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TASK-SWITCHING IN BILINGUALS: FURTHER

INVESTIGATION OF THE BILINGUAL

ADVANTAGE

Jennifer M. Brown

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Recent research has suggested that speaking more than one language may lead to benefits across a variety of different cognitive tasks (Bialystok, Craik, Green, & Gollan, 2009). This effect has been dubbed the Bilingual Advantage. It has been suggested that this advantage relates to the development of greater efficiency with processes involved in task-switching. The current study used a task-switching task to investigate three of these processes: reconfiguration, monitoring, and inhibitory control processes.

Monolingual and bilingual participants were presented blocks of trials in which they had to either categorize words as either abstract or concrete, or pictures as human-made or natural. In some blocks, only one task was presented (single-task). In other blocks, both word and picture trials were presented (mixed-task). Stimuli were presented in two formats: univalent stimuli contained only words or pictures and bivalent stimuli contained both a word and a picture. In the bivalent conditions, participants were cued to respond to either the picture or the word. Reconfiguration corresponds to the participants' ability to change from one task set (e.g., categorizing words) to another (e.g, categorizing pictures). This is measured in this task by comparing the switch (categorizing words →

categorizing pictures) to non-switch trials (categorizing words → categorizing words) within the mixed-task bocks. Monitoring processes are activated on a trial-by-trial basis when the participant decides if a switch in mental sets is necessary. This process was measured by comparing performance between non-switch trials in single-task and mixed-task blocks. Inhibitory processes were measured by comparing performance between the univalent and bivalent trials.

The results showed no evidence for the Bilingual Advantage. Switching and inhibitory costs were present, which demonstrates the effectiveness of the task; however, the lack of interaction did not support the hypotheses. The interaction results for monitoring costs did replicate the findings of Prior and MacWhinney (2010) and Hernandez et al. (2013). There were no group differences for monitoring costs. There are several potential explanations for the results of the current study. Overall, it is unclear how monolinguals and bilinguals differ in terms of cognitive functioning.

TASK-SWITCHING IN BILINGUALS: FURTHER INVESTIGATION OF THE BILINGUAL ADVANTAGE

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A Thesis Submitted in Partial
Fulfillment of the Requirements
for the Degree of

MASTER OF SCIENCE

Department of Psychology

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TASK-SWITCHING IN BILINGUALS: FURTHER INVESTIGATION OF THE BILINGUAL ADVANTAGE

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CHAPTER I

THE PROBLEM AND ITS BACKGROUND

Statement of the Problem

Certain cognitive tasks such as the flanker and Stroop tasks yield results suggesting that bilinguals perform faster than monolinguals on tasks that require the same types of cognitive processes that are used in lexical selection (Bialystok et al., 2008; Engel de Abreu et al., 2012). This trend in results has been dubbed the Bilingual Advantage. A possible explanation for the cognitive differences between monolinguals and bilinguals are the processes used during bilingual lexical selection. Lexical selection and the Bilingual Advantage are reviewed in depth in later sections of the paper. One aspect of this research used task-switching to study cognitive differences between monolinguals and bilinguals. A task-switching task allows for the inspection of three key processes: reconfiguration, monitoring, and inhibition. Three specific studies were reviewed in the overview of task-switching: Prior and MacWhinney (2010), Hernandez, Martin, Barcelo, and Costa (2013), and Richter and Yeung (2012). The current study incorporated aspects of these studies in the design and in forming hypotheses.

CHAPTER II

REVIEW OF RELATED LITERATURE

General Literature Review

Language-Specific Bilingual Effects

When producing speech, a number of variables come into play before a word or phrase can be uttered. Production starts with a concept, essentially the information that the person wishes to convey. Next, components of the concept must be mapped onto linguistic representations (i.e., words). Activated words compete for selection, with the most activated representations getting selected. Selected words are then ordered (e.g., by organizing them according to the language's syntax) and then articulated. For monolingual speakers, this process is simpler because there is only one lexicon (mental dictionary) available. When a monolingual is producing a phrase, he thinks of the words that he wants to say, and the most highly activated ones are then chosen for production. For example, if a monolingual wants to name a picture of a four-legged, furry animal that barks, he will utter the most activated word in his lexicon, which fits that description. In this case, the word is dog. This process is essentially the same in bilinguals; however, bilinguals have two lexicons to choose from when producing speech.

At the start of the lexical selection process is a concept, and in bilinguals this concept could create links between their two languages known as concept mediation. Concept mediation is the conceptual representations of words that are shared between languages (de Groot & Hoeks, 1995). What is being mediated are the semantic links between a person's first and second language (i.e., the concepts of the words are being connected but not the actual words). For example, the words "dog" and "Hund" (German) are connected because these words are both the name for a four-legged, furry animal that barks.

There is evidence to suggest that these links between the words exist due to a conceptual semantic system, which is shared across languages (Dufour & Kroll, 1995). Additionally, it has been suggested that categorization of words and pictures access similar types of semantic representations, which means that concept mediation should occur no matter what stimulus is being categorized (Dufour & Kroll, 1995). For example, when the picture of a dog is categorized as an animal, it will access similar types of semantic representations as when the word "dog" is being categorized as an animal. Either type of stimulus could be used for concept mediation to occur. Dufour and Kroll (1995) determined that both balanced and unbalanced bilinguals were able to use conceptual links effectively in categorization. Balanced bilinguals are able to speak both of their languages with the same level of fluency, whereas unbalanced bilinguals have a clear dominant language, which is typically their native language. However, less-fluent bilinguals could only do this during within-language categorization, which means that less-fluent bilinguals only use the conceptual semantic system to link words together when the category and the words to be categorized are presented in the same language (Dufour & Kroll, 1995).

Semantics is a key concept in categorization. In order to categorize a word a person needs to access the semantic representation of the word to know which category it properly fits into. Caramazza and Brones (1980) conducted a study that focused on processing semantic information in monolingual and bilingual speakers. They found that monolinguals and bilinguals did not differ at the semantic level, which means that they processed semantic memory information in the same way. If this information were applied to categorization, it could be concluded that there should not be any difference in a categorization task between monolinguals and bilinguals because categorization is done solely on semantics. Gollan, Montoya, Fennema-Notestine, and Morris (2005) found just that; they reported that monolinguals and bilinguals categorize stimuli equally as fast. They suggest that differences between language groups might arise when the task involves accessing lexical representations such as picture naming (Gollan et al., 2005). This information suggests that monolinguals and bilinguals do not differ cognitively during basic stimuli categorization and also that at the concept level of lexical selection that there is no difference between bilinguals and monolinguals.

Despite the similarities at the "concept" level of lexical selection (i.e., the level at which categorization takes place), the overall process is still more complicated for bilinguals because they have two lexicons. There are a several different theories for how the selection process takes place in bilinguals (For a review see Costa, Miozzo, & Caramazza, 1999). Most theories assume that both lexicons are activated at the same time. The dispute lies in whether the lexicons compete for selection or not. There are two main approaches in these theories: either both lexicons are considered for selection (language-nonspecific) or only the target language (i.e., the one intended to be spoken) is considered for selection (language-specific). The language-nonspecific approach (e.g., inhibitory control model; Green, 1986) states that there is an inhibitory mechanism that suppresses the non-target language (Green, 1986; Meuter, & Allport 1999). Initially, representations in both languages are activated, but after the initial activation the non-target language is suppressed in order to facilitate the selection of the target language (Meuter & Allport, 1999). For example, if a bilingual was trying to name a picture of a dog, the words for dog in English and German (i.e., dog and Hund) would be initially activated, but the non-target language would be inhibited in order to produce in the target language. If the bilingual were trying to speak in English, he would inhibit “Hund”.

In contrast, according to the language-specific approach, only the activated representations in the target language are considered during lexical selection (Costa et al., 1999). Because the representations of the non-target language are not considered, they do not act as competitors during lexical selection; therefore, there is no inhibitory component to this approach (Costa et al., 1999). For this approach, only one lexicon is activated for bilinguals. For example, if a bilingual were trying to speak in English, his German lexicon would not be activated at all during the lexical selection process because his English lexicon would have been initially selected.

Researchers who have conceptualized bilingualism as an example of task-switching have typically adopted the language-nonspecific approach (Kiesel et al., 2010; Prior & MacWhinney, 2010). This approach is a better fit in the task-switching literature because it involves conflict resolution. Under the premises of this approach, the languages are competing for selection, and the speaker needs to inhibit the representations of the non-target language in order to facilitate selection of the correct language. Similarly in a task-switching task, both sets of instructions are active, and the person needs to inhibit the non-target set according to a cue given in each trial. In both cases, the conflict is between the two languages or sets of instructions that are competing to be selected. The inhibition of one language or one set of instructions allows the other to be used, which resolves the conflict. Because bilinguals are inhibiting a language on a daily basis, they become increasingly faster and more practiced for these types of tasks that require conflict resolution and inhibition. This logic is the underlying process for the Bilingual Advantage and an explanation as to how bilinguals excel in these types of tasks. In the following section, I discussed a number of tasks that involve the mental processes of lexical selection such as conflict resolution and inhibition.

General Cognitive Bilingual Effects

Although it is not surprising to find differences between monolinguals and bilinguals in tasks involving language, there is a growing body of research suggesting that these differences may also extend to non-language domains of processing. The previous section focused on lexical selection and the underlying processes used during the selection process, and here I map those processes onto general cognitive tasks in order to make connections between the two.

Research on the bilingual advantage. In addition to lexical selection and categorization, differences between monolinguals and bilinguals have been found in a number of cognitive tasks. Early research on bilingualism focused on vocabulary-based tasks; participants were tested on the number of objects they could name or words they could define (Bialystok, 2009). A popular way to test vocabulary has been by using the Peabody Picture Vocabulary Test (Bialystok, 2009; Bialystok et al., 2008; Dunn & Dunn, 1997; Prior & MacWhinney, 2010). Many studies have determined that bilinguals have smaller vocabularies. For example Bialystok (2009) reported that monolinguals scored significantly higher (average of 105) on the Peabody Picture Vocabulary Test than bilinguals (average of 95). This led some researchers to believe bilinguals were disadvantaged in relation to monolinguals (Oller & Eilers, 2002; Perani et al., 2003; Portocarrero, Burright, & Donovick, 2007) .

Unlike vocabulary-based tasks, meta-linguistic awareness tasks initially showed the Bilingual Advantage. These types of tasks require the participant to judge if a sentence is syntactically correct as opposed to semantically correct. Bialystok and Craik (2010) proposed that bilinguals excel at these types of tasks because they are better at attending to the structure of the sentence as opposed to the semantics. This action requires higher levels of selective attention, inhibition, and the ability to intentionally retrieve the knowledge of the linguistic structure (Bialystok, 2009; Bialystok & Craik, 2010). Inhibition and selective attention are used in this type of experiment because the participant needs to focus on the syntax of the sentence while ignoring the semantics, which is much like ignoring activated words for the non-target language during lexical selection.

