THE ROLE OF CONFLICT IN EXECUTIVE CONTROL IN BILINGUAL YOUNG ADULTS

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This study examined differences in executive control between monolingual and bilingual speakers in one verbal and one nonverbal behavioral task. Each task had two versions examining different components of executive function: one version that required active inhibition and one version that also required conflict monitoring and resolution. Members of the bilingual group also completed a self-reported survey about their language proficiency and use, the Language Experience and Proficiency Questionnaire (Marian, Blumenfeld, & Kaushanskaya, 2007). Responses on this survey were analyzed in order to determine the relationship between proficiency in a second language and performance on the tasks. Results indicated that bilingual speakers may have an advantage in active inhibition on the nonverbal task. However, bilinguals were outperformed by monolinguals in the verbal task. Furthermore, the bilingual advantage in the nonverbal task was predicted most robustly by speaking proficiency in the second language, but the bilingual disadvantage in the verbal task had no correlation to second language proficiency.

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1.0 INTRODUCTION

Do people who speak more than one language have any cognitive differences from their monolingual peers? If so, what is the source of these differences? Much controversy exists regarding the idea of a bilingual "advantage" in cognition, specifically in certain executive control functions, which manage planning, short-term memory, reasoning, and problem solving. Earlier studies suggest that bilinguals may have many cognitive advantages over their monolingual peers in terms of nonverbal executive function (Abutalebi et al., 2012; Bialystok & Barac, 2012; Bialystok & Viswanathan, 2009; Blumenfeld & Adams, 2014; Colzato et al., 2008; Costa, Hernández, & Sebastián-Galles, 2010; Kavé, Eyal, Shorek, & Cohen-Mansfield, 2008; Teubner-Rhodes et al., 2016). Nonverbal executive controls manage tasks that do not involve language, such as problem solving with pictures or other visual stimuli. For example, indicating the direction of one specific arrow that is surrounded by other arrows would require executive control: remembering the task, focusing on the correct target arrow while ignoring the irrelevant arrows, and responding in the appropriate way are steps that necessitate executive functions that do not involve language. There is significant evidence that bilingual speakers have advantages over their monolingual peers in such tasks (Abutalebi et al., 2012; Costa et al., 2008).

Some evidence suggests that bilinguals have advantages in linguistic tasks requiring executive function, as well (Galambos & Goldin-Meadow, 1990; Moreno, Bialystok, Wodniecka, & Alain, 2010). An example of a linguistic task requiring executive control would be judging whether a sentence's grammar was correct while ignoring its meaning (i.e., whether or not the situation that the sentence was describing made sense). This task taps metalinguistic awareness, which is knowledge about the language itself. It also requires executive control in order to focus on the relevant aspect of the sentence (in this case, its grammar) while inhibiting the conflicting aspect (its meaning). Prior studies have found that bilinguals have an advantage over monolinguals in this type of task (Galambos & Goldin-Meadow, 1990; Moreno et al., 2010). The finding that bilingual speakers show both nonverbal and verbal advantages suggest that bilingualism could have broader, domain-general consequences, rather than being relegated specifically to the language domain.

The source of the bilingual advantage is still a matter of controversy. Some studies suggest that a bilingual advantage appears only in situations involving some type of conflict (Bialystok & Viswanathan, 2009; Blumenfeld & Adams, 2014; Galambos & Goldin-Meadow, 1990; Moreno, Chabal, Bartolotti, Bradley, & Hernandez, 2014). Other studies suggest that a higher alertness could be triggered by the presence of conflict, but then generalize to an advantage for tasks both with and without conflict (Abutalebi et al., 2012; Bialystok, Craik, Klein, & Viswanathan, 2004; Costa et al., 2008; Teubner-Rhodes et al., 2016). Bilingualism's relationship with conflict could be due to bilingual speakers' constant use of inhibition: whenever they use one language, they are inhibiting intrusion from the other language, which could strengthen their abilities to inhibit conflicting information (Abutalebi et al., 2012).

However, not all studies provide evidence for any type of bilingual advantage. Some research has indicated that bilinguals actually have no difference from monolinguals in executive function. In 2014, the results of a study using four different tasks involving executive function indicated that bilinguals had no advantage—and might even have some disadvantages—

compared to monolinguals (Paap & Sawi, 2014). Additionally, a 2015 literature review by Paap, Johnson, and Sawi stated that the majority of tests for bilingual advantages in recent years have found no significant differences between monolinguals and bilinguals. Furthermore, one possibility for any significant differences in performance between monolinguals and bilinguals could be that they are due to task-specific mechanisms, not because of improved executive function in bilinguals (Paap, Johnson, & Sawi, 2015). Clearly, whether or not bilinguals have any type of advantage over monolinguals is a matter of controversy and more research must be done in this area.

Furthermore, the effect of time spent speaking a second language or level of proficiency in a second language is still unclear. Prior research has suggested that if bilinguals are constantly inhibiting one language while speaking another, then bilingualism could strengthen domain-general active inhibition abilities (Abutalebi & Green, 2008; Green, 1998). However, the question of how "much" bilingualism—either time speaking or proficiency in a second language—is necessary to enhance executive function is still a point of controversy. Some studies suggest that bilinguals with a higher level of second language proficiency have greater advantages on nonverbal tasks (Bialystok & Barac, 2012; Vega-Mendoza, West, Sorace, & Bak, 2015). Other studies suggest that differing levels of second language proficiency do not influence performance among bilingual speakers on verbal tasks (Hakuta, 1987) or that only the level of proficiency in the testing language itself is influential (Bialystok & Barac, 2012). More research must be done to determine the relationship of "level" of bilingualism and performance on verbal and nonverbal tasks.

Importantly, the constant mental inhibition of one language while another is in use could actually strengthen certain areas of the brain for bilingual speakers, who activate different regions than monolinguals during certain tasks (Abutalebi et al., 2012; Garbin et al., 2010; Marian, Chabal, Bartolotti, Bradley, & Hernandez, 2014; Moreno et al., 2010). This different use of cortical areas may strengthen the cognitive reserve of older adults and thus fend off neurodegenerative diseases, such as dementia (Kavé et al., 2008). Learning more about differences between bilinguals and monolinguals could ultimately advance evaluation and treatment practices for both groups through different ages. This study will attempt to advance knowledge about bilingualism's effect on executive function and determine under what conditions a bilingual advantage may appear: in verbal or nonverbal tasks, and in situations with or without conflict. This study will also attempt to determine if differing levels of proficiency in or experience with a second language may create differences in executive control among bilingual speakers.

1.1 EXECUTIVE FUNCTION

Executive functions can be broadly defined as cognitive processes that allow for goal-directed behavior, such as planning, problem solving, or switching between different tasks (Diamond, 2012). These processes are organized within the prefrontal cortex (Diamond, 2012). Controversy exists over whether or not executive function is one unitary construct or several independent mechanisms (Barkley, Edwards, Laneri, Fletcher, & Metevia, 2001; Best & Miller, 2010; Miyake et al., 2000). However, a broadly accepted theory proposed by Miyake et al. (2000) proposes that executive functions are a set of related yet distinct functions. Miyake and colleagues tested a large group of young adults on a variety of different executive-function tasks, and examined which tasks patterned together in these young adults' performance. The results of the study indicated that that mental set shifting, information updating and monitoring, and inhibition of prepotent responses—while moderately correlated—are separable components of executive function in young adults.

This study does not attempt to advance knowledge regarding the discreteness of the subcomponents of executive function. This topic is a large and controversial one that is beyond the scope of this study. Instead, the current study will operate under the assumption that executive function does, in fact, consist of separate components (Miyake et al., 2010) and will attempt to determine which of these components, if any, differ between monolingual and bilingual speakers. Specifically, the present study will attempt to assess differences in inhibition of prepotent responses and mental set shifting. Miyake et al. (2010) defined inhibition as the "ability to deliberately inhibit dominant, automatic, or prepotent responses when necessary." Several previous studies have found that bilinguals are more adept than monolinguals at actively inhibiting conflicting stimuli (Bialystok & Viswanathan, 2009; Blumenfeld & Adams, 2014; Garbin et al., 2010; Galambos & Goldin-Meadow, 1990; Moreno et al., 2010). From this point forward, we will refer to this component of executive function as "active inhibition." The second component of executive function examined by the present study, mental set shifting, was defined by Miyake et al. (2010) as "shifting back and forth between multiple tasks, operations, or mental sets"; this component has also been named "attention switching" or "task switching." Some studies have found that bilinguals are more adept than monolinguals at this type of shifting or switching (Abutalebi et al., 2012; Costa et al., 2008; Teubner-Rhodes et al., 2016). Teubner-Rhodes et al. (2016) described this ability as *conflict monitoring and resolution*. Specifically, conflict monitoring and resolution was described as better conflict detection and more flexible adjustments between conflict and non-conflict trials (Teubner-Rhodes et al., 2016). Because conflict monitoring and resolution involves shifting between conflict and non-conflict trials, we posit that it is a type of mental set shifting, as defined by Miyake et al. (2000). From this point forward, we will refer to this component of executive function as "conflict monitoring and resolution."

1.2 POTENTIAL MECHANISMS OF BILINGUAL AND MONOLINGUAL DIFFERENCES

1.2.1 Active inhibition

Many studies suggest that in both nonverbal executive control and metalinguistic tasks, a bilingual advantage exists only in situations that contain some sort of cognitive conflict. One cognitive function that bilinguals were found to have an advantage in was *active inhibition*, or a greater ability to ignore irrelevant or conflicting details (Bialystok & Viswanathan, 2009; Blumenfeld & Adams, 2014; Galambos & Goldin-Meadow, 1990). This type of advantage is only seen in situations requiring the suppression of conflicting stimuli. An example in which bilinguals were found to have better active inhibition than monolinguals during linguistic tasks was during a 2010 study conducted by Moreno, et al. Participants were asked to judge the grammar, or syntax, of a sentence separately from its meaning, or semantics. Because participants had to ignore the sentence's content and focus only on its grammar, active inhibition was required. If active inhibition is enhanced in bilinguals, they should be able to perform more quickly or accurately on such a task, as was found by Moreno, et al. (2010).

1.2.1.1 Active inhibition in nonverbal tasks

Several findings support the claim of enhanced active inhibition, or ability to ignore irrelevant information, among bilingual speakers when completing nonverbal tasks. Bialystok and Viswanathan (2009) found evidence consistent with this type of advantage among bilingual children. Following Miyake et al. (2000), the researchers assumed that different components of executive function could be assessed separately; they tested *response suppression*, *inhibitory control*, and *switching*. Response suppression was defined as the ability to refrain from carrying out an automatic response; inhibitory control, as the ability to selectively attend to one stimulus while ignoring another; and switching, as the cognitive flexibility necessary to switch between tasks. Switching in this study would be part of the conflict monitoring abilities described above. To test these functions, a face appeared on the screen flanked by two boxes. The face's eyes would flash either red or green, followed by an asterisk flashing in one of the boxes. The children in the study had to press the response key on the same side of the asterisk if the eyes had been green and the opposite side if they had been red. The difference between the two eye color trials assessed response suppression, as children had to suppress the automatic response to press the response key on the same side of the asterisk. Furthermore, the eyes could be looking straight ahead or gazing to one side. Gazing to the side was facilitative if they gazed at the target response and interfering if they gazed in the opposite direction; this manipulation required active inhibition. The trial could also be presented in a single color block or in a mixed red and green block, to assess switching abilities. The control condition was straight green eyes, which involved no demands for executive control.

Bilinguals were found to be faster than monolingual children in conditions that required inhibitory control. They had an advantage for gaze-shift versus gaze-straight trials, in which they had to inhibit the desire to select the box that was being looked at. In other words, in this task, bilinguals only had an advantage for trials with some type of conflict, in which they had to focus on the demands of the task rather than paying attention to the irrelevant stimuli. However, there was no difference between the groups in terms of response suppression. To reiterate, children had to press the response key on the same side of the asterisk for green eyes and the key on the opposite side for red eyes. The difference between these two types of trials assessed response suppression, as children had to suppress the automatic response to press the response key on the same side of the asterisk. Monolingual and bilingual children performed almost equivalently in terms of both accuracy and response times for both green and red eyes when presented in blocks.

Interestingly, however, the results of the study demonstrated that bilinguals also had an advantage in task switching, or switching between blocked and mixed presentations. Switching can be understood to be part of the same component of executive function as conflict monitoring and resolution. These results will be further discussed below in section 1.2.2.1 on conflict monitoring and resolution.

Nonverbal executive advantages have also been found in tasks involving audition. A 2014 study by Blumenfeld and Adams used a non-linguistic task testing working memory. Participants were trained on 12 tone-to-symbol combinations. Tones varied in timbre, pitch, and duration and were presented along with a screen containing four symbols; participants had to identify the symbol that matched the tone. Some trials contained competition, in which two symbols matched the tone in timbre and pitch, but only one matched the tone on all three qualities. After each tone trial, one asterisk appeared in each quadrant where the symbols had been. Three were black and one was grey; participants had to indicate the position of the grey asterisk. If the grey asterisk appeared in a quadrant that had been occupied by a competitor symbol (that had matched the target in two of the three components), it would index residual inhibition. Interestingly, there was no significant difference between monolinguals and bilinguals in either learning the task or during the tone-symbol trials. However, bilinguals did show stronger residual inhibition of the competitors for a longer period of time after each trial had concluded. The fact that this inhibition occurred in a non-linguistic task may suggest that bilingual active inhibition may relate to domain-general cognitive advantages that arise in situations involving conflict or competition.

