Investigation of Cognitive Flexibility in Bilinguals Modulated by L2 Proficiency and Age of Acquisition

Yoojin Oh

Honors Thesis
Mentors: Dr. Jonas Vibell and Dr. Scott Sinnett

Bilingual advantage in cognition is a topic of debate in the field of psycholinguistics. Many studies report bilingual advantage in executive functions (EF) associated with goal-maintenance, distractor-inhibition, and task-switching. However, the field remains unclear with increased reports of contrasting results. Here, we take a multidimensional approach by accounting for second language (L2) proficiency and age of L2 acquisition. In the Stroop switching task, color words were presented in congruent (e.g., RED written in red ink) or incongruent conditions (e.g., RED written in green ink). Different cues required participants to either name the color or read the word. The two tasks were presented in randomized order, requiring participants to actively switch between the tasks. Main effect was reported for the congruency condition and trial transitions. While we initially hypothesized that bilinguals would outperform monolinguals on this task, no significant differences were found between the two language groups. L2 proficiency and age of L2 acquisition did not interact with the results. Limitations and future extensions will be discussed with the consideration of more homogenized bilingual and monolingual groups and controlling for other factors that may confound the bilingual experience. Despite the lack of significant findings, current findings contribute to the field's current debate on the existence of bilingual advantage.

1. Introduction

Bilingualism is the practice of utilizing two or more languages with considerable fluency. In the modern globalized society, many individuals grow up to become bilingual. Following this trend, researchers in the various fields have been interested in the effects of bilingualism on human cognition. In the field of experimental research, Tse and Altarriba (2012) described bilingualism as a *multidimensional experience,* explaining that numerous factors influence each individual bilingual experience. Some of the factors that were identified as influencers include language proficiency of the first (L1) and second language (L2), age of L2 acquisition, years of L2 usage, and the frequency of

Yoojin Oh is an undergraduate senior majoring in Psychology B.S. and Korean B.A. Her research interests are on the effect of bilingualism on human cognition, language acquisition and processing. Yoojin will be attending University of Washington's graduate school in Fall 2022 to continue her studies.

code-switching between the two languages (i.e., the individual uses different languages in and outside of their home). The multidimensional nature of bilingualism demonstrates the richness of the bilingual research field, but also leads to conflicting results of bilingual advantage on human cognition that remain in debate.

Earlier studies that show the benefits of bilingualism have reported the increased cognitive control when comparing bilinguals to monolinguals. The central idea that bilinguals benefit from speaking multiple languages is based on the argument that bilinguals employ different linguistic and neural pathways depending on the specific language usage (Bialystok, 2011). According to this theory, a bilingual speaker needs to exercise sufficient cognitive control to employ the correct language system (e.g., L1) and inhibit the competing language (e.g., L2). Under such maintenance control, it is argued that multiple cognitive functions are subsumed, including, selective attention, short-term memory, conflict monitoring, and task-switching (Bialystok, 2011). Furthermore, bilingual advantage has been shown across the lifespan in different age groups in developing children (Bialystok et al., 2005), young adults (Blumenfeld & Marian, 2014), and older adults (Chan et al., 2020).

Cognitive advantages in bilinguals are explained through their ability to control executive functions (EF) more aptly, leading to enhanced selective attention, information processing, task switching, and conflict resolutions. Maintaining two language systems requires greater EF control leading to enhanced activation at the neural level (Diamond, 2013). This argument is further supported by physiological measurements of brain areas associated with language maintenance overlapping with the functional regions responsible for executive functioning (Chan et al., 2020). If increased neural activation leads to the strengthening of the synapses and neural proliferation, the researchers argued that these areas would be more developed in bilinguals than in monolinguals (Chan et al., 2020).

The number of studies in the field is growing exponentially, but the field is currently afflicted with several issues including a great inconsistency in the results of studies exploring the same questions with similar methodologies. A meta-analysis conducted by Noort et al. (2019) showed a sharp increase in the proportion of bilingual studies that challenge the previously held belief about bilinguals and their cognitive performance. Moreover, some studies reported cognitive disadvantages found through various measures in participants who were bilinguals (Noort et al., 2019). The discrepancy in the results can be attributed to the lack of reliability and validity in the current testing methodologies, especially because bilingualism cannot be randomly assigned (Laine & Lehtonen, 2018). More specifically, bilingualism is a participant characteristic that is acquired over a number of years throughout the lifetime and cannot be simply assigned to a group. This leads to difficulty in determining the direction of the causality and accounting for confounds (Laine & Lehtonen, 2018). The field is also afflicted with confirmation and publication bias, where researchers are more inclined to publish research that shows bilingual advantage (de Bruin et al., 2015). Most importantly, many studies failed to recognize the multidimensional factors associated with multiple language processing (Tse & Altarriba, 2012). The issue with the multidimensional characteristic of bilingualism is that it makes the topic very difficult to test in experimental settings.

