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Language Proficiency and Executive Control in Proactive Interference: Evidence from Monolingual and Bilingual Children and Adults

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Abstract

Two studies are reported in which monolingual and bilingual children (Study 1) and adults (Study 2) completed a memory task involving proactive interference. In both cases, the bilinguals attained lower scores on a vocabulary test than monolinguals but performed the same on the proactive interference task. For the children, bilinguals made fewer intrusions from previous lists even though they recalled the same number of words. For the adults, bilinguals recalled more words than monolinguals when the scores were corrected for differences in vocabulary. In addition, there was a strong effect of vocabulary in which higher vocabulary participants recalled more words irrespective of language group. These results point to the important role of vocabulary in verbal performance and memory. They also suggest that bilinguals may compensate for weaker language proficiency with their greater executive control to achieve the same or better levels of performance as monolinguals.

Previous research with children and adults has shown that lifelong bilingualism, defined as the regular use of two languages, has systematic consequences for language and cognitive performance. The impact on language proficiency is generally in the direction of a disadvantage for bilinguals: bilingual children develop vocabulary more slowly in each language than monolinguals speakers of that language and perform more poorly on measures of language proficiency (Bialystok & Feng, in press; Oller & Eilers, 2002), and bilingual adults have a smaller vocabulary (Portocarrero, Burright, & Donovick, 2007), produce fewer words in verbal fluency tasks (Gollan & Kroll, 2001; Michael & Gollan, 2005), with more and tip-of-the tongue experiences (Gollan & Acenas, 2004), and record longer reaction times on picture naming (Roberts, Garcia, Desrochers, & Hernandez, 2002), and lexical decision tasks (Randsell & Fischler, 1987).

Another aspect of verbal performance is simple verbal recall. Here, too, bilinguals often perform more poorly than comparable monolinguals. In a combined analysis of three experiments involving 190 6–9 years old children, half of whom were bilingual, there was no difference in children's ability to recall increasingly long lists of animal names (Bialystok & Feng, in press), but similar research with adults indicates a different pattern. A memory study in which participants had to recall a list of 20 related words after either simply hearing the list or hearing the list while performing a distracting task showed significantly lower performance

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by bilinguals in all conditions, for both younger (20 years old) and older (70 years old) groups of participants (Fernandes, Craik, Bialystok, & Kreuger, 2007).

The vocabulary measures and performance on tasks requiring rapid lexical retrieval and naming may be related. Hedden, Lautenschlager, and Park (2005) reviewed evidence showing that performance on tasks based on lexical retrieval, in particular verbal fluency measures, is related to language proficiency especially as determined by vocabulary size. However, vocabulary is rarely measured in research comparing monolingual and bilingual adults performing these tasks, so it may be that the reduced scores obtained by bilinguals reflect differences in vocabulary size rather than differences in verbal processing.

Evidence from two studies supports the possibility that bilingualism may be confounded with lower vocabulary and that equating vocabulary would produce comparable performance by monolinguals and bilinguals. First, in a study comparing monolingual and bilingual young adults, the usual bilingual disadvantage on the category fluency task (Gollan, Montoya, & Werner, 2002; Portocarrero, Burright, & Donovick, 2007; Rosselli et al., 2000) disappeared when participants were equated for score on a receptive vocabulary test (Bialystok, Craik, & Luk, in press). Scores on category fluency reflect levels of language proficiency (Delis, Kaplan, & Kramer, 2001). Second, in the free recall memory study described above by Fernandes et al. (2007), the monolinguals scored higher than the bilinguals on a vocabulary test, and this might have also influenced the pattern of results. An analysis of covariance that statistically controlled for differences in vocabulary score revealed no significant difference in recall. Therefore, because it is typically the case that bilinguals control a smaller vocabulary in each language than comparable monolinguals, it is not clear whether the poorer performance by bilinguals on verbal tasks is a consequence of bilingualism, smaller vocabulary, or both.

In contrast to these results, there is extensive evidence showing bilingual advantages in executive functioning using tasks based on response conflict, switching, and flexibility. This bilingual advantage has been found for children (Bialystok & Shapero, 2005; Carlson & Meltzoff, 2008; Martin-Rhee & Bialystok, 2008; Kovacs, in press; Yang & Lust, 2005), adults (Costa, Hernandez, & Sebastián-Gallés, 2008), and older adults (Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Craik, & Ruocco, 2006; Bialystok, Craik, & Ryan, 2006). A crucial aspect of these results is that the tasks were all nonverbal measures of attention and control and bore no obvious connection to language processing. Nonetheless, bilinguals consistently outperform monolinguals on these tasks that measure inhibitory control and cognitive flexibility.

These two bodies of research point to opposing effects for the role of bilingualism in shaping performance: for verbal tasks, bilinguals perform more poorly, but for nonverbal executive control tasks, bilinguals perform more efficiently than monolinguals. However, unlike laboratory tasks that are designed to isolate specific processes so they can be studied in detail, most cognitive processing is more integrative. Therefore, it is not known how these costs and benefits interact in a task that requires both verbal processing and executive control.

There is some evidence that the bilingual advantage in executive control can be used to boost performance in verbal tasks for which there are usually bilingual disadvantages. The first case is the study mentioned above in which bilinguals who were matched to monolinguals on vocabulary size performed verbal fluency tasks. Unlike category fluency, which is considered to reflect language proficiency, letter fluency also involves executive control (Delis, Kaplan, & Kramer, 2001). In this case, the bilinguals equated on vocabulary size with the monolinguals outperformed them on the letter fluency task (Bialystok, Craik, & Luk, in press).

A second example is a study that employed the process dissociation paradigm developed by Jacoby (1991, 1998) to distinguish between automatic and controlled aspects of memory.

Automatic memory indicates recognition and is reflected in a score called familiarity, whereas controlled memory indicates intentional recall and executive control and is reflected in a score called recollection. Research with this task has consistently shown that familiarity remains stable across the lifespan but recollection declines with age (e.g., Light, Prull, LaVoie & Healy, 2000; Prull, Dawes, Martin III, Rosenberg, & Light, 2006). In a study of older and younger monolinguals and bilinguals, all participants achieved the same score on familiarity, but bilinguals obtained higher scores for recollection than monolinguals, especially for the older adults (Wodniecka, Craik, & Bialystok, 2007).

