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Multilingualism And Ego Depletion In Interference Task Performance – Are Multilingual Brains More Intelligent Than Monolingual Brains?

Dorota B. Botwina
CUNY Hunter College

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Dorota Botwina

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04/25/2017	Dr. Virginia Valian
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Abstract

In recent years, research linking multilingualism with better executive control has produced inconsistent findings. Since definitive empirical evidence is not available, this study seeks to further explore whether these advantages really exist. The Flanker Task followed an ego depletion task that was introduced to participants who were monolingual, bilingual, or trilingual. The ego depletion task was employed in an effort to deplete participants of self-regulatory resources and therefore decrease their performance on a subsequent interference task. Flanker Task measured reaction time and accuracy. There were three conditions in the study: strong ego depletion, mild ego depletion and a control condition. The 196 undergraduate student participants in the study performed all of the tasks on a computer. The findings indicated that there are no significant cognitive control differences between monolinguals, bilinguals, and trilinguals. This failure to find a difference between these three language groups is discussed in the context of previous research as well as in the context of methodological changes that need to be addressed in order to investigate cognitive processes of multilinguals. Cognitive benefits seem to be more observable in the studies of children and older adults, whereas they disappear in a group of young adults.

Keywords: cognitive advantage, executive control, Flanker, ego depletion, monolingual, bilingual, trilingual.

Introduction.

There are no doubts that an ability to speak multiple languages is one of the most unique abilities that we have as human beings. Multilinguals have to learn how to navigate between one language and another. In order to be successful in this process, they need to select appropriate lexical representations in a given context and prevent interference from a competing language. If multilinguals were not equipped with a set of necessary skills that allow them to perform this extraordinary navigation, conversation would be interrupted. According to researchers, there has to be a system that allows multilinguals to switch effectively between languages. They call this mechanism the attentional control network (Costa, et al., 2006).

According to Posner, the attentional control network can be divided into three different components that are responsible for different cognitive abilities: the alerting network (maintaining a state of alertness), the orienting network (selecting specific information from sensory input) and the executive network. Although, these three components are distinct from each other, they are not independent but instead work in an orchestrated manner (Posner & Peterson, 1990).

One major component of the attentional control network is executive function. As noted by with Valian, "executive functions are those that manage, integrate, regulate, coordinate, or supervise other cognitive processes, such as attention and visual perception". Executive function is an umbrella term that can include a set of different complex cognitive processes such as cognitive flexibility, working memory, problem-solving, inhibition, reasoning and planning (Valian, 2014).

Since executive functions are abstract, poorly understood phenomena, they are the subject of enormous debate as many researchers are in disagreement about what kinds of cognitive processes should be incorporated in the definition. There have been many attempts to provide a definition of executive function, however all of them have resulted in just listing a few cognitive abilities that should be included in the actual definition. This clearly demonstrates that executive function is still not perceived as one unitary concept. Nevertheless, all researchers mention a "common factor" when defining executive function. As Miyake claims, the "common factor" thought to underlie all examples of executive function is "about one's ability to actively maintain task goals and goal-related information and use this information to effectively bias lower-level processing" (Miyake and Friedman, 2012).

Methodological shortcomings and interference tasks in the study of the executive system

It is important to mention that issues with defining executive function are not the only problem that researchers encounter when investigating this concept. Another obstacle is, without any doubt, measurement of executive function. Presently, interference tasks such as the Simon Task, Flanker Task, ANT task and Stroop Task have been used to investigate the efficiency of cognitive control mechanisms. All these tasks measure different components of executive function, so performance of participants can vary from one task to another. Even within the same task, there are different cognitive processes that are being measured. Therefore, researchers have demonstrated that these tasks show uncertain validity and test-retest reliability.

Nevertheless, in recent years, interference tasks have been recognized as one of the best methods in cognitive psychology to study cognitive mechanisms, especially those responsible for self-control (Okuniewska, 2007). What makes these tasks so popular and prominent nowadays? The interference tasks produce intended conflict and, as a result, allow researchers to investigate the efficiency of attentional control mechanisms. For example, in studies of interference, participants are forced to pay attention to and concentrate on the stimuli in the presence or absence of distracting information. In general, the item or items that cause distraction require a different response from the participant than the stimulus itself. As a result, the participantsparticipants are often involved in automatic and unintentional processing of the distracting information which interferes with their choice of the correct response. This conflict needs to be resolved before the response is made. Not surprisingly, conflict resolution absorbs time and decreases performance (more errors) in comparison to the situation in which the distracting stimuli are absent. Interestingly, research shows that performing one of these tasks activates the area of the brain called the anterior cingulate cortex that is responsible for detection of conflict. Usually, this structure is activated in the case of conflicting tasks such as the Flanker Task, Color Stroop and Simon task. Conflict tasks have gained more popularity as tools in investigating areas of the brain responsible for cognitive processing (Stins et al., 2005).

Interference Tasks.

There are many interference tasks that are used to examine self-control mechanisms such as the Stroop, the SSxSR, the Simon, the reverse Simon, Cross-Modal tasks, the Flanker Task and many more. However, for the purpose of this study, I will only be looking at the Flanker Task, go/no go task and ANT Task.

The Flanker Task. The Flanker Task is also known as the Eriksen flanker task. It is a choice reaction time task in which the participantsparticipants must select a central target in the presence of distractors (also called flankers) around it. These distractors have to be ignored (Sevilla et al., 2003). Arrowheads are the most commonly used stimuli, but it is possible to also use letters, shapes, words or symbols. In the typical Flanker Task, the participants participantsare presented with stimuli such as arrows, and they must make a lexical response. This task is divided into two conditions: congruent and incongruent. In a congruent condition, all arrows point in the same direction as the target stimuli whereas in an incongruent condition, arrows point in the direction that is incompatible with the target stimulus. For further reference, see Figure 1 in the appendix.

As expected, the experiments show that the reaction times for congruent stimuli are faster than for incongruent stimuli. Also, participants make fewer errors in a congruent condition than in an incongruent one (Zhao et al., 2014). Even in the case where participants are aware of the location of the target, they are not able to block the interference and focus their attention in order to avoid the Flanker effect. This indicates that participants do not experience problems with the location of the target nor with ability to look for it. Instead, the interference is responsible for delays in the response. However, the good news is that it "is not constant over time" (White et al., 2011).

The go/no-go task. The go/no-go task is a procedure that measures response inhibition (Simmonds et al., 2008). The participantsparticipants are presented with visual stimuli such as a stream of letters X and Y, or other types of stimuli. In this task, participants are required to respond to one of the choices while inhibiting the other alternative. Accuracy and reaction time are recorded for every event (Gomez et al., 2007). For example, participants are instructed to respond to the stimuli in go trials by pressing the button and to withhold their responses during no go trials. In a typical test, X's and diamond-shaped stimuli interchangeably occur on the screen. Diamonds are the go signal, and participants need to respond by pressing the key that corresponds to the direction of the arrow. X’s are considered the no-go signal, and participants are not allowed to press the button and are instructed to withhold their responses. For further reference, see Figure 2 in the appendix.

The ANT Task – The ANT Task was developed based on the idea that attention consists of three aspects or components which are responsible for separate attentional functions that individuals may differ on (Redick & Engle, 2006). The task measures three attentional networks -- alerting, orienting and executive attention. Tto investigate the speed of processing and efficiency within these three networks, reaction time is observed and measured. The task takes about 30 minutes and is so simple that it can be done not only by adults but also by children and even monkeys. In the ANT task, participants are instructed to decide whether an arrow located in the center points toward the left or right direction. They perform the task by pressing two keys (left or right) that indicate the direction of the central target. In addition, the central arrow is surrounded by congruent, incongruent or neutral flankers. The task also has four cues conditions (no cue, double cue, center cue, orienting cue). For example, in the orienting condition, a cue is presented on the screen, and it indicates a position on the screen where the main stimuli will appear. In the double cue, an asterisk is presented in the location of the main target above and below the fixation cross. In the center cue condition, a cue appears at the location of the fixation cross. These four conditions make it possible to test different aspects of the executive attention system such as alerting, orienting and executive function. (Costa, Hernandez, Galles, 2008).

Multilingualism and Interference Tasks

Many previous studies have shown that bilingualism influences cognitive performance as well as language development. Scientists claim that speaking two languages has many negative consequences. For example, studies show that bilinguals perform worse on language proficiency tasks in comparison to monolinguals. In addition, they also have slower development of vocabulary in childhood and less word resources available to them in adulthood. It takes bilinguals longer to name a particular image on a picture naming task as well as on a lexical decision task and a verbal recall task (Bialystok & Feng, 2009).

In spite of a large body of evidence suggesting verbal disadvantages for bilinguals, quite opposite effects can be observed in non-lexical executive control tasks. As Bialystok claims, many studies have demonstrated the link between bilingualism and faster reaction time in interference tasks that require self-control and cognitive flexibility (Bialystok et al., 2004), but these differences seem to be very inconsistent and vary across ages. For example, studies have shown that advantages are more noticeable throughout the period of childhood and adulthood; however, although the effect is smaller in many cases, it is still visible for younger adults (Bialystok, Martin, Viswanathan, 2005).

Differences in interference task performance between monolinguals and bilinguals.

Many previous studies have demonstrated that bilinguals are more successful and outperform monolinguals in interference tasks that require self-control and cognitive flexibility (Bialystok &Feng, 2009). However, these advantages are strongly expressed in young children and older adults (e.g., Bialystok & Martin, 2004; Bialystok et al., 2004) and sometimes occur to a smaller degree in younger adults. Bialystok suggests that younger adults are already in possession of efficient processing, and as a result, this advantage is not as obvious for them. (Bialystok et al., 2005).

Unfortunately a closer investigation of the above theory reveals potential problems with it. It does not take into account inconsistencies that are found between and within studies. Bialystok's theory does not fully explain why, in some tasks, bilinguals tend to perform better than monolinguals but do not outperform monolinguals on other tasks. Although this theory clearly has flaws, in my opinion it also has tremendous scientific value because it prompted debate among many researchers leading to even more intensive investigation of cognitive control phenomena.

To conclude, the benefits of being bilingual can be observed only in two periods during the lifespan. First, advantages are visible in childhood when "these processes are developing" and allow the bilingual child to excel in certain tasks in comparison to monolinguals peers. Later, benefits can be seen in adulthood when bilingual ability protects older people from a steep cognitive decline (Bialystok et al., 2005). Since age plays such a significant role in development and decline of cognitive functions, I will examine these differences according to age.

Bilingual advantage in children

Some studies show that bilingual children perform significantly better in comparison to monolinguals in tasks that require high levels of self-control. Bilingual children are also more successful in resisting distraction and are able to concentrate more on abstract dimensions of language (Bialystok, 1999). Although the majority of research studies that have examined cognitive control in bilingual children have used metalinguistic tasks, some studies have used tasks that are non-linguistic in order to examine these advantages (Kovács & Mehler, 2009). It is unknown why bilingual children have better ability to resist distracting information and pay more attention to abstract dimensions of language in comparison to monolinguals; any possible explanations are based on pure speculation (Bialystok, 1999).

Nonetheless, these differences in cognitive control can be visible very early on, even in infants. For instance, Kovács and Mahler (2009) showed that 7-month-old bilingual infants outperformed monolingual infants in a task that required executive control. In the first part of the study, monolingual and bilingual infants were presented with 9 trisyllabic meaningless words followed by a visual reward (a puppet) that appeared on the same side of the screen. This task required the infants to learn that the reward is preceded by a visual cue. In the second task, the infants had to overwrite previously acquired stimuli by turning their gaze to the opposite side of the screen where meaningless words started to appear. The authors used eye-tracking to measure the "proportion of anticipatory looks". The results showed that bilinguals were able to suppress the previously learned response and switch their attention to the opposite side of the screen whereas monolinguals could not learn the new response (Kovács & Mehler, 2009).

The authors of the study suggest that bilingual infants receive mixed input very early on, and as a result, they are forced to create two representational systems that are relevant and proper to each language. Tto be able access and acquire construction of each language, they are forced to use their controlling and monitoring ability. Furthermore, bilingual infants gain more practice well before they start producing first utterances and words. Constant exposure to two languages improves development of executive functions in bilingual children, and as a result, it makes them significantly better in tasks that require cognitive control in comparison to monolinguals (Kovács & Mehler, 2009).

Most of the existing research that investigates aspects of cognitive control was conducted with somewhat older children (Mikulak, 2012). In one study, 3-5 year-old bilingual children outperformed monolinguals in tasks that measured selective attention. In one of the tasks, children were shown two pairs of block towers, one composed of Lego Blocks and one of Duplo Blocks. Each Lego block was "half the size of a Duplo block on each dimension", (Bialystok &Codd, 1997).The children were asked to count the number of blocks and decide which tower was larger. The task measured the selective attention of the children. In order to count the number of blocks, they had to disregard the visible distracting information that the Duplo tower was bigger in comparison to the Lego tower. The study result showed that bilingual children were more advanced in this task in comparison to monolingual children (Bialystok & Codd, 1997).

Surprisingly, Bialystok and Codd did not find a significant difference between bilinguals and monolinguals in their understanding of the relation between numbers. The researchers used a sharing task in order to examine the children's understanding of cardinality. In this task, the children received an equal number of blocks, and they were instructed to equally share them between two animals. After the blocks were evenly shared, children were asked to count the number of blocks that each animal had in its possession. Children who understand the relation between numbers should be able to know that each pile consists of the same number of blocks. There was no cognitive advantage in the sharing task for bilingual children. The authors claim that bilingual children were better in solving problems that demanded from them higher levels of attentional control just because they had to attend to different sorts of information that came from two languages early on. However, bilingual children did not have any experience with problems that required analysis of knowledge, and as a result, they were not able to understand the relation between numbers (Bialystok &Codd, 1997).

Another study demonstrated cognitive advantages for older children in the Dimensional Change Card Sort Task (DCCS). In this task, children were required to sort a series of cards by one of two dimensions, either shape or color. When the children completed sorting all cards, the rules were changed and they were instructed to sort by the other dimension. For example, children received a set of cards that contained pictures of blue squares and red circles. They were first instructed to sort them according to one dimension, such as color, and to put the cards into two boxes – the red cards in the box with the red square and the blue cards in the box with the blue circle. In the next part of the experiment, participants were asked to organize the cards according to a different dimension, shape. The children were expected to put cards with red circles into the blue box with the blue circle and to place cards with blue squares into the box with the red square. This task requires better cognitive control; children have to inhibit and ignore distracting information in order to organize the cards correctly. In one study, Bialystok and Martin (2004) found a selectional advantage in a DCCS task for four and five year-old Chinese-English bilinguals. Chinese-English speakers in this study were much better and made fewer errors than monolinguals in ignoring distracting information and attending to one dimension in order to make a correct classification of the cards (Bialystok and Martin, 2004).

Also six year-old bilingual children exceed monolinguals in tasks that require inhibitory control and switching. In one study, children were instructed to complete the standard Simon Task (described in the Interference Tasks section) and the ANT designed for children (Poarch & van Hell, 2012). The results showed that in the ANT task, bilingual and trilingual children were significantly better in their ability to inhibit conflicting stimuli while responding to a valid one. Also, they benefited more from an orienting clue than monolingual children. Moreover, trilingual and bilinguals displayed less interference in the incongruent condition of the Simon Task. Bilingual and trilingual children performed similarly on both tasks. This might suggest that navigating between three languages was not enough to improve attentional control even more than that of bilinguals (Poarch & Hell, 2012).

Cognitive advantages have been also found for eight year-old bilingual children. Peal & Lambert discovered that French- English speaking children performed significantly better on the Raven Progressive Matrices test in comparison to monolingual children. This test requires children to identify the missing element (from the set of elements) in order to complete a pattern. Bilingual children also performed better on Primary Mental Abilities Figure-Grouping in which children need to decide which figure does not belong to the group. The authors of the study claim that bilingual children demonstrate superior ability in tests that require concept formation and "symbolic flexibility" (Peal & Lambert, 1962)

Above studies show that even four year-old children can benefit from being bilingual. They are much better than monolinguals in solving tasks that require attentional control and inhibition. A possible explanation for these advantages in bilingual children can be that the same control processes responsible for solving problems are also used to navigate between two language systems. As a consequence, bilingual children have more opportunity than monolinguals to practice an important cognitive skill, which speeds up the development of that skill (Bialystok et al., 2003).

It is important to note that although many studies have demonstrated bilingual benefits for children, there are also studies that do not find any advantage at all or produce inconsistent findings. These studies offer a challenge for Bialystok's theory. A good example of this is a study by Anton and colleagues (2014). The researchers examined a group of 180 Spanish monolingual children and 180 bilingual children using a version of the ANT task that was modified for use by children. In the ANT task, participants had to indicate whether an arrow displayed on the screen is pointing to the left or right. The main arrow is surrounded by two arrows located on each side and pointing in the same (congruent) or opposite direction (incongruent) as the main arrow. There is also a neutral position in which the main arrow is surrounded by simple lines. Before each trial or randomly, participants can be given a cue about the position of the main arrow since it can be located in the upper or lower part of the screen. There are many different types of cues that participants can be given: a spatial cue (when an asterisk occurs in a congruent cueing position), a double cue (when one asterisk is located in the upper and one in the lower part of the screen), a neutral cue (when an asterisk is located in the center), and no cue at all. The study results did not show any cognitive benefits for bilinguals as bilinguals and monolinguals performed the task similarly regardless of the condition. Both groups were significantly faster and more accurate on double cue trials than on no cue trials. In addition, as predicted, monolinguals and bilinguals were slower on the incongruent condition and faster on the congruent one (Anton & Colleagues, 2014).