To address this issue, multiple studies took into consideration factors such as language fluency (Tse & Altarriba; 2012), code-switching frequency (Bosma & Bloom, 2019), and degree of proficiency balance between two languages (Chan et al., 2020). Winskel (2013) explored the age of second language acquisition (L2) of bilingual subjects, while Verhagen et al. (2020) also measured whether the toddlers were raised by multiethnic parents who could speak different native languages. Past studies demonstrated the significant influence of these factors on bilingual experiences, including increased executive functioning abilities in cognitive tasks. However, the field is still in need of more extensive investigation to identify other influential factors that could affect EF considering the dynamic nature of bilingualism. One of the biggest issues is that the studies have yet to develop ways to consider the multiple factors that influence bilingualism in laboratory settings. Therefore, future studies should aim to incorporate a number of these factors that not only compare monolinguals versus bilinguals but also within the bilingual group.

One of the notable factors is second language (L2) proficiency. A study comparing EF abilities in bilinguals of varying L2 proficiency found that higher L2 proficiency was associated with better performance on the Stroop task (Tse & Altarriba, 2012). A study conducted by Xie (2018) associated higher L2 proficiency with greater performance on EF tasks involving conflict monitoring. Another study that utilized brain imaging techniques to look at neurological activity differences in bilinguals also found that higher L2 proficiency was associated with increased neural activities in various regions of the left hemisphere when conducting a picture naming task (Wang et al., 2020).

Age of L2 acquisition is another variable that is often studied in bilingual research. The age of L2 acquisition refers to the point of time when the speaker started learning/using the L2. How early- vs. late-acquisition can impact the speaker's cognition is extremely complex—there are behavioral advantages in being a late-bilingual, while there are also advantages in being an early-bilingual. For example, Luk et al. (2011) found that bilinguals with earlier age of acquisition performed better on the Flanker task, displaying the smallest flanker effect compared to monolinguals and bilinguals with later age of acquisition. Similarly, a study involving early and late bilinguals found evidence of conflict resolution advantage in late bilinguals and enhanced monitoring processes in early bilinguals (Tao et al., 2011). Different variables that influence the bilingual experience are also heavily interconnected. For example, the proficiency level is impacted by the age of acquisition. Therefore, studying these covariates individually in a single study is less effective.

In consideration of these additional measurements to accurately assess the bilingual effects on cognition, the current investigation attempted to expand the understanding of bilingualism literature by considering some of the multidimensional factors in the experimental investigation. More specifically, the study incorporated L2 proficiency and the age of L2 acquisition as covariates in investigating cognitive performance between bilinguals and monolinguals with the inclusion of covariates to account for notable confounds.

It is important to note that the current study specifically focused on L2 acquisition but did not account for participants who may speak more than two languages. For simplicity of the study, only L2 acquisition information was collected, and no further questions were asked about other languages. Based on the discussed introduction, the current study aimed to examine the following 3 questions:

1. To what extent do bilinguals display better cognitive flexibility than monolinguals?
2. To what extent does L2 proficiency level influence cognitive flexibility?
3. To what extent does L2 acquisition age influence cognitive flexibility?

The experimental paradigm used for the current study is a modified version of the Stroop task (Stroop, 1935), in which participants are presented with a series of color words written in different ink colors with a singular direction (either to read the words while ignoring the color or to name the color while ignoring the written word). To better assess cognitive flexibility, the modified task requires switching between the color-naming task (where participants name the color that they see) and the word-reading task (where participants read the text). This task is designed based on Kalanthroff and Henrik (2014), except that the current study's task presents all stimuli in the English language. Reaction time (RT) and accuracy of correct responses are recorded to measure the participant's ability to switch from one task to another. The switch cost, which is the cognitive cost resulting from resolving conflicts as participants are prompted with a sudden shift in the task, is measured as an index of cognitive flexibility. A lower switch cost (faster RT in switching from one task to another) would suggest a higher cognitive control, while a greater switch cost (slower RT) would suggest a disadvantage in cognitive control.

The paradigm involves shifting attention control processes by focusing on the primary visual task and simultaneously inhibiting the distracting features to maintain attentional control. Beyond comparing bilingual and monolinguals, the current investigation will also assess L2 proficiency and L2 age of acquisition as the covariate measures. Based on past studies (Bialystok, 2011; Chan, 2020; Kousaie & Phillips, 2012; Tao et al., 2011; Tse & Altarriba, 2012) and the neuroplasticity theory explanation discussed by Chan et al. (2020), it is hypothesized that:

1. Bilinguals will display higher cognitive control compared to monolinguals during the Stroop switching task, indexed by smaller switch costs.
2. Bilinguals with greater L2 proficiency will display higher cognitive control than bilinguals with lower L2 proficiency, observed through the switch-cost assessment.
3. Bilinguals with earlier L2 acquisition age will display higher cognitive control than bilinguals with later L2 acquisition age, observed through the switch-cost assessment.

2. Methods

2.1 Participants

Forty-five participants (33 females, average age = 21.3) from the University of Hawai'i at Mānoa participated in the study in exchange for course credit. The sample size was determined a priori using G-power (Erdfelder et al., 1996), which indicated a 94% chance of detecting a medium effect and 97.5% of detecting a large effect size at a significance level of 5%. All participants were prescreened for normal or corrected-to-normal vision and signed informed consent prior to beginning the experiment.