Another task that involves both verbal processing and executive control is the paradigm used to demonstrate the effect of proactive interference (PI) on memory. PI occurs when retrieval of recent material is impaired by the prior exposure to similar items. The continued presentation of material to be learned that shares category membership makes it difficult to keep track of which information was heard most recently and the ability to accurately recall the items on the last presented list decreases. This decrease in recall over similar lists reflects the buildup of PI. If the category membership of the items is changed on a subsequent list, recall is restored to the original level, indicating the release from PI. This PI effect in which memory declines with subsequent presentation of similar material and is restored when the stimulus category changes has been has been found with both children (e.g., Dempster, 1992; Kail, 2002) and adults (e.g., Hasher, Chung, May, & Foong, 2002).

In a widely-used version of the task developed by Engle and colleagues (Kane & Engle, 2000), participants are given four sequential lists of words to recall. Following each list, participants engage in a filler task to prevent rehearsal and are then asked to report as many words as possible from the words just presented. The words in the first three lists are members of the same semantic category but the words in list 4 belong to a different category. In this way, PI is built up through the first three lists and the release is shown when the category changes in list 4. The decline in the number of words recalled in lists 2 and list 3 compared to list 1 is the index of the PI buildup and the restoration of recall in list 4 is the index of the PI release.

The PI buildup and release paradigm is used to indicate levels of controlled processing as it is assumed that the ability to control attention to previously presented information is part of the executive function (e.g., Hedden & Yoon, 2006; Kane & Engle, 2000; Lustig, May & Hasher, 2001; Roberts & Pennington, 1996; Zelazo, Carter, Resnick, & Frye, 1997). Studies using fMRI have shown that Brodmann’s area 45 of the left inferior prefrontal cortex demonstrates sensitivity to PI (e.g., Postle, Brush, & Nick, 2004). Therefore, the PI paradigm involves executive control in a verbal task.

Research using this paradigm with monolingual children has indicated that the interference effect of PI decreases between 4 and 13 years of age as children develop better cognitive control (Kail, 2002). In a review of 26 studies in which children performed a PI task, Kail (2002) showed that age-related change in memory performance reflected an age-related decrease in susceptibility to interference for children and that this change was mediated by an age-related increase in speed of information processing.

The interference created by the PI paradigm is larger for older participants (Borella, Carretti, & Mammarella, 2006; Hasher & Zacks, 1988; Lustig, May, & Hasher, 2001; May, Hasher, & Kane, 1999) and for people with amnesia (Warrington & Weiskrantz, 1970). The larger effect is usually attributed to the increased difficulty of inhibiting an inappropriate response from a previous list (Hasher & Zacks, 1988). An alternative explanation, however, is that greater susceptibility to interference results from lower scores for recollection (Jacoby, Hessels, & Bopp, 2001). Bowles and Salthouse (2003) reported that disproportionate reactivity to proactive interference accounted for approximately half of the age-related variance in working memory performance. It has also been shown that PI task explained a significant portion of the variance of fluid intelligence as measured by the Raven test (Borella, Carretti, & Mammarella, 2006).

For these reasons, the PI effect stands at the intersection of the processing advantages and disadvantages found for bilinguals. Executive control is required to monitor and control attention to the words in each list, updating working memory as interference builds across the lists from the same category. At the same time, overall recall is related to language proficiency and vocabulary size, but also taps a skill that bilinguals perform more poorly, namely, simple recall of word lists. The question, therefore, is whether the bilingual advantage in executive control will extend to a task based on verbal processing and improve the performance of bilinguals in a domain for which their scores are frequently poorer than monolinguals.

On most views of executive function, the components responsible for controlled attention are domain general and applied to a wide range of contents (e.g., Denckla & Reiss, 1997; Zelazo, Carter, Reznick, & Frye, 1997). However, Friedman and Miyake (2004) have argued that resistance to PI is different from the abilities involved in prepotent response inhibition and suppression of interference usually investigated as part of inhibition. On this view, bilinguals would not benefit in the PI task. However, because of the trade-offs between executive control and language proficiency in the PI task, it is possible that even if bilinguals and monolinguals achieve the same overall level of performance, it may be accomplished through a different balance between these abilities. Therefore, in addition to overall levels of achievement, the results will be examined in more detail to determine the role of language proficiency and executive control for each group of participants. The intention is also to isolate the role of language proficiency in order to understand the nature of the bilingual disadvantage in verbal tasks. For these reasons, the purpose of these studies is partly exploratory. A PI task was administered to both children (Study 1) and adults (Study 2) to determine the relation between executive control and language proficiency in performance and to identify the potential changes in these relationships change with development.

Study 1

Participants

The study included 40 7-year-old children, half of whom were bilingual. The monolinguals (9 girls and 11 boys) had a mean age of 86.5 months (SD = 7.8), and the bilinguals (11 girls and 9 boys), a mean age of 82.8 months (SD = 4.0). Although the bilingual children were somewhat younger than the monolinguals, the difference was not significant $F(1, 38) = 3.56$, $p = .07$, and subsequent analyses showed there was no correlation between age and performance on any of the tasks. The bilingual children spoke a non-English language at home and attended school and community events entirely in English. There were seven different non-English languages represented in the sample: Cantonese, Arabic, Korean, Spanish, Farsi, Tagalog, and Tamil. All the bilingual children had been raised speaking both languages and spoke both languages daily. Parents completed a questionnaire inquiring about the home language environment, including questions about the language used for specific activities and for interactions between specific family members. The responses were indicated on a 5-point scale in which 1 meant “entirely in English” and 5 meant “entirely in the non-English language”, so that a rating of 3 represented a balance between the two languages. The results from this questionnaire yielded a mean score of 2.3 (SD = 0.8) for the language used by children at home, indicating that children used more English than the other language, $t(19) = -4.27$, $p < .0005$. In contrast, the language used by the parents when speaking to the children was 3.5 (SD = 1.1), $t(19) = 1.83$, $p = .08$, and the language used by the parents when speaking to each other was 3.8 (SD = 1.1), $t(19) = 2.78$, $p < .02$, both indicating a preference for the non-English language.

