, inhibiting a given name and switching to a new one also requires cognitive flexibility, and this aspect of executive control is more developed in bilinguals. Thus, because of their advantage in executive control, bilingual children may be less bound by ME than monolinguals. No previous study has combined executive function tasks with mutual exclusivity to directly test the hypothesized relation between them.

Finally, comparisons of monolingual and bilingual children are always difficult because it is problematic to guarantee that the two groups are similar in all aspects except the relevant language experience. Ideally, it would be helpful to replicate the design in which monolingual and bilingual children are compared in two cultures, but there would still be differences between the cultures that made that design problematic. Instead, our approach is to incorporate an additional group of children from a different culture and compare them to one of the two language groups. In a previous study, Bialystok and Viswanathan (2009) compared monolingual children in Canada with bilingual children in Canada and bilingual children in India on a set of executive function tasks. The results showed that the two bilingual groups performed similarly and both were different from the monolingual group, irrespective of country. The present study takes the opposite approach: children who are monolingual or bilingual in Canada are compared to an additional monolingual group from France. The hypothesis is that the two monolingual groups will perform similarly and that the bilingual group will be different from both, irrespective of country. Such results will confirm the generality of these effects and release them from the specific details of the culture or language that define the bilingual experience.

To summarize, the present study investigated whether the cognitive benefits of bilingualism can be detected in young preschool children, whether there are implications of bilingualism for children's word-mapping strategies that may be related to differences in executive control, and whether the processing differences between monolinguals and bilinguals are sustained when the comparisons of language experience are made across cultural and linguistic contexts. To provide a broad test of the hypothesis of differences in executive control, a set of tasks was administered in which each task relied on a different component of control.

Method

Participants

The participants were 162 children (range: 29 months to 60 months) comprised of 37 monolingual French-speaking children in France, 69 monolingual English-speaking children in Canada, and 56 bilingual children in Canada. Children in each of these three language groups were further divided in two age groups: a younger group ($M = 40$ months, $SD = 5.3$ months) and an older group ($M = 53.6$ months, $SD = 3.6$ months) to examine developmental differences.

The French monolingual group consisted of 20 younger children ($M = 42.3$ months, $SD = 4.0$ months, range = 34.7–46.9 months, 10 girls and 10 boys), and 17 older children ($M = 54.2$ months, $SD = 3.9$ months, range = 48.3–59.2 months, 7 girls and 10 boys). None of these children had exposure to any language other than French. These children lived in a small city in the south of France.

The children in Canada lived in a large multicultural urban city. All the parents in Canada completed the Language and Social Background Questionnaire (LSBQ) which examined both the child's receptive and expressive language skills (i.e., home language exposure versus languages spoken by the child at home, in the community, and at school). Parents indicated their answers to a series of questions about language use patterns in the home on a scale from 1 to 5, where 1 referred to the exclusive use of English, 5 referred to the exclusive use of a non-English language and 3 indicated a balanced use between the two. The English monolingual group included 40 younger children ($M = 38.3$ months, $SD = 5.3$ months, range = 30.3–47.7 months, 19 girls and 21 boys), and 29 older children ($M = 53.2$ months, $SD = 4.04$ months, range = 48.1–60.4 months, 6 girls and 23 boys). Parents' responses to the LSBQ confirmed that the children were monolingual. The mean score for children's home use of English was 1.0 and for adults' was 1.1, with 1.0 indicating exclusive use of English.

The bilingual group consisted of 27 younger children ($M = 40.9$ months, $SD = 5.5$ months, range = 29–47.4 months, 13 girls and 14 boys), and 29 older children ($M = 53.5$ months, $SD = 3.01$ months, range 48.1–58.2 months, 17 girls and 12 boys). The bilingual children spoke English and one of eighteen non-English languages at home: Italian (9), Spanish (7), Arabic (6), Russian (5), Urdu (5), Mandarin (4), Cantonese (3), French (3), Hebrew (3), Persian (2), Tamil (2), Amharic (1), Hindi (1), Hungarian (1), Portuguese (1), Punjabi (1), Romanian (1), or Serbian (1). The average value for the language spoken at home by the parents was 3.6 ($SD = 1.0$) and the language spoken by the child was 2.7 ($SD = 0.9$). A one sample *t*-test revealed that both scores were significantly different from the balanced rating of 3, with children being biased toward speaking English at home, $t(55) = 2.22$, $p < .05$, but parents more likely to speak the non-English language, $t(55) = 4.82$, $p < .0001$.