In another study, Duñabeitia and colleagues administered a version of the Stroop Task to monolingual and bilingual children in order to investigate potential benefits of bilingualism. Children were matched on a large number of variables such as immigrant status, education, etc. There were Spanish monolinguals and Basque-Spanish bilinguals in the study. The study results demonstrated that monolingual and bilingual children performed similarly across all blocks. In addition, a lack of differences was also observed across the age ranges from 8-13 years old. As the authors noted, those studies that do not show any differences usually have a larger number of participants (Dunabeitia et al., 2014).

A similar study showed an advantage for French-English bilingual children on the Simon Task. The task was modified for young children by reducing the number of trials to prevent boredom, and the presentation rate was slower as well. Bilingual English-French speaking children were recruited from after-school childcare programs whereas monolingual English speaking children were recruited from day-care centers. The bilingual children were significantly faster than the monolinguals on congruent and incongruent trials. The experiment was repeated with a larger number of trials and different participants were used. The results again showed faster response times in congruent and incongruent conditions, however, this difference was smaller (Bialystok et al., 2005). This finding was surprising because most of the studies suggest that bilingual children rely on their ability to inhibit attention while responding to conflicting stimuli, which makes them faster in interference tasks (Poarch & Hell, 2012; Bialystok et al., 2005). This explanation can clearly account for the incongruent condition, but it does not explain why bilingual children overall performed better in the congruent condition that did not require any inhibition whatsoever. Bialystok and colleagues believe that bilingual children in general were faster in the congruent condition and that they were better at controlling changes between trials. In order to test for that, additional studies included control conditions without conflict created by Simon Task. In the control conditions, there was no difference found in a reaction time between monolinguals and bilinguals (Bialystok et al., 2005a). The above study clearly demonstrates that studies with inconsistent children can be inconsistent.

Although many more studies have found advantages than disadvantages, one cannot forget about those studies that do not find any benefits of bilingualism. Sometimes even in the same task bilingual children can either show a superior performance or fail to show any differences when compared to monolingual children. It is possible that inconsistent findings might be a result of the particular composition of the group. Similarly to adults, in some groups of children, the benefit of bilingualism might be competing with other cognitive benefits and, as a result, effects are less pronounced (Valian, 2015).

Bilingual advantage in young adults

Although many executive functions, such as inhibitory control, develop in childhood, these different brain systems start to be better consolidated throughout adolescence. During this period, inhibitory control significantly improves as well as memory (Bialystok et al., 2005). As Bialystok claims, perhaps young adults are at the "developmentally peak age for cognitive control" (Bialystok et al., 2012). As a consequence, advantages for young bilingual adults are even less visible than those for young children.

For instance, Bialystok and colleagues (2005) administered a version of the Simon Task to undergraduate students. The study results showed that there was no significant difference in reaction time between bilinguals and monolinguals (Bialystok et al., 2005). Similarly, Salvatierra & Rosselli gave a Simon Task to young adults and found that there was no reaction time advantage for the bilingual group (Salvatierra & Rosselli, 2011).

Bialystok and colleagues (2008) conducted a study in which they gave a Stroop Task to undergraduate psychology students. The participants were divided into two groups: English speaking monolinguals and bilinguals. The study results demonstrated a cognitive advantage for bilinguals in a reaction time. However, when the Simon Task was given to the same group of participants, no cognitive advantage for bilingual students was found (Bialystok et al., 2008).

Similarly, Humphrey and Valian (2012) conducted a study in which they used participants who were undergraduate students with different language backgrounds. Some students were monolinguals, while others were proficient in two or more languages. Students were instructed to complete English proficiency tests and a language self-assessment task as well as Simon and Flanker tasks. The study results showed that there was no significant difference in reaction time between bilinguals and monolinguals on the Simon and Flanker tasks. There was also no significant difference between monolinguals and bilinguals in the Simon and Flanker effects. Moreover, there was no significant difference between trilinguals and other groups (monolingual and bilingual) on the Simon Effect. However, trilinguals had much longer reaction times and showed larger flanker effects in incongruent trials in comparison to monolinguals. This study demonstrated that there are no cognitive benefits for bilinguals. Trilinguals were even at a disadvantage because their reaction times were very large. However, as Valian and Humphrey note, this does not mean that there are no benefits of bilingualism or multilingualism. Perhaps teenagers and young adults are at the peak of cognitive processing so more demanding tasks are necessary to reveal bilingual advantages. According to Humphrey and Valian, it is necessary to remember that "multilingualism is not monolithic"; as a result, some factor such as age can have a strong impact on cognitive performance (Humphrey & Valian, 2012).

Humphrey and Valian also noted that benefits for bilingual young adults are more visible in tasks that are challenging and difficult. For example, Bialystok provided monolingual and bilingual undergraduate students with two Simon Tasks that were either less or more demanding because of the number of intertrial response switches in a block of trials. In the first task, participants had to press the right shift key when the square that appeared on the screen was red and the left shift key when it was blue. In the second task, participant pressed the right shift key when arrow pointed to the right and left shift key when it pointed to the left. According to Bialystok, "the arrow task produced more perceptual conflict than the square task because it requires the simultaneous activation of two spatial codes, one for each of the position and direction of the arrow. In that sense, the arrows task presents a competition analogous to that created by two language systems; performance depends on attending more directly to one representation than to a similar competing representation". The result of the study demonstrated that bilingual young adults were significantly better than monolinguals in the Simon Task, but only when the task required more monitoring and switching than a simple condition. Moreover, when bilingual individuals performed better than monolinguals, they did it in both conditions, congruent and incongruent. The study also included video-game players because clearly additional practice with video games can improve performance on the Simon Task. Interestingly, even video game players were not able to overtake bilinguals in the more demanding condition (Bialystok, 2006a).

There are more studies that reported advantages for bilinguals but only under specific conditions. For instance, Costa and colleagues instructed undergraduate students from the

University of Barcelona to perform different versions of the Flanker tasks in two experiments. In the first experiment, two undemanding Flanker Tasks were used in which the majority of trials were either congruent or incongruent. These tasks did not require much inhibitory control from participants because the same processes had to be engaged during the entire time. In the second experiment, two demanding Flanker Tasks were used in which trials were constantly changing from congruent to incongruent. There were either 50% congruent and 50% incongruent trials or 75% congruent and 25% incongruent trials. These tasks were more demanding because participants had to constantly monitor changes and adjust to them. The study results demonstrated that a bilingual advantage existed only in the condition that required high monitoring. The advantage was found in a condition where there were 75% congruent and incongruent trials. Nonetheless, this benefit also decreased over blocks of trials. Costa et al. argued that this advantage stems from a possession of a much more efficient monitoring system for conflict resolution. The authors further claimed that this system allows bilinguals to make a decision when the conflicting information can be ignored (Costa et al., 2009)

Another study used a nonlinguistic version of the Stroop Task in order to examine cognitive advantages in young bilingual adults. The authors used Catalan-Spanish bilinguals and Spanish monolinguals in their study. The age range was from 17 to 29 years old. In the experiment, participants were instructed to decide how many items appeared in each trial. The numbers ranged from 1 to 3 and participants had to press corresponding keys (1, 2, 3) on the keyboard with the index, middle and ring fingers. There were three conditions: 1) a neutral condition in which there were letters such as: A,BB, GGG; 2) a congruent condition in which digit values corresponded to the numbers of items in each trial (1,22,333); 3) an incongruent condition in which digit values did not correspond to the numbers of items in each trial. Hernández and colleagues discovered that bilinguals were faster than monolinguals in all experimental conditions. Bilinguals also had an enhanced Stroop facilitation effect in comparison to monolinguals. Furthermore, the Stroop interference effect was smaller for bilingual students, suggesting that these individuals might be better at conflict resolution (Hernández et al., 2010).

In another study, Luk, DeSa and Bialystok compared cognitive performance of monolinguals with bilinguals who began using two languages either early or late. Participants were undergraduate university students. The researchers used the Flanker task in order to observe the difference in performance. The study results showed that all participants were able to complete the task with high accuracy rates. There was no significant difference between monolinguals and late/early bilinguals across all conditions (congruent, incongruent, control). The Flanker effect was significantly smaller for early bilinguals in comparison to monolinguals and late bilinguals, who did not display any difference. Moreover, further correlational analysis demonstrated that the earlier one started to actively use two languages, the smaller Flanker effect was. This study demonstrates that an advantage for bilinguals increases gradually as a function of experience (Luk, DeSa& Bialystok, 2011).

In recent years, many researchers have started observing the bilingual brain in order to understand the mechanisms responsible for its processing of information. One study that was done by Assche (2009) found that brains of bilinguals function differently in comparison to monolinguals. According to this research, the knowledge of a foreign language can influence how we read in a native language. When we know the second language, we do not look in the same way at words that we read. The study tested a group of 45 students who spoke Dutch and who had learned English when they were 14-15 years old. Students were instructed to read texts in their native language which contained cognates (words that have similar meaning, for example “sport”).

In addition they were asked to read texts that did not contain cognates. The researchers observed their eye movements during the reading. They discovered that the students, on average, spent 8 milliseconds less on words that occurred in their native language as well as in the foreign language. They concluded that the brain processes words much faster when they exist in both languages, rather than in only a native language.

Luk, Anderson, Craik, Grady, and Bialystok (2010) conducted a study in which they used fMRI to examine the brains of young bilingual and monolingual adults performing the Flanker task. The study results did not demonstrate a significant difference in reaction time between bilinguals and monolinguals for all trials. The fMRI showed that in the control trials during incongruent and go/no-go conditions, participants activated the same parts of the brain, such as bilateral cerebellum, bilateral middle and posterior cingulate cortex, etc. The authors hypothesized that that there should be a difference between bilinguals and monolinguals in incongruent trials because these trials require interference suppression whereas there should be no difference in no-go trials because these trials require response suppression. As expected, the study results demonstrated that indeed there was no difference in no-go trials between the two groups. However, bilinguals and monolinguals displayed a significant difference in incongruent trials. It seems that the two groups process conflict trials differently because bilinguals have more practice at inhibiting distracting information (they are forced to deactivate the language that is not in use). Clearly, there is no difference in processing in no-go trials because bilinguals do not have to inhibit their response more frequently than monolinguals. Luk and colleagues claim that bilingualism modifies neural networks that have responsibility for better cognitive control of "nonverbal stimuli" (Luk et al., 2010).

Another similar study that used fMRI and adaptation of the Flanker Task in order to observe differences between monolinguals and bilinguals demonstrated that the two groups used a "different type of neural networks in congruent and incongruent trials"(Luk and colleagues, 2010). Further studies confirmed that the higher activity in the neural network of a bilingual is strongly related to faster reaction time on incongruent trials (Luk and colleagues, 2011)

Garbin and colleagues (2010) conducted a study in which they tested two groups of students, Spanish monolinguals and Spanish/Catalan bilinguals. The participants were introduced to a task that required them to pay attention to either colors or shapes. They were presented with two figures (a square and a circle) that could be red or blue. The study participants had to press one of two buttons using their right hand. In addition, they were instructed to press one button when the figure was a circle ("when the cue was shape") or red (when the cue was color) or another button when the color was blue or the figure was a square. Researchers observed brain activity as the participants were performing the task that was given to them. The results demonstrated a significant difference between monolinguals and bilingual on the task. Monolingual participants made significantly more errors and it took them longer to react to appropriate stimuli in switching trials in comparison to non-switching trials. Bilingual participants performed similarly in both trials. Brain activity was also different for the two groups. In switch trials in comparison to non-switch trials, the brains of monolinguals consumed larger amounts of oxygen in the left inferior pariental lobe, ACC and IFG. Surprisingly, this phenomenon was not present in the brains of bilingual students. Interestingly, the type of trial modulated left IFG activity in bilinguals. Moreover, in bilinguals, left IFG was more activated during switching trials in comparison to monolinguals. These findings suggest that bilinguals are better in cognitive control, and as a result, they perform equally well in switch trials and non-switch trials. Garbin and colleagues believe that monolinguals and bilinguals might have different brain networks that are often interconnected with the control of executive functions. In bilinguals, these different networks develop during the process of language acquisition. According to Garbin and colleagues, left IFG activity is involved in maneuvers between tasks. Higher left IFG activity in bilinguals allows them to switch between one task and another so that they are able to perform better than monolinguals. These findings suggest that early acquisition of two languages can "have a long lasting consequence for the establishment of the cognitive control network, leading to the involvement of language control brain areas in non-linguistic switching tasks" (Garbin et al., 2010)

Abutalebi and colleagues (2011) conducted research with two groups of students, Italian monolinguals and Italian-German bilinguals. The participants were given the Attentional Network version of the Flanker Task, and fMRI measured the participants' brain activity when they were doing the task. Although there was no significant difference between monolinguals and bilinguals in reaction time on congruent and incongruent trials, the results showed that some neural functioning areas in the brain were activated much more in monolinguals than in bilinguals. Abutelabi and colleagues also noted the involvement of the ACC area in cognitive control and task switching in bilinguals. The researchers discovered increased grey matter in this area for bilinguals but not monolinguals. It is possible that increased grey matter allows bilinguals to activate this part of the brain to a smaller degree than their monolingual colleagues (Abutelabi et al., 2011).

Many of the studies described above have demonstrated that overall bilingual advantages in young adults are very inconsistent. Researchers report small advantages (Luk, 2010), large advantages (Hernandez, 2010), or no advantages (Valian &Humphrey, 2012). Other researchers report that advantages exist only in tasks that are demanding (Costa et al., 2009). Some studies also indicate that, in certain circumstances, knowledge of more than one language might slow down performance. For example, trilinguals are at a cognitive disadvantage in comparison to monolinguals and bilinguals (Valian & Humphrey, 2012) Therefore, one might be tempted to claim that multilingualism brings more harm than good because, although it increases our performance in one area, it decreases it in another. Some studies suggest that our cognitive abilities are best at age 22 (Salthouse, 2009). Therefore, according to Bialystok, any potential benefits can become invisible when all young adults are at the "peak of their cognitive abilities" when the brain works as efficiently regardless of the number of languages that one speaks. Consequently, only in tasks that are very demanding can young multilinguals exceed and outperform monolinguals (Bialystok et al., 2012). This argument could be a possible explanation of why advantages for monolinguals and bilinguals become invisible in young adults. However, it does not take into account studies that did not observe any advantages in children and older adults. Children and older adults are not at the peak of cognitive abilities, however, more and more studies demonstrate that bilingual children and older adults do not outperform monolinguals on interference tasks. (Anton et al., 2014; Yang et al., 2011). These findings certainly create a serious challenge for Bialystok's explanation of bilingual advantages.

Bilingual advantage in middle aged and older adults.

A significant amount of research has shown that inhibitory control begins to decline in later adulthood (Bialystok et al., 2005). For instance, it becomes harder to ignore distracting stimuli and focus on the one that is relevant. Also, attentional processes function less efficiently, leading to poor detection and discrimination of stimuli (Bialystok et al., 2004a).

There have been many studies that examine executive inhibitory control in aging adults. For example, in one study, participants were either 30-45 years old or 60-88 years old. In addition, each age group was divided into monolingual English speaking participants from Canada and bilingual Tamil-English speakers. There were the same number of males and females in each group. Participants completed the Peabody Picture Vocabulary Test (a test that measures receptive vocabulary), Raven's Standard Progressive Matrices, and the Simon Task. The results demonstrated that bilinguals' overall performance was comparable to monolinguals on the Peabody Picture Vocabulary Test and Raven's Test, however, they were significantly better on the Simon Task. Furthermore, they also showed a smaller Simon effect (the incongruent items were less interfering). In the older group, monolingual participants committed more errors than bilinguals. Additionally, bilinguals in both groups were faster on incongruent trials. The bilinguals' advantage in speed was relatively small on congruent trials, but it still existed. Younger adults performed faster on incongruent trials in comparison to older adults (Bialystok et al., 2004a).

In another study, Bialystok and colleagues demonstrated that the aging process can profoundly impact the brain and cognitive processes. The experimenters divided participants into two age groups: 30 to 59 years old and 60 to 80 years old. Additionally, each group consisted of half English monolingual participants and half bilinguals who spoke English plus another language. In total, there were 40 participants in the study. The researchers controlled for age, education and language experience. Monolingual participants lived in Canada whereas bilingual participants lived in India. The Simon Task was given to all participants. The results of the study demonstrated that language group as well as age significantly influenced reaction times in this task. The older adults were slower in comparison to younger adults thus confirming the hypothesis that the aging process is responsible for cognitive decline. In addition, bilinguals in both groups were much faster than monolinguals in congruent and incongruent conditions. The fact that bilinguals were faster in the congruent cognition that did not have any misleading cues could suggest that bilinguals are overall faster. The experimenters conducted another study to test for this difference (Bialystok et al., 2005)

Bialystok, Martin and Viswanathan included a control condition where red and blue stimuli always appeared in the center of the screen. Participants only had to respond to the color of stimulus, so the position of the stimuli was irrelevant in this case. The experimenters used two groups of new participants. They were divided into two age groups. One group ranged from 30 to 59 years old whereas the other group ranged from 60 to 80 years of age. Also, half of the group consisted of monolinguals and half of bilinguals. The study was conducted in Hong Kong, India and Canada. The results again demonstrated a bilingual advantage over monolinguals in reaction time. Moreover, younger adults were significantly faster than older adults in all conditions. However, in the control condition there was no difference in reaction time between the language groups. In the experimental condition, generally bilinguals were significantly faster than monolinguals. This phenomenon occurred in each group. Bialystok and colleagues claimed that this difference is not a result of differences in speed but rather should be attributed to "differences in efficiency with which these two groups can make the response decisions in the experimental condition" (Bialystok et al., 2005).