These scores portray a home environment that is very bilingual, with both languages being used regularly, and a slight bias for children to use English and the parents to use the non-English language.

Tasks

Children were assessed for language knowledge and short term memory using Peabody Picture Vocabulary Test (PPVT), digit span, and sequencing span, as well as the PI task. The tasks were administered in a fixed order: digit span, sequencing span, PI, and PPVT-III. The testing session lasted approximately 25 minutes and children were given stickers upon completion to thank them for their participation. All the tasks were administered in English to all participants.

Peabody Picture Vocabulary Test III-A (Dunn & Dunn, 1997)—This is a standardized test of receptive vocabulary. The test consists of a series of plates, each containing four pictures. The experimenter names one of the pictures and the participant indicates which picture illustrates that word by pointing. The starting item is determined by the child’s chronological age. The items become increasingly difficult, and testing continues until the participant makes 8 errors out of 12 items in a set. The score is calculated by tables that convert the raw score to a standard score in terms of the age of the participant. The test was administered in English to all participants.

Forward Digit Span—The task is a measure of short-term verbal memory adapted from Wechsler (1974). Children were asked to repeat a string of numbers in the order in which they were heard. Testing began with a string of two numbers, and the string length increased by one item after every second trial, producing two trials for each string length. Testing continued until the child failed to correctly reproduce both examples at a given string length. The span was recorded as the longest string length at which children could correctly reproduce one of the trials. The score was calculated by assigning one point for each number reproduced in the correct order in each string. The maximal span length was 9, and the maximum score was 88.

Sequencing Span—The task is a measure of working memory. As in the digit span task, children were asked to repeat a string of numbers, but in this case the numbers needed to be reordered into ascending sequence, hence it required holding information in mind and working with re-ordering it. For example, the string “8, 2” would be repeated as “2, 8”. Testing began with a string of two numbers, and the string length increased by one item after every second trial, producing two trials for each string length. Testing continued until the child failed to correctly reproduce both trials at a given string length. The span was recorded as the longest string length at which children could correctly reproduce one of the trials, and the score was calculated by awarding one point for each number reproduced in the correct order in each string. The maximum span was 7 and the maximum score was 54.

Proactive Interference Task—The PI task was programmed in E-prime and presented on a Dell Latitude C840 laptop computer. Children were presented with four consecutive lists of words containing 5 words each. The words were presented both visually and orally at the rate of one word every 2 seconds and children repeated each word aloud when they saw and heard each one. The auditory files were recorded into wave files that were presented through the computer speakers at the same time as the word appeared. The completion each list was immediately followed by a filler task: a number randomly chosen between 14 and 29 was shown on the screen and children counted forward from that number for 10 seconds. At the end of the 10 seconds, children were asked to recall the words from the list they just saw and were given 10 seconds to report as many as they could remember. The next list of words followed using the same procedure. Children’s responses were recorded by the experimenter on the testing sheets.

The stimuli were high frequency words from the categories fruit, clothing, colors, and body parts (Battig & Montague, 1969). The first three lists were words from the same category and the fourth list represented a different category. Four versions of the task were constructed by using a different category for the primary category in the first three lists and the release category for the fourth list. These four versions were counterbalanced across participants.

Results

The mean scores and standard deviations for the vocabulary and memory measures are reported in Table 1. A series of one-way ANOVAs comparing the two language groups indicated that the monolinguals had higher vocabulary scores than the bilinguals, F (1, 38) = 6.51, $p < .02$, with no language group differences in either of the memory tests, both *F*s < 1.

The mean number of words recalled in each list by language group is shown in Table 2. The results conform to the standard pattern for this task in which there is a main effect of list, F (3,102) = 11.23, $p < .0001$. Contrasts showed a significant decline from List 1 to List 2, F (1, 34) = 8.55, $p < .01$, but only a marginal effect for the decline from List 2 to List 3, F (1,34) = 3.59, $p = .07$, and a significant recovery on List 4, F (1,34) = 17.02, $p < .0002$, that returned performance to the level found for List 1, *F*s < 1.

Although there was no main effect of language or interaction of language and list, the change in performance across lists appeared to be different for each language group so they were analyzed separately by group to detect more subtle patterns. For monolinguals, the pattern conformed to the overall effect, indicating significant interference between List 1 and List 2, an insignificant decline from List 2 to List 3, F (1,16) = 2.11, n.s., and a recovery with the category change in List 4, F (1,16) = 9.66, $p < .01$. Again, there was no difference in recall between Lists 1 and 4, *F*s < 1. The bilingual children showed less build up of interference: there was no significant decline between List 1 and List 2, F (1,18) = 1.80, n.s., or between List 2 and List 3, F (1,18) = 1.46, n.s., although there was an improvement in List 4, F (1,18) = 7.46, $p < .01$.

Performance can also be considered in terms of the difference in recall in each list relative to the child's own baseline established in List 1 (see Kane & Engle, 2002). This score, which represents the proportional change across lists, is calculated by dividing the difference between the number of words recalled on List 1 and List n by the number of words recalled on List 1. For example, the proportional change for List 2 is the number of words recalled in List 1 minus the number of words recalled in List 2, divided by the number of words recalled in List 1. These proportional changes in recall for List 2 and List 3 are shown in Figure 1. A 2-way ANOVA indicated no difference between the lists, F (1, 34) = 2.02, $p = .16$, and a trend for the bilinguals to show a smaller decline, although it was not significant, F (1, 34) = 3.55, $p = .07$.

The errors in Lists 2 and 3 indicate intrusions from words in the same category that appeared on a previous list; the ability to prevent these intrusions reflects executive control. A one-way ANOVA showed that the monolingual children (M = 1.10, SD = 0.97) committed more intrusions than the bilingual children (M = 0.40, SD = 0.68), F (1, 38) = 7.00, $p < .01$.