Existing evidence also supports a neural basis for a bilingual advantage in active inhibition. Garbin et al. (2010) used a non-linguistic task to examine the difference between monolinguals and bilinguals when inhibiting different dimensions of stimuli they had to respond to. Participants were shown a shape on a screen and were told to press one button if the figure was blue or a square and another if it was red or a circle. They were also given a written cue that told them whether to classify by shape or color. Thus, regardless of which property of the stimuli they had to respond to—shape or color—participants had to ignore the other property. Participants were also given an equal number of non-switch trials, in which the target category remained the same between trials (shape-shape or color-color), and switch trials, in which the target category changed (shape-color or color-shape).

The results showed that monolinguals had a higher reaction time for switch trials than they did for non-switch, while bilinguals had no such cost and had almost equal reaction times for switch and non-switch trials. In this case, although participants were required to switch their focus, this task can be understood as assessing active inhibition and not conflict monitoring because each trial, regardless of whether it was switch or non-switch, involved conflict between the competing stimuli: color and shape. The researchers in this study used fMRI to monitor brain activation while participants completed the task. Bilinguals were found to activate areas contributing to inhibition and also to language production, whereas monolinguals did not have activation in areas contributing to language production. According to Garbin et al., these findings supported the hypothesis that because bilinguals switch back and forth between languages, they learn to activate regions of the brain that are involved in verbal control even when they are completing nonverbal tasks. Furthermore, these findings support the theory of a domain-general advantage in bilinguals that is not specific to verbal tasks.

1.2.1.2 Active inhibition in verbal tasks

Bilinguals, especially children, may show enhanced active inhibition during certain linguistic tasks in addition to nonverbal tasks. A 1990 study by Galambos and Goldin-Meadow contributed to the idea that bilinguals are better able than monolinguals to separate semantic content from grammar. Monolingual and bilingual children in pre-school, kindergarten, and first grade were given sentences with varying types of grammatical errors and asked if there was an error, told to correct the error, and told to explain why the original sentence was said incorrectly. The researchers found that bilinguals had an advantage over monolinguals in noting and correcting grammatical errors, but less of an advantage for explaining the errors. Specifically, bilingual children detected more grammatical errors than monolinguals within the same age group. The pre-school bilinguals produced more grammar-oriented—instead of content-oriented—corrections than did pre-school monolinguals; this type of correction was more typically found only in the older monolinguals. For example, the participants were presented with the sentence "Boy plays with dolls." When asked to correct the sentence, the grammar-oriented answer would be to add the missing article: "*The* boy plays with dolls." Many pre-school monolinguals were unable to separate the grammar of the sentence from its meaning and gave a content-oriented response—“*The girl* plays with dolls.” However, the pre-school bilinguals tended to give grammar-oriented responses, demonstrating that they could be more adept at inhibiting the anomalous semantics of the sentence and able to focus solely on the grammar before most monolingual children were able to. This advantage could be due to the conflict between the correct semantics and incorrect syntax. The ability of the bilingual children to more accurately identify and correct errors in syntax, while ignoring the meaning of the sentence, could indicate an enhanced executive control in the presence of conflict. This suppression of irrelevant aspects of the stimuli—in this case, the sentence’s meaning—points to active inhibition as the cognitive ability that is being tapped by bilinguals in this task.

According to Galambos and Goldin-Meadow (1990), because bilingual children have differentiated their two languages by the time they reach pre-school, they “have developed automatized procedures for attending to the forms of their language” (p. 49), which could account for their heightened attention to the grammar of the sentences (as opposed to the content) during the study. However, because bilingual children did not have an advantage in grammar-oriented *explanations*—only in detecting and correcting—Galambos and Goldin-Meadow stated that the bilinguals are not actually better able to understand and articulate the construction of the language. One possible explanation for the differences is that bilinguals are able to inhibit the irrelevant content of the sentences.

Another study that examined bilingual and monolingual differences during language tasks was conducted by Moreno et al. (2010). This study used two different tasks that assessed different components of verbal abilities. In one task, the acceptability task, participants indicated whether the sentence contained an error in either grammar or meaning. In the other task, the grammaticality task, participants indicated only whether the sentence contained an error in grammar. Some of the sentences in the grammaticality task also contained anomalous meanings, but participants had to focus only on whether the grammar was correct, regardless of whether or not the meaning made sense. Their event-related potentials (ERPs), which measure the brain's electrical response to stimuli, were recorded during both tasks.

In the acceptability task, bilinguals were actually less accurate than monolinguals. However, this difference may have been due to a lower degree of familiarity of the bilinguals with the language of testing, English. All monolingual participants were raised in English-speaking countries, whereas bilingual participants were from a variety of countries, including Canada, Russia, Romania, and Israel. Due to the diversity of their backgrounds, some bilinguals may have been unfamiliar with certain English structures, making the acceptability task more difficult for them. In terms of the ERP findings for the acceptability task, the N400 peak—which is emitted in response to words that do not fit into their semantic context—was equivalent for both groups.

In the grammaticality task, the bilingual and monolingual groups performed about equally in terms of accuracy. However, bilinguals generated smaller P600 amplitudes, which are found in the presence of syntactic violations. Bilinguals also generated a more bilateral distribution of activation than monolinguals in this task. According to Moreno et al., the grammaticality task required more executive control than the acceptability task because participants had to confine their decision to syntax while ignoring meaning, which is an unusual requirement. These results showed that bilinguals had enhanced executive control for linguistic processing, but only during trials involving conflict during the grammaticality task and not during simpler conditions. Furthermore, the bilateral distribution of their response may again indicate a domain-general advantage, as activation was more wide-spread and did not occur solely in areas that contribute to language processing. These results support the idea that bilinguals actively suppress irrelevant information more effectively than monolinguals—in other words, they have enhanced active inhibition when irrelevant or conflicting information is present.

Another study used fMRI to examine the neurological differences between bilinguals and monolinguals during a linguistic task (Marian et al., 2014). In the linguistic task, bilinguals and monolingual young adults were shown four pictures and presented aurally with a word; they were asked to choose the picture that matched the cue word. In some trials, there was a phonological competitor in addition to the target. For example, when presented with the word "candy," the screen showed a picture of a candle, as well as the target candy and two unrelated images. The results of the study indicated that both groups were slower on the trials containing competitor words, and bilinguals were not significantly faster than monolinguals for those competition trials. However, this lack of difference may have been due to the behavioral measurement; according to the researchers, it was possible that response time was not a sensitive enough measure to demonstrate differences between the two groups.

Despite similar behavioral results, cortical differences were found between the two groups in the neuroimaging results. These differences included the cortical resources that were recruited in the trials with phonological competition. The members of the bilingual group used fewer areas of the brain when there was competition compared to when there was no competition, which could suggest that they manage competition efficiently by reducing activation of areas that are not relevant. Monolinguals, on the other hand, used a much larger network of areas involved in executive function. These findings suggest that monolinguals use must use more resources compared to bilinguals when they are resolving linguistic or phonological competition. Furthermore, these neurological findings suggest that bilinguals may have an advantage in active inhibition: although no behavioral advantage was seen, bilinguals recruited fewer cortical resources than monolinguals did—but only in trials that contained competition, not in trials without competition. For that reason, these findings support the claim of enhanced active inhibition in bilinguals.

1.2.2 Conflict monitoring and resolution

Another cognitive function identified in some studies in which bilinguals may have an advantage is *conflict monitoring and resolution* (Costa et al., 2008; Teubner-Rhodes et al., 2016). According to Teubner-Rhodes et al. (2016), conflict monitoring and resolution is the ability to switch between trials with and without conflict. Unlike active inhibition, conflict monitoring and resolution is necessary for both types of trials, not only those containing conflict. As discussed previously, because conflict monitoring and resolution is tapped when switching between types of trials, this ability can be understood to be a type of mental set shifting, as defined by Miyake et al. (2000). In other words, when a person completes a series of tasks—some containing conflict, some not—he or she is primed to suppress irrelevant information and will be able to react more quickly, even on tasks that do not require inhibition. This type of cognitive capacity is also sometimes referred to as cognitive flexibility (Bialystok & Viswanathan, 2009). One kind of task that would elicit conflict monitoring and resolution would be the Flanker task, in which a participant must indicate the direction of a central, target arrow that is surrounded by distractor arrows. If the distractor arrows point in the same direction as the target arrows, no conflict occurs: the information is the same from both. However, if the distractor arrows point in the opposite direction of the target, they present conflicting information, and the participant must inhibit the irrelevant stimuli in order to select the correct direction. If bilingual speakers are faster in responding only in trials that contained conflicting information, they have an advantage in active inhibition. However, if conflict and no-conflict trials are presented in a randomized mix, and the bilingual speakers are faster in both types of trials, then they have an advantage in conflict monitoring in resolution because they are primed to react faster in both types of trials (Costa et al., 2008).

1.2.2.1 Conflict monitoring and resolution in nonverbal tasks

Conflict monitoring and resolution has been found to be enhanced in bilinguals in several studies using nonverbal tasks. One study that supports a bilingual advantage in conflict monitoring and resolution with neurological findings was by Abutalebi et al. in 2012. The results of this study indicated that bilingualism tunes the anterior cingulate cortex (ACC) for conflict monitoring. The ACC is a neural structure that aids in mediating cognitive control and monitoring conflicting information. In this study, young adult bilinguals' and monolinguals' brain responses were monitored using fMRI during two sessions of the flanker task. During the second session, bilinguals had a significantly reduced time on the incongruent trials of the task—which required conflict monitoring—but monolinguals did not. Furthermore, both groups had an activation of the ACC, but bilinguals had significantly less activation than monolinguals, indicating that bilinguals use less effort to resolve conflict.

Costa et al. (2008) also used a version of the flanker task with young adults. This study demonstrated that the magnitude of the bilingual advantage was influenced by how much switching was necessary between congruent and incongruent trials on a flanker task. To reiterate, a congruent trial is a trial in which both the target and the distractor arrows are pointing in the same direction, whereas an incongruent trial is one in which the target and distractors point in opposite directions. When trials switched frequently between congruent and incongruent, heavy demands on conflict monitoring were imposed, and the participants were forced to adjust their cognitive control. Interestingly, bilinguals were significantly faster at both trial types when the type of trial frequently switched. However, when very little switching occurred, bilinguals performed no differently from monolinguals. These results suggest that conflict monitoring and resolution are enhanced in bilinguals: active inhibition would be used only for incongruent trials, with conflict, not both types of trials.

Bialystok and Viswanathan (2009) also tested cognitive flexibility with monolingual and bilingual children. Cognitive flexibility was defined as shifting, or the ability to switch between tasks. Again, this type of cognitive flexibility or shifting can be understood to be the same component of executive function as conflict monitoring and resolution, as discussed above in section 1.1. The faces that were presented to the children appeared either in mixed blocks, in which consecutive trials had faces with different colored eyes (green-red or red-green), or in single blocks, in which consecutive trials had faces with the same colored eyes (green-green or red-red). Participants had to indicate the direction of the eyes. The participants' level of cognitive flexibility was assessed by the measuring the difference between mixed and single block presentations. Bilinguals had a faster response time than monolinguals in both blocked and mixed presentations. Because bilinguals were faster than monolinguals in these tasks, both for blocked and for mixed presentations, Bialystok and Viswanathan concluded that they had an advantage in cognitive flexibility, or conflict monitoring and resolution.

Finally, another study with both middle-aged and older adults found that bilinguals had an advantage in both congruent and incongruent trials. Bialystok et al. (2004) presented monolinguals and bilinguals with a square appearing on either side of a computer screen. Participants were asked to press a key on the left if the square was blue and a key on the right if the square was red. When the square appeared on the same side of the screen as the correct response key, it was a congruent trial without conflict; when the square appeared opposite the response key, it was an incongruent trial with conflict. All participants—both age groups of both monolinguals and bilinguals—had a slower response time for the incongruent trials compared to the congruent trials. However, bilinguals had less of a cost than monolinguals of the same age group. This advantage was significantly larger for the incongruent trials, but it was still present even for the congruent items. Because bilinguals were faster not only for incongruent trials, but also for congruent trials, the results can be taken as evidence for enhanced bilingual conflict monitoring and resolution.