All the children living in Canada came from the same middle-class neighborhoods and attended the same daycare centers. Although we did not formally measure socioeconomic status (SES), there is no evidence for a systematic bias in SES that could be correlated with language experience. The schools were private daycare centers in which parents paid fees; there were no subsidies available. The large sample size also attenuates the possibility of bias. Moreover, the wide range of bilinguals in the sample precludes the possibility that bilingualism is confounded with language, ethnicity, or culture. Although some have argued that monolingual and bilingual children in Canada cannot be compared because of differences in SES (Morton & Harper, 2007), our carefully matched groups of children in targeted neighborhoods provide a reliable control over extraneous factors and isolate home bilingualism as the relevant factor that distinguishes between the groups (Bialystok, 2009).

If the mechanism for developmental differences that are attributable to SES is the early experiences of the children, then all the Canadian children in the present study had comparable early experiences but the monolingual children in France had different experiences. The children in France attended free public daycare centers and were probably of somewhat lower SES than were the children in Canada.

Procedures and Tasks

Children were tested individually in a quiet room at their daycare center during a single session that lasted between 30 and 45 minutes. However, eight of the children in Canada (7 monolinguals and 1 bilingual) were tested in their homes, but parents were not present during testing and there is no apparent difference in performance between these children and those tested in the daycares. Parental written consent and child's assent were obtained prior to testing. All the children in Canada were tested in English by the same female experimenter, and a different French-speaking experimenter conducted the testing for children in France. There were five tasks that assessed language proficiency, word mapping, and executive control. These tasks were administered in a fixed order: Luria's tapping test, mutual exclusivity task, Opposite Worlds, ANT Flanker (for children older than 42 months only), and PPVT. Participants in Canada were also tested on an additional executive control task, Reverse Categorization, that was not included in the battery in France. Children received stickers upon completion of each task.

Peabody Picture Vocabulary Test, 3rd edition (PPVT-III) and EVIP—Language proficiency was assessed by the Peabody Picture Vocabulary Test (PPVT-III; Dunn and Dunn, 1997) for children in Canada and by its French adaptation, Echelle de Vocabulaire en Images Peabody (EVIP; Dunn, Theriault-Whalen, & Dunn, 1993) for children in France. The test consists of 17 sets of stimuli, each set including 12 target words. The child is shown a page with four pictures while the experimenter says a word, and the task is to point to the picture that best illustrates that word. The test was administered and scored in both languages in the standard fashion for preschool children.

Mutual exclusivity task—Following the procedures used by Markman and Wachtel (1988), the task included two conditions: novel label and control. The order of presentation was counterbalanced across participants. The testing material consisted of six familiar objects whose names were known by children and six novel objects for which the children would not have words. The familiar objects were a banana, a crayon, a toy dog, an orange, a plate, and a small ball. The novel objects were a bottle stopper, a coaster, a garlic press, a fish tackle, a hair braider, and a towel holder. Familiar and novel objects were randomly combined into six pairs for each child.

The task and the instructions were introduced with the help of a stuffed toy bear called Mario. Children were told: "Mario is going to play a game with you. He will show you two things and ask you to pick one of them. What you need to do is listen carefully to what Mario is saying and then give him what he is asking for." In the novel label condition, children were shown one of the three pairs of objects and were asked by the bear to "Give me the blicket/jeeter/mido". In the control condition, children were shown the other three pairs of objects and were instructed to "Give me one". After the child made a response, the bear took a bow, said "Thank you" and placed a new pair of objects in front of the child. The dependent variable was difference between choices for the novel object in the novel label and control condition, with a greater difference score indicating a larger bias for mutual exclusivity.