The categorization of monolingual or bilingual was evaluated using a post-experimental survey. The participants were asked to self-report their first and second language (if applicable), proficiency in both languages (on a scale of 1–5, 1 being not fluent and 5 being fluent), at what age they acquired the second language, and the number of years they spoke/learned the second language. Participants who reported speaking more than one language were considered bilingual.

The proposed study was approved by the University of Hawai'i at Mānoa Institutional Review Board (IRB). Prior to the study, all participants were informed about the procedures of the experiments. All participants provided written and online consent before taking part in the present study.

2.2 Apparatus & Stimuli

The experiment was conducted in a well-lit room on a consistent computer and web browser. The participants were seated in front of a 21-inch Dell computer monitor with a black background with no other items obstructing their views and experimental conditions remained constant throughout the entire investigation. The study was programmed and presented using the Labvanced platform (Finger et al., 2017), and the participants used a keyboard response by pressing the "A" key or "L" key on the keyboard with their left and right index finger, respectively.

To avoid any language barrier that could obscure the task-switching cost, the current study used the English alphabet as the task cue and target stimuli in a sample of American participants. Two critical English words were GREEN and RED displayed in red or green ink, such that GREEN displayed in green ink and RED displayed in red ink were congruent target stimuli. Targets were incongruent if GREEN was shown in red ink and RED was shown in green ink. The experiment also included the same texts GREEN and RED displayed in white serving as neutral target stimuli in the word-reading task and meaningless XXXX displayed in red and green ink serving as neutral target stimuli in the color-naming task. The text measured 38 x 38 mm. In a total of 288 trials, there were twelve conditions of text and colors: two congruent stimuli, two incongruent stimuli, and two neutral stimuli for each task (see figure 1 below).

2.3 Procedure

Participants were screened for health clearance before entering the room to ensure the safety of the lab members and the participants during the COVID pandemic. All participants were either fully vaccinated or showed proof of a PCR test conducted 48-hours prior to participation. The clearance was checked by the university's health clearance app LumiSight. Participants were seated in front of the desk and given the consent form to sign. Verbal instructions were given only to assist if they had questions about the task, but more detailed written instructions were displayed on the computer screen.

In each trial, a fixation cross alerted a new trial for 700ms followed by a 50ms of blank screen. Afterward, a circular task cue and an English text appeared simultaneously and were located at the center of the screen. The target always appeared inside the task cue until the participant responded with a keypress. A correct response triggered 1000ms of CORRECT feedback message, whereas an incorrect response triggered 1000ms to INCORRECT feedback message (see Figure 2). The Stroop switching experiment consisted of 12 training trials followed by four blocks of 72 trials (288 total trials). Critically, the word-reading task and color-naming task were counterbalanced across trials, requiring participants to switch goals cued by the circular rings. Such setup allowed for a more accurate investigation of participant's switch performance, with trial transition conditions comprised of color-naming to word reading (CW);