Emmorey, Luk, Pyers and Bialystok (2008) used 45 adults in their study. The participants were divided into three groups, monolinguals, bimodal[1] and unimodal. A version of the Flanker task was given to participants. The study results demonstrated that there is no difference in reaction time and accuracy in the control trials between monolinguals, and bimodal and unimodal bilinguals. In the go, congruent, and incongruent trials, there was no significant difference between monolinguals and bimodal bilinguals, but unimodal bilinguals were faster than the others across all these trials. Emmorey and colleagues suggested that no difference between monolinguals and bimodal bilinguals might result from the fact that bimodal bilinguals often do not have to suppress one language when using another. Instead, they can use both languages simultaneously. Emmorey and colleagues also suggested that bilinguals might be at an advantage not only in terms of better inhibitory control but also in "other aspects of executive control, such as attentional mechanisms, monitoring processes, and task switching" (Emmorey, 2008). This argument stems from their finding that bilinguals performed better than monolinguals on the go/no-go task. Interestingly, it seems that bilinguals do not have to refrain from speaking more frequently than monolinguals. As a result, perhaps they have better attentional or monitoring ability that allows them to excel in the go/no-go task (Emmorey, 2008).

The cognitive advantage for bilingual older adults is not only limited to better inhibitory control; it seems that bilingualism can protect older people from early onset of memory problems and losses caused by dementia and Alzheimer's disease (Craik et al., 2010). Previous studies that were done by other scientists show an indirect relationship between knowledge of another language and Alzheimer's disease. Perquin (2012) found that the knowledge of more than two foreign languages protects the memory of seniors. This conclusion was based on a careful examination of 230 men and women who were an average of 73 years old and spoke a few foreign languages. Some of them suffered from abnormalities in cognitive functioning. According to Perquin, people who are bilingual are more often forced to speak both of their languages, and in doing so, they have to switch between languages and not confuse them. This process positively influences cognitive functions because it decreases the risk of problems with memory. Based on careful observation, Perquin concluded that patients who spoke only one language experienced cognitive problems four years earlier than those who were fluent in two or more languages.

Bialystok (2009) drew similar conclusions. She discovered that the brains of people who know foreign languages are better in dealing with dementia. Physicians noticed that their patients without second or third language abilities start having cognitive problems four years earlier in comparison to those that are proficient in more than one language. It is difficult to explain why, but CT scans revealed that the effects of dementia in the brains of monolinguals were in a much more advanced stage than in the brains of bilinguals. Surprisingly, both groups were at the same cognitive level and the same age (Bialystok, 2009).

Inconsistencies in the study of bilingualism.

For many years, it was unknown how learning a new language affects the brain and whether it gives any advantages to those who speak it. The majority of studies that were done in this area concentrated on negative aspects of being bilingual. Moreover, a large number of invesitgators claimed that there must be a correlation between bilingualism and negative scores on different measures of intelligence tests. Later, this trend changed as more and more studies claimed to demonstrate that multilinguals significantly outperform monolinguals in many cognitive tasks and that there might be at an advantage in some areas of cognitive functioning (Carlson & Meltzoff, 2008). For example, bilingual children and young adults were significantly better than monolingual children on conflict tasks, but they performed similarly on tasks that did not have distracting perceptual information. This pattern was observed in the Attention Network Task (ANT). (Costa and colleagues et al., 2008; Yang and colleagues, 2011)

Costa and colleagues conducted a study in which they administered the ANT task to two groups, Spanish speaking monolinguals and Catalan-Spanish speaking bilinguals. The task was a combination of the Flanker Task and four cue conditions. The results demonstrated that bilingual participants performed significantly better than monolingual participants on conflict tasks. For instance, both groups performed similarly on a congruent trial. The difference appears when the incongruent condition is added to the Flanker Task. As Costa indicates, this trend might suggest that only when greater monitoring resources are required do bilinguals respond faster. Interestingly, this advantage exists and affects subsequent trials even if they do not require conflict resolution. The advantage disappears when the Flanker task has only congruent trials. The results of this study indicate that differences between monolinguals and bilinguals exist only on conflict tasks. In comparison to monolinguals, bilinguals are not severely affected by interference coming from incongruent flankers (Costa, Hernandez, Galles, 2008).

Costa and colleagues administered the ANT task to monolingual and Catalan-Spanish bilingual speakers. Participants were instructed to indicate whether a target arrow pointed to the right or left. The target arrow could be presented below or above a fixation point. The central arrow was surrounded by four additional distracting arrows, two of them located on the right side and two on the left side of the central arrow. Distracting arrows could be compatible with the direction of the central arrow (congruent trials) or incompatible with the direction of the central arrow (incongruent trials). In addition, there was a neutral trial in which, instead of four arrows, there were four nondirectional horizontal lines. Before each trial, an orienting cue was presented to participants in order to indicate the position of the central target on the screen.

Bilinguals performed significantly better on the ANT task than monolinguals (Costa et al., 2008). First of all, bilinguals, in comparison to monolinguals, took more advantage of the orienting clue. In addition, bilinguals were faster than monolinguals on both congruent and incongruent trials. The switching cost was greater for monolinguals in comparison to bilinguals. Bilingual participants also experienced less interference from incongruent flankers in comparison to monolingual participants (Costa et al., 2008).

Yang & colleagues gave a version of Flanker Task to 4 year old bilingual and monolingual children. The Flanker task was specially modified in order to take into account the age of the children. The central stimulus was a fish surrounded by two fish on the left and two fish on the right. The central fish could be swimming in the left or right direction. Participants had to press the key compatible with the direction of the central fish. There were three conditions, congruent, incongruent, and neutral. In the neutral condition, the fish was not surrounded by other fish. In the congruent condition, all surrounding fish swam in the direction that was compatible with the central fish. In the incongruent condition, all flanking fish swam in the direction incompatible with the central fish. In addition, the ANT task was composed of four cues, no cue, a double cue, a central cue, and a spatial cue. The results showed that, overall, bilingual participants were significantly faster and more accurate than monolingual participants. The bilingual participants were more accurate than monolingual participants on the distracting incongruent condition. However, the researchers did not see any significant difference in reaction time between monolinguals and bilinguals on the congruent and neutral conditions (Yang, 2011). Similarly to Costa and colleagues' findings (2008), Yang (2011) discovered that only in tasks that involve conflict resolution did bilinguals tend to outperform monolinguals. In the trials that did not require greater monitoring resources, both groups performed equally well. The results suggest that bilinguals seem to possess some cognitive benefits that allow them to adapt better to resolve cognitive conflicts in the ANT task.

Other studies have found that bilingual adults are significantly better than monolingual adults on the Simon task, the Stroop task and the Flanker task (Bialystok et al., 2004; Bialystok et al., 2008; Costa et al, 2009). More of these studies will be discussed at length later in this paper. However, although much research shows benefits for bilingualism, other research has failed to find a difference between monolinguals and bilinguals. A careful examination of the prior literature shows that evidence for a bilingual advantage in executive processing is very inconsistent. As a result, it is not clear whether there are any cognitive benefits of being bilingual and, if so, to what extent bilinguals are at an advantage. For example, some research demonstrates that bilingualism helps the executive control network by making it more efficient, leading to a smaller cognitive cost on tasks such as the ANT task (Costa et al., 2008; Hernandez et al., 2012).

A similar pattern was discovered by Hernandez and colleagues (2010) in a study with 40 monolinguals and 40 bilinguals. Participants were instructed to look for “the only tilted line” in the target. Participants were informed to press the right key if the line was tilted towards the right and to press the left key if the line was tilted towards the left. The experiment had three conditions, WM, Identify, and Singleton. In the WM condition, participantsparticipants were shown a visual cue and were instructed to remember it. In the next part of this condition, participants had to discriminate other surrounding stimuli and look for the main target with a tilted line, and decide whether the line was tilted towards the right or left. After that, a visual clue appeared on the screen and participants had to decide whether the color and shape was the same as the initially memorized visual clue. In the identify condition, participants did not have to memorize anything. Instead, they were presented with two examples of visual clues and they had to compare them and decide whether they were the same or different. Just as in the WM condition, participants also had to look for the main target and identify its direction. The Singleton condition was similar to the WM condition; the only difference was that on some trials a singleton distractor was present – it was a geometrical figure that was usually bigger and had a different color and shape in comparison to other geometrical figures presented on the screen. The results demonstrated an advantage for bilinguals on this task. For example, it was easier for bilingual participants than for monolingual participants to ignore distractors and irrelevant information. Bilinguals were significantly faster than monolinguals on a visual search task. In addition, bilinguals displayed smaller cognitive costs and benefited from information preserved in working memory. Bilingual participants were not affected by irrelevant memory distractors. According to Hernandez et al. (2010), this suggests that the constant demand to ignore the irrelevant language in a particular context might benefit bilinguals.

Other researchers have found that bilinguals have better executive control skills and consequently demonstrate overall speed advantages in response times (Bialystok et al., 2004; Bialystok & Viswanathan, 2009). For example; Bialystok and colleagues (2004) gave the Simon Task to monolingual and bilingual participants. The participantsparticipants had to press the left key when they saw a blue square and the right key when they saw a red square. Half of the trials presented "square on the same side as associated response" (congruent trials) and half of the trials presented the square on the other side (incongruent trials). The findings demonstrated that bilinguals were significantly faster in comparison to monolinguals on the Simon Task. The bilingual speed advantage was more visible on incongruent trials, however, it still existed on the congruent trials. In addition, bilingual participants were affected by interference to a smaller degree than monolingual participants (Bialystok et al., 2004).

There is also research that finds bilingual benefits in some cognitive tasks but not others (Costa et al., 2009; Hernandez et al., 2010). For example, Costa and colleagues conducted two experiments in which they administered two versions of the Flanker task to monolingual and bilingual participants.

In the first experiment, participants received two versions of the Flanker Task, one in which the majority of the trials consisted of incongruent trials (8% congruent, 92 % incongruent), and the second version in which the majority of trials consisted of congruent trials (92% congruent, 8% incongruent). This task was relatively simple because it involved the use of the same repetitive processes; it was referred to as the low-monitoring condition. In experiment 2, different types of trials were mixed. In the first version, 75% of the trials were congruent and the rest were incongruent. In the second version, 75% of the trials were incongruent and the rest were congruent. This task was more demanding due to a constant need to switch between trials; it was referred to as the high-monitoring condition. Participants were required to indicate whether the central arrow pointed towards the left or right. The central arrow was presented along with four flankers, two located on the right side of the central arrow and two located on the left side. In the congruent condition, the direction of the flankers was compatible with the central arrow. In the incongruent condition, the direction of flankers was incompatible with the central arrow. Costa and colleagues found that bilinguals were faster overall than monolinguals on the Flanker task only when it required high-monitoring resources but failed to find benefits when the task required low-monitoring resources (Costa et al., 2009). Hernandez discovered that bilinguals were better than monolinguals on a Stroop task but did not outperform them on a visual cueing task (Hernandez et al., 2010).

Some studies have found no benefits of bilingualism in executive functioning (Paap & Greenberg., 2013., Paap & Sawi, 2014). Paap and Greenberg administered the Simon Task to 90 monolingual and bilingual participants. The participants were instructed to press the corresponding key as fast as possible and avoid making errors. The target could be located on the center, right, or left side. In the congruent trials, the target was located on the same side as the correct response on the keyboard. In the incongruent trials, the target was located on the side opposite to the correct response on the keyboard. There was no advantage in monitoring and inhibitory control for bilinguals. Bilinguals and monolinguals performed about the same on every block. In another experiment, using the Flanker Task, there was again no significant advantage for bilinguals. In fact, each block demonstrated a very small, insignificant disadvantage for bilingual participants (Paap &Greenberg, 2013). Paap & Sawi (2014) replicated the Simon Task of the previous experiment, similarly finding no significant difference between monolingual and bilingual participants.

When taken together, the studies described above are extremely inconsistent. Some studies show a bilingual advantage in one area of cognitive functioning and do not find it in another (Costa et al., 2009). Some studies do not find any advantage at all for bilinguals on cognitive tasks (Paap & Sawi, 2014), whereas other research claims that there is one (Bialystok et al., 2004). There are also studies that show a disadvantage for bilinguals (Paap & Greenberg, 2013). To sum up, review of the literature suggests that evidence for a bilingual advantage in executive processing in young adults is extremely inconsistent. This might stem from the fact that executive function is an abstract concept; as a result it is not yet clear how to measure it or define it. The same applies to bilingualism - there is a lack of clarity in how to measure it and define it. Moreover, a variety of factors might have an influence on executive functions, and they can often be beyond control

(Hilchey et al., 2011, Valian, 2015).

In the face of the challenges that inconsistent findings present, some researchers have suggested how to understand and approach them. For example, Valian (2015) proposed two logical alternatives that must be considered when investigating the existence of cognitive benefits for bilinguals. The first possibility is that indeed there are some advantages of being bilingual. However, these benefits are masked simply because there are so many other ways to improve executive functioning, such as by playing video-games. Therefore, benefits of bilingualism become invisible when competing with other benefits that bilinguals and monolinguals have. The second possibility is that there are no cognitive benefits for bilinguals. According to Valian, the experiments that have not found significant differences between monolinguals and bilinguals are due to a high number of other factors or benefits, for instance, high SES. Therefore, depending on the composition of a group of participants in a particular study, monolinguals might have more of these other factors or benefits than bilinguals, as a consequence masking benefits of bilingualism. Inconsistencies in studies might also stem from the fact that seemingly similar tasks might measure different aspects of executive function. As a result, researchers cannot with certainty decide which aspect of cognition they are measuring (Valian, 2015).

Since executive function is a broad term that describes many different aspects, such as inhibition, planning etc., there are numerous ways to improve it. Therefore, young adults, besides being bilingual, have many other ways that allow them to enrich their cognition. As Valian states "children and young adults engage in many cognitively challenging activities and […] those challenges are at least equivalent to the cognitive challenges provided by bilingualism" (Valian, 2015).

There are many activities that contribute to improvement of executive function,for example, musical experience. As Valian noted, studies show that monolingual musicians and bilingual non-musicians are better on the Simon Task when compared to monolingual non-musicians. Valian also listed education, exercise, video-game experience, socioeconomic status, leisure and social activities as factors that can potentially promote better cognition. Moreover there may be a wide variety of other mechanisms that enhance executive function and which are yet to be discovered. Since young people and children engage in many of these cognitively enriching activities, the evidence for bilingual advantage often becomes invisible in this age range. Monolinguals are able to compensate for their lack of a second language with other equivalent activities. As a result, they perform similarly to bilinguals on interference tasks (Valian, 2015).

To summarize, according to one of Valian's hypotheses, if bilinguals' advantages in executive processing really exist, they are masked by other factors and activities that are just as cognitively challenging as speaking another language (Valian, 2015). Therefore, perhaps one way to detect any benefits for bilinguals is to create a task in which bilinguals could excel and outperform monolinguals. If there are any cognitive benefits for bilinguals, they should manifest themselves only in tasks that are extremely demanding. One of the tasks that can offer challenges and perhaps detect any potential benefits is a standard executive function task that is preceded by an ego depletion task.

Ego Depletion Theory and Ego Depletion Tasks

Ego Depletion is the idea that our ability to control emotions, behavior, and desires is based on a fixed amount of resources that are available to us at a given time. Thus, the ego depletion phenomenon occurs when a person is deprived of personal resources due to previous acts of the self that require effort; as a result of that, a decrease can be observed in his or her performance.

More interestingly, in accordance with this idea, personal resources tend to recover very slowly, and the exhaustion of this so called "ego strength" can reduce the amount of energy that is available for future self-control. In addition, the amount of energy that one possesses determines the success of willpower. For example, when resources are depleted, performance is more likely to decrease to a minimum, whereas when there is much ego strength available, the ability to cope with temptation is high (Muraven, 2011).

The concept of ego depletion can be traced back to Sigmund Freud, who claimed that personality is divided into three parts, the ego, superego, and id. According to Freud, an ego mechanism is responsible for controlling and maintaining a balance between the basic desires of id and moral norms of super ego. If this balance is disturbed in some way, conflict occurs and problems start to appear. Freud believed that the ego needs to possess some kind of energy to perform the task it has been given (Baumeister et al., 1998).

The idea of ego depletion is tightly related to self-control. Self-control distracts us from temptations and directs our attention toward other goals and ambitions. Self-control (also known as willpower) is defined as the mental capacity to overcome impulsivity in our emotions, behaviors and thoughts. This unique capacity distinguishes humans from other creatures. Self-control is highly dependent on controlled processes to regulate impulses and maintain attention. Dysfunctional self-control leads to social problems such as obesity, criminality, drug abuse, debt problems and many more. Therefore, it is no wonder why self-control is such a frequently investigated phenomenon (Inzlicht & Schmeichel, 2012).

The first study that examined willpower and self-control was in the 1960s and is known as "the marshmallow test". The author of the research, Walter Mischel and colleagues (1989), seated pre-school children alone at a Table and presented them with an object of desire, such as a marshmallow. Before the experimenter exited the room, he gave participants two options. They could either ring the bell calling the experimenter to the room and eat one marshmallow upon his coming back or they could wait until the experimenter decided to come back by himself and be rewarded with two marshmallows instead. The experimenter discovered that some children were not able to wait even one minute and labeled them with the term "low delayers" while others waited up to 20 minutes ("high delayers") using various distracting techniques. In the next experiment, the experimenter told children to imagine that what they saw in front of them was a cotton ball instead of a marshmallow and in this way he improved their performance. A follow-up study, conducted a few years later via self-report, demonstrated that the children who were able to wait more for the reward were better adjusted. For example: they had better academic achievements, a lower divorce rate, and better health in comparison to those participants who were labeled as "low delayers". Mischel showed that children can learn willpower and that it may serve as an advantage in the future. His experiment also opened the route to studies on mechanisms underlying self-control (Lehrer, 2009).

Presently, many researchers study ego-depletion phenomena because it plays a significant role in understanding processes that are responsible for self-control and lack of it (Muraven, 2007). The majority of studies that investigated ego-depletion theory come from Roy Baumeister, Mark Muraven, and colleagues. In addition, Baumeister, Muraven, and colleagues were the first to demonstrate direct experimental evidence of this phenomenon (Inzlicht & Schmeichel, 2012).

