Aha! Voila! Eureka! Bilingualism and insightful problem solving

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1. Introduction

Creative problem solving is an important aspect of human cognition. While our capacity for complex computation is extremely limited, creative thought can help us to succeed in spite of ourselves. The history of scientific advancement is punctuated by accounts of sudden realizations that break from past thinking and propel us forward. Yet, the circumstances and causal antecedents of creative breakthroughs, often experienced as Aha! or Eureka!

Solution seems phenomenologically similar to real-world creative breakthroughs, often experienced as Aha! or Eureka! moments (e.g. Duncker, 1945/1972; Wertheimer, 1954/1959) and is believed to rely on a particular set of executive functions, those functions that underlie flexible shifting of attention between alternate representations, is thought to require the ability to focus on new possibilities in the face of other inappropriate responses, may predict creative potential (Schooler & Melcher, 1995). As disengaging from a previous set, or flexibly directing attention between alternate representations, is thought to rely on a particular set of executive functions, those functions that underlie flexible shifting of attention may be critical for insightful solutions.

Both Martindale (1995) and Schooler et al. (Schooler, 2002; Smallwood & Schooler, 2006) have suggested that success at solving insightful problems may actually require a combination of both non-goal-directed associative processes and more controlled, attentionally-demanding processes. As such, one could hypothesize that insightful problem solving may be most successful in individuals who have both a large set of diverse and accessible associations, as well as superior executive functioning allowing for more flexible control of attention.

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Example Insight Problem (Triangle of Coins):

The triangle below is pointing towards the top of the page. Figure out how to move 3 circles to get the triangle to point to the bottom of the page. The circles must still form a perfect triangle.

\[ \begin{align*}
\text{1} & \\
\text{2} & \\
\text{3} & \\
\text{4} & \\
\text{5} & \\
\text{6} & \\
\text{7} & \\
\text{8} & \\
\text{9} & \\
\text{10} & \\
\end{align*} \]

Example Non-Insight Problem:

Solve for Y.

Find the exact number that the variable Y equals by using only the necessary equations from the set of equations below.

\[ \begin{align*}
3Z + 3 & = 27 \\
P - C & = 2D \\
2X + 56 + A & = 8M - C - Y \\
3Y + 14 & = X \\
\end{align*} \]

Fig. 1. Example insight and non-insight problems.

1.1. Bilingualism and creativity

In the present study, we explore the hypothesis that bilingualism may impart a cognitive profile conducive to solving insight problems. Prior work has suggested advantages in divergent thinking for bilingual versus monolingual individuals. In her review on bilingualism and creativity, Ricciardelli (1992) found that, in 20 of the 24 reviewed articles, bilingual individuals outperform monolingual individuals on divergent thinking tasks. More recently, Kharkhurin (2007) has found that bilingual adults demonstrate advantages over monolinguals in performance as assessed by fluency, flexibility, and elaboration on many idea generation tasks.

Explanations of this divergent thinking advantage highlight the diversity of experience encountered by bilingual individuals (Cummins, 1976; Kharkhurin, 2007). As bilingual individuals have at least two words for many objects and ideas, and because they have additional conceptual and phonological connections across their lexicons, their response to the presentation of a single concept may be to activate a greater and more diverse set of associations and may be less likely to lead to label-induced sets. This may explain their ability to generate a greater number of ideas than monolinguals when prompted in divergent thinking tasks.

As noted above, insightful problem solving may require not just access to a breadth of associations, but also superior attentional control. Indeed, there is reason to believe that individuals who acquire multiple languages by the age of 6 can demonstrate an advantage in the executive functions that allow for effective switching between tasks or representations. Bialystok (2001) has elaborated a popular theory in which bilingual advantages depend not on fluency in multiple languages per se, but rather on the acquisition of multiple languages (and thus the need to deal with lexical competition) within a critical period of early childhood (see also Green, 1998). This acquisition, occurring early in the development of executive control, influences the cognitive abilities of early bilinguals. To support this position, she and her colleagues have demonstrated advantages of young bilingual children over monolingual peers on a number of executive tasks including dimensional-change card-sort tasks (Bialystok & Martin, 2004). Bilingual children are also better able to identify and shift between multiple interpretations of ambiguous-figure and figure-ground illusions (Bialystok & Shapero, 2005), which requires flexibly directing attention to various features of the same stimulus.

1.2. Purpose of the current study

The present study focuses on two questions. The first is whether bilinguals and monolinguals demonstrate different rates of success on a set of insight and non-insight problems. The use of insight problems here moves the understanding of bilingual creativity beyond the use of idea generation paradigms, which may not replicate real-world creative problem solving as well as insight problem solving tasks, which require a mix of free association and controlled processing.

The second question is whether these differences will be specific to individuals who were bilingual from an early age. Solving insight problems has been suggested to depend on both the ability to consider diverse associations and also to overcome initial biases or misconceptions. As advantages in executive function, which may underlie the ability to direct attention away from initially inappropriate problem representations, have been suggested to develop specifically in early bilinguals, it may be only those individuals who experience an increased likelihood of solving insight problems relative to non-insight problems. Note the prediction is not that these individuals will go about solving these problems in qualitatively different ways but rather that, due to their cognitive profiles, they will exhibit different likelihoods of success.

