The Effects of Language on Cognitive Flexibility and Related Properties of Executive Functioning

by

Lena Hildenbrand

A THESIS

submitted to

Oregon State University

Honors College

in partial fulfillment of
the requirements for the
degree of

Honors Baccalaureate of Science in Psychology
(Honors Associate)

Honors Baccalaureate of Science in Business Administration
(Honors Associate)

Presented May 1st, 2020
Commencement June 2020
AN ABSTRACT OF THE THESIS OF

Lena Hildenbrand for the degree of Honors Baccalaureate of Science in Psychology and Honors Baccalaureate of Science in Business Administration presented on May 1, 2020. Title: The Effects of Language on Cognitive Flexibility and Related Properties of Executive Functioning.

Abstract approved: _____________________________________________

Christopher Sanchez

In the literature, a controversy persists over whether speaking multiple languages may result in what has been referred to as a bilingual advantage that is an advantage for executive functioning (EF) skills. While evidence in favor of such has been reported, the reliability of these findings has been questioned. To provide additional evidence towards this debate, the current study addresses an important concern that is convergent validity between EF tasks. Seeking to replicate earlier findings of a bilingual advantage, if it does exist, we hypothesized that multilinguals (those speaking two or more languages) would consistently outperform their monolingual peers across measures of cognitive flexibility. Results show no reliable difference in between group performance for any of these measures, providing strong evidence against the argument for a bilingual advantage. Consistent with a number of other recent studies, we are adding to a growing body of literature that has failed to replicate that a bilingual advantage truly exists.

Key Words: bilingualism, executive functioning, cognitive flexibility, language

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I understand that my project will become part of the permanent collection of Oregon State University, Honors College. My signature below authorizes release of my project to any reader upon request.

________________________________
Lena Hildenbrand, Author
Introduction

More than half of the world’s population uses two or more languages in their everyday lives and may thus be considered bilingual (Ansaldo et al. 2008). But how does being bilingual affect our mind? Is the ‘bilingual brain’ different, and if so, in which ways? While learning and speaking multiple languages may be considered advantageous for a number of reasons, recently it has become of interest to examine the specific effects of bilingualism on cognitive abilities and specifically whether it provides benefits for executive functioning abilities that would be considered a ‘bilingual advantage’.

The appeal of a bilingual advantage

It has been argued that there are explicit benefits for executive functioning skills stemming from the increased cognitive demands placed on any individual who is switching back and forth between languages in their everyday lives. To switch between languages successfully, cognitive control mechanisms must be activated and adapt depending on the context in which language is being used. As a result, it has been suggested that bilinguals may be better at monitoring (i.e., managing their attention and resolving potential conflict) even in situations where demands are changing rapidly (Arizmendi et al., 2018; Green & Abutalebi, 2013; Kroll & Bialystok, 2013).

In addition to monitoring, bilingualism also potentially requires increased inhibition over monolingual contexts. Even in situations when bilinguals consistently only use one of their languages, all known language sets generally remain active. Auditory input, for example, has been demonstrated to activate vocabulary in all language sets regardless of the specific language to which the initial input belongs (Marian & Shook, 2012). This is true for both balanced bilinguals, (i.e., individuals who are highly fluent in multiple languages to a degree where they
would be considered native speakers for each) as well as non-balanced bilinguals (i.e., who have learned an additional language (L2) to what is their native language from birth (L1) and for which the degree of proficiency may vary; Duñabeitia et al., 2014). Therefore, not only must bilinguals decide which language is appropriate to use in a given context (a function of monitoring and goal orientation), but competing language sets must be actively inhibited at the same time when another is explicitly being engaged (Arizmendi et al., 2018; Green & Abutalebi, 2013; Paap & Greenberg, 2013).