The flanker task also shows the Bilingual Advantage. This task consists of a row of arrows shown on a computer screen, and the participant's job is to say which way the center arrow is pointing. In this task it is possible to have congruent and incongruent trials. A congruent trial is where the majority of the arrows are pointing in the same direction as the one in the center, and an incongruent trial is where the majority of the arrows point in the opposite direction of the center arrow. The incongruent trials were where the Bilingual Advantage was evident (Engel de Abreu et al., 2012). The ability to complete this task accurately displays inhibition because the incongruent trials require that the participant inhibit the impulse to press the direction that most of the arrows are pointing. Completion of this task also displays conflict resolution because of the high monitoring demands when the congruent and incongruent trials are interwoven (Hernandez et al., 2013). Monitoring is the process that is activated when constant switching is required because the person needs to constantly update his mental set in that he needs to decide on a trial-by-trial basis whether or not he needs to engage in conflict resolution (Hernandez et al., 2013). In this task, the conflict that needs to be resolved is in the incongruent trials where the center arrow is not pointing in the same direction as the others.

Bialystok et al. (2008) found that bilinguals were able to perform the Stroop task significantly faster than monolinguals. This task consists of a list of colors (e,g., red, green, blue) that are presented in different color ink than the actual color. For example, the word "red" may be shown in blue ink. The participant is expected to either name the color of the ink or read the word while ignoring the color of the ink. This task also involves inhibition because the participant would need to inhibit either the word that is presented or the color the word is presented in to accurately perform this task. Bilinguals are more practiced with these types of tasks because they are accustomed to inhibiting one language while producing in the other. Here they are inhibiting the actual text of the word or the color of the ink. Both cognitive processes require inhibition.

The Simon task is an additional cognitive task used to study the Bilingual Advantage. Because of this task's similarity to the flanker task, participants could yield similar results in relation to the Bilingual Advantage. The difference between the tasks lies in that the participant has to press a specific button based on which color they see appear on the screen. For example, if green were presented, the participant would press a button with his right hand and press a button with his left hand if blue were presented (Bialystok, 2009). In this case an incongruent trial would be when blue is presented on the right side of the screen because they would have to press with the left hand (i.e., the directions do not map onto one another). A congruent trial would be if blue were presented on the left side of the screen because the directions would map onto one another (i.e., presented on the left side of the screen and left hand press). This type of task requires inhibition because in incongruent trials the participant would need to inhibit the inconsistency between the hand press and the side on which the color was presented. Bilinguals were more easily able to inhibit their cognitive impulses during the incongruent trials, which makes them able to complete this task overall more quickly than monolinguals (Bialystok, 2009). The inconsistency between the direction mappings can be thought of as a conflict needing to be resolved. As in the flanker task, the monitoring processes could be underlying the conflict resolution and ultimately the Bilingual Advantage that is shown in these types of tasks. Bilinguals use monitoring when they are determining if a switch in languages needs to take place; in the task, they use monitoring to determine if they need to switch mental sets between trials.

A card sort task is another effective way to show how monolinguals and bilinguals perform differently on tasks. Bialystok (1999) implemented a card sort task where there were three phases. The phase shift was unknown to the participant, but the participant was told that the rules had changed. For example, in phase one, the participant sorted the cards by color, but in phase two the participant sorted the cards by shape. The participant was not told how the rules have changed so he learned the new rule through trial and error; feedback is usually given on a trial-by-trial basis. According to Bialystok (1999), the Cognitive Complexity and Control (CCC) Theory accounts for how people perform in a card sort task. The CCC Theory states that people are able to increase control over their behavior as they acquire complex rule systems and feedback for how to properly function under these rules (i.e., awareness of the changes in the rule systems). This theory explains why children often fail at these types of tasks because they lack rule systems and awareness (Bialystok, 1999). Despite children's poor performance on a card sort task, Bialystok (1999) found that bilingual children were able to outperform monolingual children on trials in which more attentional control was needed (i.e., trials immediately following a rule change). Inhibition is an important aspect of these tasks because solutions in later phases of the experiment often require the participant to inhibit earlier response sets (Bialystok, 1999). Reconfiguration is also important for these tasks because after a phase shift the participant needs to reconfigure the set of rules they are using for categorization. The reconfiguration process is activated when the participant needs to switch between mental sets (Hernandez et al., 2013). For example, after phase one the participant would need to reconfigure the categorization rules from sorting by color to sorting by shape. For bilinguals reconfiguration takes place when they need to switch between producing in their first language to producing in their second language or vice versa.

Mathematical word problems are an additional way to study the performance gap between monolinguals and bilinguals. This paradigm was utilized in a study conducted by Kempert, Saalbach, and Hardy (2011). Here the researchers gave monolingual and bilingual children mathematical word problems that either had distractor information (i.e.

information that was not needed to solve the problem) or no distractor information. There was a trend in the results suggesting that bilingual children were better at solving the problems with distractor information; however the difference was not significant (Kempert et al., 2011). It is possible that the difference was not significant due to bilinguals typically having smaller vocabularies. If the bilingual children did not know the words used in the math problem, then they would not know how to properly solve it.

All of these tasks mentioned above (with the exception of vocabulary-based tasks) showed evidence for a Bilingual Advantage. The first study to show this effect was conducted by Peal and Lambert (1962). They found that French-English bilingual children in Montreal had higher performance than English monolingual children on verbal and non-verbal intelligence tests (Peal & Lambert, 1962). Generally speaking, there seems to be a trend in the evidence for the Bilingual Advantage that suggests that bilinguals are inherently better at tasks that involve one or more than one of these cognitive processes: inhibition, control, selective attention, conflict resolution, monitoring, reconfiguration, and problem solving (Bialystok, 2009; Hernandez et al., 2013). With the language-nonspecific approach in mind, the Bilingual Advantage is present in these tasks because of the use of an inhibitory mechanism. In all of these tasks mentioned, there is an aspect of the task that is being inhibited at all times. For example, the flanker task requires inhibition of the arrows pointing in the inconsistent direction, and the card sort task requires inhibition of the previous set of instructions. An interesting note is that these cognitively based tasks do not map onto bimodal bilinguals such as those that speak American Sign Language and English because these bilinguals do not have to suppress one language in order to comprehend/produce in the other (Traxler, 2012).

Task-switching. In addition to the tasks discussed in the previous section, task-switching is another cognitively based task that gives evidence for the Bilingual Advantage. However, before it was used to study bilingualism, it was a widely known task used to study several phenomena and effects such as cognitive control and cognitive decline. Task-switching can be defined as having two active sets of instructions and deciding which set to use on a trial-by-trial basis depending on the cue given in each trial (Kiesel et al., 2010).

A typical task-switching exercise is comprised of a series of blocks that each contains a set number of trials. A general depiction of this task can be found in Figure 1, which describes the procedures used by Prior and MacWhinney (2010). There are two types of blocks: single-task and mixed-task. A mixed-task block consists of both types of stimuli, and both types of categorization are required. Within a single-task block there will only be one type of stimulus presented, which required only one type of categorization, so the entirety of single-task blocks will consist of non-switch trials; however, mixed-task blocks will consist of switch and non-switch trials because there is more than one type of stimulus being presented and therefore, more than one type of categorization taking place. Task-switching is only taking place in mixed-task blocks. A non-switch trial involves the same type of categorization for two trials in succession, and a switch trial involves different types of categorization for two trials in succession.

The use of these blocks allows specific analyses that measure different aspects of executive control to be conducted. Mixing costs can be defined as the performance gap between single-task blocks and non-switch trials in mixed-task blocks. Switching costs are the difference in response time between switch and non-switch trials in mixed-task blocks. Performance in both cases is measured using reaction time. In the case of mixing costs, the analysis is quantifying whether there is a difference between sustaining control (i.e., prolonged suppression) in the different blocks. Hernandez et al. (2013) referred to this process as monitoring. Monitoring is the process that detects when the switch between sets of instructions needs to take place.

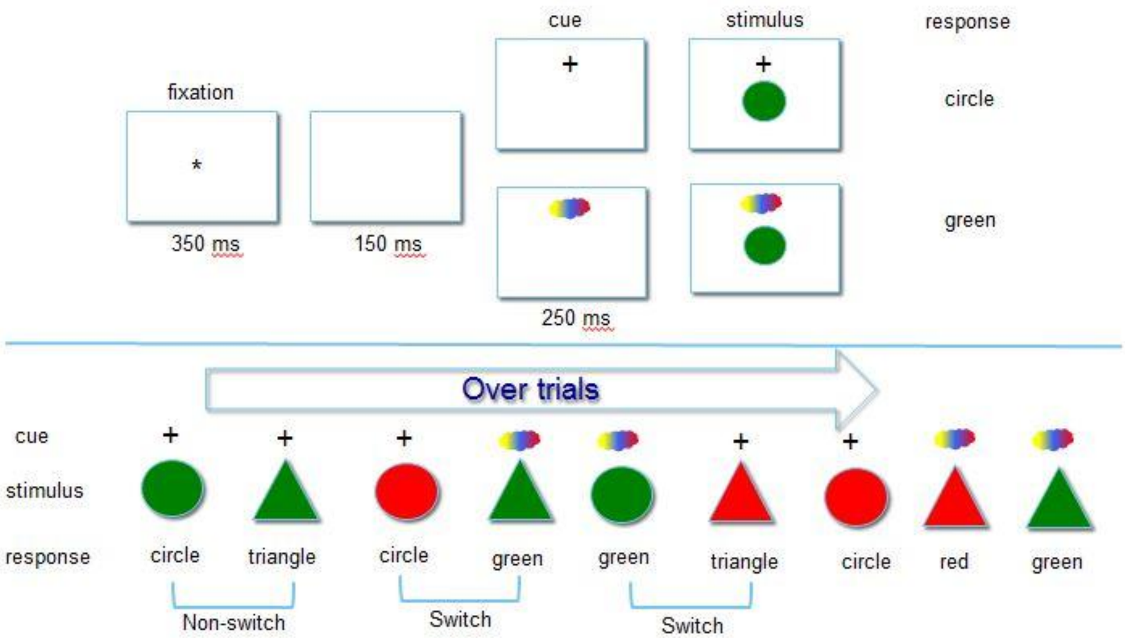

Figure 1. Example Trial and Series of Trials in a Task-switching Task. The top half of this figure depicts a trial sequence in a task-switching task. It starts with a fixation cross, which is followed by a blank screen, the cue, and then the stimulus. The bottom half of the figure represents a series of trials in a task-switching task. The switch and non-switch trials are indicated underneath with brackets. In this example, the cue of a cross indicates that the participant should categorize the stimulus by shape (i.e., circle or triangle), and the cue of the colored figure indicates that the participant should categorize the stimulus by its color (i.e., red or green).

In the case of switching costs, the analysis is quantifying a switch in mental sets. It is essentially calculating how long it take a person to shift between trials when they are switching instruction sets as opposed to using the same set twice in succession. The act of switching between mental sets is called reconfiguration (Hernandez et al., 2013). This process of shifting mental sets involves inhibition because the person needs to suppress the set of instructions they used on the previous trial. Inhibition is the same process that is used during bilingual lexical selection. Bilingual lexical selection is essentially the underlying procedure for how bilinguals process the information presented in a task-switching paradigm. The two tasks (task-switching and lexical selection) are the same in terms of the mental processes used; the only difference lies in what is being suppressed.