Luria's tapping task—This is a reverse imitation task in which children have to perform the opposite of an action modeled by the experimenter. The task requires the child to avoid executing a primed response, so it requires inhibition of a manual response. The experimenter introduced the task by announcing that they were going to play a tapping game with a magic wand (a wooden dowel, 22.5 cm long with a diameter of 2.5 cm). Following Diamond and Taylor (1996), the experimenter introduced and demonstrated the two rules of the game sequentially. The experimenter started with the first rule: "When I tap one time like this (experimenter demonstrates), I want you to tap two times like this (experimenter demonstrates). Let's try. When I tap one time (experimenter taps once), you tap...Show me." At this point the experimenter handed the magic dowel to the child. If the child's response was correct, the experimenter gave the child positive feedback and introduced the second rule, but if the response was incorrect, the sequence was repeated. The second rule was explained in the same way, instructing the child to tap once when the experimenter tapped twice. The practice session continued with the experimenter repeating the two rules. If the child was correct on both trials, they counted as the first two trials of the testing session. If the child responded incorrectly on either of the two practice trials, the child was reminded the two rules starting with the one performed erroneously, followed by the testing session.

The task included sixteen trials with no feedback presented in a preset random order that was the same for all children. The session continued beyond the first two trials if the child was correct for both rules at least once during the practice and if the first two testing trials were correct (cf. Diamond & Taylor, 1996) to ensure that children understood the instructions. The dependent variable was the number of correct responses out of 16.

Opposite worlds task—This task is an adaptation of Manly, Robertson, Anderson, and Nimmo-Smith's (1999) Opposite Worlds subtask from the Test of Everyday Attention for Children. The task requires children to avoid assigning a practiced name and switch to a different naming system to comply with the rule. The testing material consisted of a large board (75 cm × 50 cm) with a windmill and a barn at the top and 24 pictures of cows and pigs placed along a curvy path. In the same-world condition, children were instructed to follow the path and name each animal they encountered. In the opposite-worlds condition, children were presented with a dramatic scenario in which the windmill was blown so hard that the barn was turned upside down. Because of the strong wind all the names became upside down as well. Children's task was to follow the same path and name each animal in order by its silly, upside down name (i.e., "cow" for the picture of pig, and "pig" for the picture of cow). The conditions were administered in a fixed order, starting with the same-world condition. The dependent variables were the number of errors in each of the two conditions and the increase in errors for the opposite world condition calculated individually as a function of each child's performance in the same world condition.

ANT flanker task—This task is an assessment of the inhibitory control required to ignore a conflicting cue in order to respond to a target cue. The task was programmed in E-Prime software (Rueda, Posner, Rothbart, & Davis-Stober, 2004) and administered on a Lenovo X61 touch-screen tablet computer with a 12-inch monitor. On each trial children were presented with a row of five fish in the center of the screen flanked by two green squares. Children's task was to feed the target middle fish by pressing one of the two lateral squares depending on the direction in which the middle fish was swimming. On congruent trials, the four flanker fish and the target fish were swimming in the same direction, and on the incongruent trials the four flankers were swimming in the opposite direction. The ratio of congruent to incongruent trials was 6 to 4, consistent with other research of this type.

The experimenter explained the instructions with the aid of two drawings corresponding to the images on the screen to demonstrate the congruent and incongruent trials. Subsequently, children completed one or two practice sessions as decided by the experimenter's judgment of children's understanding of the instructions. Each practice session included 12 trials. The experimental trials were organized in 8 blocks containing 10 trials each. Children could take breaks between the experimental blocks. Each trial consisted of the following sequence of events: a fixation cross appeared in the center of the screen for 450 ms, the stimulus appeared for 3000 ms, and feedback was provided for 1000 ms. If the child's response was correct they heard a "whoo-hoo" sound and saw bubbles coming up from the fish's mouth to signal that the target fish was happy. If the child made an error, the feedback consisted of a "bang" sound to suggest that the center fish had not been fed and was unhappy. Children were instructed to feed the fish in the middle as fast as possible. The testing session lasted between 10 and 15 minutes. During testing it was found that children less than 42 months of age found this task to be very difficult, so eventually the task was administered only to children who were more than 42 months old.