Finally, cognitive benefits may also result from the fact that speaking multiple languages can encourage flexible thinking by allowing individuals to approach a problem from different perspectives. For each object in a given bilinguals’ lexicon, those who speak multiple language have likely learned at least two words or symbols. This can be considered an advantage, especially in problem solving contexts where symbolic reorganization might be required. For example, when the goal is to identify hidden relations between a set of given objects, bilinguals might be able to switch to another language which may allow the solution to become more apparent. Obviously, this would be less likely for monolinguals, and thus it is much harder for these individuals to step out of their initial approach to solve the problem (Peal & Lambert, 1962; Arizmendi et al., 2018).

Despite the appeal of such an advantage, in the current literature a controversy persists over whether a bilingual advantage truly exists. On the one hand, a number of studies have presented evidence documenting such benefits when comparing bilingual to monolingual speakers (i.e., Costa, Hernandez, & Sebastian-Galles, 2008; Barac and Bialystok, 2012). On the other hand, follow up studies have failed to consistently replicate these findings (i.e., Paap & Greenberg, 2013; Gathercole et al., 2014; Dick et al., 2018), and especially among adolescent
and adult populations (as compared to children). The results of these studies are considered more in-depth next.

*Studies in favor of a bilingual advantage*

Barac and Bialystok (2012) recruited 104 children between the ages 4 and 7 who in about equal numbers belonged to four different groups that were Spanish-English bilinguals, French-English bilinguals, Chinese-English bilinguals, and English-only speakers. Executive functioning skills were assessed using a computerized color-shape task switching measure for which they found that all three bilingual groups experienced smaller global switching costs than did the monolingual group. While for linguistic measures (vocabulary and metalinguistics) performance varied with educational experience and language similarity across the bilingual groups, they did not find significant differences in performance on the cognitive task when excluding the monolingual group from the analysis. These findings suggest that it seems to be bilingualism itself that is driving the observed benefit for executive functioning skills among the bilingual children (Barac & Bialystok, 2012).

In a longitudinal study, Crivello et al. (2016) examined the effects of bilingual growth on executive functioning skills in toddlers. The researchers administered conflict tasks (Stroop Shape Task, Reverse Categorization Task), a delay task, and a working memory measure to a group of 49 bilinguals and 43 monolinguals. While for either the delay or working memory tasks there were no significant between group differences, they found that bilinguals marginally outperformed monolinguals on the conflict task which suggests a task-specific advantage for inhibitory control. Further, within the bilingual group an increase in translation equivalents (but not vocabulary growth per se) was found to be correlated with better performance on the conflict
task providing evidence consistent with the idea that it is the switching between lexical systems that may be driving a so-called bilingual advantage (Crivello et al., 2016).

In a sample of young adults, Costa, Hernandez, and Sebastian-Galls (2008) compared the performance of Spanish-Catalan bilinguals to monolinguals in the attentional network task (ATN), a task that was specifically designed to tap into different attentional networks which are alerting, orienting, and executive control networks. They found bilinguals outperform their monolingual counterparts in terms of switching cost (that is they performed better at a faster rate) being more efficient in both responding to alerting cues (monitoring) and also resolving conflict (Costa, Hernandez, & Sebastian-Galles, 2008).

Finally, in terms of brain structure, differences have been reported when comparing the brains of bilingual to monolingual speakers. These differences include white matter integrity (e.g., Luk, Bialystok, Craik, & Grady, 2011; Pliatsikas, Moschopoulou, & Saddy, 2015), cortical thickness (e.g., Klein, Mok, Chen, & Watkins, 2014; Mårtensson et al., 2012), gray matter density (e.g., Berken, Gracco, Chen, & Klein, 2015; Mechelli et al., 2004) and functional activity in various brain regions (e.g., Berken, Gracco, Chen, Watkins, et al., 2015; Kovelman, Baker, & Petitto, 2008). While structural differences do not per se suggest any actual advantage, they do document that the bilingual brain does in fact appear to be ‘different’. Further, in a study of 200 patients with Alzheimer’s disease it was reported that the average age of onset for symptoms was delayed by 5.1 years for bilinguals. This effect is larger than any that has been achieved through the use of pharmaceuticals currently available on the market. Again, this evidence supports the idea that speaking multiple languages does affect cognitive abilities, and may even be considered a protective factor for disease, though further research is needed to validate such findings (Craik, Bialystok, & Freedman, 2010).
Studies against a bilingual advantage