1.2.2.2 Conflict monitoring and resolution in verbal tasks

Another study whose findings are evidence for enhanced bilingual conflict monitoring and resolution was performed Teubner-Rhodes et al. (2016), in which bilinguals participated in the N-Back test, a working memory task. Subjects viewed single words sequentially and were asked to indicate whether an item appeared *n* items previously. For example, participants were told to listen for items that were three positions back and heard the sequence of words “calidad, pieza, escena, calidad.” The second “calidad” is a target; participants should indicate that it had also appeared three trials previously. The high-conflict version of the task contained “lures”—words that appeared two, four, or five items before. An example of a high-conflict block would be the sequence of words “calidad, pieza, calidad, escena, pieza,” presented in a three-back block (when participants had to say “yes” whenever the current word also occurred three positions back). In this instance, the second “calidad” is not a target; it is a lure because the same word had appeared two—but not three—positions back. The second “pieza” is the correct target because the same word had appeared three trials previously. Because the participant had seen the lure close to the *n* position, they were forced to override the familiarity bias and desire to incorrectly indicate the item. Bilinguals were more accurate than monolinguals on the high-interference version of the N-Back task, but not on the low-interference version. In other words, when conflict was present in some trials, bilinguals outperformed monolinguals in all trials (both conflict and no-conflict) due to the heightened awareness and readiness to detect and resolve conflict.

1.3 THE EFFECT OF LEVEL OF PROFICIENCY IN SECOND LANGUAGES AMONG BILINGUAL SPEAKERS

Another question that is raised by past studies is whether the “degree” of bilingualism affects the amount of advantage in a speaker. The proficiency of a bilingual speaker in either language, as well as how frequently and in what contexts they are used, could have a different neurological impact. Additionally, different levels of proficiency in a second language may affect nonverbal and verbal cognition in different ways. For example, a study conducted by Hakuta (1987) examined bilingual Spanish-English children with differing degrees of proficiency in their languages, as measured by tests of vocabulary. To test metalinguistic awareness, the younger participants were asked whether or not sentences were said correctly in Spanish: some contained grammatical errors; some contained a word in English. Older participants were given ambiguous sentences and were asked to identify the different meanings that the sentence could have.

Nonverbal tasks included Raven's Matrices and Thurstone's Primary Mental Abilities, which require geometric and spatial reasoning, and Chandler's Bystander Cartoons, which requires an understanding of perspective. The results indicated that children with a greater degree of bilingualism did have a greater advantage on the nonverbal tasks. However, this effect attenuated over time, and when the children were tested again in subsequent years, the bilinguals performed at about the same level. Additionally, the degree of bilingualism did not cause a difference in performance on the metalinguistic tasks: performance was correlated with their proficiency in the language of testing, but not with their level of bilingualism. In other words, children with a higher proficiency in the language of the metalinguistic tasks performed better; their proficiency in other languages was not found to influence performance significantly. According to Hakuta (1987), however, none of the children who were tested were proficient enough in their second language to be classified as "balanced" bilinguals, which could have influenced the results. Hakuta suggested that it would be likely that more balanced bilinguals would perform better on both verbal and nonverbal measures; more research would have to be done in this area.

Bialystok and Barac (2012) found similar results regarding level of bilingualism and performance on verbal and nonverbal tasks. The study tested metalinguistic awareness (measured via judgments about either the grammaticality or acceptability of sentences) in children who were enrolled in an immersion program in Hebrew; they varied greatly in competence of the two languages that they spoke, as measured by vocabulary tests. All bilinguals performed about equally to one another and to the monolingual group. The results indicated that there was no relation of the bilinguals' performance to their time spent in the immersion program or to their level of proficiency in the language that was not being used for testing. Rather, performance was related solely to their level of proficiency in the language of testing. This lack of correlation between bilingualism and metalinguistic awareness is consistent with the results of Hakuta (1987). However, when participants were asked to complete a nonverbal flanker task, a greater advantage was seen in students who had a greater degree of bilingualism. The children who had been in the program for the most time had the shortest reaction times for the Flanker task.

In contrast to the above findings, Galambos and Goldin-Meadows (1990) and Moreno (2010) both found that bilingual speakers did have an advantage in certain types of metalinguistic tasks in which participants had to judge the syntax of a sentence. However, their samples were more uniform in their language use: the children in the 1990 study were all intermediate or proficient in both languages, and the adults in the 2010 study all spoke English at school or work but used another language at home. One possible explanation for this difference from Hkuta (1987) and Bialystok and Barac (2010) is that because there was less variation among the sample—the participants in Galambos and Goldin-Meadows (1990) and Moreno (2010) were all fairly balanced. Therefore, an advantage for the bilingual participants in these studies appeared more clearly.

These contrasting findings suggest that measuring the level of proficiency in a sample of bilingual speakers is important for determining whether they will exhibit a bilingual advantage in verbal and non-verbal tasks. Furthermore, this pattern of differences suggests that bilingual speakers with greater proficiency in their L2 (more balanced bilinguals) are more likely to show a bilingual advantage. Because the sample of bilingual speakers in the present study is diverse in terms of their language acquisition and proficiency, it is likely that differences between the monolingual and bilingual group will not be as clear as they would be every subject in the bilingual group was balanced. Based on the previous findings, it is expected that bilinguals' performance on both the verbal and nonverbal tasks will be positively correlated with level of proficiency in their second language.

1.4 BILINGUAL DISADVANTAGES

Despite the advantages discussed above, bilinguals have also been found to have disadvantages in certain types of tasks. For example, Moreno et al. (2010) found that bilingual speakers actually performed less well than monolingual speakers in an acceptability judgment task, when they had to say whether a sentence contained an error in meaning or grammar. Bilinguals have also been found to have lower vocabulary knowledge in each of their languages than monolinguals who speak that language (Bialystok & Craik, 2010). Although Kavé et al. (2008) found that participants who spoke multiple languages outperformed monolinguals on certain cognitive screening tests, the results also showed that those who spoke more than one language had several disadvantages, including retrieval failures and fewer correct responses on verbal fluency tasks. Michael and Gollan (2005) found this same disadvantage: bilinguals were slower and committed more errors in picture naming tasks than monolinguals, even in their dominant language. One possible reason for these errors is that bilingual speakers might have competition from the same word in each language. Bilinguals also experienced more “tip-of-the-tongue” states than monolinguals and demonstrated interference from their language that was not currently in use. These studies suggest that bilingualism can cause disadvantages, not solely advantages.

Three possible reasons for a bilingual disadvantage in naming and retrieval were examined by Sandoval, Gollan, Ferreira, & Salmon (2010). One reason examined by researchers was that a speaker’s languages could interfere with each other, which is when the language not currently being used intrudes into the current language. A second reason was that bilingual speakers have reduced time using each language individually. Finally, the last reason examined by the study was that bilinguals could have smaller vocabularies within each of their languages. The study found that between-language interference had a powerful effect on verbal fluency: retrieval time for bilinguals was higher than for monolinguals, and bilinguals had fewer responses in a verbal fluency task. Bilinguals were also found to have between-language intrusion errors when being tested in their non-dominant language. The results of this study imply that even when speaking in their dominant language, bilinguals were not able to completely "shut off" activation of the non-dominant language and function like monolingual speakers. Specifically, interference between languages, differences in vocabulary knowledge, and differences in frequency of use compared to monolinguals may affect language production for bilingual speakers. The studies discussed in this section illustrate why bilingual speakers might need to have enhanced executive-function abilities: these results all suggest that bilingual speakers experience significant difficulty in lexical retrieval for which they may need to compensate.

1.5 SUMMARY

The body of research discussed above indicates that differences in executive function exist between bilingual and monolingual speakers. Studies have suggested that bilingual speakers can have advantages in both verbal and nonverbal tasks (Abutalebi et al., 2012; Bialystok & Barac, 2012; Bialystok et al., 2004; Blumenfeld & Adams, 2014; Moreno et al., 2010). Some studies suggest that the bilingual advantage is due to enhanced active inhibition of conflicting stimuli

(Garbin et al., 2010; Bialystok & Viswanathan, 2009), but others suggest that the advantage is due to enhanced conflict monitoring and resolution, which enables bilinguals to switch more easily between tasks with and without conflict (Costa et al., 2008; Teubner-Rhodes et al., 2016). Furthermore, evidence as to whether increased degree of proficiency in a second language is correlated with improved executive function among bilinguals is inconclusive (Hakuta, 1987; Bialystok & Barac, 2012). More research must be done to determine which component of executive function—active inhibition or conflict monitoring and resolution—is enhanced in bilinguals, and whether this advantage appears in verbal or nonverbal tasks. Finally, more research must be done to determine the relationship between "level" of bilingualism and level of executive function.

This study will attempt to contribute to the existing body of research on bilingualism. Bilingual and monolingual participants were asked to complete one nonverbal and one verbal task. The nonverbal task was a modified flanker task (Eriksen & Eriksen, 1974), and the verbal task was modified from a task originally used by Gibson, Bergen, and Piantadosi (2013). Each task had two versions to assess different components of executive function: one version contained only trials with conflict, to assess active inhibition, while the other version contained a mix of trials with and without conflict, to additionally assess conflict monitoring and resolution. Accuracy and response time were analyzed from each task to determine whether monolinguals and bilinguals had differences in either component of executive function. Members of the bilingual group were asked to complete the Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian et al., 2007) to account for variability within the bilingual group and to determine if a relationship existed between level of bilingualism and performance on the behavioral tasks.

1.6 EXPERIMENTAL TASKS

1.6.1 Flanker task

The Flanker task, designed by Eriksen and Eriksen (1974), was used to assess the cognitive processes required to detect targets while distracting stimuli, or "noise," is present. The original task used a sequence of letters. A target letter was flanked by non-target stimuli on either side; flanker stimuli could call for either the same response (congruent Flanker) or the opposite response (incongruent Flanker) as the target stimulus. Participants were instructed to respond in certain ways when different letters appeared in the target position. For example, the participants would be told to press the right response buttons when the letters H and K were in the target position and to press the left response button when the letters S and C were in the target position. An example of a congruent trial, then, would be HHHKHHH, in which both the target and flanker letters correspond to the right response button. An example of an incongruent trial would be HHHSHHH, in which the target letter corresponds to the right response button but the flanker letters correspond to the left response button. Eriksen and Eriksen found that incongruent flankers slowed response time significantly compared to congruent flankers, which indicates that inhibition difficulty is increased when flanker stimuli are inconsistent with the target response.

The present study used a modified version of the Flanker task, using a sequence of arrows instead of letters. One version of the task used only trials that contained incongruent flanker arrows, while a second version used trials that contained both congruent and incongruent flanker arrows. The all-conflict trial assessed participants' abilities in active inhibition, as this component of executive function is tapped only in trials that contain conflicting stimuli. The mixed version assessed participants' abilities in conflict monitoring and resolution, as this component of executive function involves switching between stimuli with and without conflict. In other words, participants had to monitor for conflict because congruent and incongruent trials appeared randomly. The accuracy and response times of the versions were analyzed in order to determine if either group had an advantage in either component of executive function.

1.6.2 Gibson task

Sentence processing theories generally assume that language processing mechanisms receive a sequence of words with no errors as input. However, this assumption does not account for the noise that is present in typical language use, such as environmental noise or errors on the end of the producer or the receiver. This noise can affect whether listeners or readers rely on grammatical information or semantic information in deciding what a sentence means, because noise affects how easy it is to perceive words and other information (like prepositions, auxiliaries, or verb endings) that can be important for the grammatical structure of sentences. For example, the preposition "to" in "The principal sent the child <u>to</u> the teacher" can easily be skipped when reading quickly, or misheard when listening in a noisy environment. This would lead to understanding the sentence as "The principal sent the child the teacher."

Gibson, Bergen, and Piantadosi (2013) developed a sentence comprehension task to evaluate predictions about a rational noisy-channel language comprehender, which would account for how listeners comprehend language when interference from noise is present. This hypothetical comprehender would be well-designed to recover the intended meaning from noisy utterances, and would tend to rely more on semantic information than on grammatical form in deciding what sentences mean. In this task, the investigators pitted grammatical structure against semantic information, to see whether participants would rely more on syntactic or semantic information in interpreting sentences.

To test these predictions, Gibson et al. gave participants a questionnaire consisting of 60 sentences that varied in their grammatical structure: they were either active sentences or passive sentences, or were double-object or prepositional-object sentences. Below are examples of each of these kinds of sentences:

The girl chased the boy.	*Active sentence*
The girl was chased by the boy.	*Passive sentence*
The principal sent the child the teacher.	*Double-object sentence*
The principal sent the child to the teacher.	*Prepositional-object sentence*

Each sentence also contained semantic information that was consistent or inconsistent with the grammatical structure of the sentence. Sentences were followed by a yes/no comprehension question. For example, the sentence "The woman handed the candle the girl" would be followed by the question, "Did the woman give something/someone to the candle?" In this case, the grammatical structure of the sentence (double-object structure) would indicate that the candle received the girl. However, semantic information and our world knowledge would be inconsistent with that interpretation, because candles are very unlikely to receive girls. A "YES" answer to the yes/no comprehension question would indicate that the participant paid attention to the grammatical structure of the sentence and ignored world knowledge in deciding what this sentence meant. A "NO" answer would indicate that the participant was not able to ignore or inhibit the influence of this semantic information/world knowledge, and instead assumed that they had misheard or misread the sentence and failed to perceive the preposition "to."