Prior and MacWhinney (2010) used a task-switching task to determine if life-long bilingualism would lead to enhanced efficiency (i.e., speed of performance) in a task-switching task. Participants were asked to categorize objects by shape or color. Prior and MacWhinney (2010) used a sandwich design, which is distinct in the way it split up the different types of trials; this separation allowed for specific types of analyses to be used. This design allowed them to look at switching costs, which is the difference in performance for switch trials and non-switch trials in mixed-task blocks and mixing costs, which is the difference in performance between single-task blocks and non-switch trials in mixed-task blocks. These analyses can reveal the activation of control processes for selecting the appropriate task (switching costs or reconfiguration) and activation of a sustaining mechanism that is used to maintain the two competing tasks (mixing costs or monitoring) (Hernandez et al., 2013; Prior & MacWhinney, 2010). Their sandwich design consisted of two single-task blocks followed by four mixed-task blocks and two additional single-task blocks. According to Prior and MacWhinney (2010), a mixed-task block consists of both types of categorization as opposed to a single-task block, which only requires one type of categorization. Their paradigm and analyses are depicted in Figure 2. Their results demonstrated that bilinguals incurred smaller switching costs, which shows evidence for reconfiguration (Prior & MacWhinney, 2010). Additionally, their results demonstrated that bilinguals performed faster on switch trials in mixed-task blocks (Prior & MacWhinney, 2010).

Hernandez et al. (2013; third experiment) did an exact replication of Prior and MacWhinney (2010). Hernandez et al. (2013) looked at the underlying mental processes involved in switching and mixing costs. Switching costs reflect the reconfiguration of the mental sets to the new rule, and mixing costs reflect the activation of a monitoring system. The researchers found no mixing costs in relation to language group, which is the same as Prior and MacWhinney. However, Hernandez did not detect any evidence for switching costs when language group was taken into account. The latter result conflicts with Prior and MacWhinney. These conflicting results for switching costs could be due to characteristic differences in the bilingual samples being studied (Hernandez et al., 2013). For example, Hernandez et al. (2013) only studied Catalan-Spanish bilinguals whereas Prior and MacWhinney (2010) studied bilinguals who spoke English and another language, which was not controlled for. Another example is that the sample examined in Hernandez et al. (2013) spoke both languages interchangeably on a daily basis, but the sample studied in Prior and MacWhinney (2010) most likely did not. This line of thinking could be beneficial to the current study because the sample being studied more closely resembled the sample in Prior and MacWhinney.

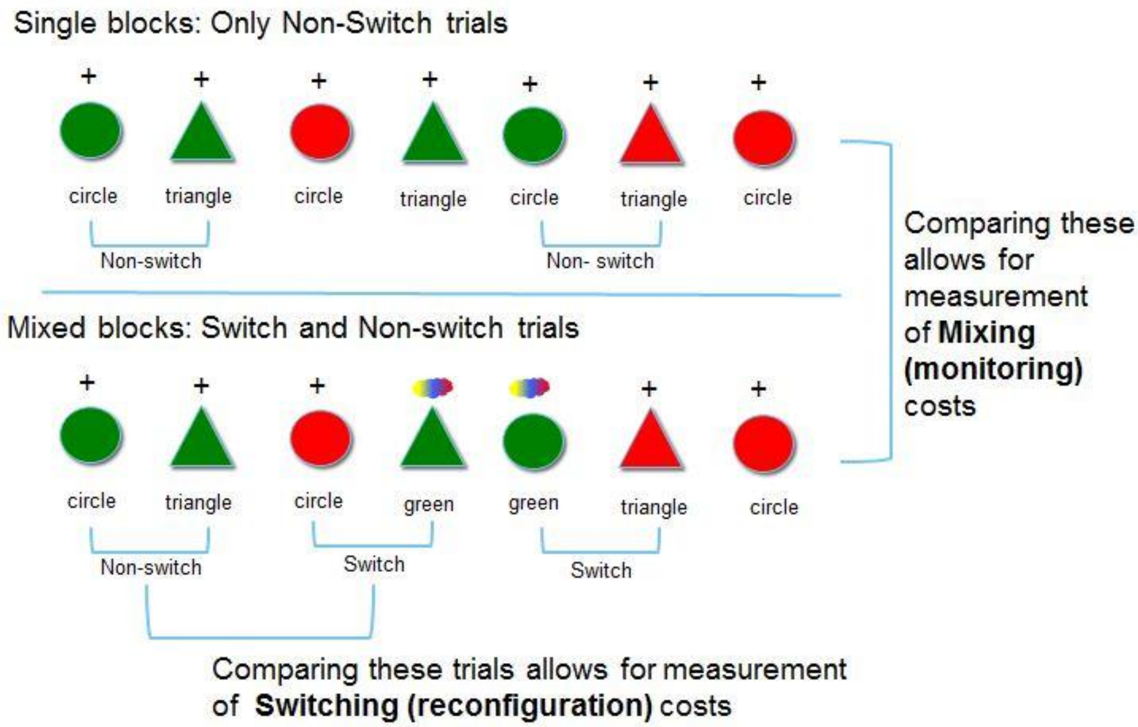

Figure 2. Example Series of Trials in a Single- and Mixed-task Block. A representation of the paradigm used in Prior and MacWhinney (2010). The top half of the figure depicts a single-task block; there are only non-switch trials. The bottom half of the figure depicts a mixed task blocks; this is where the task-switching takes place because both types of categorization are required. This figure also illustrates the comparison of trials for switching and mixing costs.

Richter and Yeung (2012) developed a task-switching task that used a more complex categorization that included a new kind of stimulus; they asked their participants to categorize objects as natural or human-made and to categorize words as abstract or concrete. They also used different types of stimuli. A univalent stimulus consists of only one item presented at a time (i.e., a word or an object), and a bivalent stimulus consists of both items being presented at one time (i.e., a word superimposed over an object) (Richter & Yeung, 2012). In the case of bivalent stimuli, Richter and Yeung (2012) denoted which stimulus to categorize with a colored border. The researchers found that trails with bivalent stimuli were performed significantly slower than trials with univalent stimuli. Using bivalent stimuli can reveal the possible underlying inhibitory control processes that are used during categorization like attention allocation, and inhibition.

Current Study, Justification, and Predictions

The purpose of the current research was to determine if bilinguals perform differently in a task-switching paradigm than monolinguals. The current study used many elements of a typical task-switching paradigm. The basic task was categorization, but bivalent and univalent stimuli, similar to those used in Richter and Yeung (2012), were included. The bivalent stimuli used in Richter and Yeung have not been previously used to study the Bilingual Advantage. This part of the study explored how bilinguals performed on tasks that included bivalent stimuli, and ultimately added to the knowledge surrounding the Bilingual Advantage. The study design was based on Prior and MacWhinney (2010): it was a sandwich design, which consisted of two single-task blocks followed by four mixed-task blocks and two additional single-task blocks. Using these blocks allowed mixing and switching costs to be incorporated into the analyses and the analysis of the reconfiguration and monitoring processes. Overall, the current study incorporated Richter and Yeung's stimuli into Prior and MacWhinney's design.

The predictions given here focus on the presence/absence of the Bilingual Advantage. For the first hypothesis, I predicted that bilinguals should incur smaller switching costs (difference in response time between switch and non-switch trials in mixed-task blocks; Prior & MacWhinney, 2010). These results would support reconfiguration as an underlying process. This pattern represents a replication of Prior and MacWhinney (2010) and would be expected if this approach is true. Bilinguals should incur smaller switching costs than monolinguals because they are practiced at switching mental sets. Normally bilinguals switch between languages of production, but here they were switching between sets of instructions. This constant need for switching in their daily lives might lead to enhanced performance in switching mental sets.

For the second hypothesis, I predicted that there would be no evidence for the bilingual advantage in mixing costs (difference in performance between single-task blocks and non-switch trials in mixed-task blocks; Prior & MacWhinney, 2010). These results would show evidence for the monitoring processes underlying categorization, but no differences in performance between monolinguals and bilinguals. In these types of trials, no switching is required – only continued inhibition of the same set of instructions. Because there was no switching required, it was very possible that monolinguals would be able to perform at the same level as bilinguals. Typically the Bilingual Advantage is shown when the tasks are more cognitively taxing (i.e., switching mental sets). If this hypothesis were supported, the findings from Prior and MacWhinney (2010) and Hernandez et al. (2013) would be replicated. In the previously mentioned categorization literature, it was stated that monolinguals and bilinguals did not show any differences in speed of stimulus categorization (Gollan et al., 2005). These studies only used univalent stimuli (i.e., no switching is taking place), and this hypothesis focused on places in the task where no switching was taking place. Based on this literature, a finding of no bilingual advantage for mixing costs was to be expected.

For the third hypothesis, I predicted that bilinguals would perform faster on trials with bivalent stimuli in mixed-task blocks. This hypothesis was exploratory, and if these results were found, it would add to the information known about the Bilingual

Advantage, and it would support the idea of inhibitory control processes underlying the categorization of bivalent stimuli. These results would also show support for the language-nonspecific approach because inhibition was still being used but in a slightly different way. Normally bilinguals are only inhibiting one language, and in a typical task-switching paradigm they are inhibiting one set of instructions. With bivalent stimuli they are inhibiting two things: one set of instructions and one stimulus. This situation is different from their normal realm of functioning, but the practice they get from inhibiting one language could help their performance in more complex situations such as this. With regard to univalent stimuli in mixed-task blocks, the Bilingual Advantage would be present in switch trials but not non-switch trials because this was essentially looking at switching costs, which was addressed in the second hypothesis.

CHAPTER III

RESEARCH DESIGN

Method

Participants

Participants for this study were undergraduate and graduate students from Illinois State University. A power analysis revealed an ideal sample size of 40 participants in each language group for a total of 80 participants. Eighty-nine participants were recruited, and a 90% accuracy rate on the categorization task was required. Data from four participants had to be discarded due to computer problems, and 14 participants had accuracy rates below 90%. These 18 participants were not included in the final sample. The final sample size was 71; there were 40 monolinguals and 31 bilinguals in this sample. The average age of participants was 20.71, and the ages ranged from 18-37. There were 48 females and 22 males in the sample (one participant did not respond). Of the bilinguals in this sample, 10 spoke English as a first language, and 20 spoke English as a second language (one participant did not respond). The most common first language for bilinguals was Spanish (11) with English in second place (10). Bilinguals most often spoke English (20) as a second language, which was followed by Spanish (4). Some of the other common languages spoken in the bilingual sample were Polish, Italian, Russian, and German.

Participants were recruited through the Psychology online sign-up system and through the Languages, Literatures, and Cultures department on ISU's campus. Students were compensated for their time with extra credit toward a course in the Psychology department if they signed up using the online system. If students were recruited outside of the Psychology department, they were compensated by entering a raffle for the chance to win a $30 Amazon gift card. During the recruitment process, there were specific instructions asking for people to sign up only if they were monolinguals or bilinguals. Monolingual and bilingual criteria were determined through answers given on a self-report questionnaire (LEAP-Q).

Materials and Design

Language group. Language group (monolingual vs. bilingual) was a between-groups variable. Monolingual participants only had the ability to speak one language, and they spoke this language 100% of their time. Bilingual participants were able to speak at least two languages with some fluency/proficiency and regularity. The bilinguals' ability to speak two languages were determined through their answers given on the LEAP-Q (Marian, Blumenfeld, & Kaushanskaya, 2007). Some of the information that helped determine proficiency in a second language was percent of time spent speaking both languages on a daily basis and a self-rated level of proficiency.