Despite the published evidence in support of a bilingual advantage, criticism has been voiced regarding the methodology used in that literature and the overall reliability of the findings has also been questioned. In terms of methodology, many of the studies finding group differences only use one task, most commonly a task-switching measure, to assess executive functioning skills. As such, there often is no test for convergent validity, and any effects observed may be task-specific mechanisms rather than a domain general advantage for executive functioning abilities (Paap & Greenberg, 2013). This is especially important given that some aspects of executive functioning are rather poorly defined, and therefore difficult to measure. For example, beyond task switching, cognitive flexibility encompasses multiple elements which also include working memory (the maintenance of two or more rule representations), inhibition (to adapt to changing rules previous responses must be inhibited), and attention (Dajani & Uddin, 2015). Only if evidence is consistent among different tasks tapping into each of these abilities, should we then speak of a ‘true’ bilingual advantage (Paap & Greenberg, 2013).

Additionally, some also think a bilingual advantage is not reliable as samples used to identify this advantage are either being too small and/or non-representative. Those studies that do find such effect also often do not account for important factors such as socio-economic status, cultural differences, and immigrant status which when controlled for (i.e. when participants are matched on these characteristics), often turn a previously observed cognitive advantage into an elusive phenomenon (Paap & Greenberg, 2013; Paap, Johnson, & Sawi, 2015).

Gathercole et al. (2014) examined whether a bilingual advantage can be observed in large samples of different age groups (ranging from three years of age to over 60 years of age) for three different tasks, the Simon task, a card sorting task, and a metalinguistic task. Across all
tasks and for all ages tested there was no evidence suggesting bilinguals performed better than their monolingual counterparts. In fact, there was a trend (though nonsignificant) where monolinguals actually appeared to do better than bilinguals on some of the tasks. Important to note is that participants were homogenous in educational and cultural backgrounds. Given that findings are consistent across measures, this study provides strong evidence for that a bilingual advantage as it has been propagated may not actually exist.

In a large sample study, Dick et al. (2018) analyzed data from 4524 participants, 9- and 10-year-old children, to examine whether exposure to multiple languages during childhood is associated with better executive functioning skills. They examined performance on three executive functioning tasks which were the NIH Flanker Inhibitory Control and Attention Test, the NIH Dimensional Change Card Sort task, and a stop signal task. Despite this being an ideal sample, they also did not find any consistent evidence that would suggest a bilingual advantage exists.

**Current study**

The objective of the present study is to provide additional evidence towards this debate over whether or not a bilingual advantage for executive functioning skills exists. While previous research has heavily focused on examining such effects in children, it has also been argued that bilingualism provides a lifelong cognitive advantage connecting findings among children to benefits observed among elderly populations (Craik, Bialystok, & Freedman, 2010; Kroll & Bialystok, 2010, Luk, Bialystok, Craik, & Grady, 2011). For this study, we were especially interested in examining how speaking multiple languages may impact executive functioning skills among young adults who are considered to be at (or near) the peak of their abilities (Dajani & Uddin, 2015). Not only is data for this population currently a lot more limited, but it may also
provide for important insights into how a bilingual advantage could be conceptualized. For example, assuming it is true that benefits among young children do exist, is that evidence for a lifelong advantage, or could it instead be more of a developmental phenomenon such that bilingual children develop executive functioning skills faster, but do not achieve an overall gain relative to their peak ability later in life? Further, we also seek to address the concern of convergent validity between measures that is present in the current literature.

To provide a more balanced view, participants completed a battery of seven executive functioning tasks tapping such facets as task switching, inhibition, reaction time, and global/local orientation, all which are considered elements of cognitive flexibility. Seeking to replicate earlier findings in favor of a bilingual advantage, we hypothesized that multilinguals (those speaking two or more languages) would consistently outperform their monolingual peers across all measures of cognitive flexibility.