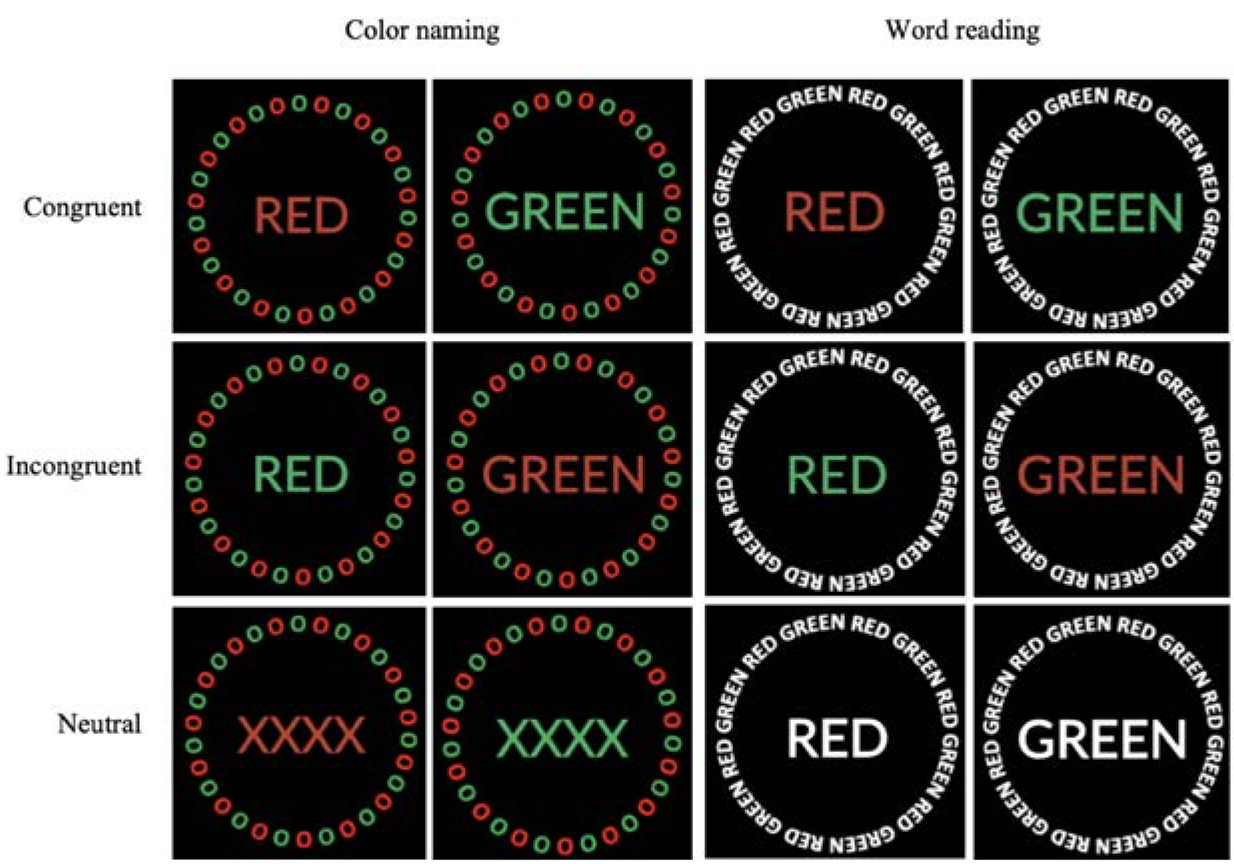

Figure 1. Display of all 12 conditions used in Stroop switching task. Left column shows color naming task stimuli, in rows of congruent, incongruent, and neutral stimuli. Right column shows word reading task in the same order of rows.

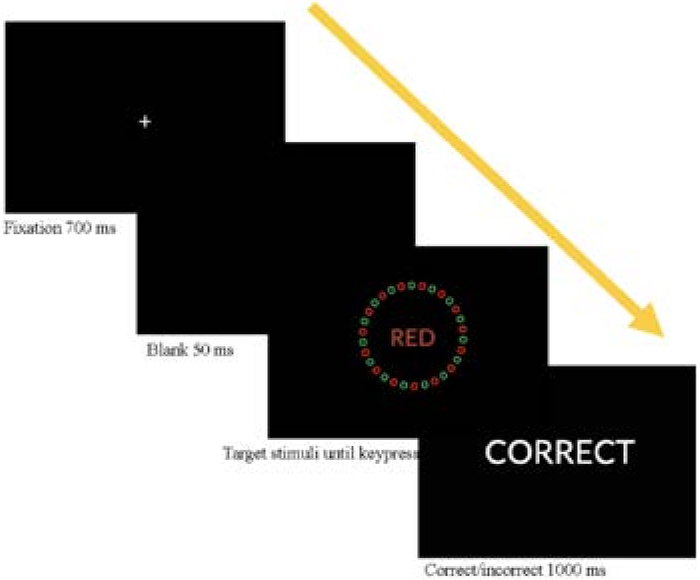

Figure 2. A trial sample of display sequence (color naming task with congruent stimuli and correct response if participant presses "A"). After 1000ms duration of accuracy screen, new trial starts again with fixation.

word-reading to color naming (WC), and repeats (CC or WW). After the experimental blocks, the participants went through a post-experiment survey that assessed their demographic information and language background. The entire task took about 30 minutes.

3. Results

3.1 Survey Responses

Out of 45 total data sets, four were removed from the analysis due to failure to follow directions or for having above 50% error rate of the primary task. Of the remaining participants, 23 responded 'yes' to the survey question that asked whether they speak a second language. These participants were grouped as the 'bilingual' group. On the proficiency scale of 1–5, all monolinguals rated their L1 proficiency as a 5, while bilinguals had an average L1 proficiency of 4.68. The bilinguals rated their L2 proficiency as a 2.82 on average. Furthermore, the average age of acquisition for bilingual groups was 7.22 years old.

3.2 Congruency and Trial transitions

The 41 participants performed better than chance. The exclusion criteria for the trials included incorrect responses, responses greater than 2000ms or below 200ms. Furthermore, the first trial for each block and trial immediately followed an erroneous trial (*n*-1 trials) resulting in 18% of trials being removed.

A 2 (Trial transitions: repeat & switch) x 3 (Congruency: congruent, incongruent, and neutral) x 2 (Language group: bilingual, monolingual) mixed-model analysis of covariance (ANCOVA) was conducted, with Language group as a between-subjects factor and the other factors as within-subject factors. Before analyzing language group results, it is worth noting the main effects found for congruency and trial transitions to establish the validity of the Stroop switching task. The main effects for congruency and trial transitions are described below in terms of RT and ACC.

3.2.1 Reaction Time (RT) in Congruency and Trial transitions

The main effects of congruency (= 0.811) and trial transitions (= 0.329) were significant ($p < .001$). For the congruency main effect, the post-hoc analysis revealed significant RT differences between neutral (910 ms) and congruent trials (965 ms), $p < .001$, $d = 0.674$; between incongruent trials (1181 ms) and congruent trials, $p < .001$, $d = -2.621$; and between neutral trials and incongruent trials, $p < .001$, $d = 3.296$). For trial transitions, the mean RTs were similar for color-word transitions (1057 ms) and word-color transitions (1045 ms), but there was a significantly faster RT in repeat transitions (954 ms), ($p < 0.01$). Due to the insignificant difference between color-word and word-color transitions, the averages of these conditions were collapsed as switch transitions. In the following, post-hoc pairwise t-test comparisons were used for multiple comparisons. The results showed that there was significant, 96 ms, difference between repeat and switch transitions ($p < .001$, $d = -1.593$).

