Effects of Bilinguals' Controlled-Attention on Working Memory and Recognition

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The present study investigated whether bilinguals could show higher working memory (WM) capacity by controlling their attention well on an attention-impeded Stroop-span task while undergoing constant interference. Our research question sprang up from the two existing bodies of research in Cognitive Psychology as an effort to connect the two.

First, in the area of bilingualism research, it was thought that bilinguals' long-term experience of using two languages disciplined bilinguals to have a better controlled-attention than monolinguals by helping them pay their attention directly to relevant information under the pressure of interference (Bialystok and Majumder, 1998). As an initial attempt to explore this cognitive difference between bilinguals and monolinguals in language processing, Been-Zeev (1977) employed metalinguistic tasks such as Symbol Substitution and provided a context of competition between the usual and unusual semantic reference function. It turned out that bilinguals surpassed monolinguals in the task suggesting that bilingual children might have developed "particular strategies" through the process of dual language acquisition. In Bialystok (1992a), these "particular strategies" which is redefined as "control of attentional processing," refers to the child's ability of executive attention to focus on specific aspects of a stimulus in the presence of conflict or distraction. To test her hypothesis that bilingual children would demonstrate a significant advantage over monolingual children in tasks requiring advanced controlled- attention, Bialystok (1986, 1988, 1992b, 1998) designed a task that asked children to make judgments of grammaticality ignoring the semantic meaning of the sentence. In numbers of experiments and replications, bilinguals' higher levels of control processing has been supported to facilitate the direction of attention to relevant information in a distraction condition.

Second, in the area of working memory research, Baddeley and Hitch (1974) proposed the "central executive" which is related to what Bialystok (1992a) called the controlled-attention, as one the element of their working memory model. This attention mechanism is thought to control the limited cognitive resources in all forms of information processing (Rosen & Engle). Turner and Engle (1989) found that individual differences in working memory capacity are likely to be individual variation in the attentional capacity. Engle (2002) further confirmed in a series of published experiments that the greater working memory capacity relies on the ability to use controlled-attention in the presence of interference. And recently, Kane and colleagues (2001) proved strong correlation between controlled-attention and working memory capacity on the conflict resolution task.

However, although the logic and empirical evidences are strong in the two areas of research, little attempt has been made to connect the findings from the tow bodies of research. Therefore, based on the assumption that bilinguals are better at controlled-attention than monolinguals and the different attention capacity appears to make individual differences in the measures of working memory capacity, we hypothesized that bilinguals would show significantly greater working memory capacity than monolinguals on an attention-impeded task while bilinguals and monolinguals would show no difference in working memory capacity on attention-aided tasks.

1. Method

1.1 Subjects

Seventeen balanced English-Korean bilinguals and ten English monolinguals, all from Cornell University, participated in the study. Bilingual participants were screened according to their self-rated

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proficiency of both languages in understanding, speaking, reading, and writing (Weber-Fox and Neville, 1996). All had not participated in any related experiments.

1.2 Materials

The experimental word stimuli were drawn from Battig and Montague (1969) and McEvoy and Nelson (1982). All of them were nouns and high in overall frequency. We tried to ensure that the number of word syllables, noun categories (abstract vs. concrete), and beginning letters of each item were all controlled. Care was also taken to avoid the overlapping of letter stems, relatedness to colors, item complexity and difficulty and associations among items.

1.3 Design

Three WM-span tests (the operation-span test, the color-Stroop test, and the word-Stroop test) and set size (3 vs. 6) -- the total number of items to recall -- were manipulated within subjects. The operation-span test was always administered first, followed by both Stroop-span tests. A total number of recalled items from each WM test and proportion of recognition on the recognition test were recorded as dependent variables.

1.4 Procedure

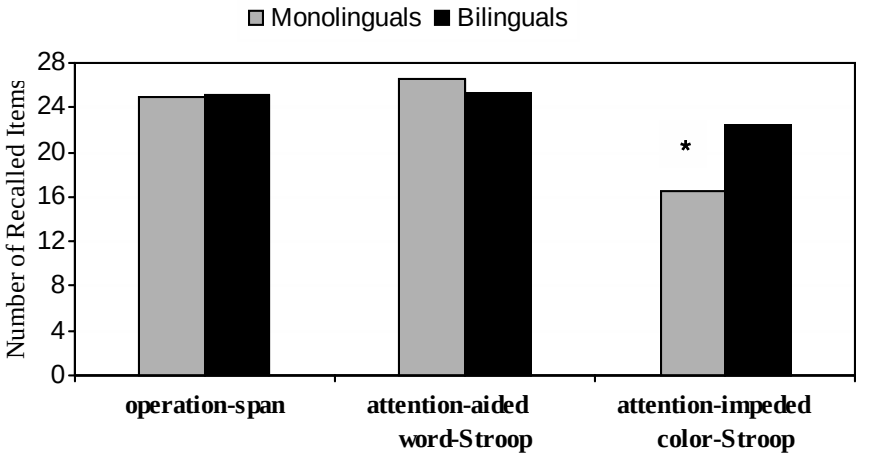
Three WM-span tests were administered within subjects to measure WM capacity: the operation-span test (Turner & Engel, 1989) under normal circumstance, the color-Stroop-span test (C-Stroop) under attention-impeded circumstance, and the word-Stroop-span test (W-Stroop) under attention-aided circumstance. After these tests, subjects received a recognition test for both presented and non-presented words.