Methods

Participants

A total of one-hundred sixty-six ($N=166$) undergraduate students (70% female; mean age = 19.69 years) were recruited as participants through the SPS subject pool at Oregon State University. For the purpose of this study, being multilingual was defined as speaking two or more languages fluently, and participants self-identified as multilingual relative to this criterion. Based on this definition, 105 of our participants were classified as monolingual English speakers and 61 were classified as multilingual speakers. While we did not take into account the age of second language acquisition, we did control for English proficiency (see below). All participants received course credit for their participation consistent with subject pool policy.
Materials

All participants completed a scrambled words task as a proxy measure to assess their English language abilities, as well as a battery of 7 executive functioning tasks (cued task switching, Wisconsin Card Sorting Task, Navon task, N-back task, a go/no-go task, a stop signal task, and the Deary-Liewald Task) each tapping into some facet of cognitive flexibility (inhibition, monitoring, task switching, set shifting, and reaction time). All tasks were fully computerized and programmed in, and administered through the open access online software PsyToolkit (Stoet, 2010, 2017).

Scrambled words task: To assess English language ability, participants were presented with a list of 20 scrambled words adapted from the Ekstrom Kit of Factor Referenced Cognitive Tests (Ekstrom et al., 1976). The 20 words were presented in random order and participants were allowed 10 seconds to think of and type their answers in a textbox provided. For each there was only one correct answer. Total number of correct unscrabbled words was later used as a covariate in the analysis of between group differences to control for potential native language effects.

Navon task: This task measures attentional processing style and monitoring ability by assessing the speed by which global and local information is being processed. Participants were presented with a global stimulus (i.e., a big letter) which is composed of different smaller letters (local stimuli). These letters can be congruent (‘H’) or incongruent (‘O’) with the global letter. As such, for each trial, participants had to decide whether “H” and/or “O” were included (on the global and/or local level), or not at all, by making a ‘yes’ or ‘no’ response. The total number of correct trials as well as the average response time for correct trials was recorded.
Stop signal task: This task is a simple measure of response inhibition. Depending on whether a stop signal was present (red circle, don’t respond cue) or not (white circle, respond cue) participants were asked to respond to left and right arrows presented on the screen by pressing the corresponding arrow keys on their keyboard. We recorded the total number of correct trials as well as average response time.

Go/ no-go task: Similar to the stop signal task, this is another measure of response inhibition. When “Go” appears on the screen, participants were required to respond within 2 seconds by pressing a key. For “No-go”, they did not need to respond. As there is a greater number of “Go” than “No-go” trials, this makes it more difficult to later inhibit that response for “No-Go” trial. The variable of interest for this task was percentage of correct trials.

Wisconsin Card Sorting Task: This task measures set shifting and more specifically how well participants adapt to changing rules. Participants were asked to sort cards according to one of three criteria: color of symbols, shape of symbols, or number of symbols on a card. Without any further instructions the only feedback was whether they were sorting them correctly. Rules changed after every 10 trials, which then required for the original rule to be updated accordingly. The primary variable of interest was total trials correct which reflects how easily participants dealt with change of rules.

Cued task switching: This is a measure of task switching ability similar to what has been commonly used in the existing literature on the bilingual advantage (i.e., Barac & Bialystok, 2012). There was a shape and a color condition. The cue consisted of a briefly presented one-word description (“shape” vs. “color”). Pressing assigned keys, participants responded to circles and shapes while ignoring the color in the shape condition; in the color task, participants needed
to respond to the color presented while ignoring the shape. The primary variable of interest was total number of correct trials.

*N-back task:* This task is designed to measure working memory capacity. Participants were presented a sequence of stimuli, one-by-one. For each stimulus, they need to decide if it was the same as the one presented \(N\) trials ago. For this experiment, \(N\) was set as 3. Each stimulus was presented for 2000 milliseconds maximally. The primary variable of interest was total number of correct trials.