Gibson and colleagues (2013) found that young monolingual adults were often unable to ignore semantic information and world knowledge in this task. They often responded "NO" to the yes/no comprehension questions when semantic information was inconsistent with the grammatical structure of the sentences. They also found that participants were more likely to respond "NO" for passive sentences (which have a low frequency, complex structure) and double-object sentences. In a separate study, Gibson, Sandberg, Fedorenko, Bergen, and Kiran (2015) found that people with aphasia were even more likely to pay attention to semantic information and world knowledge (and not pay attention to grammatical structure) than unimpaired monolingual adults. The investigators concluded that this evidence shows that comprehenders are rational and adapt to noisy input.

The present study used a modified version of the Gibson task to assess whether bilinguals are more capable than monolinguals of interpreting the literal syntactic meaning of the sentence, despite conflicting semantic information. Participants heard a sentence and saw two pictures on the screen; they were asked to select the picture that matched what the sentence was saying. One version of the task contained sentences with only impossible meanings, such as "The ball kicked the girl," in order to assess active inhibition. Participants had to inhibit their automatic response to select the picture that makes the most sense semantically and instead choose the one that actually depicted the meaning conveyed by the sentence structure. A second version of the task contained both impossible and plausible sentences, such as "The mother handed the candle the daughter" (which is impossible) as well as "The girl kicked the ball" (which is plausible). Because participants had to switch between impossible and plausible—or conflict and no-conflict—trials, this version assessed conflict monitoring and resolution. Again, accuracy and response time were analyzed to determine if monolinguals and bilinguals differed in either component of executive function. It is also possible that active inhibition may be tapped by the sentences with uncommon linguistic structures: participants may want to inhibit DO sentences in favor of PO, and passives in favor of actives. However, based on previous findings, we expected the semantic influence to be more influential and require greater active inhibition when conflicting with expectations.

1.6.3 Language Experience and Proficiency Questionnaire (LEAP-Q)

The LEAP-Q was developed by Marian, Blumenfeld, and Kaushanskaya (2007) in order to create a "reliable and valid questionnaire of bilingual language status with predictable relationships between self-reported and behavioral measures" (p. 940). Rather than creating one composite "score" for bilingualism, the LEAP-Q gives self-reported data for several domains, including language competence, language acquisition, and prior and current language exposure. The LEAP-Q will be used in the present study as a measure of individual difference to account for variability within the bilingual group. Because young adults who had spoken a second language for at least the past five years were placed in the bilingual group, variability within the group was expected. In the study, some bilinguals had acquired multiple languages from birth, while others acquired their second languages through formal schooling beginning in kindergarten through high school. The results of the LEAP-Q—particularly, proficiency in and time speaking L2—will be analyzed to determine if "level" of bilingualism influences performance within the bilingual group, and if greater time and proficiency in L2 is correlated with better performance.

2.0 CURRENT STUDY: GOALS AND QUESTIONS

This study seeks to answer the following research questions:

1) Does a domain-general advantage exist for bilingual speakers in both verbal and nonverbal tasks that tap executive functions?
2) Does the presence of conflict play a role in triggering an advantage for bilingual speakers? Is there a bilingual difference only in trials in which there is conflict (active inhibition) or overall, in both congruent and incongruent trials (conflict monitoring and resolution)?
3) Does degree of proficiency in or time speaking the second language affect the degree of advantage for bilingual speakers?

This study included two groups of cognitively healthy young adults between the ages of 18 and 25 recruited from the University of Pittsburgh campus. One group consisted of monolinguals (with fewer than five years of exposure to or instruction in a second language), and the other consisted of bilinguals (with exposure to or instruction in a second language for at least the past five years). The bilingual group completed the Language Experience and Proficiency Questionnaire (LEAP-Q) to account for differences in experience with and use of a second language. Participants were asked to complete two different computerized tasks, which used reaction time and accuracy to assess their executive function in one verbal and one nonverbal task. Furthermore, both groups were split into two subgroups. Each subgroup completed a different version of the tasks: one version contained conflict in all trials, and one contained a mix of conflict and no-conflict trials. These different versions were used to detect whether the presence of conflict in a task can act as a trigger for an advantage in bilinguals. Response time and accuracy of the tasks were analyzed with the LEAP-Q to determine what amount of exposure and proficiency in a second language is necessary to cause an advantage. Ultimately, results of this study should help inform the assessment and treatment of language disorders in bilingual populations. If bilinguals are found to have an advantage in a component of executive function, they may be more susceptible to certain therapy techniques. For example, if bilinguals are found to have enhanced conflict monitoring and resolution abilities, they may benefit more than monolinguals from therapy tasks that involve some type of switching. The results of the study will help us understand where and when bilingual speakers show advantages (or disadvantages) compared to monolingual speakers, as well as what factors affect the size of the bilingual advantage.

2.1 HYPOTHESES

Given the existing body of research, we expect that bilinguals will have an advantage over monolinguals in either active inhibition or conflict monitoring and resolution. If bilingual participants have an advantage in active inhibition, they will outperform monolinguals in the all-conflict versions of the Flanker and Gibson tasks, as well as in trials containing conflict of the mixed versions of the tasks. If bilinguals have an advantage in conflict monitoring and resolution, we expect that they will outperform monolinguals on all trials of the mixed versions of the Flanker and Gibson tasks, which require participants to switch between conflict and no-conflict trials. Because active inhibition and conflict monitoring and resolution have generally been treated as being in opposition with one another in the existing literature on bilingualism, we expect that only one of these components will be enhanced in bilinguals, but it is possible that both could be enhanced. If both components are enhanced, we expect that bilinguals will outperform monolinguals on all trials in both versions. Finally, we expect that a greater level of proficiency in the bilinguals' second languages, as reported in the Language Experience and Proficiency Questionnaire, will be positively correlated with their performances on both the Flanker and Gibson task.

3.0 METHOD

3.1 PARTICIPANTS

Participants were divided into two main groups: monolingual and bilingual speakers. Each group had forty participants. Bilingual speakers were required to have spoken or taken formal education in a second language for at least the past five years. Five years was chosen as the cut-off point in order to create diversity among the bilingual group. One aim of the study was to examine links between level of proficiency or duration of exposure to a second language and performance on the behavioral tasks; thus, a wide range of proficiency levels and durations of exposure was desired. Members of both groups were required to have normal or corrected-to-normal vision and hearing, were between the ages of 18 and 25, and had no history of speech, language, or neurological problems. All participants were current students at the University of Pittsburgh.

3.1.1 Recruitment

Participants were recruited in three ways: both monolingual and bilingual participants were recruited from a course in the Communication Science and Disorders department of the School of Health and Rehabilitation Science and were granted extra credit at the discretion of the instructor. Both monolingual and bilingual participants were also recruited by word-of-mouth at the University of Pittsburgh and received no compensation or credit of any kind. Finally, bilingual speakers were recruited through the University of Pittsburgh psychology pool and received one of their four required hours of credit for their participation in the study.

3.1.2 Demographics

The ages of participants ranged from 18 years and 3 months to 22 years and 1 month, with the mean age of the monolingual group being slightly lower than the mean age of the bilingual group. The mean age of monolingual participants at the time of testing was 21 years and 1 month, ranging from 19 years and 4 months to 23 years and 10 months. The mean age of bilingual participants at the time of testing was 19 years and 8 months, ranging from 18 years and 3 months to 22 years and 1 month. 35 of the monolingual speakers were female; 5 were male. 30 of the bilingual speakers were female; 10 were male. The average Raven's score of the monolingual group was 33.6 out of 36, and the average score of the bilingual group was 34.1 out of 36. The differences in Raven's scores were not significant (p=.25).

Within the bilingual group, 21 had begun acquiring their second language(s) before age 5, and 19 began acquiring their second language after age 5. All monolinguals spoke only English, and all bilinguals spoke English and a variety of other languages: Spanish, Korean, Vietnamese, French, Taiwanese, Mandarin, Thai, Portuguese, Twi, American Sign Language, Urdu, Italian, Greek, German, Hindi, Japanese, Punjabi, Hebrew, Filipino, Kapampangan, Cantonese, Telegu, Arabic, and Russian. More detailed information about the bilingual group is presented below in Tables 1-4.

Table 1: Second language characteristics of bilingual participants. L2 Time=duration of exposure to L2 in years; L2 Speaking and L2 Understanding=self-rated second-language proficiency in speaking and understanding, respectively, on a scale of 1 to 10 (10 being most proficient)

Partici-pant	L2 Time	L2 Speaking	L2 Under-standing	Partici-pant	L2 Time	L2 Speaking	L2 Under-standing
4805	5	6	9	**4836**	14	8	8
4808	9	6	5	**4837**	10	9	9
4809	7	4	5	**4838**	15	7	7
4810	7	6	8	**4839**	17	7	8
4811	11	9	9	**4840**	15	7	8
4812	18	9	9	**4841**	18	10	10
4813	14	9	9	**4842**	13	8	9
4814	15	9	9	**4843**	17	10	10
4815	6	6	5	**4844**	13	8	9
4817	20	6	8	**4855**	9	8	9
4819	11	8	9	**4856**	13	9	10
4820	17	10	10	**4857**	14	8	9
4821	7	8	9	**4858**	8	7	7
4822	13	9	9	**4859**	19	9	9
4823	16	9	9	**4862**	18	8	8
4824	15	10	10	**4863**	4	5	3
4826	13	8	9	**4865**	15	7	6
4827	2	7	7	**4866**	11	10	10
4830	16	9	9	**4877**	14	10	10
4835	12	8	9	**4880**	8	8	9
				Mean:	**12.6**	**8**	**8.3**

Table 2: First languages of bilingual participants

First (Most Dominant) Language	Number of Participants	First (Most Dominant) Language	Number of Participants
English	32	Greek	1
Chinese	2	Kapampangan	1
Spanish	2	Thai	1
Hindi	1		

Table 3: Second languages of bilingual participants

Second Language	Number of Participants	Second Language	Number of Participants
ASL	1	Mandarin	1
French	4	Telegu	1
English	8	Russian	2
Spanish	8	German	1
Korean	6	Vietnamese	1
Portuguese	1	Urdu	1
Italian	1	Twi	1
Hebrew	1	Hindi	1
Cantonese	1		

Table 4: Number of languages spoken by bilingual participants

Number of Languages Spoken	Number of Participants
2	20
3	17
4	1
5	2

3.2 MATERIALS

3.2.1 Screening tests

All participants completed a researcher-developed basic medical history questionnaire and underwent a pure-tone bilateral hearing screening at 40dB using a standard audiometer with over-the-ear headphones. All participants enrolled in the study passed the hearing screening. Furthermore, all monolingual participants enrolled in the study reported English as their primary language, and all bilingual speakers reported English as their first or second language. No participants reported prior history of hearing disorders or speech, language, or neurological problems. All participants also completed Raven's Coloured Progressive Matrices (RCPM), with responses recorded on a researcher-developed form. The RCPM is used to test nonverbal reasoning ability (Raven, 1965). All participants enrolled in the study had to make 6 or fewer errors on the RCPM in order to complete the experimental tasks.

3.2.2 Experimental tasks

All participants completed one session of the Flanker task, one session of the Gibson task, and a second session of the Flanker task. Participants completed two separate sessions of the same Flanker task version in order to gain more data without the risk of participants becoming fatigued during one longer session. Both Flanker sessions were the same version (i.e., each participant completed either two all-conflict Flanker tasks or two mixed Flanker tasks). Bilingual participants also completed the Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian, Blumenfeld, & Kaushanskaya, 2007) as a measure of individual differences in language experience and proficiency.

The Flanker and Gibson tasks were programmed and run using Psychology Software Tools's E-Prime software on a Dell 4500 series desktop computer. Verbal stimuli were presented via speakers, and visual stimuli via a flat-screen monitor. For the Flanker task, participants responded using arrow keys on a standard US keyboard, which were marked with pink tape for easy identification. For the Gibson task, participants responded using number keys 1 and 5, which were marked with white tape for easy identification. Participants' accuracy and response time for each item were recorded by the E-Prime software and later imported to Microsoft Excel spreadsheets for data analysis.

3.3 PROCEDURE

3.3.1 Screening

As part of screening procedures, participants completed a questionnaire asking about their personal medical history, language status, and vision status. All participants also underwent a short hearing screening of pure tones at 500, 1000, 2000, and 4000 Hz at 40dB bilaterally. Finally, all participants completed Raven's Coloured Progressive Matrices (Raven, 1965), which is a test to assess individuals' nonverbal reasoning ability. As indicated above, participants were required to receive a score of at least 30/36 correct in order to proceed with the study.

3.3.2 Experimental tasks

Once the screening procedures were complete, participants who indicated that they had been speaking a second language for at least the past five years were given the Language Experience and Proficiency Questionnaire (Marian et al., 2007). Verbal instructions were given. Once the instructions were understood, the bilingual participants completed a pencil-and-paper version of the questionnaire before beginning the computerized experimental tasks.

Both monolingual and bilingual participants were given verbal instructions for the Flanker task and completed a short practice session as outlined in the appendix. A sequence of five arrows appeared on the screen (see Table 5, below); participants were instructed to indicate the direction of the middle arrow by pressing one of two keys on a keyboard. Once the instructions were understood and the practice items mastered, participants began the experimental tasks.