An insightful study that was done by Baumeister, Bratslavsky, Muraven, and Tice (1998) provided evidence of ego depletion by illustrating that executive function in humans is highly dependent on the amount of personal resources that are available. In this experiment, Baumeister and colleagues used an ego depletion task in order to demonstrate that it has the capacity to deplete one's personal resources (Baumeister et al., 1998).

The participants were 67 introductory psychology students. The participants were deprived of food for many hours in order to be later presented with a bowl full of radishes and chocolate cookies. There were three conditions in the experiment: radish eating, chocolate eating, and non-eating. In the first condition, participants were allowed to eat a few pieces of radish; in the second condition participants received permission to eat a few pieces of candy; and in the non-eating condition participants did not eat anything. In addition, participants were instructed to solve some unsolvable geometrical puzzles and they were also told that they could quit trying to solve the puzzles at any time. As expected, the smell and sight influenced responses of the participants. Participants in the radish eating condition quit solving the puzzle much faster than participants in the other conditions. The participants in the control group and chocolate eating group performed similarly. Moreover, participants in the radish eating condition reported feeling tired more frequently than did the others. This result provides evidence for ego depletion theory. The subjects in the radish condition had to resist the temptation to eat chocolate chip cookies; as a result they invested all of their energy in this activity, thus decreasing their psychic energy. Since they were deprived of mental resources faster than the other groups, they decreased their determination and persistence in solving the geometrical puzzle (Baumeister et al., 1998).

The purpose of the next experiment by Baumeister and colleagues was to see whether ego depletion can also decrease performance in tasks that are solvable. This experiment had two conditions. In the first, the participants were instructed to suppress their emotions while watching a movie, whereas in the second condition the participants were told to do the opposite. Also, half of the participants in each condition were shown a sad clip whereas the other half watched a humorous clip. After watching the movies, the participantsparticipants were given anagram letter sets to solve. The results of the study again showed that an ego deprivation task can impair the ability of the participants. The participants who were instructed to suppress their emotion solved significantly fewer anagrams in comparison to those who were in the no-emotion regulation condition. The type of clips that the participants watched did not influence their solving ability. This experiment demonstrated that self-regulation can use up a lot of energy and worsen performance even on solvable tasks (Baumeister et al., 1998).

A similar finding was discovered with children in Muraven and colleagues' research. Children who were forced to resist the temptation of playing with a nice toy were significantly worse in being able to use self-control in comparison to those that did not have to inhibit their temptation. Their worst self-control was manifested in their inability to draw a line slowly, in comparison to children who could play with a nice toy. Also, this research showed that modification of emotions or mood did not change these effects (Muraven et al., 1998).

All of the above experiments led Baumeister to a conclusion that our will power, like a muscle, and can be fatigued. More interestingly, there are many ways to deprive people of it and discourage them from continuing their task (Baumeister et al., 1998). For example, in one of the experiments, Baumeister and colleagues showed that tasks that require the use of self-control can deprive people of energy resources. The experimenters divided college students into three groups. One group was instructed to give a speech that supported tuition hikes at their college, another group had the option to talk either against or for tuition hikes, and the third group proceeded to the next task without giving a speech. The next stage of the experiment involved solving an unsolvable puzzle. The results demonstrated that even a simple choice that participants had to make can absorb their energy. Participants who selected the speech that supported a raise in a tuition, when given the option, gave up significantly faster on the puzzle in comparison to participants that did not have the choice and to participants who proceeded to the next task. Also, the participants who selected the speech against a tuition rise spent less time on the unsolvable puzzle. The experiment shows that making a speech that is contrary to someone's beliefs system does not necessarily cause ego exhaustion. Moreover, these findings suggest that any choice at all is able to cause ego depletion and reduce the performance of participants (Baumeister et al., 1998).

One more experiment done by Baumeister and colleagues showed that self-control can also wane as it is used. The experimenters utilized the famous Stroop task in order to examine self-control. The findings showed that participants who perform many tasks in a row that require self-control have a tendency to do worse as time passes (Baumeister et al., 2007).

Gailliot believed that it is possible to find even more direct evidence for ego depletion. As a result, he started investigating the relationship between glucose and self-control. In one of his experiments, participants watched a silent video that presented a woman talking, with different unrelated words shown in the lower right corner of the screen. The experimental group was told to ignore the words as much as possible, whereas the control group could watch the movie without any special instruction. The glucose measures of all participants were taken before and after the movie. Not surprisingly, people who had to ignore the set of words had significantly lower glucose levels in comparison to those who could watch the movie without any restrictions. Moreover, in another experiment, participants received either Kool-aid with sugar or with Splenda after watching the movie. Then they received a set of tasks that measured self-control such as Stroop Task, etc. The results showed that people who got their energy replenished did significantly better than those who only thought that they drank the energy boosts. According to Gailliot, mental resources can be strengthened by eating and drinking before a challenging task (Gailliot et al., 2007). However, other studies indicate that food and drinks are not the only solution for replenishing depleted ego or maintaining resources of energy. Researchers discovered that regular exercising in self-regulation is an excellent way to become less vulnerable to ego depletion (Baumeister et al., 2006). For example, participants who kept track of what they ate significantly improved their self-regulation (Muraven et al., 1999). Also, self-awareness increased one's chances of not becoming ego-depleted (Hugo and colleagues, 2011). Moreover, the role of rest, good sleep, and positive emotions cannot be underestimated (Tice et al., 2007).

As Tice claims, the good news is that ego depletion cannot last forever; otherwise, a human's ability to control desires, behavior ,and emotions would be diminished over time. Ego depletion is often related to physical tiredness (Tice et al., 2007). For example:, participants in Baumeister and Muraven's study (1998) who were exposed to an ego-depleting task reported exhaustion, whereas those who were not exposed to such a task did not feel any tiredness. Even more evidence showing an interrelationship between ego depletion and physical tiredness emerges from studies that discovered that ego depletion tasks require effort. This was shown in a lower heart rate, drop in glucose, or weaker error-related negativity[1](Vohs et al, 2011) (Inzlicht & Gutsell, 2007).

On the other hand, some studies show that the state of ego depletion does necessarily have fatigue as an essential variable. For example, participants who were ego-depleted experienced prolonged perception of time, which is characteristic of a psychological state rather than exhaustion (Vohs et al., 2011). Although there is clear indication that ego depletion and exhaustion are somehow related, Baumeister and colleagues warn us against treating those two terms

[1]Error Related Negativity is an electrical brain signal often linked with activity in the anterior cingulate. Participants who were ego depleted performed significantly worse on the Stroop Task, a deficit which was correlated wih weaker Error related negativity (ERN) signals.

interchangeably. The experimenters believe that "fatigue is only a marker for the strength of the self-control resource" (Webb & Sheeran, 2003). Also, Muraven (1998) suggests that physical tiredness might serve as a motivational cue informing an ego-depleted individual that there is a need to conserve self-control resources (Muraven et al.,1998). However, neither Muraven nor Baumeister have provided scientific evidence for their claim.

Only Vohs and colleagues (2011) were able to demonstrate that ego depletion is different from fatigue. In one of their studies, participants were assigned to two conditions, a rested condition and a sleep-deprivation condition. Participants in the rested condition were allowed to sleep throughout the entire night, whereas participants in the sleep deprivation condition did not sleep for even one minute throughout a period of 24 hours. Instead, they could watch movies or perform some other activities. Next, participants were again divided into two groups, ego depleted versus non-ego depleted, and they watched two disgusting movies. Participants in the ego depletion condition had to remain neutral whereas participants in non-ego depletion condition could behave freely. Later, they were exposed to a task that measured their aggression. The participants had to play a game by pressing a key faster than their opponent. Before each trial, individuals could select a level of volume. If they were better, that level of volume would strike the opponent. In order to provoke, the opponent (the computer in this case) stroke participants with the level of volume that was one unit higher if it was faster. The measure of aggression was the choice of volume that the participant made. The results supported two conclusions. First, although the majority of data supports the idea that ego-depleted participants are often in a state of physical exhaustion, depletion of resources is not "tantamount to fatigue." The evidence for that comes from the study results. The participants who were ego depleted were not able to inhibit themselves and behaved aggressively. At the same time, people who were sleep deprived did not display aggressive behavior. These data show that one's sleep state is not a good indicator of aggressiveness. In this particular case, aggressive behavior is a direct result of the amount of resources that one possesses (Vohs at., al, 2011).

Since this phenomenon is so tightly related to the state of physical tiredness, the assumption that periods of rest, naps, or relaxation might help in restoring self-control resources would not be irrational. The studies undeniably imply that rest can boost performance of participants. A study by Tyler and Burns (2008) introduced a period of relaxation after an ego-depleting task. The findings confirmed that ego depleted participants who were given the opportunity to rest after the task did significantly better on the subsequent task in comparison to those who did not have this opportunity. Their participants had to squeeze their non-dominant hand as strongly and as long as they could. This action is a good measure of self-control because one must maintain squeezing while inhibiting the urge to stop and relax. In the later part of the study, participants were divided into two conditions, ego depletion and non-ego depletion, and also to an interval condition (1, 3, 10 minutes). In the ego depletion condition, the participant had to stand on their weaker leg when doing complex arithmetic problems such as counting down from 2000 by sevens, whereas participants in the non-ego depletion condition had to count down from 2000 in multiples of 5 but were not required to stand. This activity required the use of self-control in the ego-depleting condition because the participants had to inhibit their urge to quit the task in order to make better responses, so they were forced to maintain balance between standing on one leg and answering appropriately on the mathematical tasks. The experimenter instructed them to stop and right after this task gave them a questionnaire. Participants then were divided into three additional groups. The first group had only 1 minute to complete the questionnaire. The second group had 3 minutes to complete the questionnaire. The third group had 10 minutes to complete it.

When the time had passed, and the experimenter re-entered the room, none of the experimental participants could have completed the questionnaire on time; as a result, they did not have time to rest. After this task they were required to repeat the squeezing task from the first part. The results demonstrated that a 10 minute interval between two self-regulatory tasks refueled depleted ego. The performance of depleted participants after a 10 minute interval was comparable to that of those who were not ego-depleted; however, this effect was not found for 1 and 3 minute intervals.

Consequently, in the second experiment Tylerand Burns (2008) investigated conditions under which the participantsparticipants would be able to replenish depleted resources. The participantsparticipants were divided into depletion and non-depletion conditions as well as into relaxation or control conditions. They were instructed to complete a thought-listing task. In the ego depleting conditions, participants had to write down anything that came to their mind, but they were also instructed to avoid thinking about a white polar bear and to write a check mark on the list anytime a thought about a white bear did occur. In the non-ego depleting condition, participants only had to write down their thoughts. After 6 minutes, participants were told to terminate and forget about the task. Additionally, in the relaxation conditions, they were instructed to relax as much as they could while listening to a CD whereas in the control condition participants did not listen to anything; they simply waited for another task. After 3 minutes, participants were told to complete a mood questionnaire, and they proceeded to another task upon successful completion. In this part of the experiment, the participants used a multiplication task that required solving multiplication of three digit numbers by hand as long as they wished. This task is considered ego-depleting because participants find it to be extremely boring, and they have to continue this task in spite of their consistent urge to terminate it. The time they performed this task was measured. The results showed that the participantsparticipants who were told to concentrate on relaxation were able to replenish their depleted ego during the period of three minutes. However, as the authors of the study emphasize, the interval must include concentrated effort to relax. In fact, when ego depleted participants were allowed to relax, their performance increased so significantly that they did better than a less-relaxing control group on the consecutive task. Their performance was comparable to participants that were not ego depleted (Tyler & Burns, 2008). Based on this study, Tyler and colleagues concluded that "restoration of self-control capacity is proportional to the duration of recovery period" (Wood, 2010).

Nevertheless, some researchers believe that it is highly unlikely that one can deplete a limited pool of mental resources and as a result impair self-control. For instance, as Muraven has pointed out some people who fail at self-control are still capable of maintaining at least some level of control. Therefore, researchers need to incorporate a role of motivation when discussing the theory of ego depletion (Muraven. 2011).

Researchers demonstrated that motivation can play an important role in self-control. A good example of this is a study conducted by Muraven, Pogarsky and Shmueli (2006). Participants were assigned to two conditions. In the control condition, participants had to type some text on a computer. In the experimental condition, participants had to type the same text but they had to avoid using the space bar and the letter “e”. This task was ego depleting because participants had to avoid using the most frequent characters in English and therefore the task required inhibition. On the subsequent task, both groups of participants had to solve three logic puzzles, and they were given only three minutes to complete this task. Some participants were instructed to provide information that could allow researchers to identify them, such as their name. Other participants could remain anonymous. Researchers discovered that participants who were ego depleted lied and cheated on the task much more often in comparison to participants who were not ego depleted.

Nevertheless, ego depleted participants lied only under circumstances when they believed that it was highly unlikely they could "get caught". However, when ego-depleted individuals believed that it was highly probable they could get caught, they did not use deception (Muraven et al., 2006).

In another experiment, Muraven and Slassareva (2003) again divided participants into two groups and introduced an ego depleting task. Participants in the control condition were instructed to watch a movie whereas participants in the ego depleting condition had to suppress their emotion while watching the same movie. In the subsequent task, participants received money "based on self-control performance". The ego depleting group that was paid performed just as well as participants who were not ego depleted. For instance, ego depleted participants who were paid 1 cent for a cup of a vinegar flavored drink drank fewer cups in comparison to those who were not ego depletion. However, when participants received 25 cents per cup, the ego depletion group drunk as much as those who were not ego depleted (Muraven and Salssareva, 2003).

The results of the above study indicate that people are able to overcome ego depletion when they are sufficiently motivated. Therefore, problems with self-control might stem from low motivation (Muraven, 2011).

In recent studies, Baumeister's theory of willpower has been challenged. Many studies failed to find any evidence for the existence of ego depletion. For example, in one study, researchers recruited 200 participants from the University of Colorado. They replicated the video-viewing attention control task. Participants were divided into two groups and instructed to watch a short video. One group had to ignore words that appeared in the corner of the screen whereas the other group could watch the movie freely. In the next part of the experiment, participants were given the task that was considered to be ego depleting because it required the use of executive functions. Participants had to verify if simple mathematical calculations were correct. In order to do so, participants had to read the equation out loud and decide if the result was true or false. Depending on their answer, the experimenter pressed true or false on the keyboard and entered one target word, for example "lamp". This word appeared on the screen so that participants could see it for 750 ms after each equation. Later, participants were asked to list aloud all words of that trial in correct serial order. The proportion of the words that participants were able to remember was the dependent variable. Researchers used very strict inclusion criteria in the study and recruited more participants in order to account for confounding factors and to detect smaller effect sizes. The study results did not reveal any significant differences between participants. The researchers suggested that the current literature that focuses on ego depletion phenomena might be biased because it promotes studies that favor Baumeister's theory of willpower and excludes any studies that are not able to demonstrate significant results. Therefore, there is a tremendous pressure on researchers to contribute to the literature that favors ego depletion (Lurquin et al., 2016).

Those who examine ego depletion phenomena encounter similar conceptual problems as researchers who study cognitive control. Unfortunately, researchers do not have a consistent definition of self-control and therefore cannot explain why they decide to use a self-control task in some studies but not in others (Lurquin, 2016). In my opinion, it is necessary to remember that currently researchers are forced to define abstract variables and operate on concepts that are not very well understood. As a result, inconsistent findings will be a major problem until one finds an operational definition that is precise and well grounded.

Ego depletion and multilingualism

An interesting theory by Green (1986) suggests that language use can be perceived as similar to any other action that requires skill. As a result it can be deprived of its mental resources. Consequently, speaking one language requires the activation of a target language and the suppression of another language. Green further claims that there must be an operational system that has responsibility for activation and suppression of our speech. Furthermore, this system has a limited amount of energy, so when resources are consumed they directly affect subsequent activities. Although Green's theory does not have any scientific evidence to support it, it's extremely similar to ego depletion theory developed by Baumeister (2006) and also somewhat similar to Bialystok's theory. Bialystok and Green both suggest that bilingualism enhances inhibitory control. They also both believe in the existence of a system or mechanism that controls activation of two languages. However, Bialystok also suggests that bilinguals have not one but two representational systems in the brain, whereas monolinguals have only one representational system. Bialystok also claims that these systems remain active competing with each other (Bialystok, 2009).

Just as Green does, Grosjean (1989) believes that one language must be inhibited when the other one is in use. A good example of that can be seen in a study by Grainger and Beauvillian (1987), who discovered that people who had to activate two languages (a task that required a great deal of effort) were significantly slower in reading words compared to those who had to activate only one non-native language. Grainger and Beauvillian were convinced that this experiment served as evidence that in the use of two languages one language needs to be suppressed, which absorbs mental resources, whereas in the use of one language there is no need to suppress another one. Grainger and Beauvillian used participants who were equally fluent in both languages, which might suggest that this task would be even more difficult and would absorb more energy for those participants than from those who were dominant in one language over another (Grainger &

Beauvillian, 1987).

Studies suggest that interference and the necessity to suppress the more dominant language can vary in degree. Clearly, age seems to be a good predictor of the amount of interference in the second language. Guion and colleagues (2000) demonstrated that English-Korean and English-Italian bilinguals who emigrated at an early age had experienced significantly less interference in the use of the second language in comparison to those who had arrived later. The experimenters operationalized interference in terms of the length of time that is needed to read the assigned sentences. As the authors claim, the more time participants were exposed to their native language, the more interference can be expected in their second language, in this case English. Obviously the process of speech production takes away more resources to suppress the well-established native language (Guion et al., 2000).

Major hypotheses

There are two main hypotheses that explain how bilinguals are able to navigate and control two activated languages so efficiently that they outperform monolinguals on interference tasks.