2. Method

2.1. Participants

One hundred and sixty-six undergraduates at a diverse, large Midwestern university participated in this research in partial fulfillment of course requirements. One hundred and two individuals were English-speaking monolinguals and 64 were bilinguals. Based on previous work on bilingualism (Bialystok et al., 2004; Bialystok et al., 2006; Costa et al., 2009), these individuals were divided into a group of 28 foreign-born bilinguals who acquired fluent English at the age of 7 or later (late bilinguals), and 36 early bilinguals who were either born in the US or were foreign born, and acquired fluency in English and another language by the age of 6. All participants, with the exception of one late bilingual, reported having attended high school in the United States. While all bilinguals in the sample spoke English, other languages varied greatly. The most commonly reported other languages were Spanish dialects (17 individuals), but responses also included Indian dialects (11), Chinese dialects (8), Korean (4), Polish (5), Tagalog (5), and Albanian (3), among others (Amharic, Arabic, Bulgarian, Greek, Lithuanian, Romanian, Vietnamese).
was no main effect for language group, as monolinguals demonstrated worse performance on the insight problems than on the non-insight problems, $t(101) = -2.395$, $MSE = .11$, $p = .02$, Cohen’s $d = - .24$. Alternately, early bilinguals demonstrated marginally better performance on insight problems than on non-insight problems, $t(35) = 1.57$, $MSE = .19$, $p = .13$, Cohen’s $d = .26$. Late bilinguals demonstrated similar performance on both insight problems and non-insight problems, $t(27) = .26$, $MSE = .27$, ns.2 (See Table 2 for group means and standard deviations.) These results suggest that monolinguals are advantaged in solving the non-insight problems, relative to their own performance on the insight problems. However, early bilinguals show a trend in the opposite direction, suggesting an advantage in solving insight problems over non-insight problems.

Another repeated-measures $2 \times 3$ ANOVA was performed on solution times for correctly solved problems. As shown in Fig. 3, there were no differences in correct solution time for insight problems versus non-insight problems, $F(1, 64) = 1.44$, $MSE = 1263.32$, ns. Further, language status did not influence solution times, $F(2, 64) = 1.48$, $MSE = 3106.88$, ns, nor did it interact with problem type, $F(2, 64) = .04$, $MSE = 325.74$, ns. These results indicate that, when problems were solved, they were solved in approximately the same amount of time between language groups. This pattern suggests, as predicted, that the groups did not differ qualitatively in how they were going about solving each problem, but rather in their likelihood of success.

A repeated-measures $2 \times 3$ ANOVA was performed on problem type (insight versus non-insight) and language group (monolingual, late bilingual, and early bilingual). There was no main effect for problem type ($F(1, 163) = .123$, $MSE = .083$, ns), meaning that, as in our previous studies, the two types of problems were matched for overall difficulty. Average solution rate (out of 3) was the same across insight ($M = .89$) and non-insight problems ($M = .98$). Further, there was no main effect for language group, $F(2, 163) = .484$, $MSE = .494$, ns, as monolinguals ($M = 1.95$, $SD = 1.42$), late bilinguals ($M = 1.79$, $SD = 1.34$) and early bilinguals ($M = 1.69$, $SD = 1.51$) demonstrated similar overall solution rates across all problems.

2 An alternative explanation for the difference between late and early bilinguals is that the latter group has, on average, a greater number of years of fluency in English. This variable, however, did not predict performance well. Across both bilingual groups, years of fluency did not correlate with either solutions on insight problems ($r = .01$, $p = .96$) or non-insight problems ($r = .02$, $p = .89$). Within groups, there was also no relationship between years of fluency and problem solving for late bilinguals (insight, $r = -.27$, $p = .17$; non-insight, $r = .04$, $p = .84$). For early bilinguals, however, there was a significant relationship between years of fluency and performance on insight problems ($r = .43$, $p = .01$), but no relationship with non-insight problems ($r = .26$, $p = .13$). These results are consistent with the theoretical position that early and late bilingual groups are qualitatively different from one another, and that simultaneous acquisition of multiple languages during early childhood is the critical variable for this advantage, not years of fluency.

1 A similar analysis collapsing across bilingual groups also showed a significant interaction, $F(1, 164) = 6.19$, $MSE = 4.30$, $p = .014$. 