Table 5: Flanker task stimuli

Congruent Stimuli	Incongruent Stimuli
← ← ← ← ← → → → → →	→ → ← → → ← ← → ← ←

The participants were then given verbal instructions for the Gibson task. They were asked to listen to a sentence presented via speakers while viewing two pictures on a screen and to select the picture that best represented the sentence by pressing one of two keys on a keyboard. Examples of the sentence stimuli that participants heard are presented in Table 6. An example of the picture stimuli can be seen in Figure 1. Responses were scored as correct if participants selected the picture that matched the sentence structure (for example, the picture of a ball kicking a girl for the passive sentence “The girl was kicked by the ball”). For conditions where that picture showed an impossible situation (as for “The girl was kicked by the ball”), a correct response indicates that participants attended to the sentence structure and ignored the contradictory semantic information.

Table 6: Examples of Gibson task linguistic stimuli

Linguistic Structure	**Example**
Plausible Double Object	The mother gave the girl the candle.

Impossible Double Object	The mother gave the candle the girl.
Plausible Prepositional Object	The mother gave the candle to the girl.
Impossible Prepositional Object	The mother gave the girl to the candle.
Plausible Active	The girl kicked the ball.
Impossible Active	The ball kicked the girl.
Plausible Passive	The ball was kicked by the girl.
Impossible Passive	The girl was kicked by the ball.

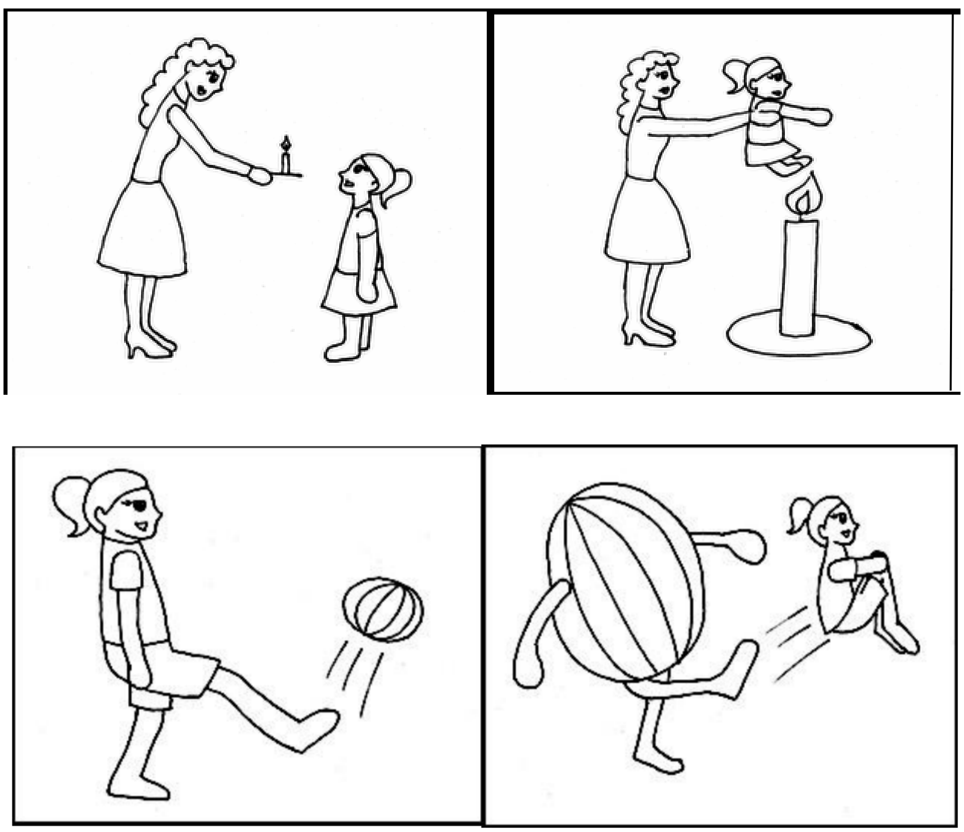

Figure 1: Examples of Gibson task visual stimuli, for the linguistic stimuli from Table 2

After hearing the verbal instructions, participants completed a short practice session. Once the instructions were understood and the practice items mastered, participants began the experimental trials.

Finally, the participants reviewed the instructions for the Flanker task and again completed a short practice session before beginning the task for a second session. As noted above, the second session was the same version (either all-conflict or mixed) as the first session for each participant.

4.0 ANALYSIS AND DESIGN

This study used a mixed (between-participants and within-participants) experimental design. Two participant groups (monolingual and bilingual) experienced two different test versions (all-conflict and mixed) for two separate tasks. The Flanker task contained two types of trials within the test conditions: congruent and incongruent. The Gibson task contained four linguistic structures within the test versions: double objects, prepositional objects, actives, and passives. The double-object and prepositional-object sentence structures formed a set, and the active and passive sentence structures formed a separate set of structures. Each of these sentence structures presented either plausible or impossible semantic information (i.e., described either a plausible or an impossible situation).

For the Flanker task, within-subject independent variables thus included trial type (congruent versus incongruent), and between-subject variables included group (bilingual versus monolingual) and version (all-conflict versus mixed). For the Gibson task, within-subject independent variables included sentence structure (double-object versus prepositional-object for one set, and active versus passive for the other set) and plausibility (plausible versus impossible). Between-subject variables included group (bilingual versus monolingual) and version (all-conflict versus mixed).

The Flanker and Gibson programs recorded two dependent variables: participants' accuracy and reaction time for each trial. As described above, accurate responses in the Gibson task indicated that the participant had chosen an interpretation based on the structure of the sentence, possibly ignoring semantic information (in the impossible conditions). Analyses of reaction-time and accuracy data were performed using Microsoft Excel, SPSS, and linear and logistic mixed-effects regression in R, with the lme4 package (Bates & Sarkar, 2005).

The LEAP-Q was administered as a pencil-and-paper survey. Responses were transferred into a Microsoft Excel spreadsheet, in which means and ranges for self-reported language proficiency and exposure were calculated. Three components from the LEAP-Q were ultimately analyzed along with reaction-time and accuracy data from the Flanker and Gibson tasks: speaking and understanding proficiency in bilinguals' second language (self-rated on a scale of 0 to 10), and time speaking their second language (measured in years). LEAP-Q data were used for individual-difference analyses examining the basis of bilingual participants' performance on the other tasks. These analyses were performed using linear and mixed-effects regression in R, with the lme4 package (Bates & Sarkar, 2005).

4.1 FLANKER RESULTS

Accuracy data for the Flanker task are presented in Figure 2. Average accuracy for both groups for congruent trials was at ceiling (bilinguals=99%; monolinguals=100%). Both groups were also at ceiling for the all-conflict version, which contained only incongruent trials (monolinguals and bilinguals=98%). However, bilinguals were less accurate in the incongruent trials of the mixed version than monolinguals (bilinguals=92%, monolinguals=97%). Between the first and second sessions, both groups had approximately equal accuracy for both versions. In the all-conflict version, bilinguals performed with a mean accuracy of 98.5% in session 1 (SD=12.0%)

and 98.3% in session 2 (SD=12.8%); monolinguals performed with a mean accuracy of 98.5% in session 1 (SD=11.8%) and 98.4% in session 2 (SD=12.5%). In the mixed version, bilinguals performed with an accuracy of 95.5% in session 1 (SD=21%) and 95.1% in session 2 (SD=22%); monolinguals performed with a mean accuracy of 98.2% in session 1 (SD=13%) and 98.4% in session 2 (SD=12%).

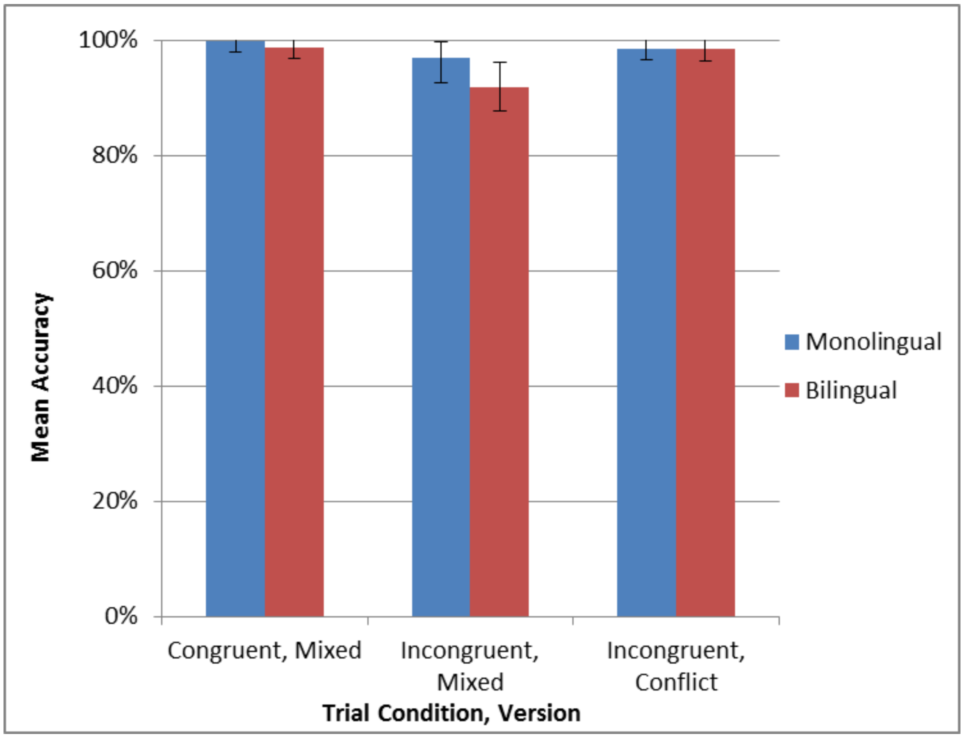

Figure 2: Average accuracy, Flanker task (error bars=standard error)

To analyze these patterns statistically, logistic mixed-effect regression models were run using the glmer function in lme4. Separate models were run for the mixed and all-conflict versions of the Flanker task. These models contained fixed effects of group (monolingual and bilingual) and trial type (congruent versus incongruent: used for the mixed version only) and their interaction, as well as the maximum random-effects structure that allowed convergence (minimally including random intercepts for participants). For the mixed version, there was a significant main effect of trial type ($z=6.85$, $p<0.0001$), but no effect of group ($z=1.31$, $p>0.1$) and no interaction ($z=1.57$, $p>0.1$). For the all-conflict version, with only incongruent trials, there was no effect of group ($z<1$). Participants were thus reliably less accurate for incongruent than congruent trials in the mixed version of the Flanker task, and there was not a reliable difference between bilingual and monolingual participants' disadvantage for the incongruent trials.

Reaction times from all trials for the Flanker task are presented in Figure 3. Bilinguals were faster overall than monolinguals, for both the mixed and all-conflict versions of the task. In addition, congruent trials had faster reaction times (RTs) than incongruent trials did. Furthermore, the difference between congruent and incongruent trials in the mixed version of the task was smaller for bilinguals (39 milliseconds) than it was for monolinguals (57 milliseconds). Both groups performed faster in both versions on the second session than the first. For the all-conflict version, bilinguals had a mean RT of 445 ms in session 1 and 426 ms in session 2, decreasing by 19 ms. Monolinguals had a mean RT of 458 ms in session 1 and 435 ms in session 2, decreasing by 23 ms. For the mixed version, bilinguals had a mean RT of 430 ms in session 1 and 415 ms in session 2, decreasing by 15 ms. Monolinguals had a mean RT of 450 ms in session 1 and 428 in session 2, decreasing by 22 ms.