The bilingual inhibitory control advantage (BICA) hypothesis

This hypothesis suggests that in order to be able to selectively attend to one language or another, brains of bilingual people must place some additional demands on a domain-general aspect of executive control (Hilchey and Klein, 2011). In accordance with this assumption, both languages are activated at the same time in response to stimuli. In addition, it does not matter whether there is an actual need to activate both languages simultaneously; they are activated even when one or the other is irrelevant to the speaker's context. As a consequence, the inhibitory system is forced to react by suppressing irrelevant information. There are some findings that support the BICA hypothesis. For instance, studies have demonstrated that bilinguals perform significantly worse than monolinguals on lexical-decision tasks, with slower lexical retrieval in bilinguals.

The BICA hypothesis is based on the assumption that the executive control mechanism that is responsible for inhibiting distracting information inhibits a language that is activated and is irrelevant. In accordance with this assumption, participants perform better and faster on interference tasks in incongruent trials because these tasks contain distracting information (Hilchey& Klein, 2011).

The bilingual executive processing advantage (BEPA) hypothesis.

This hypothesis is based on the assumption that bilinguals show reaction time and general processing advantage in interference tasks via domain-general executive functioning. In accordance with this hypothesis, it is not inhibitory processes but central executive functioning that improves efficiency when languages compete for selection. Although, aspects of executive functioning that are responsible for this bilingual advantage are unknown, researchers suggest that there must be some global conflict monitoring system that is in charge of this task. This system regulates cognitive control by supervising processes in different brain regions. According to this hypothesis, the bilingual advantage should be present in a task that requires executive functioning. For instance, bilinguals should be faster than monolinguals in interference tasks. They should outperform monolinguals on incongruent and congruent trials. There is a a great deal of evidence that supports this hypothesis. For example, there is a clear advantage in reaction time for bilinguals in difficult tasks and nonlinguistic interference tasks. Moreover, this advantage starts early in childhood and lasts throughout adulthood (Hilchey and Klein, 2011).

Nevertheless, it is important to notice that a more recent paper by Klein suggests that neither the BICA nor the BEPA hypothesis is correct. According to Klein, nowadays more studies discredit the BICA hypothesis than support it. Klein also believes that publications demonstrating support of the BEPA hypothesis might in fact be biased due to the so called “replication crisis”. Some researchers have a tendency to favor a view that is shared by experts in the field of bilingualism, and often even replicate data supporting the BEPA hypothesis. As a result, although numerous publications have already discredited the BEPA hypothesis, they are unnoticed because the data was produced by less known researchers. Klein also mentions Valian’s recent paper (2015) in which she suggests that studies are very inconsistent, especially with young adults, and therefore, as Klein believes, one should remain neutral when answering a question about potential benefits of bilingualism (Klein, 2015).

Rationale for the present study

The review of the previous literature demonstrates that some studies find cognitive benefits for bilinguals whereas other fail to do so. Perhaps, as Valian (2015) suggests, being bilingual is only one of many possible skills that might improve cognitive functioning. One should not forget that there are many other skills and activities that might be just as cognitively enriching as being bilingual. As Valian (2015) claims, the benefit of bilingualism "competes with other benefits that both mono- and bilinguals have to varying degrees" (Valian, 2015). As a result, it is not surprising that bilingual participants outperform monolingual participants only in tasks that are extremely challenging. Tasks that require greater monitoring and self-control offer much more room for improvement for bilingual participants in comparison to those that are relatively easy.

One task that requires self-control, is challenging and can reduce subsequent performance of a participant is called ego depletion, a “test of response-suppression and delay-of-gratification". This study aims to use the ego depletion tasks in order to impair self-control of monolingual, bilingual and trilingual participants. An ego depletion task should have a hindering effect on a subsequent Flanker task and reduce performance of all participants. However, bilingual participants should be able to outperform other language groups on this cognitively demanding task. The current research uses an ego depletion task that precedes an interference task in order to investigate cognitive differences between monolinguals, bilinguals and trilinguals. This study tests the prediction that bilingual participants can perform better on tasks that are cognitively demanding such as interference task after being ego-depleted because they are in possession of a better self-regulatory system.

Method

Participants

The study was conducted in New York City. Participants were recruited from an undergraduate introductory psychology class. They participated in the study in exchange for a course credit. The total number of participants was 220. However, technical problems as well as incomplete responses of some participants led to the loss of data for 24 participants. Therefore, there were 196 participants who satisfactorily completed the study.

Participant exclusions

The participants' ages ranged from 18 to 38. However, the majority of the participantsparticipants were young adults. The mean age was 19.62 years, the median was 19, and the mode was 18. Over 95.9% of the sample was 25 years old or younger. Eight participants were excluded from the analysis due to their age being over 25 years. In addition, one participant was excluded because they did not report their age. These nine excluded participants represented approximately 4.1% of the original sample size. Since reaction times have a tendency to be faster during the period of childhood and then begin to decline in late adolescence, age could be a potential confound in the study (Bialystok & colleagues, 2004). Therefore, older adults could inflate reaction time means. As a result, it was reasonable to exclude these relatively few older adults from the study.

In addition, one participant was excluded due to a failure to complete the Flanker Task properly. Moreover, since a few outliers can have a tremendous impact on the estimate of the standard deviation and can distort the mean, a cutoff score of $z= 2$ was established for the Flanker reaction time mean. Three participants whose overall mean reaction time on the Flanker task exceeded the cutoff were also excluded. Also, one participant had to be excluded from the study because of a failure to understand the image naming task. Instead of naming the picture, the participant kept pressing the Enter key throughout the entire task. In addition, for technical reasons, data for one participant was removed because it could not be extracted. Moreover, the data for one participant was inconsistent. The participant had a very low score on image naming task as a result of pressing Enter 16 times out of 45; however, he got a perfect score on MTELP (45 out of a 45 possible), which might suggest that he did not understand the image naming task; therefore he was excluded in the final analysis. The data of four participants were excluded due to technical problems in extracting the e-prime data files for MTELP and the image naming task.

Four additional participants were excluded from the survey because of inconsistencies in their responses. One participant for example reported that she started learning English when she was 15 years old. Yet, when asked if she spoke a second language she responded no. She rated English twice and she emphasized that she felt most comfortable speaking Chinese. Another participant started learning English when she was 12 years old. She rated English twice, she indicated Spanish as her third language and she reported that she felt most comfortable speaking Korean. Another participant claimed to be monolingual, but he moved to United States from China when he was 17 years old. His English childhood average was 1.5 and his adult English average was 3.75, which suggest that he had to speak another language besides English.

There were 134 female participants and 62 male participants in the study. Most participants were right handed; there were only a few left-handers in the study. The majority of the participantsparticipants had completed some college.

Forty-four participants reported speaking just one language, 121 reported speaking two languages and 29 participants reported speaking three languages.

A number of participants were born outside the United States. These participants were born in: Azerbaijan(1), Bangladesh (3), Bulgaria(1), China(13), Czech Republic(1), Dominican Republic(2), Germany(1), Guyana(2), Indonesia(1), Iran(1), Jamaica(2), South Korea(7), Mexico(1), Tibet(2), Pakistan(2), Peru(2), Philippines(1), Poland(1), Puerto Rico(1), Russia(4), Thailand(1), Trinidad and Tobago(1), Ukraine(3), United Kingdom(1), Venezuela(1). Four participants did not specify their country of origin.

Materials

Upon arrival, participants completed the consent form that described the study details. First, the participantsparticipants were directed to a computer. The experiment started when they were requested to follow the instructions that appeared on the screen at the beginning of each task. Each task, except the ego depleting task, consisted of a practice session and an experimental session. Participants were divided into three groups: control, mild ego depletion, strong ego depletion. Participants in the mild and strong ego depletion groups completed one of the two versions of the ego depletion task, two language proficiency tasks, three interference tasks and a survey on the computer. Participants in the control group completed the same tasks, except for the ego depletion task. The language tasks included an image-naming task as well as the Michigan Test of English Language Proficiency (MTLP), also called the Michigan Test Battery. The ego depletion task was in the form of a ball tracing game. The interference tasks consisted of Flanker and go/no-go tasks. All tasks were performed on the computers using E-prime software, versions 1.0 and 2.0 (Psychology Software Tools, Inc.). Once participants completed all required tasks, the experimenter opened an online survey collection service. Then, the participantsparticipants were asked the name of each language they reported speaking as well as the age when they started learning the language. The experimenter entered these data into the online survey and allowed the participants to complete the rest of the survey by themselves. The survey was administered via an online survey collection service, surveygizmo.com. The tasks were presented in the following order: ego depletion, Flanker, go/no-go, image naming, and MTELP survey.

Ego Depletion Task (mirror tracing game). Once participants completed the consent form, they were instructed to press the mouse button and follow the instructions that appeared on the computer screen. The instructions informed participants that their task was to move the cursor from the start box to the end box while staying inside of the path. They participantswere requested to click the mouse in order to start the task. The participants saw a geometric figure in the shape of a star on the screen. Inside of the star there was a smaller star. As a result, there was a path created between these two stars. The figure had a start box on the top and an end box also on the top. See the figure number 3 in the Appendix. Participants also saw a cursor that was in the shape of a green ball. The star shaped path was surrounded by black lines. Participants had to move the cursor to get from the start box to the end box while staying inside the designated path. The end box was on the right side of the start box so basically participants had to follow the longest path to get there. If they moved the cursor outside the black lines, the path would disappear and they would have to start over at the start box. The would also have to start again if they tried to approach the end box from the right side. The task was different for the mild ego depletion group and the strong ego depletion group. In the mild ego depletion group, the direction of the mouse corresponded to the direction of the cursor on the screen (left was left, up was up etc.). In the strong ego depletion group, the up and down directions were reversed, so that down became up and up became down whereas left and right directions stayed the same. Whenever participants were able to complete the task and get to the end box, another path in the shape of the star would appear on the screen. The only difference was that the designated path each time got smaller, which required more precision and attention from participants. After 5 minutes, the program automatically turned off the game and a set of instructions appeared on the screen that instructed participants to call the experimenter. The game was relatively challenging for the strong ego depletion group because it required more alertness and cognitive control from participants. In this game, participants were forced to reverse direction; as a result, they had to inhibit naturally occurring responses. In order to perform the actual task go to the link: http://pfeyz.com/ego_shapes/ .

Researchers have demonstrated that this task is ego depleting. Fennis, Janssen, and Vohs (2009) used a similar mirror tracing task, in which participants in the experimental condition had to trace the geometric figure with their left hand without looking at their hand. They discovered that this task consumed a large amount of mental resources from participants, thus making them more susceptible to sales tactics (Fennis et al., 2009).

The Flanker Task and go/no-go tasks.

Flanker and go/no go tasks were administered through E-prime software, versions 1.0 and 2.0 (Psychology Software Tools, Inc.). As I have already described in the interference tasks section, participants in the Flanker Task had to respond to the central stimuli while ignoring other present distractors. In this particular experiment, participants had to pay attention to one arrow and ignore all other distractors that could be located on either side of the central target. Two colors were used in order to differentiate between the main stimuli and other irrelevant distractors. The main arrow, the arrow of interest, was red whereas all other arrows or diamonds were black. In total, there were 5 arrows: 4 distractors and 1 target arrow. The main red arrow could be located in three different positions: it could occupy position 1, 2 or 3. It could also point towards the left or right.. For further reference, look at Figure 1 in the Appendix.

The flanker task was divided into 4 blocks of items (Control, Congruent/Incongruent, Go/No-Go and Mixed). The first three conditions were presented in two blocks each; there was one mixed block. As a result, there was a total of 7 different blocks. Control blocks contained control trials, conflict blocks contained congruent and incongruent trials, go/no-go blocks contained go and no-go trials, and mixed blocks contained congruent, incongruent, go, and no-go trials.

Control Trials estimated the time that it took participant to react when conflicting or distracting stimuli were not present. A red arrow was presented in the center of the screen. It was either pointing to the left or the right. Subjects were required to press the right mouse button when the arrow was pointing to the right and the left mouse button when the arrow was pointing to the left. Every block contained 6 practice trials and 12 experimental trials. As a result, the Flanker task had twelve practice trials and twenty-four experimental trials in total.

Conflict Blocks measured the ability of participants to attend to relevant stimuli in the presence of distracting information. The distracting stimuli consisted of black arrows that surrounded the red arrow and could either point in the same or the opposite direction as the target arrow. On this type of trial, the participantsparticipants were presented with a red arrow that could be placed in one of three possible positions within an array of four black distracting arrows. The red arrow was either in the center or one position to the left or right of center. Every block had 12 practice trials and 36 experimental trials, which made 24 practice trials and 72 experimental trials in total.

*Go/no-go blocks*measured the ability of participants to inhibit prepotent responses. The red arrow was surrounded by an array of diamond shapes or black X's. The red arrow could be located in the center or one position to the right or left of center. When the arrow was surrounded by diamonds, the study participants had to press the left or right button of the mouse (depending on the direction of the target stimuli). Every block had 12 practice trials and 36 experimental trials, which made 24 practice trials and 72 experimental trials in total.

Mixed blocks measured the ability of participants to inhibit a prepotent response when switching between rule sets. The task consisted of Go/No-Go Trials and Congruent/Incongruent Trials. These trials were randomly ordered. The participantsparticipants had to inhibit their responses on 25 % of the trials and respond to 75% of the trials (neutral go trials and both conflict trial types). There was a total of 12 practice trials and 72 experimental trials in one block.

On all trials, the participants had to respond to the direction of the red arrow that could either point to the right or left. Participants had to press the left mouse button when the arrow was pointing to the left and the right mouse button when the arrow was pointing to the right. All conditions could be presented in one of the following two orders: 1) Control, 2) Go/No-Go, 3) Conflict, 4) Mixed, 5) Conflict, 6) Go/No-Go, and 7) Control; or 1) Control, 2) Conflict, 3) Go/No-Go, 4) Mixed, 5) Go/No-Go, 6) Conflict, and 7) Control. Every block began with the set of instructions followed by a practice trial. Participants had to complete the practice trial before each task in order to continue. Also, participants were asked if they needed additional practice trials. None of the participants decided to use this opportunity. Every trial started with a fixation cross that appeared in the center of the screen for a duration of 250 milliseconds. When the fixation cross disappeared, the stimulus was presented for 2000 milliseconds or until the participant responded. Feedback preceded each practice trial. When the response of the participant was correct, a green happy face (☺) appeared on the screen for a duration of 750 milliseconds. When the response of the participant was incorrect or there was no response at all, a red unhappy face (☹) was presented on the screen for 750 milliseconds. Each trial ended with a blank screen was presented for 250 milliseconds, after which a fixation cross appeared indicating the beginning of a next trial.

Language Proficiency Tasks

The image-naming task (Peabody). This image-naming task "is a standardized test that measures productive English vocabulary" of participants. In 1980, Snodgrass and Vanderwart developed the test, which contains a set of 260 pictures. Native speakers of English provided a commonly used name for each object represented in the pictures. The researchers then determined a consensus name based on statistical probability (the response given by the largest number of participants) and the number of other available possibilities. This task has been used in many research studies in the same or a somewhat different version (Szekely et al., 2005)

In the current experiment, the participantsparticipants were shown black and white pictures of objects and were instructed to identify them. The image-naming task contained 8 practice items and 36 experimental items. The items were selected so that their names represented a wide range of word frequencies. Participants did not receive feedback in the practice and experimental trials. A set of instructions appeared on the screen before starting the task. The image was presented in the center of the computer screen. Participants were required to type the name of the object in a textbox that was located under the image. There was no time constraint; as a result, participants were allowed to spend as much time as they needed to type the answer. Participants began the task by using the keyboard to type the response in the textbox. When they finished, participantsthey had to press the Enter key, after which the image appeared on the screen. For an example, see Figure 4 in the Appendix.

Every participant response was recorded and timed, but only accuracy was scored. The responses were considered correct if the first full word typed was the same as the normed image name. For any other responses, two English-speaking raters made two decisions: 1) what was the first full word and 2) was the word correct? The raters also had to decide whether alternative responses should be considered as correct or incorrect based on judgment of whether English speakers would be likely to produce this type of response. They also had to decide if the participant had made an obvious spelling error. Any responses that deviated from normative responses or had extraordinary misspellings were considered incorrect. Although disagreements between the two raters did not occur frequently, when they did, they were resolved by a conference between the two raters.

MTELP (Michigan Test of English Language Proficiency). This is a test that was initially developed to measure the English proficiency of non-native students who wish to attend an American college or university (Baldauf, 1978). In the current study, the test contained 45 listening comprehension items. The MTELP was administered in English language. At the beginning of the test, participants received a set of instructions and were requested to use headphones. Two example items were given to participants before the experimental section started. The participants heard statements in English and questions that were related to the statements. Three possible answers were presented on the screen and participants were instructed to select only one of them. Although participants were allowed to take as much time as they needed in order to respond, the questions were played only once and could not be repeated. Participants had to press keys on the keyboard labeled with stickers A, B, and C. Every correct answer was rewarded with one point, so the maximum score that a participant could obtain was forty-five. For further reference, see Figure 5 in the Appendix.

Background Survey. This survey is a modified version adapted from the Language Experience and Proficiency Questionnaire (LEAP-Q) (Marian, Blumenfeld, & Kaushanskaya, 2007). Participants had to rate their proficiency in hearing, reading, speaking and writing in their native language as well as in up to two additional languages, if applicable. A frequency scale contained ratings from 1 “never” to 5 “always”. The proficiency scale also contained ratings from 1 to 5, however in this case 1 stood for “nonexistent” and five for “good”. The participantsparticipants were also required to report the age at which they started to learn each language. If they were born in a different country, they were also asked about the age at which they moved to an English-speaking country. English was always reported as one of their languages. Languages that are not English will be referred to as NE 1 and NE2. NE1 stands for a language that either was learned very early on or is stronger than NE2. NE2 stands for either the language that was learned as the last or weakest non-English language.