There was a significant interaction between trial transition and congruency. Participants showed smaller task-switching costs with congruent target stimuli (switch—repeat = 75 ms), $p < .001$, $d = 0.931$, compared to trials with neutral target stimuli (switch—repeat = 93 ms), $p < .001$, $d = 1.156$, and trials with incongruent target stimuli (switch—repeat = 121 ms), $p < .001$, $d = 1.686$. No other effects in RT reached statistical significance. The RT switch cost is demonstrated below in figure 3.

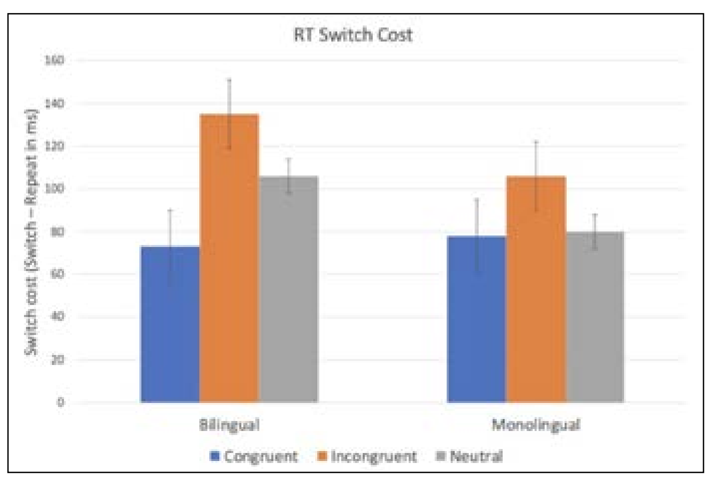

Figure 3. Display of bilinguals and monolinguals performance as a function of RT switch cost (±SE).

3.2.2 Accuracy (ACC) in Congruency and Trial transitions

Based on the analysis, Congruency and Trial transitions both had main effects (both $p < .001$). For the main effect of Trial transition, pairwise *t-test* comparisons showed a significant ACC difference between repeat (0.971) and switch (0.955) transitions, $p = .001$, $d = -0.601$. For the main effect of congruency, pairwise *t-test* comparisons showed a significant ACC difference between congruent (0.976) and incongruent trials (0.941), $p = .001$, $d = 1.077$; between incongruent and neutral (0.972), $p = .001$, $d = -0.951$. However, there were no statistically significant differences between congruent and neutral conditions ($p > .05$).

There was a significant interaction between trial transition and congruency. Participants showed a significant task-switching costs with incongruent target stimuli (switch—repeat = 1.1%), $p < .001$, $d = 1.226$, but no other significant task-switching cost was observed for the congruent and neutral conditions ($p > .05$). No other effects in ACC reached statistical significance. Figure 4 below summarizes the ACC switch cost results.

3.3 Language Group

Based on the analysis for Congruency and Trial transition, the Stroop switching task proved valid. Further analysis was done to investigate the variables of interests, including the Language group and the two covariates (L2 proficiency and Age of acquisition). Table 1 provides a summary of the descriptive statistics separated by the bilinguals and monolinguals. The RT and ACC results found for the language groups will be discussed in further detail thereafter.

3.3.1 Reaction time (RT) in Language Group

The 3-way ANOVA with mixed effects was applied on mean RT between and within conditions. No main effect of language was observed as the data revealed an insignificant difference between the bilingual and monolingual performance. On average, bilinguals performed 95 ms faster than monolinguals in terms of the RT, but this failed to reach significance ($p = .138$). The age of second language acquisition and the second language proficiency reports were included as covariates. Contrary to our prediction, both covariates revealed nonlinear effects with the RT (age of second language acquisition, $r = 0.246$, $p = 0.121$; L2 proficiency, $r = -0.101$, $p = 0.452$) and were removed from the analysis. The results of the RT comparisons are illustrated in Figure 5 below.

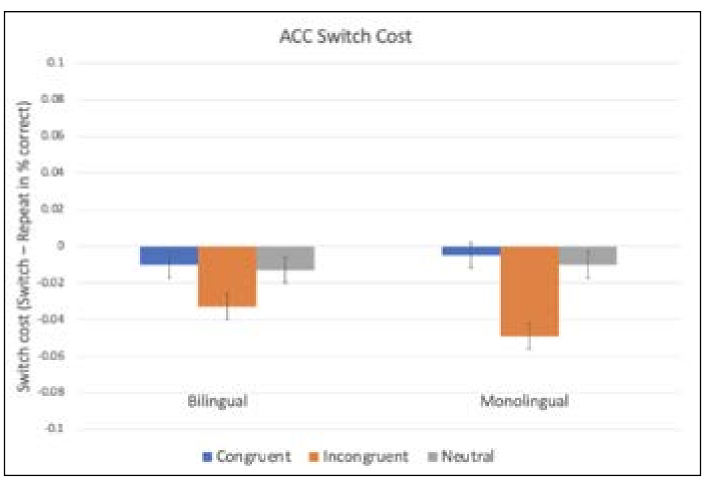

Figure 4. Display of bilinguals and monolinguals performance as a function of accuracy switch cost (±SE).