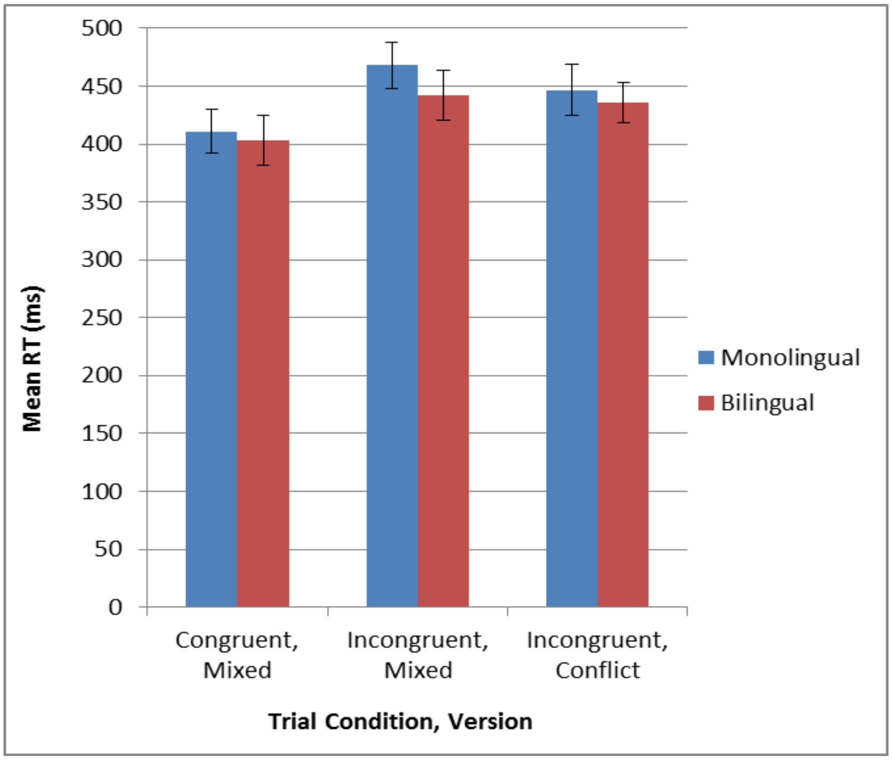

Figure 3: Average response times (ms), Flanker task (error bars=standard error)

To analyze these patterns statistically, linear mixed-effect regression models were run using the lmer function in lme4. Separate models were run for data from the mixed and all-conflict versions of the Flankers task. These models contained fixed effects of group (monolingual and bilingual) and trial type (congruent versus incongruent – mixed version only) and their interaction, as well as the maximum random-effects structure that allowed convergence (minimally including random intercepts for participants). Following Baayen (2008), effects with t values of greater than 2 were assumed to be significant. For the mixed version, there was a significant main effect of trial type (t=12.23), but no effect of group (t=0.61). However, there was a significant interaction (t=2.50). For the all-conflict version, with only incongruent trials, there was a significant effect of group (t=6.50). Bilinguals were thus faster for incongruent trials than monolinguals, both for mixed and all-conflict versions of the Flanker task, and they had a smaller difference between congruent and incongruent trials than monolinguals in the mixed version. They were also faster to respond in the all-conflict version than monolinguals, as predicted by enhanced active inhibition.

To determine whether the bilingual speakers were faster than the monolinguals even for trials without conflict, as predicted by conflict monitoring and resolution, an additional model was run comparing congruent-trial RTs for bilingual and monolingual participants in the mixed version of the task. There was no effect of group (t=0.11). Bilingual speakers did not have significantly faster RTs for the congruent trials than monolinguals.

The difference between session 1 and session 2 was significant for both the all-conflict version (t=-11.55) and the mixed version (t=-7.95). Both groups were faster in the second Flanker session than the first. There was also a significant interaction of group and session for the mixed version (t=-2.77): the monolingual group got significantly faster for session 1 versus session 2 than the bilingual group did. However, there was no interaction between group and session for the all-conflict version (t=-0.88), and no interaction between session and condition in the mixed version (t=0.01). The bilingual group's advantage for trials with conflict did not increase or decrease from session 1 to session 2, in either version of the Flanker task.

4.2 GIBSON RESULTS

Accuracy data for the all-conflict version of the Gibson task are shown in Figure 4, and for the mixed version in Figure 5. To reiterate, the proportion of accurate responses represents how often participants chose the picture that went with the grammatical structure of the sentence (active, passive, double-object [DO], or prepositional-object [PO]). For trials for which that meaning was impossible (Imposs), accuracy represents how often participants paid attention to the grammatical structure of the sentence and ignored the (impossible) meaning.

Consistent with previous results (Gibson et al. 2013, 2015), all participants had the lowest accuracy (chose the picture not consistent with the sentence structure) in the double-object (DO) conditions. They were less accurate for DO than for prepositional-object (PO) trials and for passive than for active trials, in both the all-conflict and mixed versions of the Gibson task. In the mixed version, all participants were also less accurate for trials describing impossible situations (Imposs) than plausible situations (Plaus). This is again consistent with previous results (Gibson et al., 2013, 2015). Bilingual participants also had lower accuracy overall than monolingual participants.

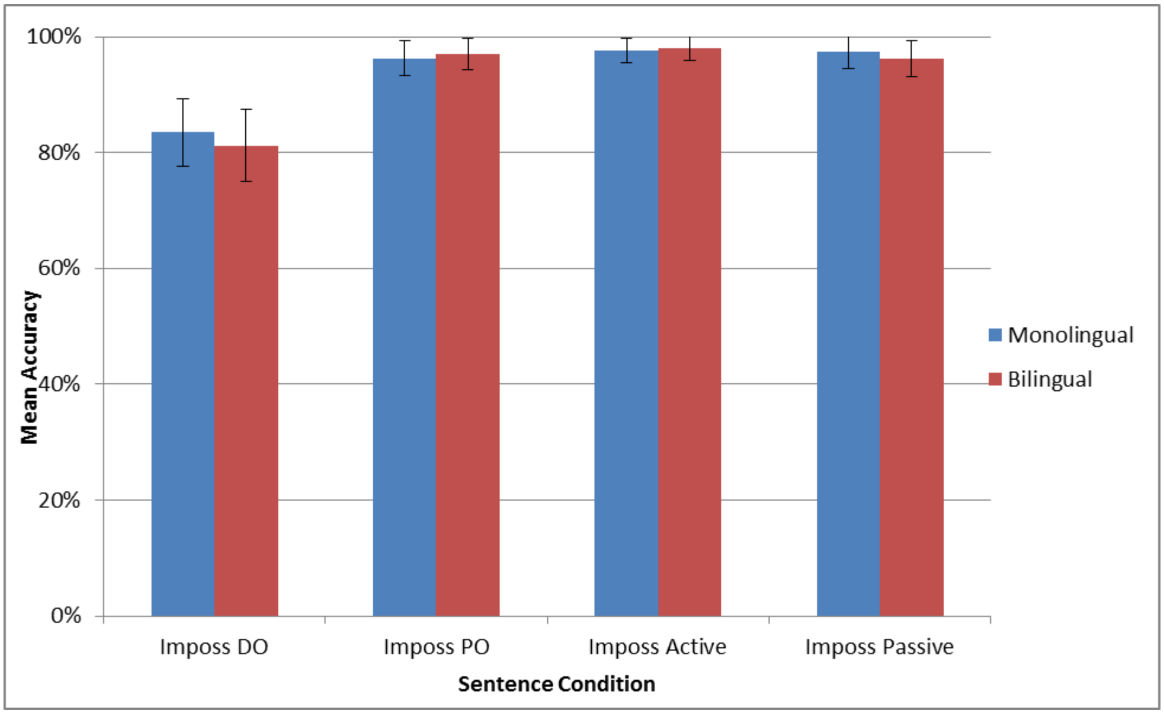

Figure 4: Average accuracy, all-conflict version of Gibson task (error bars=standard error)

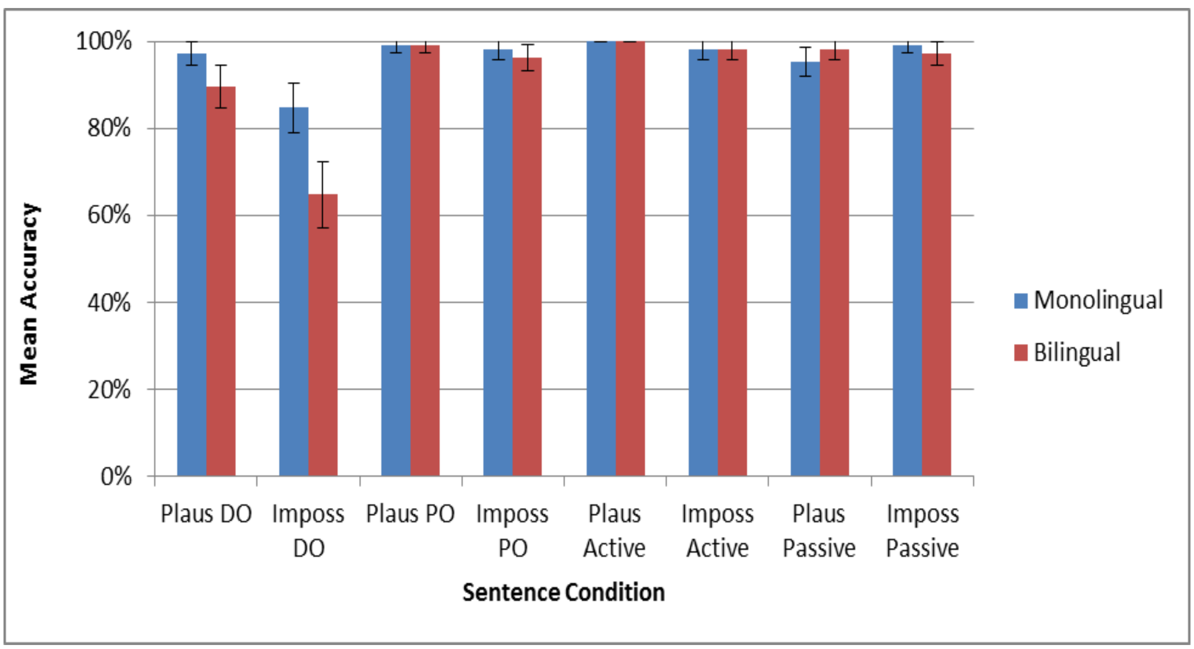

Figure 5: Average accuracy, mixed version of Gibson task (error bars=standard error)

To test these patterns statistically, logistic mixed-effect regression models were run using the glmer function in lme4. Separate models were run for the mixed and all-conflict versions of the Gibson task, and for the two different structure sets described above: double-object versus prepositional-object structure (DO vs. PO), and active versus passive structure. These models all contained fixed effects of group (monolingual versus bilingual), sentence structure (DO versus PO or Active vs. Passive), and semantic information (plausible versus impossible: used for the mixed versions only) and the interaction of these factors. The models also included the maximum random-effects structure that allowed convergence (minimally including random intercepts for participants).

For the DO-PO data from the mixed version, there was a significant main effect of sentence structure (DO vs. PO; $z=5.26$, $p<0.0001$), semantic information (plausible vs. implausible; $z=3.21$, $p<0.01$), and group ($z=2.74$, $p<0.01$). No interactions were significant (all $z<1$). For the all-conflict version, with only incongruent trials, there was a significant main effect of structure (DO vs. PO; $z=6.53$, $p<0.0001$), but no effect of group ($z<1$). For the Active-Passive data from the mixed version, there was a marginally significant main effect of sentence structure (Active vs. Passive; $z=1.76$, $p<0.1$), but no effect of semantic information (plausible vs. implausible; $z<1$) or group ($z<1$). No interactions were significant (all $z<1$). For the all-conflict version, with only incongruent trials, there were no effects of structure or group, and no interaction (all $z<1$). Thus, for the DO-PO structure set, participants were reliably less accurate for DO than PO trials, and reliably less accurate for trials in which semantic information conflicted with sentence structure. Bilinguals were also reliably less accurate than monolinguals, for the mixed version. No reliable differences appeared for the Active-Passive set.

Reaction time data from all trials for the all-conflict version of the Gibson task are presented in Figure 6, and for the mixed version in Figure 7. Across conditions for both groups, response times were highest for impossible direct object conditions. Bilinguals had a higher response time than monolinguals for every condition in the mixed versions, but had a lower response time than monolinguals for every condition in the all-conflict versions.

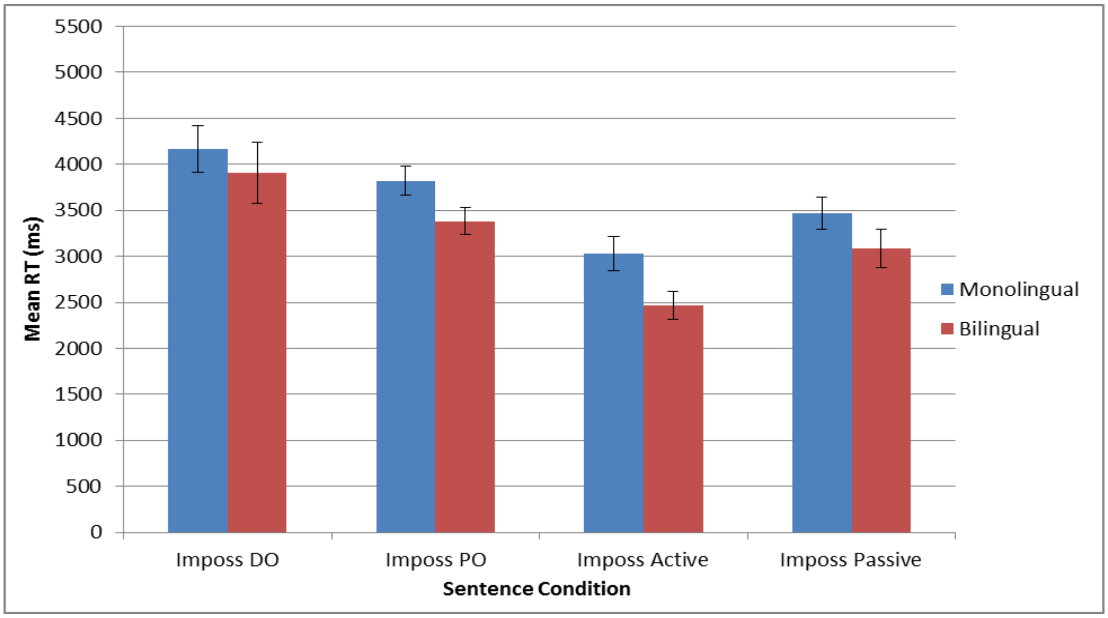

Figure 6: Average response times (ms), all-conflict version of Gibson task (error bars=standard error)