The bilinguals had lower receptive vocabulary scores and were slightly (but not significantly) younger than the monolinguals. To determine whether these variables influenced recall on the PI task, correlation coefficients were calculated between age, PPVT-III scores, and PI recall. Age did not correlate with performance on either the PPVT-III measure or recall in the PI task, but there was a moderate correlation between PPVT-III and total recall, r (36) = 0.34, $p < .05$. Therefore, an ANCOVA was conducted to determine whether controlling for PPVT-III scores would reveal different effects of language group. The least square means by list are plotted in

Figure 2. Although the graph indicates better recall by the bilinguals, an ANCOVA showed that the difference was still not significant.

Finally, to explore the effect of language proficiency as indicated by vocabulary size on recall performance, children were classified into high and low vocabulary groups. Since PPVT-III scores are standardized measures, a score of 100 indicates average ability. Therefore, children were divided into the two vocabulary groups using the criterion score of 100. There were 13 monolinguals with PPVT-III scores higher than 100 (M = 110.9; SD = 5.7) and 7 monolinguals with PPVT-III scores lower than or equal to 100 (M = 94.7; SD = 4.4); there were 8 bilinguals with PPVT-III scores higher than 100 (M = 107.8; SD = 5.3) and 12 bilinguals with PPVT-III scores lower than or equal to 100 (M = 88.8; SD = 9.5). The mean number of words recalled by list for each language and vocabulary group is shown in Figure 3. Apart from the usual difference between lists, F (3, 96) = 10.91, $p < .0001$, there was no significant effect of either language group or vocabulary size. However, the pattern shown in the graph reveals a tendency for the bilinguals in each vocabulary group to recall more words than the monolinguals, especially on List 3.

Discussion

Bilingual children who had a smaller receptive vocabulary than monolinguals but similar levels of short term and working memory performed the same as monolinguals on a PI task. Nonetheless, there were subtle differences in the performance between children in the two language groups. First, the bilinguals committed fewer intrusions than the monolinguals even though the number of words recalled was the same. Second, unlike the monolinguals, the bilinguals did not show a significant decline in recall between list 1 and list 2, or between list 2 and list 3, indicating less build up of interference from the previous material. These results provide preliminary evidence that for children there are at worst no bilingual disadvantages in the ability to control attention to lists of words and there may even be some advantages. However, the effects are small and the variance is large, making it difficult for clear patterns to emerge. Thus, these results illustrate a weak pattern that requires further evidence to confirm.

Study 2

Part of the problem in investigating cognitive and language processing in young children is the enormous individual variability that makes it difficult to detect reliable differences between groups. Therefore, the question of the relationship between bilingualism and language proficiency in proactive interference was pursued by examining a sample of young adults for whom processing was more stable.

Participants

One hundred and nine young adults participated in Study 2 in return for introductory psychology course credits or $15. Based on the Language Background Questionnaire filled out by each participant prior to testing, 54 of the participants were monolingual speakers of English (mean age = 21.9, SD = 3.1), and 55 of the participants were bilingual (mean age = 21.1, SD = 2.3). The bilinguals reported using English and another language on a daily basis, having done so by the age of 10 at the latest. For the bilingual participants, the non-English language included Cantonese, Hindi, Arabic, French, Italian, Portuguese, Somali, Spanish, Tamil, Amharick, Armenian, Chaldean, Farsi, Gujaratti, Korean, Patois, Polish, Punjabi, and Twi.

Tasks

All participants were tested individually on 3 tasks in the fixed order: Language Background Questionnaire, proactive interference task, and PPVT-III A (Dunn & Dunn, 1997). Again all testing was conducted in English with an English-speaking experimenter.

Language background questionnaire—This questionnaire was filled out by the participant to indicate extent of language use in a variety of settings, the age of the acquisition of the language(s) they speak, and the degree to which each language is used daily.

Proactive Interference Task—The PI task was programmed in E-prime and was presented on a Dell Latitude C840 laptop computer. This is a revised version of the PI task used by Engle and Kane (2000). Nine complete stimulus sets were created and each participant was shown only one stimulus set. Each stimulus set comprised four test lists of 10 words from the same semantic category, matched on word length and frequency as determined by Battig and Montague (1969). The first three lists contained words from the same semantic category, and the fourth from a different one. The categories used were animals, occupations, and sports. The same practice set containing three words that were unrelated to the words in the test lists was used for all participants, and included instructions to familiarize each subject with the task. When the participant was comfortable with the instructions, they were asked to press the spacebar on the keyboard to start the actual task. Participants were asked to treat each list independently, and were instructed to read the words out loud as they were presented at a fixed rate of 2000ms (1750 ms per word and 250ms blank screen) one at a time in the centre of a computer screen. After each list, a random three digit number appeared on the screen, at which time participants were given 16s to count backwards by intervals of 3 until a chime was heard. The chime cued the participant to start recalling as many words from the studied list as possible within a 20s time limit. After the time limit, a blank screen appeared for 2s and another chime was presented to indicate the start of the next list. All four test lists were presented consecutively with no breaks. Responses were recorded by the researcher, including any incorrect words recalled.

Results

The mean standard score on the PPVT-III was higher for the monolinguals (M = 105.93, SD = 9.10) than for the bilinguals (M = 99.04, SD = 11.55), F (1,107) = 11.94, $p < .0008$.

The mean number of words recalled in the PI task for each language group is shown in Table 3. Recall across the four lists conformed to the standard pattern of decline and recovery, F (3,321) = 95.02, $p < .0001$, with each inter-list change significant, $p < .0001$. There was no difference in this pattern for the two language groups, and no interaction of language group and list recall, Fs < 1.

As in Study 1, recall for each list relative to the participant's own baseline performance in list 1 was calculated and these proportional changes in recall are shown in Figure 4. Again, there was a strong effect of list, F (1,107) = 19.21, $p < .0001$, but no difference between language groups and no interaction. Additionally, there was no difference in the number of intrusions committed by monolinguals (M = 1.0, SD = 1.3) and bilinguals (M = 0.9, SD = 1.0), Fs < 1.