Measures. The LEAP-Q (Marian et al., 2007; see Appendix A) was completed by all participants. It consists of three sections. The first section consists of demographic questions concerning age, gender, education, and spoken languages; the second section consists of more detailed questions concerning participants' use of their native language; the third section is identical to the second section, but refers to participants' second language. Some example questions that were asked in the second and third sections are as follows: please report the ages when you began acquiring knowledge of this language/when you became fluent in this language, please list the number of years and months you spend in each language environment, please rate to what extent you are currently exposed to this language in the following contexts (Marian et al., 2007). This questionnaire was administered in an interactive Microsoft Word document. Bilinguals completed all three sections of the LEAP-Q because they spoke two languages; monolinguals only completed the first two sections because they only spoke one language.

Block type and valence. Block type (single vs. mixed) was a within-participants variable and describes the nature of the categorization task within each block. The single-task blocks consisted of only a single type of categorization for the entirety of that block. Participants categorized either words or objects. In the mixed-task blocks the participant categorized words and objects within the same block. An example of this would be if a word-categorization trial were followed by an object-categorization trial within the same block of trials.

Valence (univalent vs. bivalent) was also a within-participants variable and dealt with the nature of the stimuli. Univalent stimuli consisted of only one type of stimulus; either the participant was presented with a word or an object. Bivalent stimuli were comprised of both types of stimuli presented simultaneously – a word was superimposed over an object. In bivalent trials, stimuli appeared inside a colored border; the color of the border indicated whether participants should categorize the word (blue) or the object (red).

Stimuli. The task-switching paradigm consisted of objects and words. The objects were categorized as man-made or natural, and the words were categorized as abstract or concrete. For example, a picture of an apple would be categorized as natural, and the word "hope" would be categorized as abstract. They were obtained from Poldrack et al. (1999)

There were certain stimuli shown for each block type. In a single-task block there was only one type of stimulus presented for the duration of the block, but this could be in two different forms. The two options were that the same type of univalent stimuli was presented for the length of the block (i.e. only objects or words), or that bivalent stimuli, which required the same type of categorization, were presented for the entirety of the block. In a mixed-task block there were both categories of stimuli presented. One type of mixed-task block only had univalent stimuli presented, but objects and words were presented and categorized within the same block. The other type of mixed-task block consisted of bivalent stimuli where both types of categorization were required within the same block. These different types of blocks and the corresponding stimuli are presented in Figure 3.

Trial type. Trial type (switch vs. non-switch) concerned the sequence of the trials. In a switch trial, a word stimulus was followed by an object stimulus (or vice versa), but in a non-switch trial, two of the same stimuli were presented consecutively (e.g., a word stimulus followed by another word stimulus). In terms of bivalent stimuli, both types of stimuli were presented in all of the trials. However, in switch trials, the colored border changed, and in non-switch trials, the colored border stayed the same. For example, in a switch trial, the colored border may change from red to blue across two trials; this changes the categorization task that the participant must complete. In a non-switch trial, the colored prompt stayed the same (e.g., red will appear for 2 consecutive trials), which also kept the categorization task the same. This variable was a within-participants variable.

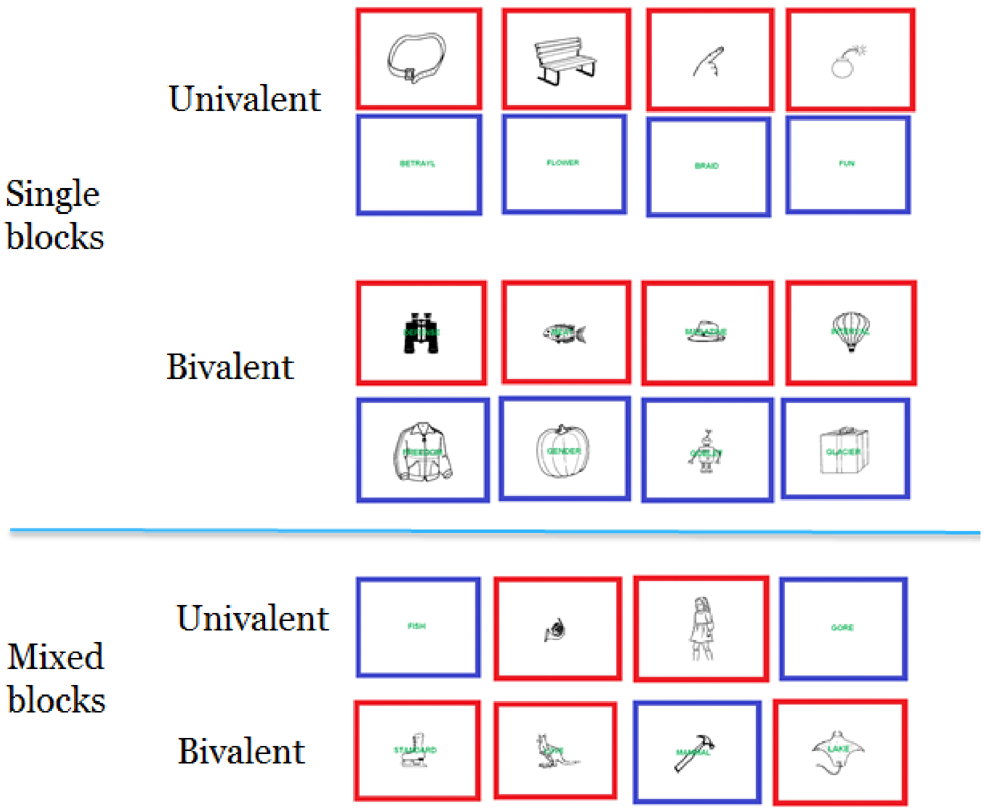

Figure 3. Example of Stimuli Presented in Each Block Type. The different block types and the corresponding stimuli presented in each.

Design. This study had a mixed-model design (See Figure 4). Bilinguals and monolinguals were exposed to all levels of the remaining independent variables (block type, trial type, and valence). Block type was separated into single and mixed; this separation was the essential part of the sandwich design. Within the single-task blocks there were only univalent stimuli and non-switch trials. In the mixed-task blocks both types of stimuli and valence were presented. The breakdown of information in each block and trial can be found in Figure 1. The dependent variable of interest was reaction time. Reaction time was defined as the difference in time from when the stimulus was presented to when the participant responded. The time was measured in ms.

Single-task Block		Mixed-task Block				Single-task Block	
S1	S2	M1	M2	M3	M4	S3	S4

Figure 4. Design of the Study. The order of the blocks is determined by the Latin square found in Figure 5.

Paradigm. The task-switching paradigm was organized in a sandwich design: two single-task blocks, four mixed-task blocks, and two additional single-task blocks. The order of the blocks was counterbalanced for each participant. The different block types were counterbalanced separately because a full counterbalance would not work with the sandwich design. The blocks needed to appear in a certain order in order to utilize the sandwich design, and doing a full counterbalance would not allow for this. The single-task blocks were counterbalanced separately from the mixed-task blocks. Counterbalancing was achieved using a balanced Latin Square for both block types. Figures 5 represents the partial Latin Square. Within these figures, the first row of the figure corresponded to its order in the overall design of the experiment, which can be found in Figure 4. A partial Latin Square was used to make the number of block combinations more manageable because there are a total of 144 possible combinations.

The partial Latin Square was constructed by placing each block type in each position in the sequence, which made 8 unique orders.

S1	S2	M1	M2	M3	M4	S3	S4
Uni – pictures	Biv – pictures	Uni	Biv	Uni	Biv	Uni – words	Biv – words
Biv – pictures	Uni – pictures	Biv	Uni	Biv	Uni	Biv – words	Uni – words
Uni – words	Biv – words	Biv	Biv	Uni	Uni	Uni – pictures	Biv – pictures
Biv – words	Uni – words	Uni	Uni	Biv	Biv	Biv – pictures	Uni – pictures
Uni – pictures	Biv – words	Uni	Biv	Uni	Biv	Uni – words	Biv – pictures
Biv – words	Uni – pictures	Biv	Uni	Biv	Uni	Biv – pictures	Uni – words
Uni – words	Biv – pictures	Biv	Biv	Uni	Uni	Uni – pictures	Biv – words
Biv – pictures	Uni – words	Uni	Uni	Biv	Biv	Biv – words	Uni – pictures

Figure 5. Partial Latin Square of Block Orders. "Uni" indicates a block with univalent stimuli and "Biv" indicates a block with bivalent stimuli. Counterbalancing for the single-task and mixed-task blocks achieved using a partial Latin Square. There are 144 possible sequences of blocks. Each type of block is represented in each position of the sequence to control for order effects. The top row of the table corresponds to the order it is presented in the overall design of the study, which is depicted in Figure 4.

In the mixed task blocks, the number of switch/non-switch trials that followed one another was controlled for; there were no more than four of the same type of stimulus in a row. Controlling for switch and non-switch trials allowed for the computation of switching and mixing costs. There were a total of 36 experimental trials in each single-task block, which totals 144 trials in all of the single-task blocks. There were 36 experimental trials in each mixed-task block, which totals 144 trials in mixed-task blocks.

Half of the trials in the mixed-task blocks were switch trials, and half were non-switch trials.

Procedure

Participants were tested individually in a laboratory setting on a laptop computer. Both the survey and the task-switching paradigm were computerized. MouseTracker software (Freeman & Ambady, 2010) was used to present stimuli and record reaction times. It also recorded whether or not participants chose the correct answer (accuracy) and mouse trajectory (i.e., path taken from the starting point to the response button).

When the participant first arrived, he was asked to read and sign the informed consent. Next, the participant was instructed to fill out a demographic survey; monolinguals and bilinguals filled out the LEAP-Q (Appendix A). After the participant filled out the survey, he was given specific instructions for the task-switching paradigm. They were as follows.

"For this experiment, your job is to categorize the items on the screen. You will see either words or objects. For the words, you see you need to categorize them as concrete or abstract. You will indicate your response by clicking a button at the top of the screen for "abstract" and clicking a button at the bottom of the screen for "concrete." For the objects, you need to categorize them as human-made or natural. You will indicate the human-made words by clicking a button at the left of the screen, and you will indicate the natural words by clicking a button at the right of the screen. You will make your responses using the mouse. On each trial there will be a colored border around the center of the screen. Red indicates that you should categorize the object, and blue indicates that you should categorize the word." These instructions were given on-screen, and the researcher asked the participant to read them.

Once these had been read, the researcher went over the rules for categorization again and gave specific examples of each type of stimulus with the participant to ensure that he understood the distinctions for categorization. The participant was given the opportunity to ask questions during this time. If the participant had no further questions concerning categorization, he was given more instructions: "There will be 8 blocks in total for this experiment, and there will be 4 practice trials at the beginning of each block. If you have questions, please ask them during these practice trials. You will be reminded of the categorization rules at the start of each block. During the experiment, you will need to categorize the stimuli as quickly as possible while still being accurate. It's not a race, but at the same time, don't spend too long contemplating each object or word."

After all instructions had been read and understood, the participant then began the task with two single-task blocks. These blocks were followed by four mixed-task blocks and then two additional single-task blocks. Each block began with 4 practice trials, and each block was separated by a break up to two minutes long. After each break, instructions were given again as a reminder to the participant.

Each trial had the following procedure. First, the participant clicked on the start button in the middle of the screen. After clicking this, the cue and stimulus appeared in the middle of the screen. They remained on the screen until the participant responded. The stimulus was dependent upon the block of the experiment; it was either a bivalent or univalent stimulus. When the participant had made a selection for that trial, a new start button appeared for him to click to begin the next trial.