Reverse categorization—This task requires children to carry out a classification based on one rule and then to shift to a new rule to reclassify the same objects, similar to the procedure involved in the dimension change card sort task. The task was adapted from one used by Carlson, Mandell and Williams (2004). Children were shown six pairs of toy animals (i.e., ducks, frogs, cows, polar bears, tigers, dolphins) in which one member of the pair was small (called the "baby") and the other was larger but otherwise identical (called the "mommy"). There were two colored toy buckets, one with a picture of a baby posted on it and the other with a picture of a woman, called the 'mommy'). The children's initial task was to sort the animals according to their size so that the baby animals go into the baby bucket and the mommy animals go into the mommy bucket. The experimenter demonstrated the rule by putting three randomly chosen baby animals and three randomly chosen mommy animals into the appropriate buckets. Participants were then asked to continue the game by sorting the remaining six animals. Following this phase, the experimenter introduced a new rule by saying: "Now we are going to play a silly game. Let's put all the baby animals in the mommy bucket and put all the mommy animals in the baby bucket". The experimenter handed each toy animal to the child while emphasizing its size (e.g., "Here is a baby frog, where does this one go?"). Children did not receive any feedback during the 12 post-switch trials and the rule was restated before the first and the seventh trials. The number of correctly sorted animals for the 12 post-switch trials was used to classify children as passing or failing the task, following the procedure used by Zelazo, Frye, and Rapus (1996) on a similar task. Because of an error in constructing the administration protocol, this task was not given to the children in France.

Results

The data from each task (except Reverse Categorization which was only administered to two groups) were analyzed using a 3 (group) $\times$ 2 (gender) $\times$ 2 (age) ANOVA with contrasts on group conducted in two steps. The first step compared English monolinguals and French monolinguals using an *a priori* set contrast to determine whether there was a difference between the two monolingual groups. If no significant difference was found, then the monolingual groups were considered statistically equivalent and were combined and compared to the bilingual group using a second *a priori* set contrast. However, if the performance of the two monolingual groups was statistically different, they were kept as two distinct groups in the subsequent step so the three language groups could be compared. The *a priori* contrasts were hypothesis-driven and were chosen over the post-hoc multiple comparisons method in order to reduce the probability of a Type I error (Howell, 2002).

Peabody Picture Vocabulary Test, 3rd Edition (PPVT-III) and EVIP

Table 1 presents the mean scores and standard deviations for receptive vocabulary. In the first step, a three-way ANOVA for age, language group, and gender as between-subject factors and English monolinguals versus French monolinguals as an *a priori* set contrast indicated a main effect of language, $F(2, 147) = 3.73, p < .03$. The first *a priori* set contrast showed no difference between the two monolingual groups, $F(1, 147) = 3.14, n.s.$, so they were combined and compared to the bilingual group in the second step. This contrast showed marginally higher scores for monolinguals than bilinguals, $F(1, 147) = 3.53, p < .07$, and a marginally significant main effect of age, $F(1, 147) = 3.82, p < .06$, with the older children having higher scores on receptive vocabulary than the younger ones. There was no main effect of gender and none of the interactions was significant.

Luria's Tapping Task

Table 1 also reports the mean number of correct responses and standard deviation for the tapping task. There were 13 children who did not complete the task and 51 children who did not pass the pretest because of errors on the practice trials or the first two test trials (cf., Diamond & Taylor, 1996) leaving a total of 98 children. This group included 33 English monolinguals, 28 French monolinguals, and 37 bilinguals. There were no significant differences in age among the children in the three groups, $F(1, 95) = 0.62, n.s.$ The first step of the three-way ANOVA for gender, age, and language group indicated a main effect of language, $F(2, 86) = 6.19, p < .005$, which was examined by comparing the two monolingual groups. The *a priori* set contrast showed that the two monolingual groups were equivalent, $F(1, 86) = 1.23, n.s.$, so they were combined and compared to the bilingual group in the second step. The second set of contrasts indicated higher performance by the bilinguals than the monolinguals, $F(1, 86) = 10.04, p < .005$, Cohen's $d = 0.6$, and a main effect of age, $F(1, 86) = 10.52, p < .0005$, with the older children being more accurate than the younger ones¹. There was no main effect of gender and none of the interactions was significant.

Opposite Worlds Task

The mean number of errors and standard deviations for the two conditions of the Opposite Worlds task, as well as the difference between them indicating the cost of the opposite world trials for each child are reported in Table 1. The two conditions were analyzed by a four-way ANOVA with gender, age, and language group as between-subject factors and condition (same and opposite) as a within-subject factor and indicated a main effect of language group, $F(2, 136) = 4.88, p < .01$. The first *a priori* contrast showed no difference between the two monolingual groups in either the same-world, $F(1, 136) = 2.52, n.s.$, or opposite world, $F(1, 136) = 0.15, n.s.$, conditions. In the second step comparing monolinguals and bilinguals, bilingual children made fewer errors than monolingual children on both the same-world condition, $F(1, 136) = 8.53, p < .005$, Cohen's $d = 0.6$, and the opposite world condition, $F(1, 136) = 6.15, p < .01$, Cohen's $d = 0.5$. The analysis also indicated a main effect of condition, $F(1, 136) = 39.83, p < .0001$, with fewer errors in the same-world condition than in the opposite-world condition, a main effect of age, $F(1, 136) = 24.03, p < .0001$, with older children being more accurate than the younger children, and an interaction of condition and age, $F(1, 136) = 10.71, p < .001$, because of a greater difference between