3.3.2 Accuracy (ACC) in Language Group

An equivalent 3-way ANOVA with mixed effects was applied on mean ACC between and within conditions. The results of the ACC comparisons are illustrated in Figure 6 below. Like the RT analysis, we found no main effect of Language (bilingual vs. monolingual) ($p = .784$). The two groups displayed very similar average ACC of 0.931 and 0.937, respectively. The

Table 1. Reaction time (RT) and accuracy (ACC) separated by bilinguals (top) and monolinguals (bottom).

MONOLINGUAL MEAN RT (MS) AND ACC PROPORTION			
CONGRUENCY	SWITCH TYPE	MEAN RT (SD) (MS)	MEAN ACC (SD) (PROPORTION)
Congruent	Repeat	880 (162)	0.984 (0.017)
	CW	965 (211)	0.986 (0.024)
	WC	950 (179)	0.971 (0.040)
Incongruent	Repeat	1081 (177)	0.918 (0.059)
	CW	1169 (246)	0.893 (0.071)
	WC	1206 (196)	0.882 (0.111)
Neutral	Repeat	827 (157)	0.979 (0.031)
	CW	892 (204)	0.978 (0.028)
	WC	921 (149)	0.960 (0.037)
BILINGUAL MEAN RT (MS) AND ACC PROPORTION			
CONGRUENCY	SWITCH TYPE	MEAN RT (SD) (MS)	MEAN ACC (SD) (PROPORTION)
Congruent	Repeat	882 (145)	0.977 (0.052)
	CW	986 (196)	0.970 (0.049)
	WC	923 (196)	0.965 (0.063)
Incongruent	Repeat	1049 (171)	0.896 (0.086)
	CW	1196 (234)	0.882 (0.111)
	WC	1170 (198)	0.844 (0.135)
Neutral	Repeat	795 (129)	0.978 (0.024)
	CW	908 (151)	0.966 (0.068)
	WC	921 (148)	0.964 (0.051)

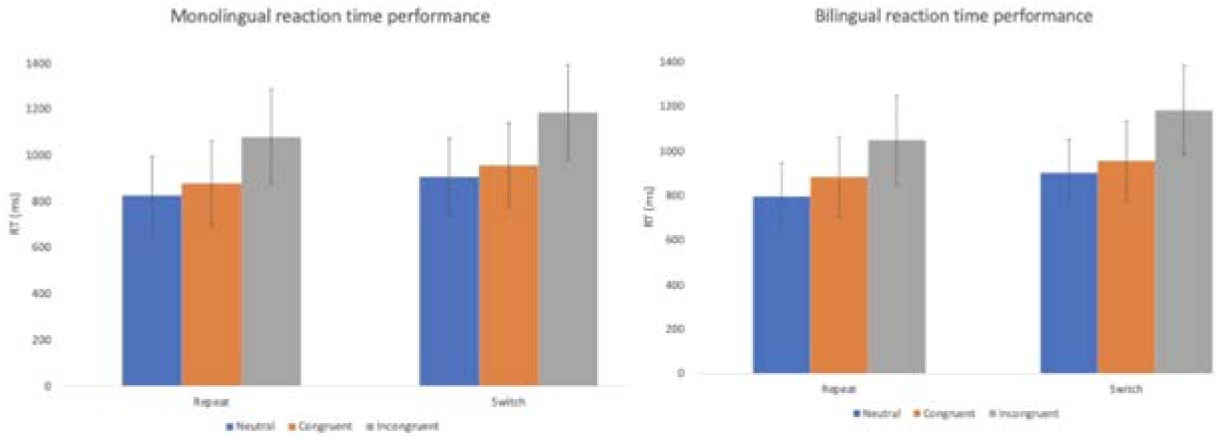

Figure 5. Graph shows reaction time (±SE) as a function of repeat or switch (CW & WC) condition for monolingual language group (left) and bilingual language group.