With the completion of the final single-task block, the participant was given compensation in the form of course credit/extra credit or was entered in a raffle to win a gift card. He was also given debriefing information and told the nature of the study.

CHAPTER IV

ANALYSIS OF THE DATA

Results

Hypotheses

There were three effects that were predicted based on the results of Prior and MacWhinney (2010) and Hernandez et al. (2013). All of these predictions were made in terms of the presence or absence of a Bilingual Advantage. The first hypothesis predicted that monolinguals would incur smaller switching costs than bilinguals. This cost is determined by comparing switch and non-switch trials in mixed-task blocks. The second hypothesis predicted that there would be no differences in performance between the language groups on non-switch trials in mixed-task blocks and single-task blocks. The third hypothesis predicted that bilinguals would perform faster than monolinguals on trials in mixed-task blocks with bivalent stimuli. This cost is examined by comparing trials with bivalent and univalent stimuli in mixed-task blocks. All analyses reported were conducted using SPSS and tested at the .05 alpha level. The dependent variable is reaction time, and this variable is expressed in ms.

Hypothesis Testing

The first hypothesis was tested with a trial type (switch vs. non-switch) x language group (monolingual vs. bilingual) mixed ANOVA, with trial type as a within-participants variable and language group as a between-participants variable. For this analysis, only trials in mixed-task blocks were analyzed to show the use of reconfiguration processes. These results are presented in Figure 6. There was a non-significant effect of language group, $F(1, 69) = 3.59$, $p = .06$, $\eta_p^2 = .05$. Non-switch trials ($M = 2037.59$, $SE = 44.03$) were performed significantly faster than switch trials ($M = 2366.07$, $SE = 53.79$), which yielded a main effect of trial type, $F(1, 69) = 131.51$, $p < .001$, $\eta_p^2 = .66$. The interaction was not significant, $F < 1.00$.

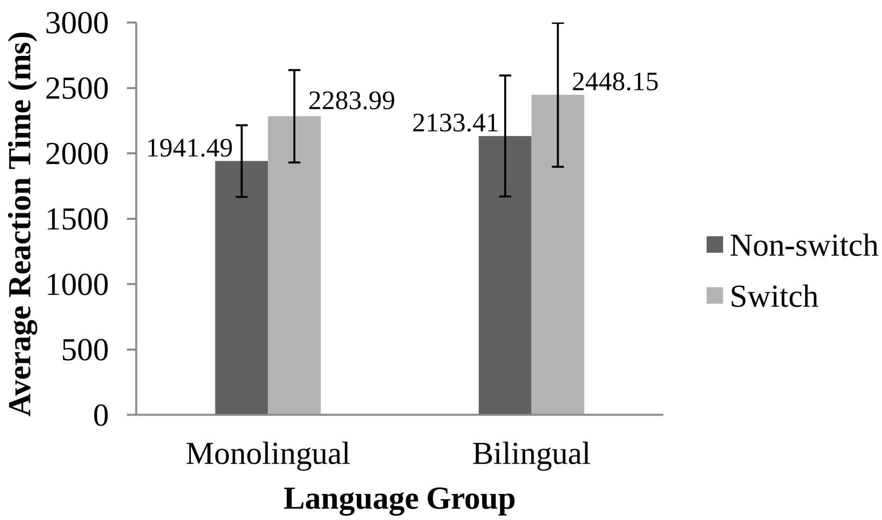

Figure 6. Results of Hypothesis One. Effects of language group and trial type on reaction times (ms), with standard error bars.

Analysis for the second hypothesis was conducted with a block type (single vs. mixed) x language group (monolingual vs. bilingual) mixed ANOVA. For this hypothesis, only non-switch trials were analyzed in order to examine the use of monitoring processes. These results can be seen in Figure 7. There was a significant main effect of language group, $F(1, 69) = 6.23$, $p = .02$, $\eta_p^2 = .08$, such that monolinguals ($M = 1765.47$, $SE = 48.86$) performed faster than bilinguals ($M = 1950.10$, $SE = 55.50$). Single-task blocks ($M = 1677.97$, $SE = 34.54$) were performed significantly faster than mixed-task blocks (M = 2037.59, SE = 44.03), which yielded main effect of block type, F(1, 69) = 162.74, p < .001, η_p^2 = .70. The interaction was not significant, F < 1.00.

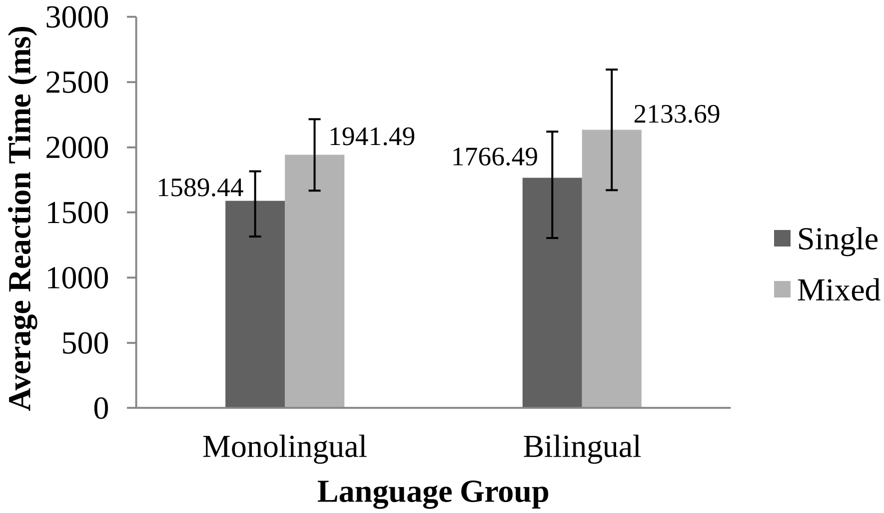

Figure 7. Results of Hypothesis Two. Effects of language group and block type on reaction times (ms), with standard error bars.

The third hypothesis was tested with a valence (univalent vs. bivalent) x language group (monolingual vs. bilingual) mixed ANOVA. For this analysis, only the trials in mixed-task blocks were examined to investigate the use of inhibitory processes. The results of this analysis can be found in Figure 8. There was a non-significant main effect of language group, F(1, 69) = 3.32, p = .07, η_p^2 = .05. Univalent trials (M = 1822.99, SE = 37.04) were performed faster than bivalent trials (M = 2598.28, SE = 62.43), which yielded a significant main effect of valence, F(1, 69) = 373.59, p < .001, η_p^2 = .84. The interaction was not significant, F < 1.00.

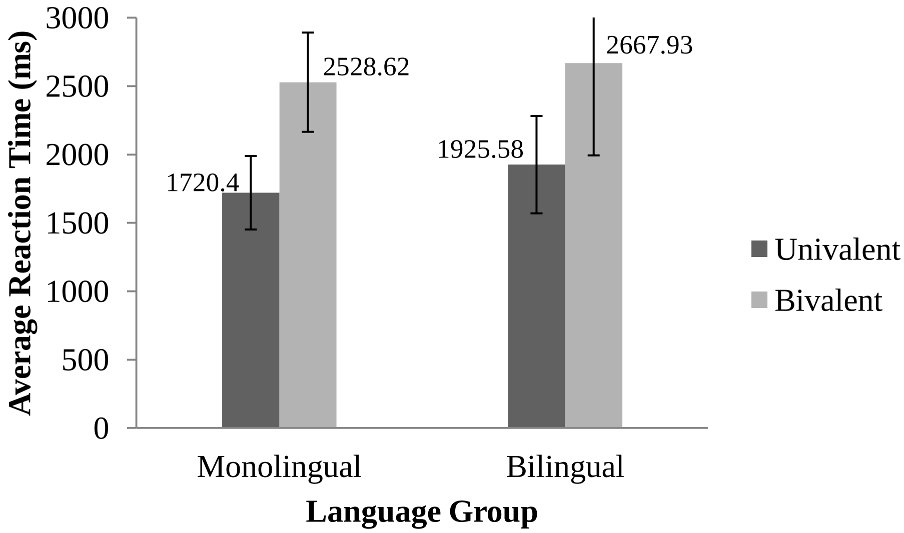

Figure 8. Results of Hypothesis Three. Effects of language group and valence on reaction times (ms), with standard error bars.

Additional Analyses

In this section, the analyses reported were not hypothesized effects. These analyses were conducted to see if they could give additional insight to the data in the sample. One set of analyses explored using initiation time (described below) as a dependent variable to retest the hypotheses. Second, stimulus type (picture vs. word) was added as a variable of interest. The researcher conducted an analysis to see if there were any language group differences for each stimulus type. Third, an error analysis was conducted to see if monolinguals and bilinguals differed in the types of errors they made. Fourth, a new grouping variable was added to the analyses. For this analysis language group was divided into three groups: monolingual, bilingual with English as a first language (EFL), and bilingual with English as a second language (ESL). Lastly, additional correlational analyses were conducted to investigate whether performance was related to age of acquisition of English.

Initiation time analyses. For this next set of analyses, the same ANOVAs that were conducted to test the hypotheses were also used; however, the dependent variable in these analyses was initiation time. Initiation time is the amount of time it took the participant to start moving the mouse after they presses the "start" button. This variable was included in the analyses because it is more conceptually similar to the initiation of a button press. Button press data was used in previous studies such as Prior and MacWhinney (2010) and Hernandez et al. (2013). None of these analyses yielded significant results (all *Fs* < 1.50).

Stimulus type analyses. Next, a language group (monolingual vs. bilingual) x stimulus type (picture vs. word) mixed ANOVA was conducted to see if there were any language group differences on performance for each stimulus type. A stimulus type analysis was conducted because performance could differ based on stimulus type. Categorizing a word and categorizing a picture could be considered different actions and require different cognitive processes, which could affect reaction times. Performance for each type of stimulus could also differ because it is confounded with categorization type. The distinction of abstract vs. concrete or human-made vs. natural was different enough that it could have affected performance.

Language group yielded a significant main effect, $F(1, 69) = 7.19$, $p = .01$, $\eta_p^2 = .09$, such that monolinguals ($M = 1838.03$, $SE = 42.07$) performed faster than bilinguals ($M = 2008.70$, $SE = 47.78$). There was no significant main effect of stimulus type ($F < 1.00$), but the interaction between language group and stimulus type was significant, $F(1, 69) = 5.27$, $p = .03$, $\eta_p^2 = .07$. These means can be seen in Figure 9. A pairwise comparison revealed that bilinguals performed slower on picture trials ($M = 2058.49$, *SE*

= 54.00) than word trials (*M* = 1958.92, *SE* = 53.33, *p* = .05); however, monolinguals did not differ between the two stimulus types, *p* = .25. The same pattern of results was found for the interaction if this analysis was conducted with initiation time as the dependent variable, $F(1, 69) = 4.08$, $p < .05$, $\eta_p^2 = .56$. Bilinguals still responded more slowly on picture trials (*M* = 466.98, *SE* = 33.44) than word trials (*M* = 423.72, *SE* = 29.24), *p* = .06. Monolingual performance did not differ between the stimulus types, *p* = .40. However, with initiation time as the dependent variable, neither main effects were significant, *Fs* < 1.60.