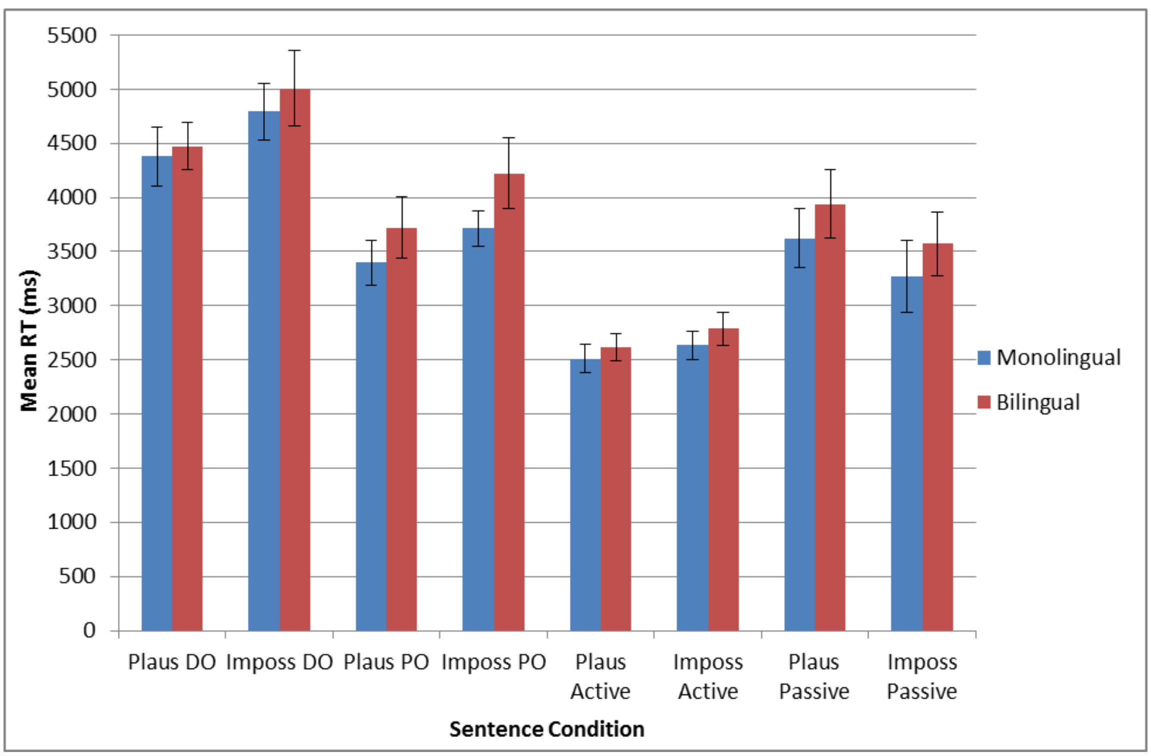

Figure 7: Average response times (ms), mixed version of Gibson task (error bars=standard error)

To test these patterns statistically, linear mixed-effect regression models were run using the lmer function in lme4. Separate models were run for the mixed and all-conflict versions of the Gibson task, and for the two different structure sets described above: double-object versus prepositional-object structure (DO vs. PO), and active versus passive structure. These models all contained fixed effects of group (monolingual versus bilingual), sentence structure (DO versus PO or Active vs. Passive), and semantic information (plausible versus impossible: used for the mixed versions only) and the interaction of these factors. The models also included the maximum random-effects structure that allowed convergence (minimally including random intercepts for participants). Once again, effects were considered significant if they had t values of 2 or greater (Baayen, 2008).

For the DO-PO data from the mixed version, there was a significant main effect of sentence structure (DO vs. PO; $t=8.21$) and semantic information (plausible vs. implausible; $t=3.89$), but no effect of group ($t=1.02$) and no interactions (all $t<1$). For the all-conflict version, with only incongruent trials, there was a significant main effect of structure (DO vs. PO: $t=4.14$), but no effect of group ($t=1.79$). For the Active-Passive data from the mixed version, there was a significant main effect of sentence structure (Active vs. Passive; $t=7.95$), but no effect of semantic information (plausible vs. implausible; $t=1.22$) or group ($t<1$). However, there was a significant interaction of sentence structure and semantic information ($t=2.92$), with the Impossible passive structure being unexpectedly faster than the Impossible active structure. No other interactions were significant (all $t<1$). For the all-conflict version, with only incongruent trials, there was a significant main effect of structure ($t=8.50$) and group ($t=3.02$), but not a significant interaction ($t=1.46$).

Thus, for the DO-PO structure set, participants were reliably slower for DO than PO trials, mirroring their lower accuracy for DO trials. They were also reliably slower for trials in which semantic information conflicted with sentence structure (Impossible versus Plausible trials), again mirroring their lower accuracy for these trials. Bilinguals were not reliably faster or slower than monolinguals, for either the mixed version or the all-conflict version. This is in contrast to the accuracy data, where bilinguals were less accurate overall than monolinguals. For the Active-Passive set, participants were reliably slower for passive than active sentences. This pattern appeared in both the mixed and all-conflict versions. Furthermore, bilinguals were reliably faster than monolinguals in the all-conflict Active-Passive set, where semantic information was always in conflict with sentence structure.

4.3 LEAP-Q RESULTS

On the LEAP-Q, bilingual participants reported a wide range of proficiency in the second language they knew, as well as a wide range of language exposure. The mean number of years they reported speaking a second language was 12.6 (ranging from 2 to 20). In rating their own proficiency in speaking and understanding that language on a scale from 0 (none) to 10 (perfect), they had a mean speaking proficiency of 8 (ranging from 4 to 10) and a mean understanding proficiency of 8.3 (ranging from 3 to 10).

To examine how different degrees of proficiency affected the bilingual participants' performance on verbal and non-verbal tasks involving conflict, additional logistic and linear regression models were run for cases where there was a main effect of group in the Flanker and Gibson tasks. So, for each model above that found a reliable main effect of group, we ran regression models using L2 speaking proficiency, L2 understanding proficiency, and time L2 has been spoken as predictor variables. These models only looked at data from bilingual subjects, and instead of using group as a predictor, they tested whether speaking proficiency, understanding proficiency, and L2 exposure affected participants' accuracy or reaction times. These models allowed us to determine which aspects of bilingual proficiency (if any) are behind the effects of bilingualism we observed in the current study.

The first place where we looked at how LEAP-Q variables may help us understand the effects of bilingualism was reaction times in the Flanker task. There was an interaction of group (bilingual vs. monolingual) and condition (congruent vs. incongruent) in the mixed version of the task, and a main effect of group in the all-conflict task.

The first set of models substituted L2 speaking proficiency, L2 understanding proficiency, and L2 time spoken for the effect of group in the analyses of the mixed version Flankers-task data. The first of these models substituted L2 speaking for the effect of group, the second substituted L2 understanding proficiency for the effect of group, and the third substituted time having spoken an L2 for the effect of group. These models did not find significant main effects of any of the LEAP-Q variables (all $t<1$). There were also no significant interactions of any of the LEAP-Q variables and condition.

The second set of models substituted L2 speaking proficiency, L2 understanding proficiency, and L2 time spoken for the effect of group in the analyses of the all-conflict Flankers task. There was a significant effect of L2 speaking proficiency ($t=2.66$) on reaction times in the all-conflict task, with higher L2 speaking proficiency being associated with faster reaction times in the all-conflict task. L2 understanding proficiency ($t=1.87$) and time L2 was spoken ($t=1.29$) did not significantly affect reaction times in the all-conflict task.

The next place we looked at how LEAP-Q variables can help us understand the effects of bilingualism was the mixed-version DO-PO data from the Gibson task. For the accuracy data, there was a significant main effect of group, with bilingual speakers being less accurate than monolinguals. Three separate models substituted the three LEAP-Q variables (L2 speaking proficiency, L2 understanding proficiency, and time L2 was spoken) for the main effect of group. None of these models found a main effect of any of the LEAP-Q variables on accuracy for the DO-PO sentences (all $t<1$).

The final place where we examined the possible influence of LEAP-Q variables on the effects seen for bilingual speakers was in reaction times for all-conflict Active-Passive data from the Gibson task. In this data set, there was a main effect of group, with bilingual speakers being faster than monolinguals. Three separate models substituted the three LEAP-Q variables (L2 speaking proficiency, L2 understanding proficiency, and time L2 was spoken) for the main effect of group. None of these models found a main effect of any of the LEAP-Q variables on reaction times for the all-conflict Active-Passive sentences (all $t<1$).

5.0 DISCUSSION

For both of the behavioral tasks, bilinguals demonstrated only limited advantages in the mixed versions (discussed further below). These versions required conflict monitoring and resolution, as participants had to switch back and forth between conflict and non-conflict trials. On the contrary, bilinguals performed worse than monolinguals in the Gibson task, particularly in the mixed version of the task. However, bilinguals did show some advantages over monolinguals, particularly in the all-conflict version of the task. Our findings from both tasks thus suggest that bilinguals may have an advantage over monolinguals in active inhibition, especially given their faster response times in trials containing conflict.

5.1 FLANKER TASK

In the Flanker task, bilinguals had no advantage in response time over monolinguals for congruent trials, in which both target and distractor arrows pointed in the same direction. However, they were slightly faster than monolinguals for incongruent trials in both the all-conflict and mixed versions, and there was a significant interaction between group and condition in the mixed version. This finding replicates the bilingual advantage for non-verbal tasks involving conflict found by (Bialystok & Viswanathan, 2009; Blumenfeld & Adams, 2014; Garbin et al., 2010).

This finding is consistent with the theory of enhanced active inhibition in bilinguals (Bialystok & Viswanathan, 2009; Blumenfeld & Adams, 2014; Garbin et al., 2010), since bilinguals only had an advantage over monolinguals in trials that required inhibition of the conflicting flanker arrows. Bilinguals do not appear to have an advantage in conflict monitoring and resolution (Costa et al., 2008; Teubner-Rhodes et al., 2016; Abutalebi et al., 2012). If that component had been enhanced in bilinguals, they should have performed better in both types of trials in the mixed version of the task. Also consistent with an active-inhibition advantage for bilinguals is the fact that they were faster than monolinguals in the all-conflict version of the task, where active inhibition of the incongruent flankers was consistently required.

Both groups had significantly faster response times in the second session of the Flanker task compared to the first session in both versions, suggesting that all participants may have adopted strategies for both inhibition and for conflict monitoring and resolution over time. Interestingly, in both versions, monolinguals' response times decreased more than bilinguals' response times, though this difference was only significant in the mixed version, and it did not affect the size of the bilingual participants' advantage for conflict trials compared to monolinguals in either version. This difference deserves further study and could be addressed in future research.

5.2 GIBSON TASK

For the mixed version of the Gibson task, monolinguals outperformed bilinguals: monolinguals were faster for all sentence types, and they were more accurate overall. This appeared particularly strongly for the DO-PO sentence-structure set (Gibson et al., 2013, 2015). This finding is contrary to our hypothesis, because bilingual speakers actually performed worse than monolingual speakers did. This finding is also inconsistent with previous findings suggesting that bilingual children may show an advantage in metalinguistic tasks (like grammaticality judgment) that require them to pay attention to grammatical structure and ignore content. However, it is consistent with findings suggesting that bilinguals may sometimes show disadvantages compared to monolinguals in language tasks (Bialystok & Craik, 2010; Michael & Gollan, 2005; Sandoval et al., 2010). Furthermore, it is consistent with findings by Moreno, et al. (2010) for acceptability judgments, where bilingual speakers did worse than monolingual speakers when they had to judge sentences that could contain either a grammatical or a semantic error. It is possible that the Gibson task, which made participants balance between sentence structure and semantic information to choose which picture best matched a sentence (see Gibson et al., 2013), was more like Moreno et al.'s acceptability-judgment task.

Interestingly, this finding suggests that bilinguals do not have an advantage over monolinguals in conflict monitoring and resolution. They were less adept at switching between plausible and impossible sentences, in which semantic information either conflicted (impossible) or did not conflict (plausible) with the sentence's structure. However, bilinguals and monolinguals had almost equivalent accuracy for all sentence types in the all-conflict version, and bilinguals had faster response times, particularly for the Active-Passive sentences. Because bilinguals were faster than monolinguals when the sentence required inhibition of normal expectations of the world, this finding suggests that bilinguals may have an advantage over monolingual speakers in active inhibition.

5.3 LEAP-Q

The analyses looking at how LEAP-Q performance affected the bilingual participants' performance can help us understand how proficiency and exposure (how balanced a bilingual speaker is) may affect the bilingual advantage. On the all-conflict version of the non-verbal Flankers task, degree of speaking proficiency affected bilingual participants' performance: bilingual speakers with higher speaking proficiency showing faster responses. Neither understanding proficiency nor time they had spoken a second language affected their performance. This finding suggests that bilingual proficiency may affect the bilingual advantage, even for non-verbal tasks (Hakuta, 1987; Bialystok & Barac, 2012). The lack of correlation between duration of exposure or understanding proficiency and performance suggests that speaking proficiency may be a better measure someone's capabilities in their language and may be more influential in any cognitive or neurologic changes.