*Deary-Liewald task:* This task is a choice reaction time measure. Participants had to respond to a black cross stimulus appearing on their screen. There were two stages of difficulty, the first for which the stimulus would always appear in the same location with the inter-stimulus interval differing between 1-3 seconds. For stage 2, the location of where the stimulus appeared would change randomly between four predetermined areas on the screen, and each location was assigned a separate response key (‘z’; ‘x’; ‘comma’; ‘full stop’). We measured average response time as well as total number of correct trials. This measure is especially interesting as it taps not only in executive functioning skills but has also been correlated with other measures of general intelligence (Deary, Liewald & Nissan, 2011).

**Procedure**

The experiment was fully computerized. All participants were tested on laboratory computers in groups no larger than four at a time. The experiment was accessed online through a Google Chrome browser using Psytoolkit. When participants first arrived at the testing room they were greeted by the experimenter and asked to read and verbally agree to a consent form provided that had been approved for use by the Oregon State University Institutional Review Board. On the computer, they then completed a brief demographics survey, followed by the
scrambled words task, and then the executive functioning tasks. The executive functioning tasks were presented in fixed order for all participants starting with the Navon task, stop signal task, go/no-go task, the Wisconsin Card Sorting Task, the cued task switching measure, the $N$-back task, and then finally the Deary-Liewald task. For each of the tasks there was a brief practice period prior to the experimental trials to ensure that instructions were clear. Once the experimental session concluded, participants were debriefed and dismissed.

**Results**

To examine the effects of language group, we conducted an Analysis of Covariance (ANCOVA), on performance for each executive task while controlling for English language proficiency (Scrambled Words task). Our results indicated there was no effect of language group on performance for *any* of the executive measures. Results are summarized in Table 1 included below.

Table 1

*Summary table of results*

<table>
<thead>
<tr>
<th></th>
<th>$F(1, 163)$</th>
<th>$MSe$</th>
<th>$p$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Task switching</td>
<td>3.05</td>
<td>17.43</td>
<td>.08</td>
</tr>
<tr>
<td>Go/no-go</td>
<td>.39</td>
<td>.36</td>
<td>.53</td>
</tr>
<tr>
<td>Stop signal</td>
<td>.30</td>
<td>.01</td>
<td>.58</td>
</tr>
<tr>
<td>Navon</td>
<td>.25</td>
<td>35.08</td>
<td>.62</td>
</tr>
<tr>
<td>$N$-back</td>
<td>1.09</td>
<td>19.59</td>
<td>.30</td>
</tr>
</tbody>
</table>
Given the high consistency of a null effect across tasks, these findings provide strong evidence against the argument for a bilingual advantage. As is visible in Figure 1, for some tasks we observed a trend in the opposite direction from what was originally hypothesized, such that monolinguals performed better than their bilingual peers, however, none of these trends reached statistical reliability.

**Figure 1:** Group performance (# of trials correct) for executive functioning tasks

**Discussion**

The purpose of the current study was to examine whether a bilingual advantage, defined here as an advantage in executive functioning skills, exists for speakers of multiple languages.
EFFECTS OF BILINGUALISM ON EF

(multi-linguals) when their performance on tasks tapping these abilities is compared with that of their monolingual peers. Given that a controversy persists in the literature over whether previous observations of such advantage are reliable (Costa, Hernandez, & Sebastian-Galles, 2008; Barac and Bialystok, 2012), in the current study we sought to address an important shortcoming from previous studies, namely the lack of convergent validity between measures. If a bilingual advantage does in fact exist, we hypothesized that multilinguals would consistently outperform their monolingual peers across measures of cognitive flexibility.