¹If children are not excluded based on their scores on the pretest, the analysis applied to the whole sample yields the same results. The first step of the three-way ANOVA for gender, age and language group indicated a main effect of language, $F(2, 134) = 6.00, p < .004$, which was examined by comparing the two monolingual groups. The *a priori* set contrast showed that the two monolingual groups were equivalent, $F(1, 134) = 3.06, n.s.$ The second set of contrasts indicated higher performance by the bilinguals than the monolinguals, $F(1, 134) = 6.66, p < .02$, Cohen's $d = 0.5$, a main effect of age, $F(1, 134) = 35.13, p < .0001$, with the older children being more accurate than the younger ones. None of the interactions was significant.

conditions for younger children, $F(1, 75) = 39.34, p < .0001$, than for older children, $F(1, 71) = 16.68, p < .0001$. There was no main effect of gender or interactions of gender and other factors.

These results were pursued by examining the cost of the opposite world condition for each child as a function of their performance in the same world condition. The cost was calculated as the difference between the scores in the two conditions for each child. This analysis controls for differences in initial ability because it assesses children's performance in the difficult condition against their own performance in the simple condition. A one-way ANOVA for language group indicated a significant main effect, $F(2, 145) = 3.19, p < .05$. The first contrast showed no difference between the two monolingual groups, $F < 1$, but the second contrast showed a larger cost for the monolinguals than for the bilingual children, $F(1, 145) = 3.81, p < .05$.

ANT Flanker Task

The mean accuracy and reaction times for the flanker task are presented in Table 2. Trials with reaction times (RTs) faster than 250 ms were excluded from the analyses because they were considered to be anticipatory responses. Analyses were performed using only the data of participants who had accuracy scores of 70% or higher on the congruent trials to assure that children understood the task². Based on this criterion, 18 children were excluded from the analyses, leaving a sample of 89 children. Because the task was only administered to children more than 42 months, age was not included as a factor in the analyses.

Accuracy data were examined by a three-way ANOVA for gender, language group, and condition. There was a main effect of gender, $F(1, 83) = 4.24, p < .05$, indicating that boys outperformed girls, and a main effect of condition, $F(1, 83) = 51.35, p < .0001$, indicating more errors on the incongruent trials than on the congruent trials. There was no main effect of language group and no significant interactions.

The mean RTs for correct trials and for trials exceeding 250 ms are presented in Table 2. A three-way ANOVA for language group, gender, and condition showed a main effect of condition, $F(1, 83) = 9.70, p < .003$, with faster RTs on the congruent trials than the incongruent trials, and a condition by gender interaction, $F(1, 83) = 5.54, p < .03$. Tests for simple effects indicated no RT difference between congruent and incongruent trials for girls, $F(1, 37) = 0.55, n.s.$, but boys were faster on congruent than incongruent trials, $F(1, 50) = 26.98, p < .0001$. There were no effects of language group and no interactions of language with other factors.

Reverse Categorization

As in the other tasks, only children who performed at a level greater than chance were included in the analysis. The criterion in this case was that children achieve more than 50% accuracy (i.e., chance) on the pre-switch trials, in other words, at least 4 out of 6 trials correct. Using this criterion six children (3 monolinguals and 3 bilinguals) were excluded from the final analyses. Four additional children (3 monolinguals, 1 bilingual) did not complete the post-switch trials. The remaining 115 children were classified as passing the task if they obtained a total score of 11 or more on the post-switch trials, or failing the task if they performed below that level. A non-parametric test was used because the distribution of data was not normal, with children either getting most of the trials correct or very few of them correct. Table 3 shows the number of monolingual and bilingual children passing or

²The data for the 18 excluded children were not analyzed because with performance at chance, even the correct responses do not indicate systematic differences between the conditions that could be interpreted.

failing the task. A chi-square analysis showed that there was a greater proportion of children passing in the bilingual group than in the monolingual group, $\chi^2 = 5.64$, $p < .02$.