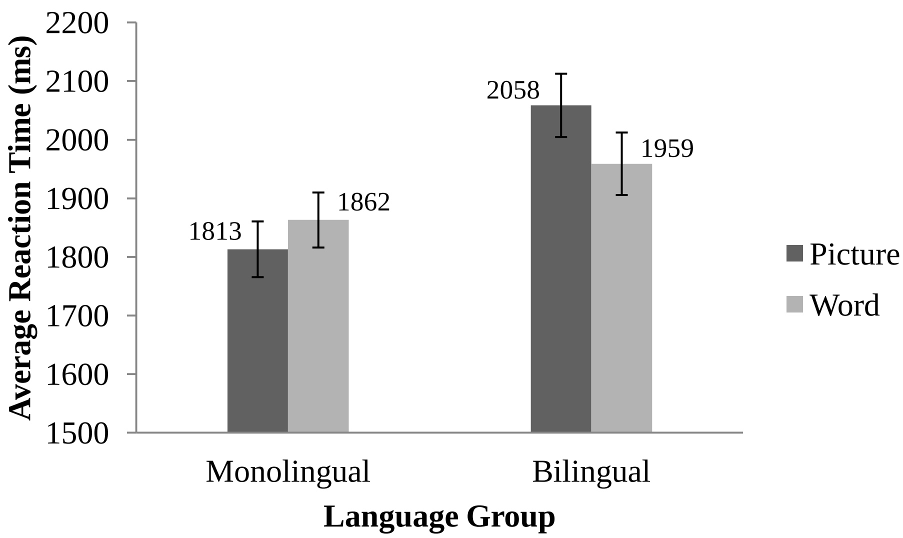

Figure 9. Stimulus Type Analysis Results. Effects of language group and stimulus type on reaction times (ms), with standard error bars.

Error analysis. Up to this point, all of the analyses have only included correct trials, but with this next analysis, only error trials were analyzed. In this study, there were two types of errors possible. The first type of error was a within-task error where the participant would miscategorize a word or an object (e.g., categorizing an abstract word as concrete). The second type of error was an outside-task error where the participant would categorize an object using a word category, or a word using an object category (e.g., categorizing an object as concrete, or a word an human-made). This analysis was conducted because it is possible that there could be between group differences in the types of errors made.

A language group (monolingual vs. bilingual) x error type (picture vs. word) mixed ANOVA was conducted to see if there were any language group differences in the types of error made with reference to stimulus type. Language group did not yield a significant main effect, $F < 1.5$. Error type did yield a significant main effect, $F(1, 69) = 119.20$, $p < .001$, $\eta_p^2 = .63$, such that more errors were made on word trials ($M = 10.65$, $SD = 4.68$) than picture trials ($M = 4.07$, $SD = 3.07$). The interaction between error type and language group was not significant, $F(1, 69) = 3.31$, $p < .07$, $\eta_p^2 = .05$. These means are presented in Figure 10.

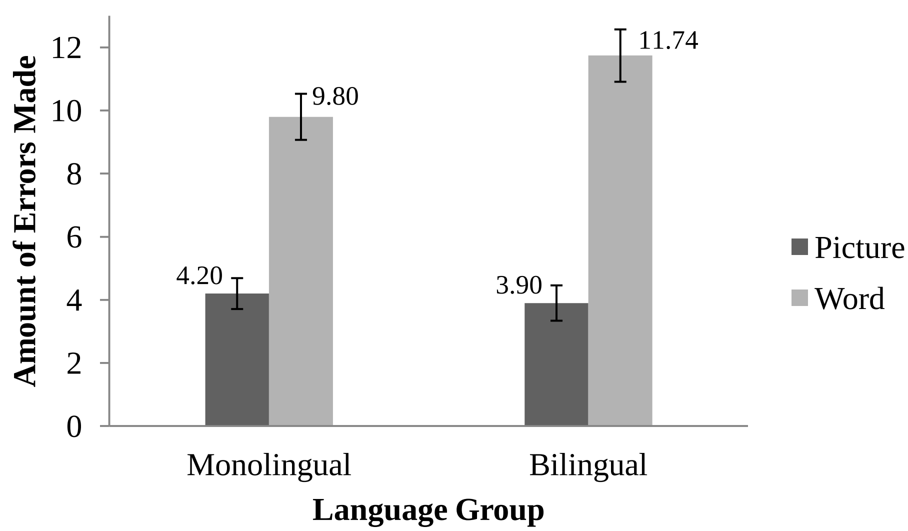

Figure 10. Error Analysis Results. Effects of language group and stimulus type on amount of errors made, with standard error bars.

Additional language group analyses. For this next set of analyses, a new grouping variable was created that split language group into three distinct categories: monolingual, bilingual with EFL, and bilingual with ESL. This variable was included to see if the differences between bilingual type would affect the results. The same analyses were conducted that were used to test the initial hypotheses. For switching costs, there was a non-significant effect of language group effect, $F(2, 67) = 2.93$, $p = .06$, $\eta_p^2 = .08$. For monitoring costs, the only novel effect was a significant effect of language group, $F(2, 67) = 4.48$, $p = .02$, $\eta_p^2 = .12$. Monolinguals ($M = 1765.47$, $SE = 48.01$) performed faster than both types of bilinguals (EFL: $M = 2059.30$, $SE = 96.02$; ESL: $M = 1921.77$, $SE = 67.90$). For inhibition costs, there was a non-significant effect of language group, $F(2, 67) = 2.77$, $p = .07$, $\eta_p^2 = .08$. None of these analyses yielded significant interactions ($F < 1$), and all of the task effects reported with the hypothesis testing were still present (i.e., non-switch trials were performed faster than switch trials, etc.).

Correlation analyses. Lastly, some of the data from the language survey were included in several correlation analyses to see whether performance was related to proficiency levels in English or age of acquisition of English. These analyses were conducted to see if they would provide additional insight to the variables in the study. A complete correlation matrix can be found in Table 1. There was not a significant relationship between age of acquisition of English and the amount of errors made ($p = .07$) or performance in mixed-task blocks ($p = .35$). Age of acquisition of English was negatively related to proficiency levels in English (speaking: $r = -.56$, $p < .001$; understanding: $r = -.42$, $p = .001$; reading: $r = -.27$, $p = .04$). These results suggested that if a person is older when they learn English, they will have lower proficiency levels.

There was also a significant negative relationship between the amount of errors made and proficiency reading, $r = -.33$, $p = .01$. This result suggested that having lower reading proficiency is associated with the amount of errors a person will make in this task.

Table 1

Correlations Between Reaction Times and Language Variables

Variable	1	2	3	4	5	6
1. Age of Acquisition of English	1.00					
2. Error Total	.23	1.00				
3. RTs for Mixed-task Blocks	.12	.05	1.00			
4. Proficiency Speaking	-.56**	-.22	-.20	1.00		
5. Proficiency Understanding	-.42**	-.18	-.22	.82**	1.00	
6. Proficiency Reading	-.27*	-.33**	-.17	.68**	.66**	1.00

Note. The Pearson correlation value is reported for each relationship. Correlations have reported significance at the .01 level (**) and at the .05 level (*). All of the proficiency levels were self-reported by each participant on their English speaking, understanding, and reading capabilities.

CHAPTER V

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

Discussion

Summary of Research Problem and Method

Several decades of research have given evidence for a Bilingual Advantage where bilinguals outperform monolinguals on tasks that utilize the same processes as lexical selection. Task-switching tasks are one of the many tasks that have shown evidence for this advantage. The main purpose of this experiment was to examine whether monolinguals and bilinguals perform differently in a task-switching task. Several aspects of the study design were manipulated to investigate the role of three specific executive functioning processes. First, reconfiguration processes were examined by comparing performance in switch and non-switch trials in mixed-task blocks. This analysis allowed insight to the cost of switching between mental sets. Second, monitoring processes were analyzed by comparing performance in single-task blocks and non-switch trials in mixed task blocks. This comparison captures the cost of how long it takes to determine if a switch in mental sets is necessary. Lastly, inhibitory processes were examined by comparing univalent and bivalent stimulus trials in mixed-task blocks. Comparing valence in this way allowed for the measurement of the time it took to inhibit a distractor stimulus.

Summary of Findings

For the first hypothesis, there was evidence for switch costs. Non-switch trials were performed faster across both language groups. This effect is important because it demonstrates the validity of the task. Switch trials require more mental resources to correctly categorize the stimulus, which takes more time, and this is reflected in the reaction time trends. However, there was no interaction between language group and trial type, suggesting that there was no evidence for the Bilingual Advantage. Bilinguals were expected to incur smaller switching costs when compared to monolinguals, which was one of the findings of Prior and MacWhinney (2010). However, Hernandez et al. (2013) did not find evidence for this interaction. The current study actually replicated the results found by Hernandez et al. (2013) with respect to switching costs. For the current study, monolingual and bilingual performance did not differ significantly regardless of trial type.

There was evidence for mixing costs, which corresponds with the second hypothesis. Trials in single-task blocks were performed faster. Single-task blocks only require one type of categorization whereas mixed-task blocks require both types. Not having to switch between mental sets shortens the amount of time it takes to complete a block of trials. There was no interaction of block type and language group, and thus there was no support for the Bilingual Advantage. It was predicted that monolinguals and bilinguals would perform equally as fast on non-switch trials regardless of block type because this effect was found by Prior and MacWhinney (2010) and Hernandez et al. (2013). The results replicated this effect because the interaction of language group and block type was not significant. Monolinguals performed faster on non-switch trials overall but not when block type was considered. This result supports the second hypothesis.

For the third hypothesis, there was evidence for inhibition costs. Performance on univalent stimulus trials was faster than bivalent stimulus trials. This effect is important to recognize because it demonstrates that the task manipulation was effective. Univalent trials do not require the use of inhibitory processes, which means that trials with this type of stimulus will take less time to categorize than trials with bivalent stimuli. This pattern of results was found by Richter and Yeung (2012), which indicated that the manipulation worked as anticipated. Because this cost did not interact with language group, there was no evidence for the Bilingual Advantage. The expected pattern of results anticipated that bilinguals would perform faster on trials with bivalent stimuli in mixed-task blocks, but the actual results showed monolinguals and bilinguals did not significantly differ in performance on these types of trials.

Overall, there was no support for the first and third hypotheses because they both predicted the presence of the Bilingual Advantage. However, the second hypothesis was supported by the data. The Bilingual Advantage was not supported with these data, but there is evidence for a monolingual speed advantage. Monolinguals performed faster than bilinguals regardless of the aspect of the task that was analyzed even though not all of these differences were significant. For instance, monolinguals performed faster on non-switch trials, in single-task blocks, and on trials with univalent stimuli. Within the task itself, the expected pattern of results was found. These are the effects relating to the task validity. This pattern of results was found in both language groups when they were examined separately but not when there was a comparison across language groups.

Comparing across language groups revealed that bilinguals are slower overall. There are a few potential explanations for these findings, and they will be discussed later in the discussion.

Connections to Previous Literature and Potential Explanations

The current study did not replicate the pattern of results of Prior and MacWhinney (2010) with respect to switching costs. Prior and MacWhinney's (2010) results suggested that bilinguals incur smaller switching costs, but Hernandez et al. (2013) suggested that there was no group differences for switching costs. The lack of switching cost interaction was found in the current study, which means that their results were replicated. The current study also replicated the interaction effect of mixing costs. Prior and MacWhinney (2010) and experiment 3 of Hernandez et al. (2013) found no differences between monolinguals and bilinguals for mixing costs. Across the three studies presented here, this task-switching task has produced different patterns of results. With the exception of the bivalent stimuli, the current task was almost identical to the task used by Prior and MacWhinney (2010) as was the task used by Hernandez et al. (2013). This task has produced a variety of results, but the results of the current study more closely resemble the pattern found by Hernandez et al. (2013). However, it still difficult to form strong conclusions about the results of the current study because the inclusion of the bivalent stimuli could have affected the pattern of results found in relation to previous studies.