There were some questions that were designed to check for any potential confounding factors. For example, participants were asked about their gender, age and handedness. These also included questions about frequency and proficiency of computer use or knowledge of programming languages. The responses of participants were used to assign them to a specific language group: monolingual, LLBB or trilingual.

Criteria for assignment to language group

In the survey, participants had to answer specific questions about proficiency in a language. For instance, participants were asked how they would rate their speaking of English, their understanding of English, their speaking of a second/third language, their understanding of a second/third language. In addition, questions also asked about two different periods of life - childhood and the present. To sum up, there were two subscales that were used for each language : Childhood Speaking and Hearing Proficiency (CSHP) and Adulthood Speaking and Hearing Proficiency (ASHP). In order to compute the total score for each participant, it was necessary to average two self-reported scores: speaking proficiency and hearing proficiency. If (CSHP) and (ASHP) sub-scales were either equal or less than than two units out of a possible five, the reported foreign language was excluded. For instance, if a participant had an average score of 2 on understanding and speaking of a second language in childhood and less than 2 on understanding and speaking of a second language at present, the participant would be considered monolingual.

Bilingual participants were divided into 9 different subdivisions: lifelong balanced bilingual, late balanced bilingual, NE1 first, late balanced bilingual English first, English Dominant, Unassigned other bilingual, unspecified, English Dominant Type 2, NE1 Dominant, NE1 type 2, Late Balanced Bilingual, heritage. In order to be classified into one of these groups, participants had to fulfill certain criteria. For example, one had to achieve an average score of 4 or 5 on proficiency in both English and NE 1 in both childhood and adulthood in order to be considered a lifelong balanced bilingual. In order to belong to the late balanced bilingual NE1 first subcategory, a participant had to achieve an NE1 score of 4 or 5 in childhood and an English and NE 1 score of 4 or 5 in adulthood. The opposite applies to Late Balanced Bilinguals English first; the participant had to achieve a score of 4 or 5 in English in childhood and a score of 4-5 on English and NE1 in adulthood. In order to belong to the English Dominant subdivision, one had to achieve a score of 4-5 in childhood and adulthood or only adulthood for English; in addition the participant had to achieve at least a score of 2 in childhood and adulthood on NE1. The same rules apply to NE1 dominant; a participant had to achieve a score of 4-5 on NE1. Bilinguals who were put into the unassigned category achieved an average score of ≥2 and <4 in childhood or adulthood on more than one language. Participants who did not belong to any of these categories belonged to the unspecified subdivision of bilinguals. Trilinguals had to achieve a score of at least 2 in adulthood on more than 2 languages.

These seemingly rigid criteria were established in order to assess the real number of languages that participants spoke. Clearly, some participants were more likely to report knowledge of foreign languages than others. For exampletheyparticipants might classify themselves as bilingual even though they had little access to the second language. Others, however, might claim that they were monolingual even though they were able to speak fluently. Consequently, an objective measure had to be developed.

General differences and demographic information for all participants.

English Proficiency

Scores on the MTELP ranged from 27 to 45, which is the highest possible score that the participant could get 45. The mean score was 42.7 (*SD* = 2.4). A one-way ANOVA demonstrated that monolinguals, bilinguals and trilinguals did not differ in their performance on MTELP, $F(2,193) = 0.262$, n.s. Also, univariate ANOVA did not show a significant difference in the MTELP score between participants in the control group and those who were either strongly ego depleted or mildly ego depleted $F(2,193) = 0.105$, n.s. Two-way ANOVA on MTELP scores showed no interaction between the three ego depletion conditions and language groups $F(4,187) = 1.664$, n.s. Accuracy on the image-naming task ranged from 61% to 100% correct, with a mean of 93%

correct (*SD* = 0.07). One-way ANOVA for the image naming task was not significant $F(2,193) = 0.262$, n.s. Also, univariate ANOVA did not show any difference in the score on the image naming task between the three ego depletion conditions $F(2,193) = 0.105$, n.s. Two way ANOVA did not show any interaction between the three ego depletion conditions and language gorups on MTELP $F(4,187) = 1.66$, n.s. As expected, there was a correlation between MTELP scores and the image naming task. Those participants who performed well on MTELP had a tendency to perform well on the image naming task $r = 0.384$, $p<0.01$

Gender

There were 134 female participants and 62 male participants in the study. One way ANOVA revealed that gender did not have an impact on Flanker overall accuracy $F(1,193) = 0.648$, n.s. (see Table 1). Two way ANOVA demonstrated that the interaction between gender and the three ego depletion conditions was also not significant on Flanker overall accuracy $F(2,190) = 0.22$, n.s. (see Table 2).

One way ANOVA revealed a significant difference between females and males on Flanker overall reaction time $F(1,193) = 13.801$, $p<0.05$. Further, multiple comparisons using LSD revealed that female participants (*M* = 445, *SD* = 61) were slower in comparison to male participants (*M* = 414, *SD* = 41). Two way ANOVA did not reveal any interaction between gender and ego depletion conditions on Flanker overall reaction time $F(2,190) = 1.392$, n.s.

Although there was no difference in accuracy between males and females on all blocks, the males had a tendency to be faster than females in all conditions in all blocks for both tasks. There was a small but significant difference between males and females in mixed blocks for the conflict effect measure. However, there was no significant difference in conflict blocks for the conflict effect measurement (see Table 1). There was no significant difference in the proportion measurement. Also, there was no interaction between gender and ego depletion conditions in all blocks (see Table 2).

Handedness

There were 182 right-handed and 14 left-handed participants in the study.

Age

As time progresses, all humans begin to experience cognitive decline in their mental capacity (Bialystok et al., 2012). In this study, individuals were young adults in the age range from 18 to 25. As a result, it was not expected that there would be an effect of age on reaction times or accuracy measures. As predicted, age was not significantly correlated with accuracy or reaction time measures on any blocks.

Education

Participants were asked to respond to questions that assessed their education level. Their level of education was rated on a self-reported scale that ranged from 1 to 7, where 1 represented primary school and 7 represented a doctoral degree. Responses of participants ranged from 2 (high school) to 4 (BA or BS) with a mean of 2.93 (SD = 0.45). The most common answer was 3 (some college); 79.1% responded in this manner. Another common choice was 2 (high school) with 13.8%, followed by 4 (BA or BS) with 7.1% of participants.

SES

Participants were asked to rate the occupation of both of their parents. A self-reported scale that ranged from 1 to 10 was used for that purpose. The questionnaire contained the descriptions of occupations, and participants had to select one for each of their parents. One represented physical types of labor such as farm workers, hunters etc., and 10 represented intellectual occupations, such as physicians or college teachers. If any of the descriptions that were available to participants did not match or represent the occupations of their parents, they could select option “other” and specify the type of job their parents performed. There were two SES scores that were calculated for the purpose of this study. The highest SES score was used to represent the score for the highest rated parent. An average SES score was used to represent the average of the two parents’ scores. In the cases where only one parent was reported, this parent’s score was used for both measures. The SES scores were collected from 183 participants. The range for highest SES score was from 1.0 to 9.0 with a mean 6.3 and *SD* = 2.0. The range for average SES score was from 1.0 to 9.0 as well, with a mean 5.6 and SD = 1.8

Computer use

One part of the survey contained questions that were asked in order to determine weekly computer use, as well as knowledge of programming languages and how comfortable participants felt using computers. The frequency of computer use was measured on a self-reported scale that ranged from 1 to 5, where 1 represented very rarely and 5 represented very often. The data were obtained from 195 participants; 1 participant did not respond to this question. The mean rating for frequency of computer use was 4.8 (SD = .49). Participants’ ratings ranged from 1 to 5. The majority of participants (n = 170, 87.2%) reported that they used a computer very often. 22 participants (11.3%) said that they used a computer often. 1 (0.5%) participant reported using a computer sometimes, 1 (0.5%) rarely and 1 (0.5%) very rarely.

In addition, as previously mentioned, participants rated how comfortable they felt when using a computer. The scale ranged from 1 to 5 where 1 represented very uncomfortable and 5 represented very comfortable. The data were obtained from 194 participants; 2 participants did not respond to this question. The mean rating for computer proficiency was M = 4.6 and SD = 0.63. Participants’ ratings ranged from 1 (very uncomfortable) to 5(very comfortable). The majority of participants, n = 145 (69.9%), reported feeling very comfortable using a computer, followed by 27.3% of participants, n = 53, who reported feeling comfortable when using a computer. 4 (2.1%) participants said that they felt somewhat comfortable using a computer. 1 person (1.0%) reported feeling very uncomfortable using a computer. No one selected the "uncomfortable" response on the scale.

Participants were also asked to report whether or not they knew any programming languages. The data were obtained from 193 participants; 3 participants did not respond to this particular question. 33 participants reported that they knew at least 1 programming language, and 160 participants reported that they did not have knowledge of any programming language.

Monolinguals and LLBBs

English proficiency assessments

There was no difference between monolinguals (M = 43, SD = 2.7) and LLBBs (M = 44, SD = 1.2) for correct responses on MTELP. The independent t-test was not significant $t(60) = -1.22$, n.s. Univariate ANOVA did not show an interaction between three ego depletion conditions and two language groups $F(2,56) = 80$, n.s. on MTELP. Also, there was no significant difference between monolinguals (M = 34, SD = 1.82) and LLBBs (M = 44, SD = 1.88) on the image naming task, $t(60) = 1.22$, n.s. Univariate ANOVA did not show an interaction between three ego depletion conditions and two language groups $F(2,59) = .01$, n.s. for accuracy on image naming task.

Gender

There were 14 male participants and 30 female participants in the monolingual group. The LLBBs consisted of 13 female participants and 5 male participants. Independent t-testa demonstrated that responses times were significantly different between females and males on control trials as well as on incongruent trials. In mixed blocks, there was also a significant difference between males and females on go trials an on incongruent trials. Male participants had a tendency to respond faster in comparison to female participants. For further reference, see Table 3. Univariate ANOVA did not show any interaction between gender and three ego depletion conditions on the Flanker accuracy measurement and on the Flanker reaction time measurement. For further reference, see Table 4.

Handedness

There were 59 right-handed participants and 3 left-handed participants in this subgroup.

Age

The age range of the sample was from 18 to 25 years old. Since, the age covered a relatively short period of time, it was not expected that there would be an effect of age on reaction time or on accuracy. Age was not correlated with accuracy. In addition, age was also not correlated with reaction time. For further reference, see Table 5.

SES

Average SES and Highest SES were not correlated with any Flanker accuracy or reaction time measure (See Table 5). Independent t-tests demonstrated that monolinguals scored higher on Highest SES and Average SES. However, this difference was not significant. Please see Table 6.

Computer use

Independent t-tests demonstrated that monolinguals and LLBBs did not differed in computer use frequency or in computer proficiency. For further reference, see Table 6.

Monolinguals and trilinguals

English proficiency assessment

An independent t-test did not show significant differences between monolinguals (M = 43, SD = 2.7) and trilinguals (M = 42, SD = 2.0) on MTELP, $t(71) = .59$, $p > 0.05$. but there was a significant difference between monolinguals and trilinguals on image naming accuracy, $t(41) = 3.1$, $p < 0.01$.

Monolingual participants were more accurate (*M* = 34, *SD* = 1.8) in comparison to trilingual participants (M = 32, SD = 3.1). This difference represents a medium effect size r = 0.4.

Gender

There were 30 females and 14 males in the monolingual group. The trilingual group had a smaller number of participants. There were 17 females and 12 males in the trilingual group. For this sub-sample of monolinguals and trilinguals, independent t-tests demonstrated that males were significantly faster in comparison to females for all blocks and conditions of the Flanker Task (see Table 7). For the control condition, Levene's test was significant, therefore equal variances could not be assumed. Univariate ANOVA for reaction time did not demonstrate any interaction between gender (males, females) and the three ego depletion groups (controls, mild ego depletion, and strong ego depletion) (see Table 8).

Handedness

There were 43 right-handers and 1 left-hander in the monolingual group. There were 2 left-handed and 27 right-handed participants in the trilingual group.

Age

The performance of monolinguals and trilinguals on the Flanker Task was analyzed by age. Since the age range was very small, there were no significant differences between these two language groups on any condition of the Flanker Task (see Table 9). There was also no correlation between age and Flanker reaction time or between age and Flanker accuracy (see Table 10).

SES

Monoliguals and trilinguals did not differ in their level of education. Independent t-tests also did not show significant differences between monolinguals and trilinguals on the average SES measure. However, the difference between monolinguals and bilinguals on the higher SES measure trended toward significance (see Table 9). There was no significant correlation between the highest SES and Flanker reaction time measures. There was a negative correlation between average SES and Flanker conflict effect reaction time measures (r = -.27, $p < 0.05$). There was also a negative correlation between average SES and flanker accuracy on conflict blocks (r = -.26, $p < 0.05$) (see Table 10).

Computer use

Independent t-tests did not show significant differences between monolinguals and triliguals in computer use frequency or computer proficiency (see Table 9).

Results

The results section is divided into three parts: 1) data for all participants, 2) comparison of monolinguals and LLBBs, 3) comparison of monolinguals and trilinguals. In addition, each part consists of subsections, so that the data is presented in the following order: 1) Flanker reaction time, 3) Flanker accuracy, 4) Flanker reaction time for three ego depletion conditions, 5) Flanker accuracy for three ego depletion conditions.

All Participants

The results that are reported below include 196 participants unless it is indicated otherwise. Participants' handedness, gender, reaction times, accuracy and characteristics were analyzed. The first section of the data analysis is for the entire sample of 196 participants. The second section includes only monolinguals and LLBBs. The third section compares monolinguals and trilinguals.

Demographics for all participants.

The average age for all participants was 19 years old. The average age for trilingual participants was 20 and 18 for unassigned participants. Socioeconomic status was similar for nearly all participants and ranged between 3.75-7.08. Late Balanced Bilinguals (Eng) had the highest economic status, 7.08, and unsigned bilinguals had the lowest economic status, 3.75. The MTELP accuracy ranged between 95-97%. Trilingual participants and late balanced bilingual (NE1) had the lowest accuracy at 94%. Lifelong balanced bilinguals had the highest accuracy, 97%, on the MTELP. Picture naming accuracy ranged between 87-95%. Unassigned bilinguals had the lowest accuracy and monolingual and late balanced bilinguals had the highest accuracy.

There were 30 monolingual females and 14 males in the study. Out of 123 monolingual participants, 43 were right handed and 1 was left handed. There were 87 bilingual females and 36 bilingual males in the study. Out of 123 bilingual participants, 112 were right handed and 11 were left handed. In addition, there were 17 trilingual females and 12 trilingual males in the study. Out of 29 trilingual participants, 27 were right handed and 2 was left handed (See Table 11).

The Flanker Task.

Speed and accuracy

Reaction Time and accuracy were analyzed in order to look for correlations between these two variables. There was no significant correlation between speed and accuracy in the Flanker control blocks (r = .050, n.s.). Also, there was no significant correlation between RT's and Accuracy in the Flanker go/no-go blocks (r = .039, n.s.). In the Flanker conflict blocks, accuracy was positively correlated with reaction time for the incongruent condition (r = .189, $p < .01$), however, there was no correlation for the congruent condition (r = .094, n.s).

In the Flanker mixed blocks, there was no significant correlation between reaction time and accuracy for go trials (*r* = -.06, n.s.). There was no significant correlation in the Flanker mixed blocks between reaction time and accuracy for congruent (*r* = .10, n.s.) and incongruent trials (*r* = .38, n.s).

In order to compare all accuracy measures for monolinguals, bilinguals and trilinguals, one-way ANOVAs were conducted (see Table 12). A one-way ANOVA that compared monolinguals, bilinguals and trilinguals on Flanker overall accuracy was not significant $F(2,193) = .167$, n.s. One-way ANOVA was also not significant for the Flanker control blocks $F(2,193) = .622$, n.s. Flanker go/no-go Blocks $F(2,193) = .524$, n.s., conflict blocks F(2,193) = .201, n.s. and mixed blocks F(2,193) = .180, n.s. For further reference, see Table 12.

Monolinguals and Life Long Balanced Bilinguals did not show a significant correlation between reaction time and accuracy for any Flanker condition (see Table 14). For bilinguals, there was a marginal correlation between incongruent reaction time and accuracy on the Flanker separate blocks $r = .239$, $p > 0.08$.Also, there was a positive correlation between control reaction time and accuracy on the Flanker separate blocks for bilinguals $r = .295$, $p < .001$ and a correlation between go reaction time and accuracy on the Flanker separate blocks for bilinguals, $r = .254$, $p < 0.05$. Again, by trying to be more accurate, bilinguals took longer to respond. In addition, there was a negative correlation between control reaction time and control accuracy on the Flanker separate blocks for trilinguals $r =-.513$, $p < 0.004$. One-way ANOVAs were used to compare monolinguals', bilinguals' and trilinguals' reaction times for all conditions as well as to compare overall reaction time, and the conflict effect. The one-way ANOVAs were not significant. For further reference, please see Table 15.

Overall accuracy on the Flanker Task ranged from 80% to 100% correct. The mean was 99% (*SD* = 0.03).

A repeated measures ANOVA that compared reaction times in control, go/no-go and conflict trials demonstrated a significant effect between conditions $F(2,193) = 605$, $p < 0.01$. For reference see Table 16. Mauchly's Test of Sphericity indicated that the assumption of sphericity had been violated, $\chi^2(5) = 111$, $p < 0.01$; therefore, the degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity ($e = 0.777$). Further, pairwise comparisons using a Bonferroni adjustment revealed that all types of trials except go and incongruent trials were significantly different from each other. Interestingly, participants in control trials were fastest (*M* = 426 ms, *SD* = 63), followed by congruent trials (*M* = 521 ms, *SD* =74), incongruent trials (*M* =578 ms, *SD* =76), and go trials (*M* =585 ms, *SD* = 96).