Mutual Exclusivity Task

A difference score was calculated to indicate the increase in choices for the novel object in the novel label condition compared to the control condition. The score reflects the shift in each child's performance based on that child's own choices in the control condition and indexes the child's adherence to mutual exclusivity. These difference scores are plotted in Figure 1. A 3-way ANOVA for language group, age group, and gender indicated significant effects of language group, $F(2,158) = 3.19$, $p < .04$, gender, $F(1,159) = 6.48$, $p < .01$, and an interaction between all three factors, $F(2, 158) = 3.83$, $p < .02$. The effect of language group was examined using the two a priori contrasts applied in the previous analyses. The first contrast showed no difference between the two monolingual groups, $F < 1$, but the second contrast indicated a significant difference between the monolinguals and bilinguals, $F(1,159) = 6.33$, $p < .01$. Therefore, the two monolingual groups were combined in the graph in Figure 1 to examine the three-way interaction. The data were analyzed separately by age group. For the younger children, there was an effect of language group, $F(1,85) = 4.80$, $p < .03$, and an interaction of group and gender, $F(1,85) = 4.96$, $p < .02$. As shown in the figure, Scheffé contrasts confirmed that monolingual girls made more selections for the novel object in the novel label condition than did any of the other children. For the older group, only bilingual boys have not switched to selecting the novel object in the novel label condition, $F(1,73) = 3.90$, $p < .05$. Thus, mutual exclusivity is adopted first by monolingual girls, then by everyone except bilingual boys.

Finally, we examined the relation among the tasks to answer three questions (Table 4). The first question is whether there was a relation between verbal ability as measured by the PPVT and performance on the executive function and word learning tasks. There was a moderate relation between PPVT and the tapping and opposite worlds task, with no overlap with the other measures. This pattern is similar to that reported by Carlson, Moses and Claxton (2004) in which they reported correlations between PPVT and some measures of executive control, especially those that relied more heavily on language. The second question was whether there was a relation between the strategies used in the Mutual Exclusivity task and the executive control tasks. No correlations were found. The third question was whether there was a relation among the various executive control tasks. All these correlations were strong, with the exception of the relation between the incongruent trials on the ANT and the proportion of correct trials on the tapping task. Separate analyses for each of the three groups revealed similar patterns with less robust results, likely attributable to the decreased power in the smaller sample.

Discussion

The three purposes of the present study were 1) to determine whether the previously reported bilingual advantages in executive control were already present in younger children; 2) to explore the possibility of differences between monolinguals and bilinguals in word-mapping strategies; and 3) to confirm the generality of the bilingual difference by comparing bilingual children to two different groups of monolinguals. The tasks assessed different components of executive control, most of which demonstrated clear advantages for the bilingual children. Moreover, young bilingual children showed less bias for mutual exclusivity in word mapping than monolingual children, and by age 4 it was only bilingual boys who showed no preference for the novel object.

The results from the tapping task were clear, extending the bilingual advantage in executive control to a task requiring inhibitory control of a manual response. Such tasks have not

always produced a bilingual advantage but the children in those studies were older than children in the present study. In the study by Carlson and Meltzoff (2008) in which there was a bilingual advantage for conflict tasks but not tasks requiring withholding a response, the mean age was 72 months; in the study by Martin-Rhee and Bialystok (2008) in which there was a bilingual advantage for conditions involving a conflict between stimulus position and response side but not for conditions requiring a response opposite to that signaled by the stimulus, the mean age was 96 months. In the present study, the overall mean age was 47 months. Although the interaction of age group and language group was not significant, it is clear from Table 1 that the greater advantage for the bilinguals in the tapping task was in the younger age group, as all the older children were performing very well. Therefore, it may be that the earliest evidence for bilingual advantages in executive control, and specifically in inhibition, is found for control required to withhold a primed or habitual response. It is possible that this difference is attenuated as all children gain control of these motor responses, so studies with older children fail to reveal group differences in this component of the executive function.