Our present findings suggest that speaking multiple languages does not appear to have an effect on executive functioning task performance. For all tasks, there was found to be no reliable difference between monolinguals and multi-linguals. Interestingly, it appeared that there was a trend in the opposite direction for some tasks, such that monolinguals seemed to outperform their bilingual peers. Gathercole et al. (2014) reported a similar observation, and which taken together with the present findings, may highlight an interesting phenomenon to examine in further research.

As the current study exclusively focused on a young adult population, we may not generalize our findings beyond this group, yet, these results are consistent with a growing body of literature that has failed to demonstrate that a bilingual advantage truly exists (Paap & Greenberg, 2013; Gathercole et al., 2014; Dick et al., 2018). Our findings are further strengthened by the fact that we have addressed an important shortcoming that exists in the current literature; namely the lack of convergent validity for measures of executive functioning that have previously been used.

However, there are also a number of important limitations to the current findings. First, for the majority of our multilingual speakers, English was not their first language. With all
instructions being strictly provided in English, there is a possibility that first language effects may be influencing the pattern of observed results. However, all tasks administered were non-verbal, and we also controlled for English language proficiency (e.g., Scrambled words task) which should minimize such a potential confound. Future research should aim to replicate our findings by administering tasks in the participant’s native language.

Secondly, executive functioning tasks were presented in fixed order for all participants. This raises the possibility that performance on these tasks was impacted by order effects. However, as group differences rather than absolute performance were of primary interest, and given that the order of tasks was consistent for all participants, this is not a major concern for the findings presented here. Yet, future research should still address this concern by randomizing the order of tasks for participants.

Third, among the multi-linguals we did not control for the age of acquisition for their second language. While being multi-lingual is a very broad definition, to better understand specific effects on cognition, it may be necessary to make a distinction between the sequential and simultaneous learners of language. Kousaie et al. (2017) reported an advantage for simultaneous bilinguals who learned their L2 from birth in terms of both intrinsic resting state networks and behavior. Specifically, they found greater anticorrelation between the default mode network (DMN) and the task-positive attention network, as well as better behavioral interference suppression both which are indicators of enhanced cognitive control. It is unclear whether such an advantage for simultaneous learners always exists, especially given that many of the studies that failed to replicate a bilingual advantage have also involved fully fluent bilinguals (Gathercole et al., 2014). Further, if we assume the bilingual advantage to be some sort of cognitive training effect, then language fluency should also be primary variable of interest. It
may be that less fluent bilinguals, which often includes sequential L2 learners, experience more of an advantage, as they need to conduct a greater level of control in every linguistic choice they make (Gathercole et al., 2014).

Finally, while a variety of measures tapping different aspects of executive functioning were used here, some of these tasks may not have been an ideal choice. For example, the N-back task has been criticized as inherently too difficult, producing floor effects and masking individual differences (Meule, 2017). This is consistent with our findings where the average number of trials correct was very low for all participants. Other working memory measures such as a combination of a Symmetry and Reading span may be better suited to test whether language group has an effect on task performance. Additionally, while the Wisconsin Card Sorting task has been validated as a measure for executive functioning, it is now primarily used to assess patient’s level of brain damage to the prefrontal cortex (Nyhus & Barceló, 2009), which makes its utility for detecting group differences among healthy participants somewhat questionable.

In closing, despite decades of ongoing research a controversy still persists about whether or not a bilingual advantage truly exists and if so, how it should be conceptualized. Null results are often set aside with the understanding that they are much harder to publish (Paap, Johnson, & Sawi, 2015). For example, in a study examining over a hundred conference abstracts submitted to 52 different conferences, it was found that those presenting findings in favor of a bilingual advantage were significantly more likely to be subsequently published than were those reporting mixed and especially null results (De Bruin, Treccani, & Della Sala, 2015). Certainly, there are great advantages to bilingualism across many domains, and it should therefore be perceived as a positive skill. However, evidence of a true cognitive bilingual advantage remains elusive, and the current study further reinforces this growing evidence. Future research should continue these
investigations, in order to definitively ascertain whether there are truly cognitive differences among individuals who speak multiple languages.
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