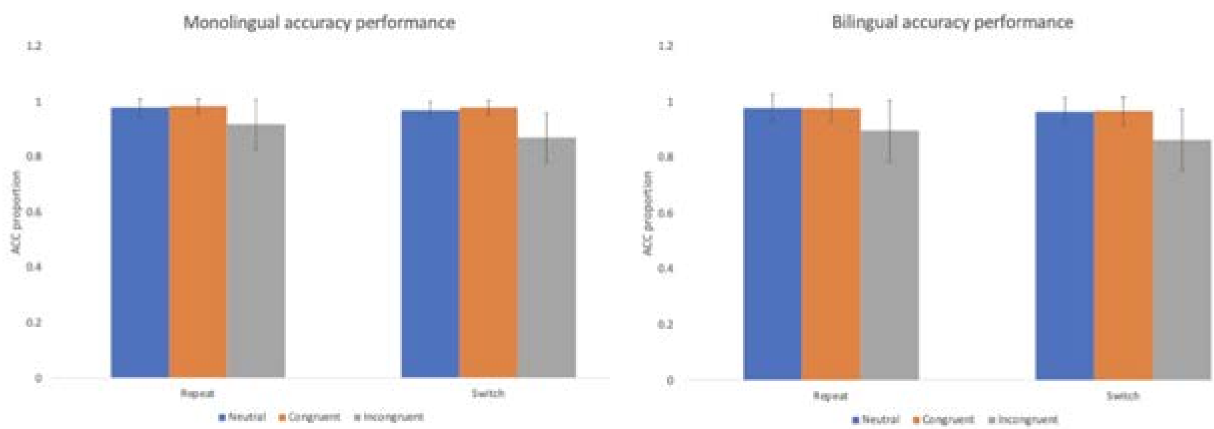

Figure 6. Graphs show accuracy (±SE) as a function of repeat or switch (CW & WC) condition for monolingual language group (left) and bilingual language group (right).

original hypothesis was that the bilinguals would have an overall higher ACC compared to monolinguals. The results of the current study did not support this claim. There were also no other significant effects found in both covariates ($p > 0.005$) and no other interactions were found between the variables.

4. Discussion

The current investigation aimed to expand on the bilingualism advantage research by assessing cognitive flexibility via following questions: 1) Do bilinguals portray better cognitive flexibility than monolinguals in an attentional control task? 2) Does L2 acquisition age influence cognitive flexibility? and 3) Does L2 proficiency level influence cognitive flexibility? The original hypotheses were that bilinguals will display greater cognitive flexibility, and that this should be observable in lower switch cost in the Stroop switching task. It was also predicted that bilinguals with earlier L2 acquisition age and greater L2 proficiency will display lower switch costs compared to those with later acquisition age and lower L2 proficiency. However, the results failed to reach any significant differences between the language groups.

The current adaptation of the Stroop Switching Task served to further investigate the bilingual advantage by requiring participants to frequently task-switch in random orders. The Stroop switching task measures the participant's task-switching ability by constantly requiring the participants to switch between the two tasks (color-naming and word-reading). The task-switching cost was also derived from other cognitive tasks such as Simon task (Simon & Rudell, 1967) and Stroop task (Stroop, 1935), which can indicate certain cognitive mechanisms occurring during challenging tasks. Understanding these mechanisms and how they differ within different groups of individuals (like that of bilinguals) can provide insights on how human cognition works, and what factors influence cognitive abilities. In the current study, Congruency and Trial transitions both proved statistical significance, which is indicative of the task's validity.

Some of the limitations of the current study included a lack of reliability in the language background survey questions. All language-related data (including the age of acquisition and proficiency level) were collected through a self-report questionnaire. Future studies can aim to implement a more systematic language assessment, such as Language Background Questionnaire (LBQ; Chan et al., 2020) or the Bilingual Language Experience Calculator (BiLEC; Unsworth, 2013). Furthermore, this study was conducted at the University of Hawai'i at Mānoa, located in a state where a majority of the population is exposed to different cultures from young age, which may include languages in forms of loan words, family or friends who speak a different language in the individual's presence, and requirement to take a second language course in public educational settings. This may influence the bilingual experience of the participants local to the state. To control for this in future studies, researchers should aim to include questions in the questionnaire that accounts for any exposure to non-primary languages. Information about non-conventional exposure could aid in redefining what it means to be bilingual. Furthermore, cognition can be measured in many ways. Even if behavioral differences were not found, they may be found in other cognitive tasks or in other measurements. Expanding the study and incorporating brain imaging techniques, such as the EEG or fMRI, into the same study can provide more implicit differences in cognition between mono and bilinguals. Investigating brain activity using neuroimaging techniques can further expand the current literature by providing more scientific and concrete data.

As we previously noted, the multidimensional factor of bilingualism indicates that individual differences (e.g., parents' education, immigration, and culture, just to name a few) are known to affect EF, which is the primary interest of bilingualism investigation. Therefore, a greater focus on individual differences via development may be necessary through a longitudinal design rather than focusing on the group differences via cross-sectional methods. Such individual differences could allow for more insights in assessing language usage patterns and within-group differences and systematically advance knowledge on how bilingualism affects cognition and the brain.

The study of bilingualism on cognition is a field that is developing relatively quickly. As mentioned, the field is still conflicted with varying results that do not paint a clear picture of mechanisms associated with bilingualism. Researchers recently began to understand the scope of bilingualism's multidimensionality. Understanding what factors influence bilingual experience can help discover in what ways bilinguals are affected by their use of multiple languages. In conclusion, our current null finding of the bilingual advantage further ensues the heated debate in the bilingualism field that is at an impasse. The examination of this individual difference investigation requires methodological nuances in the experimental designs we mentioned above. Regardless, such rigorous debate and systematic advancement in this field would allow how multiple language experiences affect the cognition and brain.

References

Bialystok, E., Martin, M. M., & Viswanathan, M. (2005). Bilingualism across the lifespan: The rise and fall of inhibitory control. *International Journal of Bilingualism, 9*(1), 103–119.