In addition to previous research, the hypotheses for the current study were based on the language-nonspecific approach (Green, 1986; Meuter, & Allport, 1999). This hypothesis states that the non-target language in a given context is inhibited while the person is speaking in the target language, but both are activated. Even though no evidence for a Bilingual Advantage was found, it is possible that the language-nonspecific hypothesis is supported by the data. It is possible that the non-target language is not inhibited and that both languages are always activated. This notion would support the language non-specific hypothesis. If this were the case, it could explain why bilinguals were slower than monolinguals overall. In the task-switching task, if bilinguals were activating words in both languages in order to categorize the stimuli, it would take longer than for monolinguals because monolinguals only have words in one language to activate. For this task, monolinguals are more efficient at categorizing the stimuli because they only have one lexicon. Based on this reasoning, the language non-specific hypothesis accounts for the results of the current study better than the language-specific hypothesis.

There are other potential sources of explanation for the current results. It is possible that the processes used during lexical selection do not directly map onto the processes used in a task-switching task. In this study, the researcher was investigating specific processes such as reconfiguration, monitoring, and inhibition. For instance, reconfiguration during bilingual lexical selection involves switching between languages for word production, but in a task-switching task, reconfiguration involves the switching of sets of instructions to be used for categorization. Both of these tasks use reconfiguration, but the reconfiguration used during lexical selection and a task-switching task may not be the same process. The differences in processes could result from the nature of the task. In bilingual lexical selection, the person completing the task is producing words, but in a task-switching task, he is categorizing words that are being presented. Because he is not producing words in the task-switching task, this could be enough of a difference such that the processes don't directly map onto both tasks. If the processes used during lexical selection do not map onto the task-switching task, then bilinguals will not have an advantage over monolinguals. In the introduction, the case was made that bilinguals will be more practiced at this task because they use the same processes on a daily basis. However, the results for this study suggest that the processes are not used in the same way for bilingual lexical selection and a task-switching task. For the current study, this difference in process utilization gives a good account of the findings because the bilinguals did not outperform the monolinguals. If the task involved producing words, a different pattern of results may have been found (Gollan et al., 2005).

Another potential explanation for the results involves the sample of bilinguals used for this study. The sample of bilinguals used for this study is not completely homogenous, especially when compared to the monolingual sample. A histogram of reaction times for both samples can be found in Figure 11. The bilingual sample is very spread out in terms of reaction time performance. Bilingual reaction times span from 1500 ms to approximately 3300 ms, but monolingual reaction times only span from 1400 ms to 2600 ms. The large span of reaction times in the bilingual sample could be due to the differing types of bilinguals that were recruited. Because of the location of the university, the researcher was not able to target a single type of bilingual. The bilingual sample consists of people who are native English speakers, people who speak English as a second language, and people who learned English and their other language simultaneously. There are also early and late bilinguals in the sample. The differing types of bilinguals in the study could have led to the reaction time differences. If the researcher had been able to target a specific type of bilingual, this could have controlled for some of the variability in reaction times.

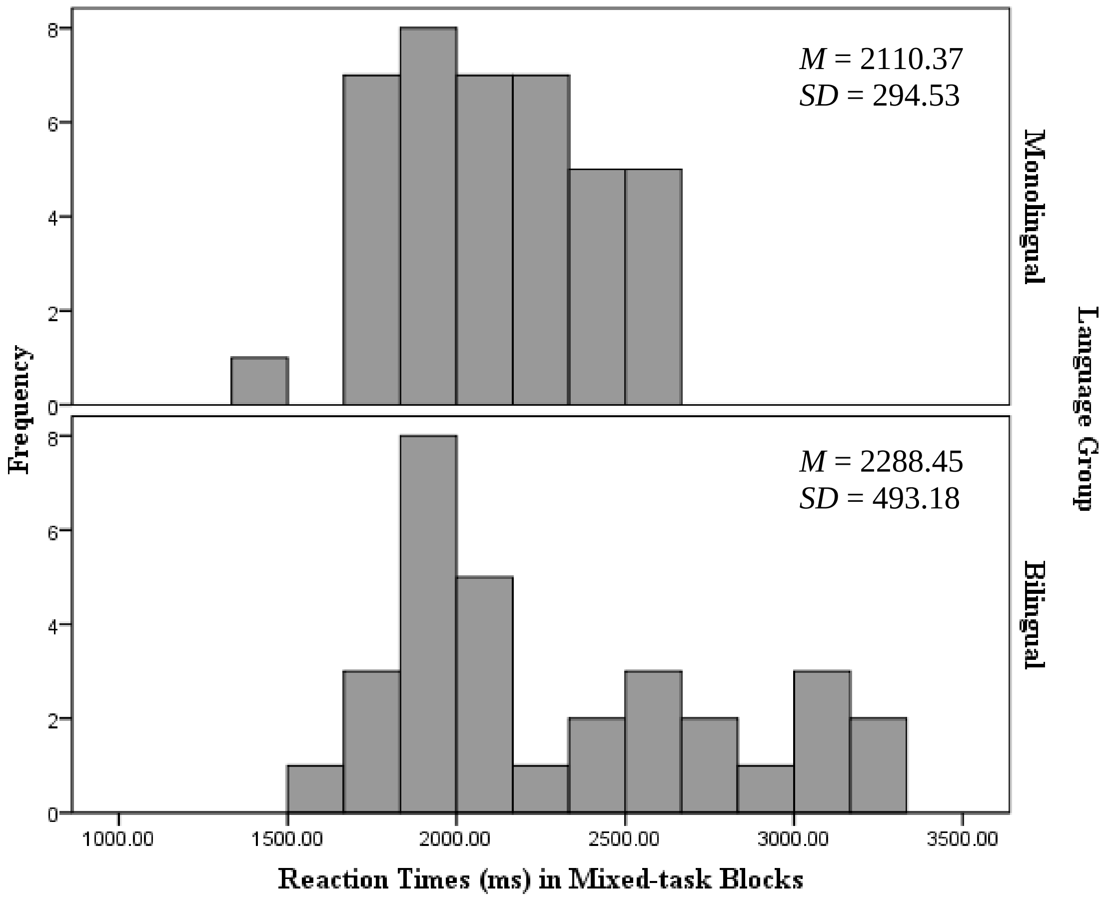

Figure 11. Histogram of Reaction Times in Mixed-task Blocks. Histogram of reaction times in mixed-task blocks for monolinguals and bilinguals.

The bilingual sample could also be an explanation as to why the replication of Prior and MacWhinney (2010) and Hernandez et al. (2013) was unsuccessful. Hernandez et al. (2013) included this as a possible reason why they did not replicate Prior and MacWhinney (2010), and the same reasoning could be applied here as well. The bilingual sample collected for the current study does not match either bilingual sample used in the previous studies. Prior and MacWhinney (2010) only studied life-long bilinguals (of varying language groups), and Hernandez et al. (2013) studied Catalan-Spanish bilinguals. It is possible that the bilingual sample plays a large role in the findings of the experiment. Thus far there are three studies using the same task with three varying patterns of results that studied three different types of bilingual samples. It does not seem unreasonable to claim that the type bilingual sample used impacted the pattern of results found for each study.

In addition to the two possible explanations already given, factors concerning the bivalent stimuli should also be considered. It is reasonable to conclude that the bivalent stimuli have a higher perceptual load than the univalent stimuli. Interpreting a bivalent stimulus required the participants to look at the colored border. Then, based on the border color, they had to inhibit one of the stimuli and categorize the other. There is more to look at and focus on in a bivalent stimulus. It is also possible that the word is harder to read because the word is on top of the object. The perceptual load alone could have made these trials more demanding for the participants. It is also possible that using the colored border as the categorization cue made these types of trials more difficult. In other tasks, a different cue was used that could have been more salient and more directly related to the categorization task. For example in Prior and MacWhinney (2010), they used a color gradient to denote color categorization and a small row of black shapes to denote shape categorization. Using a more salient categorization cue could have reduced the perceptual load for the bivalent stimuli trials and made these trials easier to complete. Perceptual load should be considered when attempting to explain the results because Hernandez et al. (2013) stated that task difficulty could affect the presence of the

Bilingual Advantage. It is possible that the perceptual load of the bivalent stimuli made the task more demanding, which obscured the Bilingual Advantage.

Related to the stimuli, the types of categorization made in this task could have affected the results of this study. The current task utilized a semantic type of categorization. The participant needed to accesses the semantic representation of each stimulus to know which category it belonged to. In the current study, words were either abstract or concrete, and objects were either human-made or natural. For instance, the participant would have to access the semantic representation of the word "dream" to know that it is abstract. Prior and MacWhinney (2010) and Hernandez et al. (2013) both used a more perceptually-based categorization system in which participants were categorizing objects by shape or color. In categorizing stimuli based on these criteria, semantics does not play a role at all. Categorization takes place at a purely perceptual level. This could be an additional reason why the results of this study did not support the Bilingual Advantage. Caramazza and Brones (1980) and Gollan et al. (2005) found that monolinguals did not differ at the semantic level, which suggests that the predicted effects should not be found in this type of task. A task that operates at the semantic level should not produce different results between language groups; however, tasks at the perceptual level could be able to capture more effectively differences between monolinguals and bilinguals.

The data from these analyses could also differ from previous studies because a different type of response was used. The current study used the program MouseTracker to collect data. This program has a default reaction time setting that records how long it takes a participant to choose the category from the time he clicks the "start" button. This was the dependent variable used in the main analyses of this study. These reaction times are much longer than previous studies because Prior and MacWhinney (2010) and Hernandez et al. (2013) used button presses as their means for data collection. The current study even attempted to account for this difference and used a second type of dependent variable: initiation time. Initiation time is the amount of time it took the participant to make their first movement with the mouse after he clicked the “start” button. This dependent variable is more similar to a button press because they both capture the initial movement made by the participant. Even with this dependent variable, the results among the three studies were still different. These differing methods of measuring response time could be an explanation for why there are differing patterns of results. Moving a mouse and pressing a button are vastly different movements, and this difference could have affected the results of the current study.

Lastly, an additional way to explain these results would be to take a whole new perspective. There is a line of research suggesting that the Bilingual Advantage is an effect that does not actually exist. De Bruin, Treccani, and Della Sala (2014) suggest that the Bilingual Advantage is a result of publication bias. De Bruin et al. (2014) analyzed conference abstracts submitted between 1999 and 2012 that were investigating bilingualism and executive control. They found that studies that showed evidence for the Bilingual Advantage were published 68% of the time, whereas studies with results not supporting the Bilingual Advantage were only published 29% of the time. A 39% difference in publication rates is definitely worthy of consideration. Another study’s results also suggested that the Bilingual Advantage is not an actual effect. Namazi and Thordardottir (2010) concluded that controlled attention is a result of enhanced working memory capacity and not a bilingual advantage. The researchers investigated visually controlled attention in bilinguals and monolingual children. They had participants complete a controlled attention task (Simon task) and examined how the two groups of children differed when working memory had been taken into account. Their results suggested that there were no differences between the monolingual and bilingual participants; however, participants with higher working memory scores were more accurate and faster when completing the Simon task. Paap, Johnson, and Sawi (2014) also concluded that bilinguals were not enhanced at tasks that involved inhibitory control, monitoring, or switching. They had participants complete 12 tasks measuring executive functioning (4 of which were nonverbal), and they found no consistent support for the Bilingual Advantage. These researchers examined the same processes as the current study, and their results are more similar than the studies that support the Bilingual Advantage. All of these studies give evidence to suggest that the Bilingual Advantage is not an actual effect. Obviously three studies do not discount an entire body of literature, but they suggest that something else could be at play here. The results of the current study could be in support of this research because the Bilingual Advantage was not evident.