Interestingly, none of the LEAP-Q variables we tested appeared to affect how much of an advantage or disadvantage bilingual speakers showed in the Gibson task. This is consistent with the findings of both Hakuta (1987) and Bialystok and Barac (2012), which suggested there was no relation between degree of proficiency in a second language and performance in linguistic tasks. Some other characteristics of bilingual speakers must be responsible for the differences in the Gibson task. The question of how degree of proficiency affects bilingual speakers' performance on linguistic tasks involving conflict resolution thus remains open.

5.4 LIMITATIONS AND FUTURE DIRECTIONS

One limitation of the current study is due to the diversity of the bilingual group. The bilingual group, consisting of 40 subjects, varied in number of languages spoken, proficiency in second language(s), and what the second languages actually were. Half of the bilingual group (20 subjects) spoke two languages, 17 subjects spoke three languages, 1 spoke four, and 2 spoke five. Additionally, all bilinguals spoke English, but they spoke a wide variety of other languages: Spanish, Korean, Vietnamese, French, Taiwanese, Mandarin, Thai, Portuguese, Twi, American Sign Language, Urdu, Italian, Greek, German, Hindi, Japanese, Punjabi, Hebrew, Filipino, Kapampangan, Cantonese, Telegu, Arabic, and Russian. As a result, we cannot say if any bilingual differences change based on which languages are spoken. The LEAP-Q also did not account for the amount or frequency that code-switching occurred among bilingual speakers, which could have affected performance during the task versions that required conflict monitoring and resolution. Some existing research has indicated that bilinguals who switch back and forth between their languages more frequently have a greater advantage in switching tasks than those who switch languages less frequently (Prior & Gollan, 2011). The present study did not account for frequency of switching, which could have influenced performance in the versions of the tasks requiring conflict monitoring and resolution. We were forced to make generalizations about the bilingual group as a whole despite these differences among the speakers.

Additionally, although the majority of the bilingual participants listed English as their first language, some listed English as their second or third language. It is possible that the speakers whose native language was not English may have been more inclined to choose semantically normal answers during the Gibson task, even when the correct answer would have been semantically anomalous or impossible. Furthermore, the LEAP-Q is a subjective measure of proficiency; no objective measures were administered to test proficiency of the bilingual participants in any of their languages.

Another limitation of this study is due to the structure of the Flanker and Gibson tasks. This study utilized only versions of tasks that involved conflict: either trials only contained conflict, or trials were a mix of conflict and no-conflict. Ideally, a third version consisting of only tasks with no conflict should have been used. Future studies could compare performances of bilinguals and monolinguals on versions of these tasks that do not contain any trials with conflict. Future studies could also manipulate the percentage of trials that contain conflict. The mixed versions of the tasks in the present study were evenly divided between trials with and without conflict. However, if the percentage of conflict trials were reduced, inhibition demands might increase because conflict is less expected. Manipulating the proportion of conflict and no-conflict trials could thus yield different results. Additionally, because the Raven's screening task may be associated with executive function (e.g., Roca et al., 2009), it is possible that the criteria of scoring at least a 30 out of 36 to participate limited the variability of the groups and created a ceiling effect in Flanker accuracy.

Other potential future directions could include examining eye movements during similar tasks. For example, tracking participants' eye movements during the Gibson task could enable us to determine differences in how bilinguals and monolinguals process sentences while hearing them. Based on the findings of this study, we might expect bilinguals to have fewer eye movements toward the incorrect picture than monolinguals. Another measurement that could provide insight into differences between monolinguals and bilinguals would be looking at local costs—or costs between single trials—rather than solely global costs, which looked at the entire mixed versus all-conflict blocks. In other words, future studies could examine how exposure to conflict in one trial affects how a participant performs in the subsequent trial.

6.0 CONCLUSION

The findings of this study suggest that bilingual speakers may have an advantage over monolingual speakers in active inhibition and not conflict monitoring and resolution when completing nonverbal tasks. However, bilinguals had no advantage over monolinguals in the linguistic task. Our results also suggested that bilinguals' speaking proficiency in their second language was correlated positively with performance on the nonverbal task, but no correlation between second language proficiency and performance was found on the verbal task. Overall, these findings indicate that bilingual speakers with a greater "degree" of bilingualism may perform better on nonverbal tasks that contain some type of conflict. The question of why bilingual performance was enhanced in the nonverbal task, but not in the verbal task, remains open. The reason why bilingual proficiency was correlated with performance in the nonverbal task, but not in the verbal task, is also uncertain. Future research could continue to compare performance of bilingual and monolingual speakers in other verbal and nonverbal tasks in order to understand their differences more clearly.

Our finding of enhanced active inhibition in a nonverbal task suggests that bilingualism affects more than solely the linguistic domain and instead has broader, domain-general consequences. These consequences could affect how bilingual speakers with language disorders perform during different assessment tasks as well as how they respond to treatments, which would have a variety of clinical implications. For example, one implication could affect the environment in which a school-based speech-language pathologist delivers services. At times, it can be difficult to work with a child directly in the classroom due to distractions from the other students, which forces the SLP to instead pull the child out from the class. If bilingual children are found to have an advantage in active inhibition, one possibility is that they might be more adept at inhibiting the activities of their classmates and focusing on their speech therapy task, which would allow them to stay in their general classroom for treatment. Ultimately, finding more evidence regarding which, if any, components of executive function are enhanced for bilingual speakers could aid in the development of new assessment and treatment strategies for the population.

APPENDIX A

FLANKER TASK

This appendix will provide the script used to present the stimuli during the experiment. The all-conflict version of the task contained only incongruent stimuli, while the mixed version of the task contained both congruent and incongruent stimuli presented in a random order. All of the information in this section was presented visually on a computer monitor; only one set of arrows was presented at a time. Each session contained 120 trials, for a total of 240 trials per participant.

A.1 PRESENTATION SCRIPT

You will see 5 arrows. Your task is to pay attention to the middle arrow and to indicate the direction of the middle arrow. Put your LEFT index finger on the left arrow button and put your RIGHT index finger on the right arrow button.

If the middle arrow points to the LEFT like this ← , press the left arrow button with your LEFT index finger. If the middle arrow points to the RIGHT like this → , press the right arrow button with your RIGHT index finger. Please respond as quickly as possible while remaining accurate. Press the right arrow button to begin.

APPENDIX B

GIBSON TASK

This appendix will provide the linguistic stimuli found in the Gibson task, along with the script used to present trials stimuli during the experiment. The all-conflict version of the task contained only sentences with impossible semantic information, while the mixed version of the task contained sentences with both plausible and impossible semantic information. Sentences were played through a speaker while two images were presented visually on the computer screen. Each participant completed one session of 70 trials.

Table 7: Linguistic stimuli presented aurally for all-conflict version of Gibson task

Sentence	Linguistic Structure	Plausibility Condition
The ball kicked the girl.	Active	Impossible
The plumber was bought by the watch.	Passive	Impossible
The table set the mother.	Active	Impossible
The daughter was folded by the blanket.	Passive	Impossible
The pizza ate the boy.	Active	Impossible
The grandfather was broken by the bowl.	Passive	Impossible
The hammer stole the electrician.	Active	Impossible
The sister was closed by the window.	Passive	Impossible
The boy handed the pencil the girl.	Double Object	Impossible
The book purchased the aunt.	Active	Impossible

The uncle was sailed by the boat.	Passive	Impossible
The secretary was licked by the stamp.	Passive	Impossible
The boy handed the pencil the girl.	Active	Impossible
The car dealer leased the plumber to the SUV.	Prepositional Object	Impossible
The diamond lost the woman.	Active	Impossible
The door opened the niece.	Active	Impossible
The sailing club leased the boat the man.	Double Object	Impossible
The candle lit the wife.	Active	Impossible
The oven cleaned the grandmother.	Active	Impossible
The seal ate the shark.	Active	Impossible
The shop sold the bike the student.	Double Object	Impossible
The sister mailed the letter the niece.	Double Object	Impossible
The train boarded the granddaughter.	Active	Impossible
The contractor lent the saw the homeowner.	Double Object	Impossible
The quarterback passed the ball the receiver.	Double Object	Impossible
The daughter passed the mother to the bowl.	Prepositional Object	Impossible
The girl tossed the boy to the apple.	Prepositional Object	Impossible
The nanny threw the child to the toy.	Prepositional Object	Impossible
The uncle sold the truck the father.	Double Object	Impossible
The father gave the car the son.	Double Object	Impossible
The janitor lent the teacher to the mop.	Prepositional Object	Impossible
The host tossed the microphone the contestant.	Double Object	Impossible
The man was ridden by the horse.	Passive	Impossible
The videostore rented the customer to the DVD.	Prepositional Object	Impossible
The magician threw the hat the assistant.	Double Object	Impossible
The saw sharpened the father.	Active	Impossible
The stamp licked the secretary.	Active	Impossible
The puppy lifted the toddler.	Active	Impossible
The nephew mailed the postcard the aunt.	Double Object	Impossible
The water sipped the grandson.	Active	Impossible
The aunt was purchased by the book.	Passive	Impossible
The janitor lent the mop the teacher.	Double Object	Impossible
The husband was written by the letter.	Passive	Impossible

The mother gave the candle the daughter.	Double Object	Impossible
The contractor lent the homeowner to the saw.	Prepositional Object	Impossible
The sun orbited the planet.	Active	Impossible
The girl tossed the apple the boy.	Double Object	Impossible
The scuba instructor rented the tourist to the equipment.	Prepositional Object	Impossible
The bartender handed the drink the lady.	Double Object	Impossible
The nanny threw the toy the child.	Double Object	Impossible

Table 8: Linguistic stimuli presented aurally for mixed version of Gibson task

Sentence	**Linguistic Structure**	**Plausibility Condition**
The sister mailed the letter the niece.	Double Object	Impossible
The mother gave the candle to the daughter.	Prepositional Object	Plausible
The uncle sold the father to the truck.	Prepositional Object	Impossible
The contractor lent the homeowner the saw.	Double Object	Plausible
The sailing club leased the boat the man.	Double Object	Impossible
The girl tossed the apple to the boy.	Prepositional Object	Plausible
The daughter passed the mother to the bowl.	Prepositional Object	Impossible
The scuba instructor rented the tourist the equipment.	Double Object	Plausible
The boy handed the pencil the girl.	Double Object	Impossible
The nanny threw the toy to the child.	Prepositional Object	Plausible
The nephew mailed the aunt to the postcard.	Prepositional Object	Impossible
The father gave the son the car.	Double Object	Plausible
The shop sold the bike the student.	Double Object	Impossible
The janitor lent the mop to the teacher.	Prepositional Object	Plausible
The car dealer leased the plumber to the SUV.	Prepositional Object	Impossible
The host tossed the contestant the microphone.	Double Object	Plausible
The quarterback passed the ball the receiver.	Double Object	Impossible
The video store rented the DVD to the customer.	Prepositional Object	Plausible

The bartender handed the lady to the drink.	Prepositional Object	Impossible
The magician threw the assistant the hat.	Double Object	Plausible
The ball kicked the girl.	Active	Impossible
The plumber was bought by the watch.	Passive	Impossible
The truck was driven by the man.	Passive	Plausible
The secretary licked the stamp.	Active	Plausible
The table set the mother.	Active	Impossible
The daughter was folded by the blanket.	Passive	Impossible
The saw was sharpened by the father.	Passive	Plausible
The niece opened the door.	Active	Plausible
The pizza ate the boy.	Active	Impossible
The grandfather was broken by the bowl.	Passive	Impossible
The diamond was lost by the woman.	Passive	Plausible
The grandmother cleaned the oven.	Active	Plausible
The hammer stole the electrician.	Active	Impossible
The sister was closed by the window.	Passive	Impossible
The water was sipped by the grandson.	Passive	Plausible
The granddaughter boarded the train.	Active	Plausible
The book purchased the aunt.	Active	Impossible
The uncle was sailed by the boat.	Passive	Impossible
The candle was lit by the wife.	Passive	Plausible
The husband wrote the letter.	Active	Plausible
The man was scared by the ghost.	Passive	Plausible
The bear ate the man.	Active	Plausible
The guard was summoned by the king.	Passive	Plausible
The comedian entertained the audience.	Active	Plausible
The sun was orbited by the planet.	Passive	Plausible
The man rode the horse.	Active	Plausible
The child was scared by the spider.	Passive	Plausible
The parent lectured the child.	Active	Plausible
The seal was eaten by the shark.	Passive	Plausible
The toddler lifted the puppy.	Active	Plausible

A.2 PRESENTATION SCRIPTS

Welcome.

You are being asked to listen to sentences and look at two pictures. Choose the picture that you feel best represents what you hear in the sentence.

Press “1” to choose the picture on the left. Press “5” to choose the picture on the right.

When you see the “+” press the SPACEBAR to move on to the next picture.

If you have any questions, please ask them now.

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