The opposite worlds task has much in common with bilingual language use: children must shift between naming systems according to an external constraint, giving items names that are appropriate within the designated system. Bilinguals committed fewer errors than either of the monolingual groups, even in the same-world condition. This pattern is similar to that in which bilingual children outperform monolinguals on congruent trials when they are presented in conjunction with incongruent trials (e.g., Bialystok, in press; Martin-Rhee & Bialystok, 2008). More importantly, however, is that irrespective of the level of performance children obtained in the same world condition, the additional cost of the opposite world condition was greater for children in the two monolingual groups than for the bilingual children.

The reverse categorization task was only administered to children in Canada, but the results conformed to the hypothesized pattern in which bilingual children were more likely to succeed in the reverse sorting condition than monolingual children. The component of executive control in this case is switching to a new rule, a process difficult for children of this age.

In contrast to the previous three executive function tasks, there were no group differences in the ANT flanker task, either in terms of accuracy or RT. Although the task seems as though it should be a prime candidate for detecting such differences, several factors may have prevented that outcome, including the sensitivity of the task, the degree of within-subject variance, and the generally long RTs. It may be that there is no difference between children in the language groups in this task, but it is equally possible that the component of executive control responsible for inhibiting attention to a misleading cue is not different in monolingual and bilingual children of this age. It was the most difficult of the executive control tasks administered, and none of the children had yet made much progress in performing the task. Previous research showing bilingual advantages in this task was based on older children (e.g., Yang et al., 2005), so further research is needed to resolve the difference in results.

Finally, the mutual exclusivity task revealed different levels of adherence to the mutual exclusivity constraint for the different groups. Evidence for this constraint appeared later in bilinguals than monolinguals and later in boys than girls. Thus, at 3 years of age, only monolingual girls showed a significant preference for the novel object when a novel label was given. By 4 years of age, all the monolingual children and the bilingual girls conformed to this pattern, with only the bilingual boys still showing no preference for mapping the novel word to the novel object. As in other studies (e.g., Davidson et al., 1997), our results

showed less influence of mutual exclusivity in bilingual children than in monolinguals. However, there was no evidence that these word mapping strategies are related to the developing abilities in executive control. Our results on this point are only suggestive and further research is required.

The important outcome of the correlation analysis is that performance on the executive control tasks indicates a coherent cluster of abilities that is related to neither receptive vocabulary nor to word-learning strategies, with bilingual children performing better than monolinguals on this cluster. Moreover, bilingual children both performed better on the executive control tasks and relied less on mutual exclusivity than monolingual children, but the absence of a correlation between these scores suggests that each of these effects has a different origin. The results from these correlations, however, are offered only as descriptive indices of the relations among the tasks and should not be over-interpreted.

These results provide new evidence for the three questions raised in the introduction. First, bilingual advantages in executive control can be detected earlier than previously reported. The youngest children in this study were 2½ years old, with the mean age of children in the younger group just over 3 years. These children have been exposed to two languages for their entire lives but have had considerably less accumulated linguistic experience than the older children usually studied in this type of research. Therefore, early sustained experience in developing two linguistic representational systems has the potential to promote executive control abilities across domains.

Second, there were suggestions in the data that these language experiences alter the strategies children use to acquire the meanings of new words. As in previous research, bilingual children controlled a smaller vocabulary in English than did monolingual children in either English or French. In addition, the young monolingual girls and all the older children were more bound to the mutual exclusivity constraint than were the young bilingual children and the young monolingual boys. This pattern is compatible with the view that the mutual exclusivity constraint is more evident in older than in younger children (MacWhinney, 1991; Frank & Poulin-Dubois, 2002) and that it is the young monolingual girls who are progressing more rapidly in the traditional path. Bilingualism may additionally alter children's path towards establishing productive strategies for rapidly acquiring new word meanings. There was no evidence, however, linking word mapping strategies to the level of executive control that children demonstrated on the other tasks. If bilinguals approach word mapping differently from monolinguals, it is more likely because of their experience with two language systems in which they have multiple labels for the same concepts. This possibility is speculative and should be pursued in further research.