Because the language groups differed in vocabulary score, the relation between vocabulary and recall was examined and found to be significantly correlated, both for the whole sample, r (109) = 0.48, $p < .0001$, and for each of the language groups: monolinguals, r (54) = 0.59, $p < .0001$, and bilinguals, r (55) = 0.39, $p < .004$. Therefore, an ANCOVA controlling for PPVT scores was conducted on recall in the four lists. The least squared mean number of words recalled for each list is displayed in Figure 5. In addition to the usual effect of list, F (3,315)

= 3.57, $p < .02$, there was also an effect of language group, F (1,105) = 5.58, $p < .02$, with bilinguals recalling more words in the adjusted scores than monolinguals, and no interaction.

Finally, participants were classified into the two vocabulary groups using the procedure described in Study 1. The subgroups included 41 monolinguals with PPVT-III scores higher than 100 (M = 109.8; SD = 5.9) and 13 monolinguals with PPVT-III scores lower than or equal to 100 (M = 93.7; SD = 6.2), and 24 bilinguals with PPVT-III scores higher than 100 (M = 110.0; SD = 7.0) and 31 bilinguals with PPVT-III scores lower than or equal to 100 (M = 90.6; SD = 5.7). The mean number of words recalled in each list by language group and vocabulary group is shown in Figure 6. A three-way ANOVA for language group, vocabulary group, and list was conducted. Again, the results conform to the standard pattern obtained from this task in which recall declines from list 1 to list 2, list 2 to list 3, and recovered in list 4, F (3, 315) = 94.22, $p < .0001$. In addition, participants in the high vocabulary group recalled significantly more words than those in the low group, F (1,105) = 25.18, $p < .0001$, but as with the ANOVA using the raw recall scores, there was no effect of language group. There is a trend, shown in the graph, for the bilinguals to recall more words than the monolinguals for those participants with low vocabulary scores, especially in list 2 and list 4.

Discussion

The overall performance of the monolinguals and bilinguals in the PI task was the same, but there were differences attributable to language proficiency as indicated by vocabulary score. Evidence of the importance of vocabulary was the correlation between PPVT-III score and recall. There were two consequences of this relation. First, because the bilinguals had a lower vocabulary than monolinguals, an analysis of covariance that corrected for differences in vocabulary revealed a significant advantage for bilinguals in the PI task. Second, an analysis of the uncorrected recall scores by vocabulary group showed a large difference in recall for participants in the two groups.

General Discussion

The results of these two studies provide a preliminary view of how the lexical retrieval disadvantages and cognitive control advantages in bilinguals interact in performing a complex task. Few studies that investigate the effect of bilingualism on performance consider both of these opposing consequences. The results of these studies refine our conception of the impact of bilingualism on cognitive and linguistic performance and our understanding of the factors responsible for performance in memory paradigms such as the PI task. The bridge between these implications is the role of language proficiency indicated by vocabulary level in the solution to these tasks and the fact that bilinguals generally have smaller vocabularies in each language than monolinguals. Although bilinguals in both studies had smaller vocabularies than monolinguals, and vocabulary size was correlated with recall in the PI task, bilinguals overall performed the same as monolinguals.

The PI paradigm is a commonly-used measure that demonstrates how interference from similar information builds up over a short period of time and requires effortful control to monitor and recall. A small change in category membership is sufficient to restore memory to the original level. Performance relies both on verbal abilities to permit efficient access to semantic domains and hold words in mind for later recall, and on executive control to monitor the words and update lists as subsequent lists are presented and avoid repeating words from a prior list. The present studies demonstrated that participants with high vocabulary scores and presumably higher verbal abilities performed the PI task better than comparable participants with lower scores. The results are parallel to those reported by Kane and Engle (2000) in which participants with high working memory resources performed the PI task better than comparable participants with lower working memory capacity. Together, the results confirm the necessity for both language proficiency and executive resources, at least in the sense of working memory, to deal with the task. The first of these abilities is generally poorer in bilinguals than monolinguals, but the second is generally better in bilinguals.

Although the data are more suggestive than conclusive, the patterns found in the two studies indicate important relationships between these factors that have not previously been demonstrated. For both children and adults, the bilinguals provided some evidence for better control of attention in the task than monolinguals. In Study 1, the bilingual children made fewer intrusions than the monolinguals and showed a trend for a smaller proportional decline with subsequent lists. In Study 2, the bilinguals recalled more words than the monolinguals once the variance attributable to vocabulary score had been controlled.

The most striking finding was the importance of vocabulary score on recall in Study 2. Most research that has reported bilingual disadvantages in verbal tasks has not taken level of vocabulary into consideration, but when vocabulary level is included as a covariate, differences between monolinguals and bilinguals disappear (Bialystok et al, in press; Fernandes et al., 2007). Thus, it may be that bilingual disadvantages in verbal tests, including verbal memory, have been misattributed to bilingualism when the underlying source of performance differences is vocabulary knowledge. Of course, the *cause* of the lower vocabulary in some real sense is bilingualism, but it is not bilingualism *per se* but rather an implication of bilingualism that is responsible. Equated for vocabulary, monolinguals and bilinguals perform more similarly. In the present studies, the bilinguals had a lower average vocabulary score than did the monolinguals at each age, as generally reported in the literature, but with vocabulary controlled, there was an indication of better control of attention to the words held in short term memory.

These data are only suggestive but extend our understanding of how bilingualism affects cognitive and linguistic abilities. In spite of having smaller vocabulary scores, bilinguals performed no worse than monolinguals on the verbal memory task. In addition, however, there is some indication that bilinguals are able to use their superior attentional control to assist their memory in this difficult verbal task. These studies are the first to explore these ideas; further research is necessary to clarify the relation between language proficiency and executive control in bilinguals.