In the operation-span test, subjects were presented series of operation-word strings such as "Is 6/3 + 2 = 4 (yes or no) Garden" on the computer screen and were asked to read aloud the operation, state its correctness, and finally read the underlined word for later recall. In both Stroop-span tests, subjects were presented series of a string of five words, four color words and one underlined to-be-recalled word, printed in all different colors. For the first four color words in both Stroop-span tests, subjects stated the ink colors in which each color word was printed. For the last to-be-recalled word, however, these two Stroop-span tests differed in a required task. In attention-impeded C-Stroop, subjects had to state the ink color of the last word, whereas in attention-aided W-Stroop, subjects had to read the word instead of the color. Subjects' recall performance was to be adversely affected by the color-naming interference on C-Stroop whereas facilitated by the word-naming on W-Stroop. The order of the two Stroop-tests was counterbalanced across all subjects. A total number of items recalled from each test was collected as a measure of WM capacity, and the proportion of recognition was computed.

2. Results

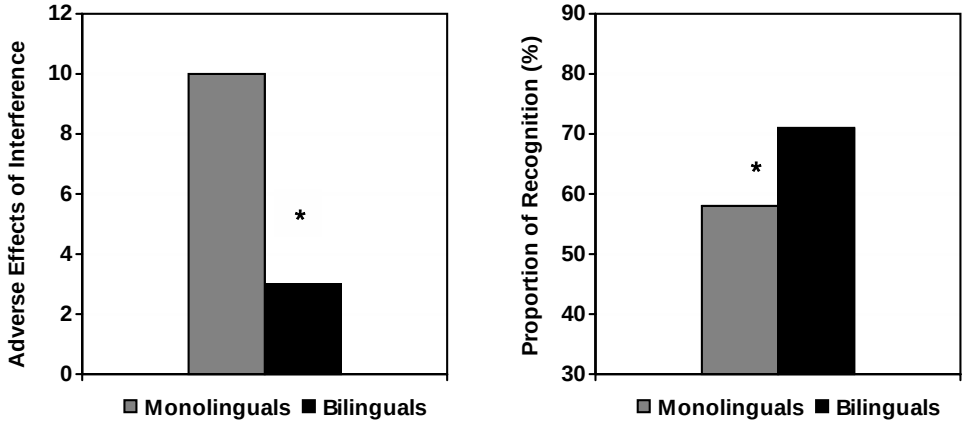
Unless specified otherwise, all differences noted were significant at the .05 level (two-tailed). Mean number of recalled items is presented in figure 1, as a function of the WM-span task. The findings favored our hypothesis that bilinguals' better controlled-attention would lead to significantly greater WM capacity in the attention-impeded C-Stroop, compared to monolinguals. The mean number of recalled items measured in the operation-span test showed no significant group difference, $p > .5$, suggesting equivalent WM capacity under normal condition. Likewise, both monolinguals and balanced bilinguals showed equal WM capacity in the attention-aided W-Stroop where subjects' recall was facilitated by word-naming, $p > .5$. In the attention-impeded C-Stroop, however, only balanced bilinguals who presumably have the advantage of controlled-attention overcame the adverse effect of color-naming interference, showing significantly greater WM capacity than the other two groups, $F(1, 25) = 7.856$, $p = .002$.

Figure 1: Mean Number of Recalled Items



To quantify the adverse effect of interference on WM capacity, we subtracted the number of items recalled in attention-impeded C-Stroop from its counterpart in attention-aided W-Stroop. Small differences would indicate a close-to-equal performance in attention-aided and attention-impeded tests by effectively maintaining one's controlled-attention. As shown in the left panel of figure 2, we found balanced bilinguals showed smaller difference than did monolinguals, $F(1, 25) = 6.891$, $p = .003$. Regarding the recognition data, as shown in the right panel of figure 2, balanced bilinguals showed marginally greater recognition rates than monolinguals, $F(1, 25) = 2.688$, $p = .08$, suggesting the positive effect of bilinguals' controlled-attention on long-term memory as well.

Figure 2: Quantified adverse effect of interference on wM (left panel) and proportion of recognition (right panel)



3. Discussion

These findings suggest that bilinguals' controlled-attention has favorable impacts on WM capacity and recognition. Compared to monolinguals, bilinguals are better able to direct their attention to task-relevant information and further maintain their attention despite adverse interference, particularly in attention-impeded condition.

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