### Table 1

<table>
<thead>
<tr>
<th>Descriptive characteristic</th>
<th>Monolingual</th>
<th>Late bilingual</th>
<th>Early bilingual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>18.76 (1.08)</td>
<td>19.21 (1.23)</td>
<td>18.61 (0.73)</td>
</tr>
<tr>
<td># Female</td>
<td>60 (59%)</td>
<td>18 (64%)</td>
<td>23 (64%)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Asian/Pacific Islander</td>
<td>23 (23%)</td>
<td>9 (32%)</td>
<td>21 (58%)</td>
</tr>
<tr>
<td>Black</td>
<td>11 (13%)</td>
<td>1 (4%)</td>
<td>0 (0%)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>16 (16%)</td>
<td>8 (29%)</td>
<td>7 (19%)</td>
</tr>
<tr>
<td>White (Caucasian)</td>
<td>46 (45%)</td>
<td>7 (25%)</td>
<td>5 (17%)</td>
</tr>
<tr>
<td>Other</td>
<td>6 (6%)</td>
<td>3 (11%)</td>
<td>2 (6%)</td>
</tr>
<tr>
<td>Years of English fluency</td>
<td>7.57 (4.00)</td>
<td>15.67 (1.47)</td>
<td></td>
</tr>
<tr>
<td>ACT Math score</td>
<td>23.62 (4.56)</td>
<td>23.71 (4.55)</td>
<td>25.73 (5.40)</td>
</tr>
</tbody>
</table>

Note: ACT Math values represent only those individuals within each group who provided their ACT Math score (Ns = 90, 24, and 33 respectively.)
have attempted to investigate whether those differences translate to differences on high-level problem solving tasks such as those used in this study. Nevertheless, a critical next step in this line of research will be to bridge the two methodologies by measuring both task-switching ability and problem solving performance. Such a paradigm could address whether differences in executive functioning mediate the relationship between bilingual status and insight performance.

Another interesting set of issues that cannot be fully addressed by these results is the degree to which culture influences this pattern of effects. There are several possible questions related to culture. One is whether benefits of bilingualism on creative problem solving may be due in part due to broader cultural experiences and not just access to multiple lexicons per se. A second related question is whether the effects of bilingualism may be better described as cross-cultural differences. In terms of the first question, multilingual experience is often associated with exposure to multiple cultures. Research has also identified a role of multicultural experience in influencing creative cognition, both in terms of culture of origin influencing creative potential (e.g. Kaufman & Sternberg, 2006; Kharkhurin & Samadpour Motallebee, 2008; Niu & Sternberg, 2001) and in cultural experience (Maddux & Galinsky, 2009) and cultural priming (Jia, Hirt, & Karpen, 2009) improving creative problem solving. As such, one might argue that the multilingual effects identified in this study may be in part due to differences in multicultural experience between the groups. Unfortunately, we do not have measures of multicultural experiences for our current sample that would allow us to disentangle the linguistic and cultural influences, but this is another important direction for future research.

In terms of examining cross-cultural differences, we note that the sample obtained in this study did not have a large enough number of observations within each cultural group to allow for meaningful subgroup analyses. However, we also note that our bilingual samples were far from representing a single cultural, ethnic, or linguistic group. When we informally examined the patterns for Asian, Hispanic and Caucasian early bilingual groups, the same trend favoring insight performance over math performance was present in all three groups. This suggests that the effects of early bilingualism are not being driven by one particular cultural group. Finally, even if culture is important to creativity, the advantage of our early bilinguals over the late bilinguals suggests there is an important role for early bilinguals’ executive function advantages, which have been found to be relatively consistent across various cultures and language pairs in other studies (Adesope, Lavin, Thompson, & Ungerleider, 2010).

The main contribution of this study is in providing the first evidence that early bilingualism can confer relative advantages on insight problem solving versus non-insight problem solving tasks, especially as compared to monolinguals who show the opposite pattern. It also provides support for theories suggesting that insightful problem solving requires a combination of access to a breadth of potential associations as well as superior executive functioning. A final contribution of this study is in showing that the potential executive function advantages from early multilingual experience can extend beyond performance on low-level attentional tasks and can be seen in promoting the kind of innovative problem solving and revolutionary thinking that may underlie real-world breakthrough discoveries.

### References


### Table 2

<table>
<thead>
<tr>
<th>Problems solved (out of 3)</th>
<th>Monolingual M</th>
<th>Monolingual SD</th>
<th>Late bilingual M</th>
<th>Late bilingual SD</th>
<th>Early bilingual M</th>
<th>Early bilingual SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insight</td>
<td>.84</td>
<td>.83</td>
<td>.93</td>
<td>1.05</td>
<td>1.00</td>
<td>1.04</td>
</tr>
<tr>
<td>Non-insight</td>
<td>1.11</td>
<td>.97</td>
<td>.86</td>
<td>.89</td>
<td>.69</td>
<td>.86</td>
</tr>
<tr>
<td>Correct solution time</td>
<td>131.08</td>
<td>43.15</td>
<td>111.20</td>
<td>43.97</td>
<td>123.21</td>
<td>47.48</td>
</tr>
<tr>
<td>Non-insight</td>
<td>143.55</td>
<td>34.81</td>
<td>136.61</td>
<td>35.67</td>
<td>136.57</td>
<td>28.89</td>
</tr>
</tbody>
</table>

**Fig. 3.** Average correct solution time on insight and non-insight problems as a function of language group (with standard error bars).