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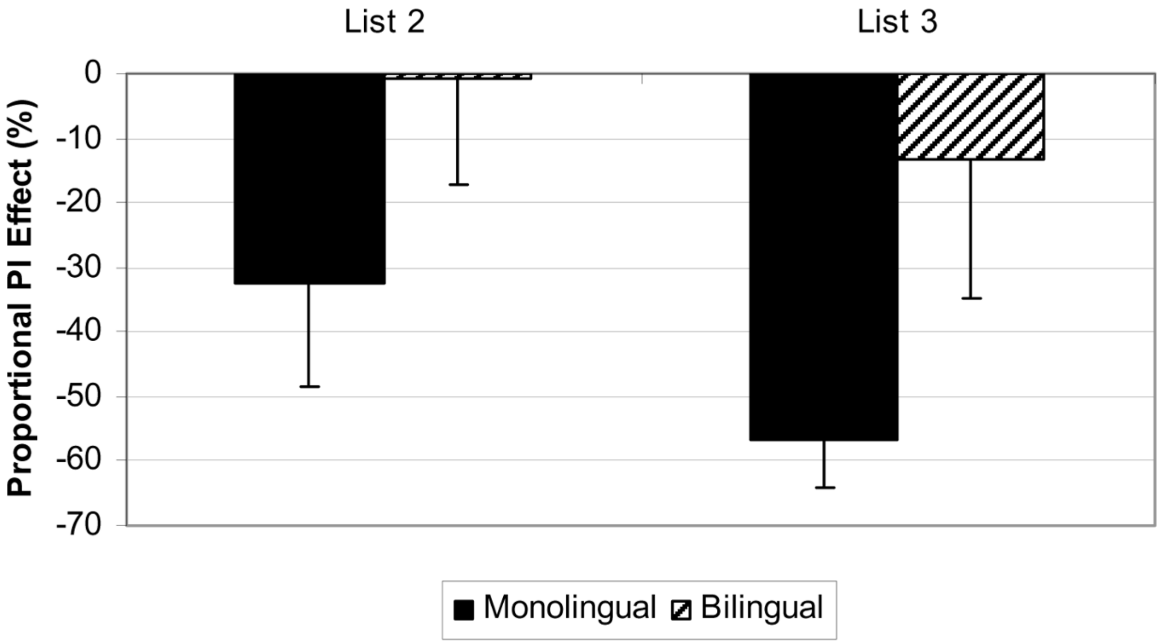

Figure 1.
Proportional PI effect and standard error in list 2 and list 3 by monolinguals and bilinguals in Study 1.

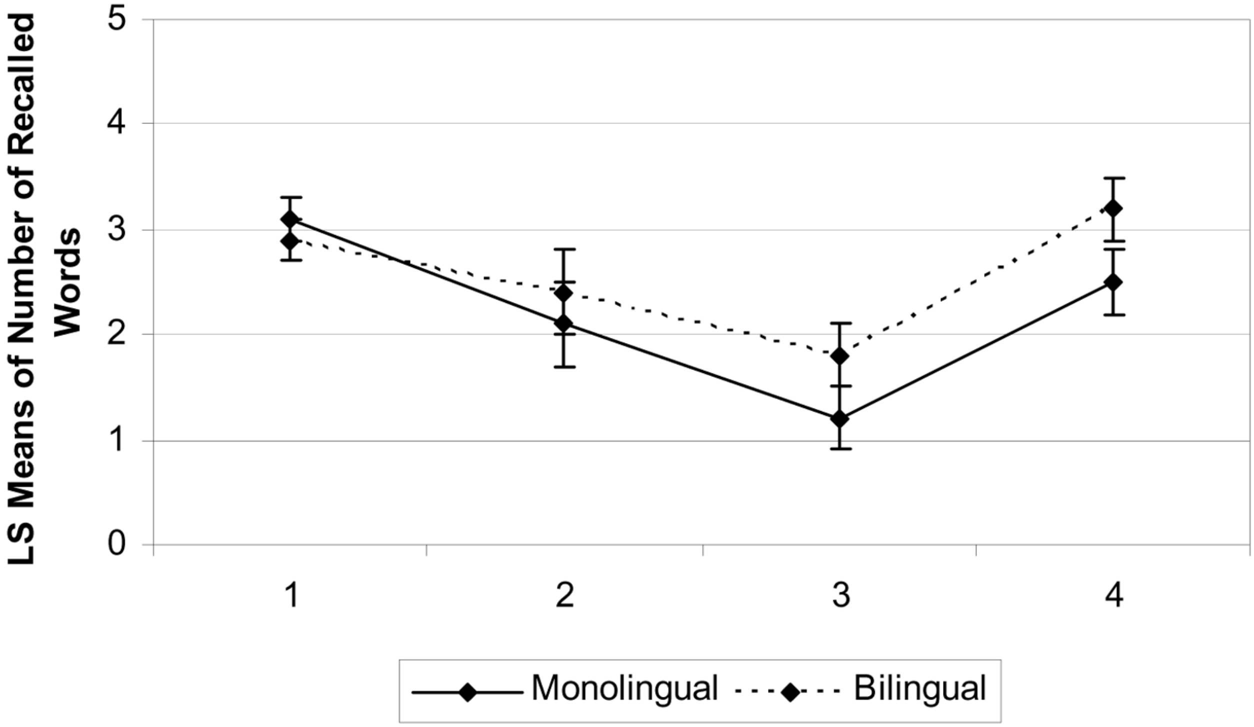

Figure 2.
Least square mean number of words recalled and standard error in each list by language group in Study 1.