Bialystok, E. (2009). Bilingualism: The good, the bad, and the indifferent. *Bilingualism: Language and Cognition, 12*(1), 3–11. https://doi.org/10.1017/S1366728908003477

Bialystok, E. (2011). Reshaping the mind: The benefits of bilingualism. *Canadian Journal of Experimental Psychology/Revue Canadienne de Psychologie Expérimentale, 65*(4), 229. https://doi.org/10.1037/a0025406

Blumenfeld, H. K., & Marian, V. (2014). Cognitive control in bilinguals: Advantages in Stimulus–Stimulus inhibition. *Bilingualism: Language and Cognition, 17*(3), 610–629. doi:10.1017/S1366728913000564

Bosma, E., & Blom, E. (2019). A code-switching asymmetry in bilingual children: Code-switching from Dutch to Frisian requires more cognitive control than code-switching from Frisian to Dutch. *International Journal of Bilingualism, 23*(6), 1431–1447. https://doi.org/10.1177/1367006918798972

Chan, C. G. H., Yow, W. Q., & Oei, A. (2020). Active bilingualism in aging: Balanced bilingualism usage and less frequent language switching relate to better conflict monitoring and goal maintenance ability. *The Journals of Gerontology: Series B, 75*(9), e231–e241. https://doi.org/10.1093/geronb/gbaa058

de Bruin, A., Treccani, B., & Sala, S. D. (2015). Cognitive advantage in bilingualism: An example of publication bias? *Psychological Science, 26*(1), 99–107. https://doi.org/10.1177/0956797614557866

Diamond, A. (2013). Executive functions. *Annual review of psychology, 64,* 135–168. https://doi.org/10.1146/annurev-psych-113011-143750

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception & psychophysics, 16*(1), 143–149. https://doi.org/10.3758/BF03203267

Finger, H., Goeke, C., Diekamp, D., Standvoß, K., & König, P. (2017). LabVanced: a unified JavaScript framework for online studies. *International Conference on Computational Social Science* (Cologne). https://www.labvanced.com/index.html

Kalanthroff, E., & Henik, A. (2014). Preparation time modulates pro-active control and enhances task conflict in task switching. *Psychological Research, 78*(2), 276–288. https://doi.org/10.1007/s00426-013-0495-7

Kousaie, S., & Phillips, N. A. (2012). Conflict monitoring and resolution: Are two languages better than one? Evidence from reaction time and event-related brain potentials.

Brain Research, 1446, 71–90. https://doi.org/10.1016/j.brainres.2012.01.052

Laine, M., & Lehtonen, M. (2018). Cognitive consequences of bilingualism: Where to go from here? *Language, Cognition and Neuroscience, 33*(9), 1205–1212. https://doi.org/10.1080/23273798.2018.1462498

Luk, G., Sa, E. D., & Bialystok, E. (2011). Is there a relation between onset of bilingualism and enhancement of cognitive control? *Bilingualism: Language and Cognition 14*(4), 588–599. http://dx.doi.org/10.1017/S1366728911000010

Noort, M. V. D., Esli, S., Bosch, P., Jaswetz, L., Perriard, B., Yeo, S., Barisch, P., Vemeire, K., Lee, S., & Lim, S. (2019). Does the bilingual advantage in cognitive control exist? If so, what are its modulating factors? A systematic review. *Behav Sci (Basel)* 9(3), 27. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6466577/#B40-behavsci-09–00027

Simon, J. R., & Rudell, A. P. (1967). Auditory SR compatibility: the effect of an irrelevant cue on information processing. *Journal of Applied Psychology, 51*(3), 300. https://doi.org/10.1037/h0020586

Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology, 18*(6), 643–662. https://doi.org/10.1037/h0054651

Tao, L., Marzecova, A., Taft, M., Asanowicz, D., & Wodniecka, Z. (2011). The efficiency of attentional networks in early and late bilinguals: the role of age of acquisition. *Frontiers in Psychology. 2,* 123. https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3114252/

Tse, C. S., & Altarriba, J. (2012). The effects of first- and second-language proficiency on conflict resolution and goal maintenance in bilinguals: Evidence from reaction time distributional analyses in a Stroop task. *Bilingualism: Language and Cognition, 15*(3), 663–676. https://doi.org/10.1017/S1366728912000077

Verhagen, J., de Bree, E., & Unsworth, S. (2020). Effects of bilingual language use and language proficiency on 24-month-olds' cognitive control. *Journal of Cognition and Development, 21*(1), 46–71. https://doi.org/10.1080/15248372.2019.1673752

Wang, R., Ke, S., Zhang, Q., Zhou, K., Li, P., & Yang, J. (2020). Functional and structural neuroplasticity associated with second language proficiency: An MRI study of Chinese-English bilinguals. *Journal of Neurolinguistics, 56,* 100940. https://doi.org/10.1016/j.jneuroling.2020.100940

Winskel, H. (2013). The emotional Stroop task and emotionality rating of negative and neutral words in late Thai–English bilinguals. *International Journal of Psychology, 48*(6), 1090–1098. https://doi.org/10.1080/00207594.2013.793800

Xie, Z. (2018). The Influence of second language (L2) proficiency on cognitive control among young adult unbalanced Chinese-English bilinguals. *Frontiers in Psychology, 9,* 412. https://doi.org/10.3389/fpsyg.2018.00412