Accuracy on the Flanker mixed block ranged from 50% to 100% correct. The mean was 99% (*SD* = 0.05). In the mixed blocks go, congruent and incongruent trials were analyzed using a one-way repeated measures ANOVA. Mauchly's Test of Sphericity indicated that the assumption of sphericity had not been violated, $\chi^2(2) = 2.491$, *ns*. One-way repeated measures ANOVA revealed a significant effect between conditions, $F(2,193) = 289$, $p < 0.01$. Further post hoc comparisons using the Bonferroni correction demonstrated that all types of conditions were significantly different from each other. Congruent Trials were the fastest (*M* = 553 ms, SD = 88), followed by go trials (*M* = 592ms, *SD* = 92), and finally incongruent trials (M = 645ms, SD = 94).

Accuracy as well as reaction time on congruent, incongruent and go trials between separate blocks and mixed blocks were compared. Accuracy remained the same regardless of whether conditions were presented in the Flanker separate blocks (99.3%, *SD* =0.05) or in the Flanker mixed blocks (99.3%, *SD* =0.05). Responses were slightly faster in the Flanker separate blocks (*M* = 528 ms, *SD* = 77) in comparison to the Flanker mixed blocks (*M* =597 ms, *SD* = 91).

For all language groups a linear regression was conducted for Flanker mixed blocks conflict effect reaction time. A multiple linear regression was calculated in order to predict reaction time based on 9 predictors. Variables entered as predictors included High SES, Education Level, Peabody Accuracy, English adult proficiency average, English child proficiency average, gender, age, ego depletion, language group. An insignificant regression equation was found $F(9,173) = 1.159$, p = n.s., with an R^2 of 0.057. Out of all the predictors, only the English adult proficiency average approached significance t = -1.703, n.s. For further reference see Table 13.

Flanker Task & Ego Depletion

There was a significant difference between ego depletion conditions on the Flanker overall reaction time measurement $F(2,193) = 3.136$, $p < 0.05$. See Table 18. Participants had the highest mean in the control condition (*M* = 447, *SD* = 59), participants in the strong ego depletion condition had a somewhat lower mean (*M* = 433, *SD* = 59), which suggests that they were slightly faster, followed by participants in the weak ego depletion condition (*M* = 422, *SD* = 51), who were the fastest. In order to check if these differences were significant, post hoc multiple comparisons were used. Post hoc comparisons using Tukey HSD demonstrated a difference between the mild ego depletion condition and the control condition. Participants were significantly slower in the control condition (*M* = 447, *SD* = 59) in comparison to the mild ego depletion condition (*M* = 422, *SD* = 51). There was no significant difference between the three ego depletion conditions on the Flanker Control Reaction Time measurement, $F(2,193) = 2.22$, n.s. See Table 18.

Multiple comparisons using Tukey HSD that compared the three ego depletion conditions on the Flanker go reaction time measurement demonstrated that participants in the control condition were slower (*M* = 605, *SD* = 106) than participants in the mild ego depleting condition (*M* = 579, *SD* = 83). A univariate ANOVA showed that the effect of groups was marginally significant $F(2,193) = 2.98$, p = .053.

There was a significant difference between ego depletion conditions on the Flanker conflict blocks congruent reaction time measurement $F(2,193) = 3.26$, $p < 0.05$. Further, Tukey HSD multiple comparisons showed that participants in the mild-ego depleting condition (*M* = 504, *SD* = 64) were faster in comparison to those participants who were in the control group (*M* = 536, *SD* = 80). Univariate ANOVA did not show a significant difference between three ego depletion conditions on the Flanker conflict blocks incongruent reaction time measurement $F(2,193) = 2.84$, n.s. Further pairwise comparisons using Tukey HSD demonstrated that participants in the control group (*M* = 591, *SD* = 78) were slower than participants in the mild ego depleting group (*M* = 560, *SD* = 58). Univariate ANOVA did not show any difference between the three ego depletion conditions on the Flanker mixed blocks conflict effect $F(2,193) = 2.84$, n.s. Univariate ANOVA also did not show any difference between the three ego depletion conditions on the Flanker conflict blocks accuracy $F(2,193) = .366$, n.s. Univariate ANOVA did not show a significant difference on the three ego depletion conditions on the Flanker mixed blocks go reaction time measurement $F(2,193) = .121$, n.s. or on the Flanker mixed blocks congruent reaction time measurement $F(2,193) = 2.64$, n.s. There was a significant difference between ego depletion conditions on the flanker mixed blocks incongruent reaction time measurement $F(2,193) = 4.02$, $p < 0.05$. Further post hoc comparisons using Tukey HSD demonstrated that participants in the control group (*M* = 664, *SD* = 98) were slower than participants in the mild ego depleting group (*M* = 618, *SD* = 85). Univariate ANOVA did not show a significant difference on three ego depletion conditions on the Flanker mixed conflict effect reaction time measurement $F(2,193) =.971$, or on the mixed blocks accuracy measurement $F(2,193) = 0.274$, n.s. For further reference see Table 18.

Univariate ANOVA was used in order to compare monolinguals', bilinguals' and trilinguals' reaction times for all conditions on the three ego depleting experimental conditions. The ANOVAs were not significant. For further reference, please see Table 19.

Ego Depletion & Accuracy

Univariate ANOVA was used in order to compare accuracy between the control group, mild ego depletion group and strong ego depletion group (See Table 20). Univariate ANOVA demonstrated that there was a significant difference between the three ego depletion experimental conditions, $F(2,193) = 3.78$, $p < 0.05$, on the Flanker overall accuracy measurement. Further, post hoc Tukey comparisons demonstrated that participants who were in the control group were more accurate (*M* = 100%, *SD* = .00) than participants who were in the mild ego depletion group (*M* = 99%, *SD* = .04). In addition, univariate ANOVA demonstrated that there was a significant difference between the three ego depletion experimental conditions, $F(2,193) = 6.86$, $p < 0.01$, on the Flanker incongruent conflict block measurement. Further, post hoc Tukey comparisons between the three ego depletion conditions showed that participants in the control condition (*M* = 100%, *SD* = .00) were more accurate than participants in the mild ego depletion condition (*M* = 97%, *SD* = .08).There was a significant relationship between the three ego depletion conditions on the Flanker incongruent accuracy measurement, $F(2,193) = 3.91$, $p < .022$. Further post hoc Tukey HSD multiple comparisons showed that participants in the control group were more accurate (*M* = 100%, *SD* = .00) than participants in the mild ego depletion condition (*M* = 97%, *SD* = .11). Univariate ANOVA did not show any interaction between language groups and ego depletion groups. (For further reference, see Table 21.)

Comparison of Monolinguals and LLBBs

The Flanker Task

Independent t-tests did not reveal any differences between monolinguals and lifelong balanced bilinguals for any condition of the Flanker Task (see Table 17). There were also no significant differences for the Flanker effect on the conflict block or on the mixed block. The univariate ANOVA did not show any interaction between the three ego depletion conditions and two selected language groups (monolinguals and LLBB) across all blocks and conditions as well as for the Flanker effect (see Table 22.)

For monolinguals and LLBBs, a linear regression was conducted for the Flanker mixed blocks conflict effect. Predictors that were used in the regression analysis included High SES, Education Level, Peabody Accuracy, English adult proficiency average, English child proficiency average, gender, age, ego depletion, language groups. Of these predictors, only gender and language group approached significance. For further reference, see Table 23.

Speed and Accuracy

Monolinguals and LLBBs did not show a speed accuracy trade off on any Flanker condition. Independent t-tests did not show a significant difference between the groups for accuracy across all blocks and conditions (see Table 24). Univariate ANOVA also did not show any interaction between the three ego depletion conditions and the two language groups (Monolinguals and LLBBs) on any block or condition (see Table 25).

Linear Regression for all bilinguals.

A linear regression was conducted for all bilinguals and monolinguals for the Flanker mixed blocks conflict effect. Predictors that were used in the regression analysis included High SES, Education Level, Peabody Accuracy, English adult proficiency average, English child proficiency average, gender, age, ego depletion, language group. Out of these predictors, only gender and language groups approached significance. For further reference, see Table 26.

Comparison of monolinguals and bilinguals when two ego depletion conditions are combined into one.

In order to investigate more closely the ego depletion phenomenon and its impact on performance of monolinguals and bilinguals, the strong and mild ego depletion conditions were merged. For the purpose of this analysis, one combined ego depletion condition was compared with a control condition. Reaction times were analyzed. Trilinguals were excluded from this analysis. Please see Table 27.

Univariate ANOVA did not show any significant difference between the two ego depletion conditions on the Flanker conflict control block control trial, $F(2,163) = 2.85$, n.s. Univariate ANOVA showed a significant difference between the three ego depletion conditions on the Flanker conflict block go trial, $F(2,163) = 2.82$, $p < 0.05$. Further pairwise comparisons indicated that participants were faster in the ego depletion condition ($M = 568$, $SD = 85$) in comparison to participants in the control condition ($M = 609$, $SD = 111$). Univariate ANOVA also showed a significant difference between two ego depletion conditions on the Flanker control blocks congruent trial, $F(2,163) = 3.19$, $p < 0.05$. Further pairwise multiple comparisons indicated that participants in the ego depletion condition ($M = 510$, $SD = 67$) were faster than participants in the control condition ($M = 538$, $SD = 83$). Univariate ANOVA demonstrated a significant difference between the three ego depletion conditions on the Flanker conflict block incongruent trial, $F(2,163) = 2.90$, $p < 0.05$. Further pairwise multiple comparisons indicated that participants in the ego depletion condition ($M = 568$, $SD = 69$) were faster than participants in the control condition ($M = 593$, $SD = 82$). Univariate ANOVA did not show any differences between the two ego depletion conditions on the Flanker control blocks conflict effect $F(2,163) = 0.13$, n.s. Univariate ANOVA also did not show any difference between the three ego depletion conditions on the

Flanker conflict block accuracy, $F(2,163) = 0.86$, n.s. Univariate ANOVA did not show any difference between the two ego depletion conditions on the Flanker mixed blocks go trial, $F(2,163) = 1.58$, n.s. Univariate ANOVA did not show any differences between the three ego depletion conditions on the Flanker mixed block congruent trial, $F(2,163) = 2.30$, n.s. Univariate ANOVA did not show any differences between two ego depletion conditions on the Flanker mixed blocks incongruent trial, $F(2,163) = 3.40$, n.s. Univariate ANOVA also did not show any difference between the three ego depletion conditions on the Flanker mixed block conflict effect, $F(2,163) = 0.83$, n.s. Univariate ANOVA did not show any difference between the three ego depletion conditions on the Flanker mixed block accuracy, $F(2,163) = 0.35$, n.s. Univariate ANOVA did not demonstrate a significant difference between the three ego depletion conditions on the Flanker overall RT, $F(2,163) = 2.47$, $p > 0.05$. Monolingual and bilingual participants performed similarly on all blocks.

Comparisons of monolinguals and trilinguals.

The Flanker Task

Independent t-tests demonstrated that there were no significant differences between monolinguals and trilinguals for any condition and trials of the Flanker task (see Table 28). However, there were significant differences during the conflict block for the conflict effect (see Table 28). Univariate ANOVA for reaction time did not demonstrate any interaction between language groups (monolinguals and trilinguals) and the three ego depletion groups (controls, mild ego depletion, and strong ego depletion) (see Table 38).

Speed and accuracy

An independent t-test did not show a significant difference between monolinguals and trilinguals for accuracy on the Flanker Task. The means were almost the same for the two groups (see Table

29). Univariate ANOVA for accuracy did not demonstrate any interaction between language groups (monolinguals and trilinguals) and the three ego depletion groups (controls, mild ego depletion, and strong ego depletion) (see Table 30).

All Multilinguals

English age. There were 152 participants who reported speaking two or more languages. The average age at which this subgroup started learning English was 3.5 years (*SD* = 3.2). The age at which these particular participants reported learning English was negatively correlated with the congruent reaction time measure in the mixed block, (r = -.17, $p < 0.05$). This suggests that starting one's learning of English earlier in life is correlated with faster cognitive processing on congruent trials.

Child English Frequency. None of the reaction time measures was correlated with childhood English frequency scores.

Child English Proficiency. Childhood speaking proficiency scores were positively correlated with the go reaction time measure in separate blocks, (r = .15, $p < 0.05$). No other childhood proficiency averages were correlated with flanker reaction time measures.

Adult English Frequency. Adult English speaking frequency scores were positively correlated with the flanker conflict blocks congruent reaction time measure (r = .167, $p < 0.05$), as well as with the flanker conflict blocks accuracy measure (r = .15, $p < 0.05$). Adult English writing frequency scores were positively correlated with the Flanker overall reaction time measure (r = 16, $p < 0.05$) as well as with the Flanker conflict blocks congruent reaction time measure (r = .15, p < 0.05) and with the Flanker mixed overall reaction time measure (r = .15, $p < 0.05$). Hearing and reading scores were not correlated with any reaction time measures.

Adult English Proficiency. English adult understanding proficiency scores were negatively correlated with the flanker conflict blocks flanker effect (r = -.15, $p < 0.05$) and with flanker conflict blocks accuracy (r = -.17, $p < 0.05$). No other English adult proficiency scores were correlated with flanker reaction time measures.

English and Accuracy. Only English adult proficiency was negatively correlated with Flanker conflict effect accuracy in the conflict block (r = -.15, $p < 0.05$).

Comparison of objective and self-report adult English proficiency. In this experiment, two tests, MTELP and the image naming task, were used in order to assess English language proficiency. These two assessment tests were positively and highly correlated with all English adulthood proficiency scores (See Table 31).

NE1 age. The mean for participants who spoke more than one language was *M* = 2.60 and *SD* = 4.04. The age at which this particular group started learning English was not correlated with any reaction time measure.

Child NE1 frequency. None of the reaction time measures was correlated with childhood NE1 frequency scores.

Child NE1 Proficiency. Flanker mixed block go RT was positively correlated with child NE1 speaking proficiency (r = .17, $p < 0.05$). Other Childhood NE1 proficiency scores were not correlated with any reaction time measure.

Adult NE1 frequency. NE1 adult writing frequency was negatively correlated with the conflict block Flanker RT effect (r = -17, $p < 0.05$). Hearing, speaking and reading were not correlated with any reaction time measures.

Adult NE1 proficiency. Adult NE1 understanding proficiency was negatively correlated with Flanker mixed blocks RT accuracy (r = -.16, $p < 0.05$). Reading, speaking and writing were not correlated with any reaction time measures.

NE1 and Accuracy. Some NE1 proficiency and frequency scores were correlated with accuracy. Speaking proficiency was positively correlated with go accuracy in mixed blocks (r = .16, p=.05). NE1 adult speaking frequency was negatively correlated with flanker conflict blocks overall accuracy (r = -.18, $p < 0.05$), as well as with flanker conflict blocks incongruent accuracy (r = -.20, $p > 0.05$) and conflict block accuracy (r = -.22, $p < 0.01$).

NE2 age. 29 participants reported knowledge of a third language. This subgroup started learning the third language when they were around 2.7 years old (*SD* = 4.9). NE2 age was not correlated with any flanker reaction time measures. In addition, it was not correlated with flanker accuracy measures.

Child NE2 frequency. None of the reaction time measures or accuracy measures was correlated with childhood NE2 frequency scores.

Child NE2 proficiency. None of the reaction time measures or accuracy measures was correlated with childhood NE2 proficiency scores.

Adult NE2 frequency. Adult writing was negatively correlated with control blocks reaction time (r = -.41, $p < 0.04$), conflict blocks overall reaction time (r = -.39, $p < 0.05$), conflict blocks congruent reaction time (r = -.38, $p < 0.01$) and conflict blocks incongruent reaction time (r = -.37, $p < 0.05$). Speaking, hearing and reading were not correlated with any reaction time measure or with accuracy.

Adult NE2 proficiency. Adult reading was negatively correlated with control blocks overall reaction time (r = -.44, $p < 0.05$) and positively correlated with conflict blocks congruent accuracy (r = .50, $p < .01$). Writing was negatively correlated with Flanker control blocks overall reaction time (r = -.40, $p < 0.05$), go/no-go overall reaction time (r = -.39, $p < 0.05$), conflict blocks overall reaction time (r = -.37, $p < 0.05$) and conflict blocks overall accuracy (r = .38, $p < 0.05$). Speaking and reading with not correlated with reaction time means or with accuracy.

Language Background and SES scores. Researchers have suggested that SES scores are correlated with cognitive control and bilingualism. As Morton and Harper remarked, "it is possible that differences in monolingual and bilingual children's attention control derive in part from differences in ethnicity and socioeconomic status" (Morton and Harper, 2007). This issue will be examined below.

In order to examine whether there is any relationship between socioeconomic status and language background, one needs to take a closer look into language survey scores and two SES measures, Highest SES and Average SES.

Surprisingly, there was no significant correlation between highest SES and the age at which multilingual participants reported learning their first non-English language (r = .15, n.s.). There was also no correlation between average SES and the age at which the multilingual participant started learning their first non-English language (r = 16, n.s.); however, the correlation was close to being significant.

Child English frequency and SES scores. Child hearing frequency was positively correlated with average SES (r = .26, $p < 0.01$) and with highest SES (r = .27, $p < 0.01$). Child reading frequency was positively correlated with average SES (r = .37, $p < 0.01$) and with highest SES (r = .38, $p < 0.01$). Child speaking frequency was positively correlated with average SES (r = .29, $p < 0.01$) and with highest SES (r = .30, $p < 0.01$). Child writing frequency was positively correlated with average SES (r = .26, $p < 0.01$) and with highest SES (r = .30, $p < 0.01$).

Child English proficiency and SES scores. Child understanding was positively correlated with highest SES (r = .37, $p < 0.01$) and with average SES (r = .31, $p < 0.01$). Child reading was positively correlated with highest SES (r = .31, $p < 0.01$) and with average SES (r = .24, $p < 0.01$). Child speaking was positively correlated with highest SES (r = .31, $p < 0.01$) and with average SES (r = .25, $p < 0.01$). Child writing was positively correlated with highest SES (r = .31, $p < 0.01$) and with average SES (r = .25, $p < 0.01$).