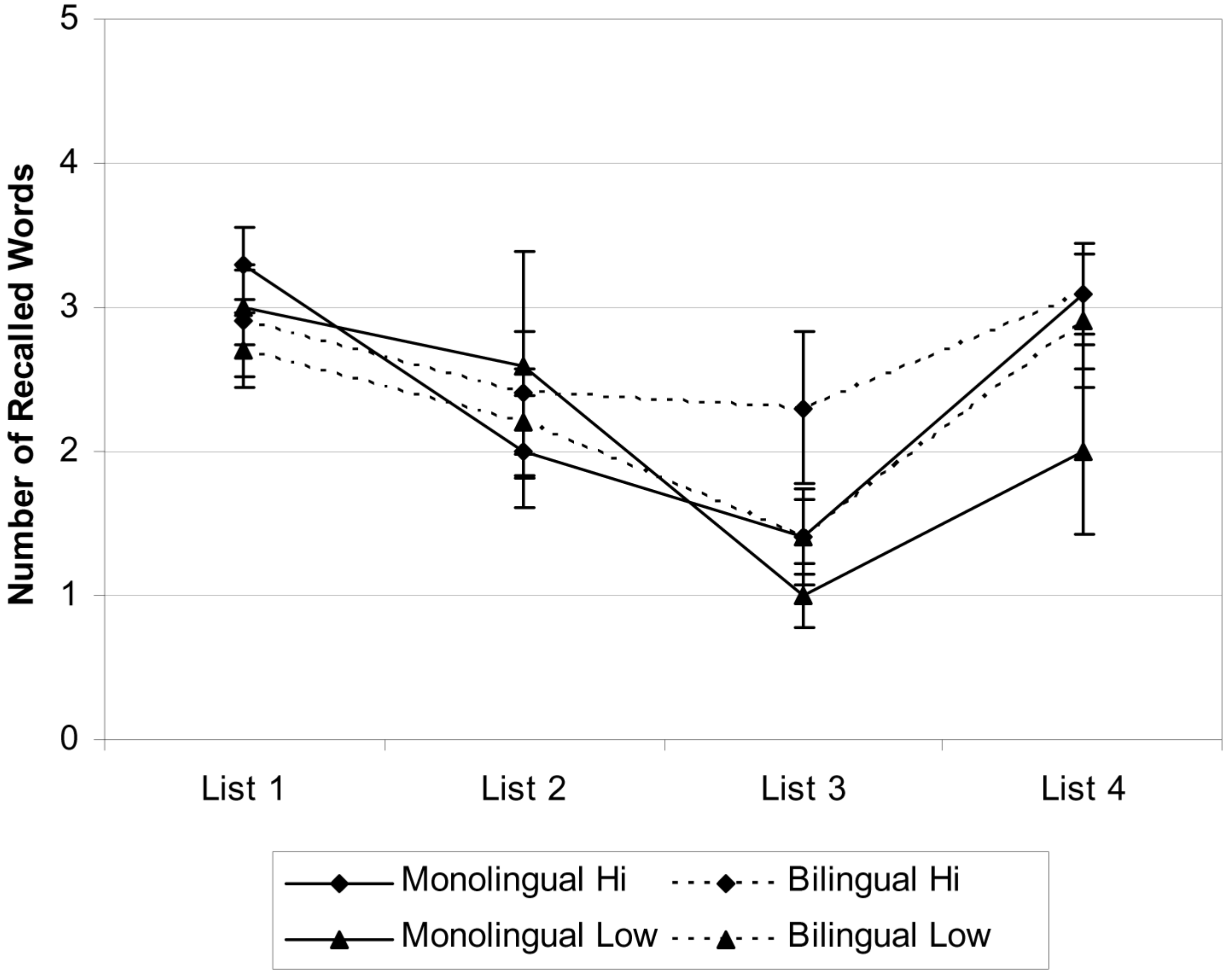

Figure 3.
Mean number of words recalled in each list and standard error by language group and vocabulary score group in Study 1.

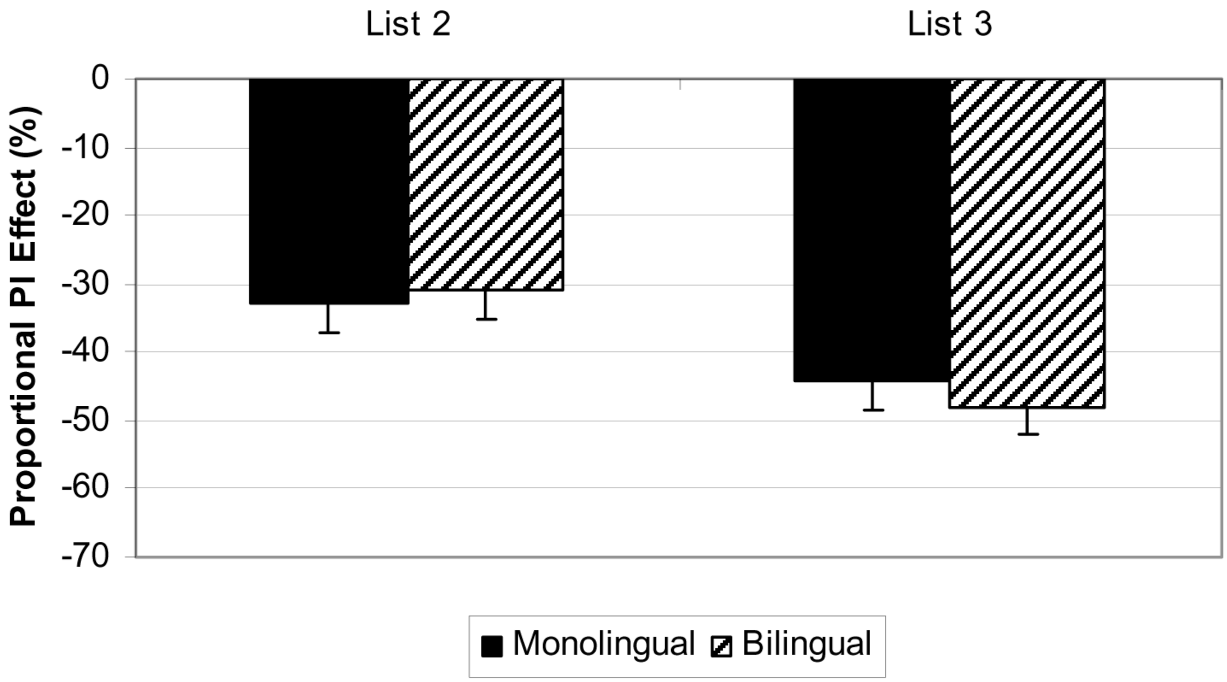

Figure 4.
Proportional PI effect and standard error in list 2 and list 3 by monolinguals and bilinguals in Study 2.