Third, where there were performance differences between monolinguals and bilinguals, they were found by comparing the bilinguals to both of the monolingual groups, and these monolinguals did not differ from each other. All of the bilinguals spoke English and one other language, so the comparison with the Canadian monolinguals had English as the common language. However, the results were identical when compared with the French monolinguals, and only three of the bilinguals spoke French. This contrast provides powerful evidence for the generalizability of the effect of bilingualism and supports the interpretation that bilingualism is responsible for the divergent performance. The children in Canada had experiences that were more similar to each other than they did with the children in France. All the Canadian children attended the same schools, lived in the same neighborhoods, and shared the same experiences. Yet, the results showed that on the crucial tasks, it was the monolingual children in the two settings who performed similarly to each other in spite of different cultures and different languages. The bilingual children were different on the relevant conditions of the executive control tasks from both the

monolinguals with whom they shared their life experiences and from those with whom they did not.

Finally, the results demonstrate that the mechanism responsible for the divergent developmental paths of monolinguals and bilinguals, leading to some advantages in executive functioning and some disadvantages in linguistic processing, is in place early in children's development. The experience of constructing two linguistic systems, of functioning in two linguistic environments, and of shifting between linguistic contexts shapes children's developing cognitive and linguistic systems irrespective of the two languages being learned and the culture in which children reside. The present results show how powerful this experience is.

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Figure 1.
Mean increase for selections of novel object in novel label condition than in control condition by age group, language group, and gender

Table 1

Mean and standard deviation for receptive vocabulary (PPVT – III/EVIP), number of correct responses on Luria's tapping test, and number of errors in Opposite Worlds task by language group and age group

Group	PPVT/EVIP	Tapping	Opposite Worlds		
			Same	Opposite	Cost
English Monolingual					
Younger	105.1 (13.7)	12.2 (4.6)	1.6 (2.8)	7.6 (7.9)	6.1 (7.0)
Older	110.6 (12.5)	14.0 (3.1)	0.3 (0.5)	1.5 (2.3)	1.2 (2.4)
French Monolingual					
Younger	96.5 (24.1)	9.2 (2.8)	1.6 (2.7)	5.2 (2.7)	3.6 (2.8)
Older	104.6 (15.0)	13.1 (4.3)	0.8 (1.4)	3.1 (3.4)	2.2 (3.1)
Bilingual Children					
Younger	97.2 (12.8)	13.9 (2.9)	0.4 (0.8)	3.6 (4.9)	3.2 (4.8)
Older	99.9 (15.3)	14.8 (2.2)	0.2 (0.4)	0.6 (1.1)	0.4 (1.2)

Means and standard deviations for proportion correct trials and median RTs in the ANT flanker task by language group, gender and condition (N = 89)

Table 2

Language group	Gender	Accuracy		RT	
		Congruent	Incongruent	Congruent	Incongruent
English Monolinguals	Girls	0.9 (0.1)	0.7 (0.2)	1527 (188)	1486 (308)
	Boys	0.9 (0.1)	0.8 (0.2)	1356 (192)	1496 (299)
French Monolinguals	Girls	0.8 (0.1)	0.7 (0.3)	1465 (338)	1484 (309)
	Boys	0.9 (0.1)	0.8 (0.2)	1376 (205)	1532 (274)
Bilingual Children	Girls	0.9 (0.1)	0.7 (0.2)	1486 (256)	1575 (283)
	Boys	0.9 (0.1)	0.8 (0.2)	1367 (208)	1554 (258)

Table 3

Numbers of monolingual and bilingual children passing or failing the Reverse Categorization task (N = 115)

Language group	Fail	Pass
Monolingual	22	41
Bilingual	8	44

Table 4
Correlations among vocabulary, word mapping, and executive function tasks for the entire sample

	Mutual exclusivity	Luria tapping	Opposite world errors	ANT	Reverse categorization
PPVT	0.06	0.28**	-0.18*	0.06	-0.04
Mutual exclusivity		-0.17	0.04	0.01	0.04
Luria tapping			-0.42**	0.01	0.57**
Opposite world				-0.23**	-0.45**
ANT					0.29**

*
 $p < .05$
**
 $p < .01$

Note. The tasks include standardized score on the PPVT ($n = 159$), the bias for selecting the novel object in mutual exclusivity ($n = 162$), proportion correct in the Luria tapping task for those children who successfully completed the first two trials ($n = 98$), total number of errors in the opposite world task ($n = 148$), mean correct RT to incongruent trials in the ANT task ($n = 107$), and the number of correct responses in the post-test of the reverse classification task for children who obtained more than 4/6 correct in the pre-test ($n = 115$).