Limitations

As discussed in the previous section, the results of this study did not support the predictions, and there are a several possible explanations for why the findings turned out as they did. However, the current study did have a few limitations as well that could have affected the results. First, there are limitations with the bilingual sample. The researcher recruited graduate and undergraduate participants. Within the time frame of data collection, I would not have been able to reach my sample size goal if I had only recruited undergraduate participants. This is a potential limitation of the study because intelligence could be a potential covariate. It is reasonable to assume that graduate students are more intelligent than undergraduate students. Including graduate students in the bilingual sample but not in the monolingual sample could have affected the results because the graduate students would be more effective at completing the task. Another limitation with the bilingual sample was the quality of bilingual data collected. Because the researcher did not have a large pool of bilinguals to draw from, almost anyone was accepted who identified as a bilingual. This led to varying types of bilinguals being included in the study. This was a limitation because some participants did not speak their second language very frequently, which could have impacted the results of the study because they may not be very proficient in their second language. If all bilinguals spoke both languages with equal frequency, it would improve the quality of the sample. Along these same lines, an additional limitation within the bilingual sample was that the sample was non-homogenous. The bilinguals in the sample were of differing proficiency levels; they were not from the same bilingual language group, and some of them spoke English as a second language. The quality of the sample would be improved if the researcher would have been able to target a specific bilingual language group (e.g., English-Spanish bilinguals) and control for second language proficiency. Having a homogenous sample of bilinguals would have minimized the range of reaction times that the bilinguals produced and could have improved the likelihood of finding evidence for the Bilingual Advantage.

Another limitation of the study was that it was difficult to find participants who were absolutely monolingual. Most of the monolingual participants had had some exposure to a second language either in high school or college, but they are not able to speak it. It was also the case that some participants knew words in a few different languages, but not to the point where they could form sentences. Or they knew enough to form a few sentences, but they did not speak it regularly nor could they read it. According to the survey (LEAP-Q) that the participants filled out at the beginning of the study, all of the different types of participant described would still be monolingual because they speak English 100% of their daily lives; however, are these participants truly monolingual? There is a possibility that these participants could have made the monolingual sample appear more like a bilingual sample because they had faster performance across all trial and block types when it was anticipated that bilinguals would have faster performance.

In addition to issues with the participant samples, there were also two limitations with word categorization in the study. First, not all of the words used in this study were of high frequency. Because of this, not all of the participants were familiar with all of the words used in this study. This could have affected the results of the study because on the trials with less familiar words the participants would have taken longer to categorize them or they could have been categorized incorrectly, which would have skewed the reaction times for those types of trials or caused trials to be thrown out. Using only high frequency words could have improved word categorization speed and accuracy. The second issue with words categorization is that not all of the participants were familiar with the categories being used for the words: abstract and concrete. It seemed like some participants never fully understood this distinction even after the researcher explained it to them because they would categorize words incorrectly in the task. Not being familiar with this distinction before the task could have biased accuracy for word trials to appear lower than it should have been. Using more familiar categories for words to be categorized into would improve accuracy for word trials in the task.

A general limitation of the current study is that the task is not generalizable to everyday life. Bilinguals are not switching between languages for every word they utter. A code-switch does happen from time to time, but for the most part, bilinguals only switch languages when they are switching contexts or situations. For example, a person might speak Spanish with their family at home but speak English when they go to school. There are always exceptions, but bilinguals generally do not rapidly switch languages in the same way that they switched between instructions in the task. Along these same lines, the bivalent stimuli used in the task are not similar to a language switching context. When producing speech, bilinguals should only have to inhibit their non-target language, which is unlike the bivalent stimuli, where two things have to be inhibited. Overall, the task-switching environment is not similar to language switching contexts that bilinguals would encounter on a day-to-day basis, which limits the generalizability of the results.

Future Directions and Conclusions

In light of these results and limitations for the current study, there are a few suggestions that could be made for future research studies on this topic. If this task were to be used again, there are a few changes that could be made. As discussed previously, it would be beneficial to change the categorization cue to something more salient to decrease the perceptual load of the task. Also, using only high frequency words would improve task accuracy. Follow-up studies using this task may benefit by making those changes. In general, follow-up studies in this research area should try to collect a larger sample than was investigated in the current study and try to target a specific bilingual language group, controlling for proficiency. These suggestions would increase the quality of results found with this type of task and could lead to better generalizability.

In conclusion, the current study set out to investigate how monolinguals and bilinguals perform differently in a task-switching task. This investigation was motivated by three key processes used during a task-switching task: reconfiguration, monitoring, and inhibition. Hypotheses concerning these processes were made in terms of the presence or absence of the Bilingual Advantage, and there was no support for any of them. In sum, the Bilingual Advantage was not supported by this data. There were several potential reasons as to why the findings turned out as they did; however, it is difficult to pinpoint an exact cause. This is the third different pattern of results found using this task, and there is a separate line of research stating that the Bilingual Advantage does not exist. Taking all of this into account, it is unclear how monolinguals and bilinguals differ in terms of cognitive functioning. More research needs to be conducted before hard conclusions can be drawn concerning the differences between monolinguals and bilinguals.

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APPENDIX A

LANGUAGE EXPERIENCE AND PROFICIENCY

QUESTIONNAIRE

Last Name		First name:		Date:	
Age:		Date of birth:		Gender (circle one):	M / F

1. Please list all of the languages you know in order of dominance:

1.	2.	3.	4.	5.

2. Please list all of the languages you know in order of acquisition (your native language first):

1.	2.	3.	4.	5.

3. Please list what percentage of the time you are *currently* and *on average* exposed to each language. (*Your percentages should add up to 100%*):

List language here:					
List percentage here:					

4. When choosing to read a text in all your languages, in what percentage of the cases would you choose to read it in each of your languages? Assume that the original was

written in another language, which is unknown to you. (*Your percentages should add up to 100%*):

List language here:					
List percentage here:					

5. When choosing a language to speak with a person who is equally fluent in all your languages, what percentage of the time would you choose to speak each language? Please report percent of total time. (*Your percentages should add up to 100%*):

List language here:					
List percentage here:					

6. Please name the cultures with which you identify. On a scale from zero to ten, please rate the extent to which you identify with each culture. (Examples of possible cultures include US-American, Chinese, Jewish-Orthodox, etc.):

List cultures here:					
Rating:					

(Scale: 0 = no identification, 1 = low identification, 5 = moderate identification, 10 = complete identification)

7. How many years of formal education do you have? _________

Please check your highest education level (or the approximate US equivalent to a degree obtained in another country):

_____ Less than high school   _____Some college   _____Masters

_____ High school   _____ College   _____ Ph.D./M.D./J.D.

____ Professional training   ____ Some graduate school   ____ Other (please specify): ________________

8. Date of immigration to the U.S., if applicable ____________________

If you have ever immigrated to another country, please provide name of country and date of immigration here.

____

9. Have you ever had a vision problem ____, language disability ____, or learning disability ____? (Check all applicable). If yes, please explain (including any corrections):

____

Language: ____________

This is my (native/second/third/fourth/fifth) language. (Circle one)

All questions below refer to knowledge of this particular language.

1. Age when you…:

Began acquiring:	Became fluent in:	Began reading in:	Became fluent reading in:

2. Please list the number of years and months you spent in each language environment:

	Years	Months
A country where this language is spoken		
A family where this language is spoken		
A school and/or working environment where this		

language is spoken		

3. On a scale from zero to ten, please select your level of proficiency in speaking, understanding, and reading this language:

Speaking		Understanding spoken language		Reading	

(Scale: 0 = none, 1 = very low, 2 = low, 3 = fair, 4 = slightly less than adequate, 5 = adequate, 6 = slightly more than adequate, 7 = good, 8 = very good, 9 = excellent, 10 = perfect)

4. On a scale from zero to ten, please select how much the following factors contributed to you learning:

Interacting with friends		Language tapes/self instruction	
Interacting with family		Watching TV	
Reading		Listening to the radio	

(Scale: 0 = not a contributor, 1 = minimal contributor, 5 = moderate contributor, 10 = most important contributor)

5. Please rate to what extent you are currently exposed to this language in the following contexts:

Interacting with friends		Listening to radio/music	
Interacting with family		Reading	
Watching TV		Language-lab/self instruction	

(Scale: 0 = never, 1 = almost never, 5 = half of the time, 10 = always)

6. In your perception, how much of a foreign language accent do you have in this language? ______

(Scale: 0 = none, 1 = almost none, 2 = very light, 3 = light, 4 = some, 5 = moderate, 6 = considerable, 7 = heavy, 8 = very heavy, 9 = extremely heavy, 10 = pervasive_

7. Please rate how frequently others identify you as a non-native speaker base on your accent in this language: _____

(Scale: 0 = never, 1 = almost never, 5 = half of the time, 10 = always)

Language: ___________

This is my (native/second/third/fourth/fifth) language. (Circle one)

All questions below refer to knowledge of this particular language.

1. Age when you…:

Began acquiring:	Became fluent in:	Began reading in:	Became fluent reading in:

2. Please list the number of years and months you spent in each language environment:

	Years	Months
A country where this language is spoken		
A family where this language is spoken		
A school and/or working environment where this language is spoken		

3. On a scale from zero to ten, please select your level of proficiency in speaking, understanding, and reading this language:

Speaking		Understanding spoken language		Reading	

(Scale: 0 = none, 1 = very low, 2 = low, 3 = fair, 4 = slightly less than adequate, 5 = adequate, 6 = slightly more than adequate, 7 = good, 8 = very good, 9 = excellent, 10 = perfect)

4. On a scale from zero to ten, please select how much the following factors contributed to you learning:

Interacting with friends		Language tapes/self instruction	
Interacting with family		Watching TV	
Reading		Listening to the radio	

(Scale: 0 = not a contributor, 1 = minimal contributor, 5 = moderate contributor, 10 = most important contributor)

5. Please rate to what extent you are currently exposed to this language in the following contexts:

Interacting with friends		Listening to radio/music	
Interacting with family		Reading	
Watching TV		Language-lab/self instruction	

(Scale: 0 = never, 1 = almost never, 5 = half of the time, 10 = always)

6. In your perception, how much of a foreign language accent do you have in this language? _____

(Scale: 0 = none, 1 = almost none, 2 = very light, 3 = light, 4 = some, 5 = moderate, 6 = considerable, 7 = heavy, 8 = very heavy, 9 = extremely heavy, 10 = pervasive_

7. Please rate how frequently others identify you as a non-native speaker base on your accent in this language: _____

(Scale: 0 = never, 1 = almost never, 5 = half of the time, 10 = always