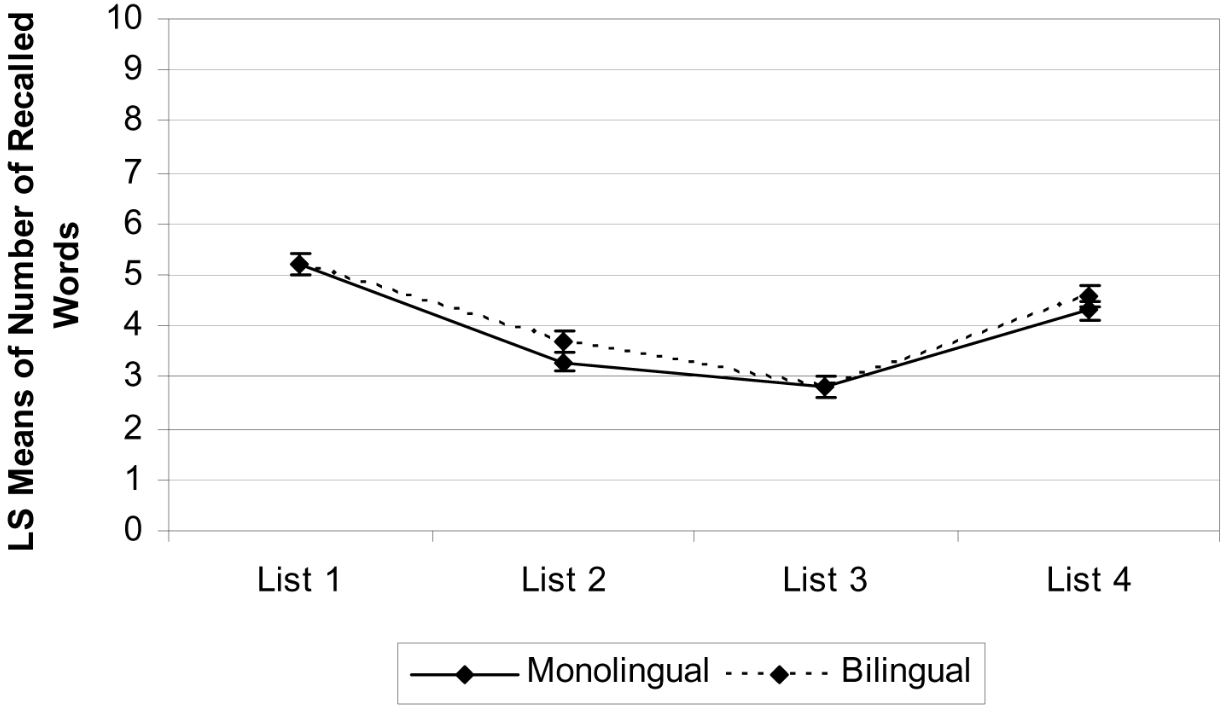

Figure 5.
Least square mean number of words recalled and standard error in each list by language group in Study 2.

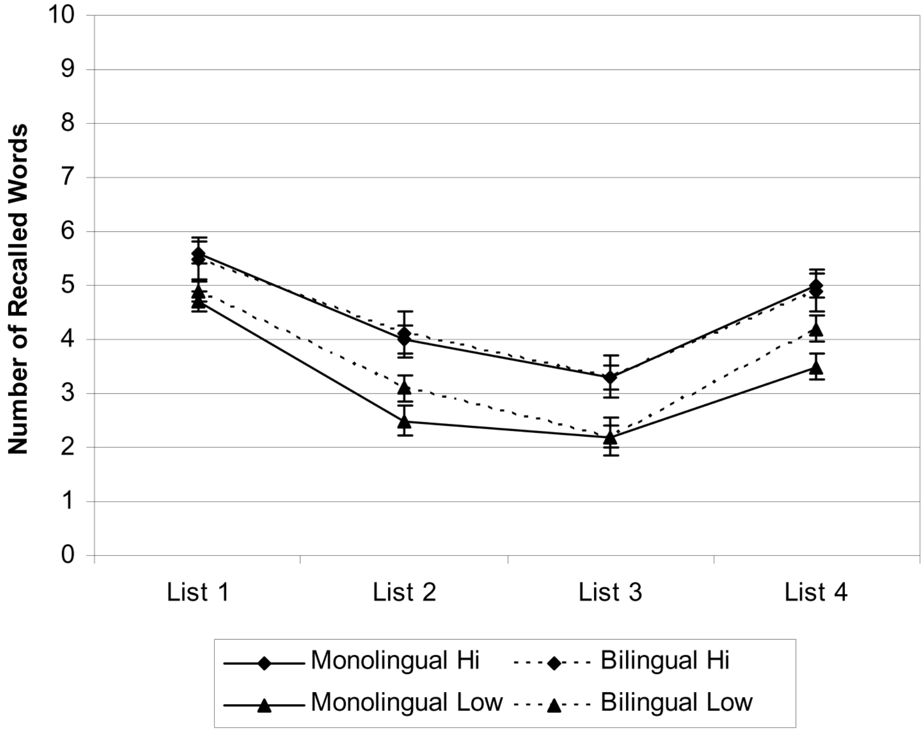

Figure 6.
Mean number of words recalled in each list and standard error by language group and vocabulary score group in Study 2.

Table 1

Mean scores and standard deviations on background measures by language group in Study 1

Variable	Monolingual	Bilingual
PPVT-III Std. Score	105.3 (9.5)	96.4 (12.4)
Forward Digit Span	5.5 (1.0)	5.5 (0.8)
Forward Digit Score	37.6 (11.8)	36.7 (8.0)
Sequencing Span	4.5 (1.1)	4.1 (1.1)
Sequencing Score	25.9 (10.0)	23.2 (11.4)

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Table 2

Mean number words correctly recalled and standard error in each list by language group in Study 1.

List	Monolingual	Bilingual
List 1	3.2 (0.2)	2.8 (0.2)
List 2	2.2 (0.4)	2.3 (0.3)
List 3	1.3 (0.2)	1.8 (0.3)
List 4	2.7 (0.3)	3.0 (0.3)

Table 3

Mean number of words correctly recalled and standard error in each list in the PI task by language group in Study 2.

List	Monolingual	Bilingual
List 1	5.4 (0.2)	5.2 (0.2)
List 2	3.6 (0.2)	3.5 (0.2)
List 3	3.0 (0.2)	2.7 (0.2)
List 4	4.7 (0.2)	4.5 (0.2)