Adult English frequency and SES scores. Adult hearing frequency was positively correlated with average SES (r = .25, $p < 0.01$) and with highest SES (r = .26, $p < 0.01$). Adult reading frequency was positively correlated with average SES (r = .22, $p < 0.01$) and with highest SES (r = .28, $p < 0.01$). Adult speaking frequency was positively correlated with average SES (r = .35, $p < 0.01$) and with highest SES (r = .39, $p < 0.01$). Adult writing frequency was positively correlated with average SES (r = .21, $p < 0.01$) and with highest SES (r = .20, $p < 0.01$).

Adult English Proficiency and SES scores. Adult understanding was positively correlated with highest SES (r = .36, $p < 0.01$) and with average SES (r = .31, $p < 0.01$). Adult reading was positively correlated with highest SES (r = .37, $p < 0.01$) and with average SES (r = .31, $p < 0.01$). Adult speaking was positively correlated with highest SES (r = .34, p<0.01) and with average SES (r = .30, $p < 0.01$). Adult writing was positively correlated with highest SES (r = .30, $p < 0.01$) and with average SES (r = .24, $p < 0.01$).

Child NE1 frequency and SES scores. Child speaking frequency was positively correlated with average SES (r = .-19, $p < 0.05$) and with highest SES (r = .-17, $p < 0.05$). Child hearing, writing, and reading scores were not correlated with any SES scores.

Child NE1 proficiency and SES scores. None of the SES measures was correlated with childhood NE1 proficiency scores.

Adult NE1 frequency and SES scores. None of the SES measures was correlated with adult NE1 frequency scores.

Adult NE1 proficiency and SES scores. Adult NE1 understanding proficiency was correlated with average SES (r = .17, $p < 0.05$). None of the other proficiency measures was correlated with highest SES and average SES.

Child NE2 frequency and SES scores. Child hearing, writing, speaking and reading scores were not correlated with highest and average SES.

Child NE2 proficiency and SES scores. Child understanding, writing, speaking and reading scores were not correlated with high and average SES.

Adult NE2 frequency, proficiency and SES scores. None of the SES measures was correlated with adult NE2 frequency scores or adult NE 2 proficiency scores.

Discussion

Monolinguals and LLBBs

In opposition to BEPA and BICA hypotheses, this study failed to find a difference in accuracy between monolinguals and LLBBs. In addition, if one takes into consideration only reaction times, monolinguals and LLBBs performed similarly on most of the blocks except for the mixed block conflict effect, where there was a considerable trend toward significance p = .07, and there was a 27 ms advantage for LLBBs. In the linear regression analysis, using the 'enter' method, language groups approached significance on the mixed block Flanker effect, $p = .06$. Overall, the above results are not in accordance with the idea that LLBBs have a tendency to perform faster on interference tasks. However, there are many studies that did not find any advantage for LLBBs[1]. For example, according to Hilchey and Klein, this advantage is indeed sporadic and “in some cases conspicuously absent” (Hilchey&Klein, 2011).

In accordance with the BEPA hypothesis, bilinguals should be faster in comparison to monolinguals on congruent and incongruent trials. However, these predictions are not always supported by the studies. For instance, in the study conducted by Bialystok, Craik and colleagues, there was no significant difference found in reaction time between monolinguals and bilinguals. There were three group of participants in their study, monolinguals, French-English bilinguals and Cantonese-English bilinguals. Participants were given the Simon Task. The researchers did not find a difference in reaction time and accuracy between monolinguals and French-English bilinguals on congruent and incongruent trials. However, Cantonese-English bilinguals were faster than the other two groups. Bialystok, Craik and colleagues believe that these differences might stem from sampling variability because there were only a few participants in each group (Bialystok, Craik et al., 2005a).

In another study, Bialystok and colleagues administered the Simon Task to monolingual English speaking participants and bilingual participants. They did not find a significant difference between monolinguals and bilinguals, as these participants performed similarly on the Simon Task (Bialystok et al., 2005b). Also, Humphrey and Valian did not find any bilingual benefits for the Simon and Flanker tasks (Humphrey& Valian, 2012).

Similarly, other researchers failed to find coherent evidence for a bilingual advantage for young adults. They are listed below and in the Appendix[2]. Some studies suggest that advantages for bilinguals can be demonstrated only in the most cognitively demanding task or under high cognitive load[3]. For example, in the study conducted by Bialystok, bilinguals were faster than monolinguals only in the high switch condition of the Simon Task. However, there was no advantage for bilinguals on the low switch condition (Bialystok, 2006a).

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[2] Paap &Greenberg (2013), Bialystok, Craik and Luk, (2008), Salvatierra&Rosselli (2010); Kousaie& Phillips (2012).

[3] Costa et al. 2009, Bialystok (2006a), Bialystok and Martin (2004), Bialystok (2010).

Some studies have demonstrated that bilinguals are faster overall than monolinguals on congruent and incongruent trials[4]. For example, Bialystok and colleagues showed that bilinguals in the Simon condition were faster on congruent and incongruent trials in comparison to monolinguals (Bialystok et al., 2006b, Bialystok et al., 2004a). Gathercole and colleagues discovered that monolinguals were faster than bilinguals on some blocks of the Simon Task (Gathercole et al., 2014).

According to the BICA hypothesis prediction, bilinguals will have more advantage on interference tasks that require conflict resolution because they have better inhibitory processes. Therefore, bilinguals are expected to have smaller conflict effects between congruent and incongruent trials. However, the studies that are available seem to produce inconsistent results. For instance, Costa and colleagues demonstrated that the conflict effect was larger for monolinguals than for bilinguals. Bilinguals also had a smaller Simon effect in Paap and Greenberg (2014). Another study conducted by Luk and colleagues, showed the same pattern, that is, that monolinguals had a larger conflict effect than bilinguals[5]. In other studies, there was a bilingual advantage in the high switch condition in the first block, but it disappeared in the next consecutive blocks[6]. In one study, bilinguals had a larger conflict effect than monolinguals[7]. Bialystok, Martin and Viswanathan did not report a conflict effect in their study (2005b). In addition, conflict effects were not reported in the next three studies that were reviewed[8]. Finally, four studies did not find

[4] Bialystok et al., (2004), Bialystok et al., 2006b

[5] Paap &Greenberg (2013), Costa et al. (2008); Luk et al. (2011)

[6] Costa et al. (2009)

[7] Bialystok et al., (2008b)

[8] Bialystok (2006a); Luk et al. (2010); Abutalebi et al. (2011)

any differences between monolinguals and bilinguals.[9]

Flanker Task

Costa, Hernandez and colleagues conducted a study in which they used a Flanker Task version that was very similar to the one used in the current study. As a result, it seems reasonable to discuss present findings in the context of their available data. Costa and colleagues used arrows (►) in their version of the Flanker Task while chevrons (>) were used in the present study. In addition, the position of groups of arrows appeared interchangeably either above or below the fixation cross. The fixation cross was displayed on the monitor during the entire trial, not just for a few milliseconds. Moreover, an asterisk appeared on the screen for 100 milliseconds before the stimuli in order to alert the participant and show where the actual target arrow will be displayed in the array. Costa and colleagues examined efficiency of the monitoring system in bilinguals. They conducted two experiments with different task versions in which the number of congruent and incongruent trials differed. The task that will be discussed here had 50 percent congruent and 50 percent incongruent trials. This part of their experiment was composed of three blocks of 96 trials. It is very similar to the present study, which had two blocks of 36 trials and contained an equal number of congruent and incongruent trials. Similar to the present study, participants in the Costa and colleagues' study were undergraduate psychology students who took part in the study in exchange for a course credit.

Participants in the present study had varied backgrounds and were exposed to different social contexts whereas participants of the Costa and colleagues' study lived and attended school

[9] Bialystok et al. (2005a); Bialystok et al. (2005b); Salvatierra & Rosselli (2011); Kousaie & Phillips (2012)

in Spain and were exposed to the same socio-cultural context. Also, bilinguals in the present study spoke a variety of languages, such as Japanese, Chinese, French etc. In Costa and colleagues' study, participants were highly proficient Catalan-Spanish bilinguals. Gender and video-game exposure were similar in both studies (Costa et al., 2009).

The congruent, incongruent and flanker effect means and standard deviations for monolinguals and LLBBs in the present study and in the Costa et al., study are presented in Table 32. Looking at congruent trials in the present study, it appears that monolinguals are faster than LLBBs although this difference is not statistically significant. In Costa and colleagues' study, it is the opposite, as LLBBs are significantly faster than monolinguals on congruent trials. For incongruent trials, there is no difference between monolinguals and LLBBs in the present study. However, in Costa and colleagues' study, monolinguals are significantly slower in comparison to bilinguals on incongruent trials. For the Flanker effect, LLBBs in the present study appear to have a smaller effect than monolinguals, whereas it is the opposite in the Costa study where monolinguals have a larger effect than LLBBs. These differences, however, were not statistically significant in either study. It is worth mentioning that in another experiment, Costa and colleagues did not find a statistically significant difference in reaction times between monolinguals and LLBBs on the Flanker Task. In that experiment, Costa and colleagues had either 92 percent congruent trials and 8 percent incongruent trials or just the opposite ratio. Because of the difference in proportions of trials, it is impossible to compare those results to the present study (Costa et al., 2009).

As mentioned above, not all studies show that LLBB bilinguals outperform monolinguals on the Flanker Task. A good example of this is an experiment that was conducted by Luk and colleagues in which young adults performed the Flanker Task as they were monitored with “functional MRI”. Although, Luk and colleagues wanted to know which regions of the brain were affected during different trials of the Flanker Task, they also reported reaction time means and standard deviations (Luk et al., 2010). The Flanker Task of their study was very similar to the mixed block in the present study. However, there were a few differences that need to be mentioned. First, the control blocks contained conflict and go/no-go trials. In the current study, conflict and go/no-go were presented as separate blocks. As a result, control blocks will not be compared with the present study because of these methodological differences. Second, Luk's Flanker version was composed of twelve 40-trial blocks, which gave 480 experimental trials in total and 72 experimental trials in the mixed block. The present study had less than 400 experimental trials, and the mixed block was composed of 72 of them (Luk et al., 2010).

There was a very small number of participants in Luk's study. There were 10 monolingual English speakers and 10 bilingual speakers. Bilingual participants started learning a second language very early on (when they were approximately 6 years old). Furthermore, the researchers decided to exclude 1 monolingual and 1 bilingual participant due to intense video-gaming experience. Our pool of participants was much larger and more diverse. There were 44 monolinguals and 18 LLBBs in the present study. Moreover, the participants in Luk's study were 3 years older in comparison to participants in the current study. Similar to this study, Luk did not find any significant difference between monolinguals and bilinguals on the Flanker Task (see Table 33). However, just like the present study, LLBBs were numerically faster on control trials, incongruent trials and the Flanker effect (Luk et al., 2010). Although, these findings are not significant, this pattern of results would be consistent with the BICA hypothesis according to which bilinguals should have a smaller conflict effect in comparison to monolinguals (Luk et al., 2010).

In another study, Luk and colleagues used a version of the Flanker Task that had control and conflict blocks and therefore closely resembled the Flanker task that was given to participants in the present study. The two studies contained two control blocks with twelve trials each. There were also 2 conflict blocks in both studies. However, there was a small difference in the number of trials in a conflict block. The present study had 36 trials per block whereas Luks and colleagues' studies included 49 trials per block. Moreover, there were three additional blocks, two go/no-go blocks and one mixed block, that were not included in the Luk et al., study. Another small difference was in the period of time that the fixation cross was displayed on the screen between trials. In the present study, it was displayed for 250 milliseconds whereas in the Luk et al., study it was presented for 500 milliseconds (Luk et al., 2011).

Similar to the present study, Luk and colleagues' experiment was conducted in a large multicultural city. Their participants were also university students. Also similar to the current study, participants in Luk's experiment were categorized as monolinguals, early bilinguals or late bilinguals based on responses that they provided on a questionnaire. Luk and colleagues determined 28 participants had to be excluded from their study because they did not use both languages actively. As a result, 123 participants were included in the final analysis, 38 monolinguals, 43 early bilinguals and 42 late bilinguals. The mean age for their participants was 21.1 whereas for participants in the current study it was 19.6. Their participants also spoke a variety of different languages (Luk et al., 2011).

Just as in the current study, one way ANOVA did not show a significant difference between language groups in the control block (see Table 34). However, numerically LLBBs had a tendency to perform a few milliseconds slower than monolinguals in both studies. In addition, in both studies the same pattern was observed in the conflict block congruent condition. Although there was no significant difference, numerically the LLBBs perform slower than the monolinguals. In both studies, there was no significant difference in the incongruent condition. In Luk's study, the Flanker effect was significant and it was smaller for LLBBs. Although, in the present study the Flanker effect was not significant, numerically LLBBs performed faster than monolinguals, although this difference was very small (Luk et al., 2011)

These findings present some support for the BICA hypothesis. However, there was only a 17 millisecond difference between monolinguals and LLBBs on the Flanker effect. Furthermore, monolinguals were 19 milliseconds faster than LLBBs in the control condition. In the congruent condition, LLBBs were ten milliseconds faster. In the incongruent condition, LLBB were 7 milliseconds faster. As one might have already noticed, the differences between these two groups are indeed very small on these two conditions (Luk et al., 2011). According to Emily Coddere and Walter Van Heuven, "the BICA hypothesis predicts superior performance" of bilinguals "on these measures due to a conflict" (Coddere & Van Heuven., 2014). Nevertheless, 7 milliseconds of bilingual advantage in reaction time certainly cannot be called "superior performance". Therefore, the small Flanker effect that was found in the Luk et al., study might stem from the fact that monolinguals were slightly faster on congruent trials whereas bilinguals were faster on incongruent (Luk et al., 2011).

Abutelabi and colleagues used a Flanker Task in order to investigate language switching using fMRI. Their experiment closely resembled that used in Costa et al. (2008). The only difference was that an alerting cue was not present in the Abutelabi study. There were two experimental blocks of 96 trials each. They were evenly distributed between congruent, incongruent and control trials. There were 14 Italian monolinguals and 17 German-Italian bilinguals in their study. Abutelabi and colleagues used a translation task in order to classify participants into a specific language group. The bilingual participants were from a part of Italy where they used German as their first language and acquired Italian very early on (Abutelabi et al., 2011).

Abutelabi and colleagues did not find a significant difference between monolinguals and bilinguals for any condition of the Flanker task. There was also no significant difference for the Flanker effect. Nevertheless, numerically, monolinguals were faster than LLBBs on the congruent and incongruent conditions and slower on the Flanker effect (Abutelabi et al., 2011). Just as in the Abutelabi study, the present study demonstrated that monolinguals are numerically faster on the congruent condition and LLBBs are numerically faster on the Flanker effect. None of these findings are significant. The only difference between the current results and the Abutelabi findings is the incongruent condition. Monolinguals and LLBBs performed equally well in the present study if one considers reaction time means. However, in Abutelabi's study, monolinguals were faster (see Table 35).

Based on previous studies that were discussed in this paper, it becomes harder to confirm with certainty that LLBBs outperform monolinguals on interference tasks. The results are very inconsistent and can be best summarized by the title of Costa's paper "On the bilingual advantage in conflict processing: Now you see it, now you don't" (Costa et al., 2009).

It seems that an inability to find a difference in reaction time between monolinguals and LLBBs is nothing unusual but rather is a persistent trend that occurs constantly in a variety of studies. Costa (2008) showed that differences between two language groups are manifested only in circumstances where the sample is very large. In her study, she used two groups of 100 participants. Although the bilingual advantage was very small, it existed; reaction times were faster for almost every condition of the Flanker Task. The present study did not have so many participants, and, as a result, it is possible that a larger sample would show benefits of being an LLBB (Costa, 2008).

One might be tempted to ask why it is so hard to find differences between monolinguals and bilinguals on interference tasks. No one can answer with certainty. Nevertheless, a possible response to that question can be potentially discovered in the age of the participants. The sample of participants consisted of young adults who were in the 18-25 age range. These participants were at the peak level of cognitive functioning; therefore any benefits that could arise between two groups were masked. According to Bialystok, young adults are “at the developmentally peak age for cognitive control”, and therefore the bilingual advantage is invisible in this age group (Bialystok, 2012). This argument is supported by evidence that young adults show a bilingual advantage much less frequently than other age groups. In addition, there are some neuro-imaging studies that demonstrate that although there is no difference between monolinguals and bilinguals on reaction time measures, bilinguals still process conflict trials in a different manner in comparison to monolinguals (Abutelabi et al., 2011; (Luk, Anderson et al., 2010). However, there are many other differences that exist between the two language groups. For instance, in the current study females were slower in comparison to males. This difference was significant for almost all blocks, and for all other blocks it approached significance. Also, there were some significance differences between left- and right- handers. Right-handers were faster in comparison to left-handers on the mixed go block, and the difference approached significance on the control block. Although there were only 3 left-handers, it was still possible to obtain a significant difference. Therefore, if there is a solid and substantial difference in cognitive processing between monolinguals and bilinguals, then it should be possible somehow to overcome the obstacle to detecting that difference which is posed by the high cognitive efficiency of young adults, so that the difference can be measured in the same way that gender and handedness differences are.

According to Costa and colleagues, it is important to design a task in the proper manner in order to see advantages for bilinguals. As the researchers note, the interference task might be either too easy or too hard, therefore making any benefits undetectable (Costa, 2009). This view is supported by Bialystok, who believes that it is very difficult to adjust the level of challenge to the ability level of the age group (Bialystok et al., 2005a). For instance, when the task is easy, the majority of participants are able to complete it fast and efficiently. On the other hand, if the task is too challenging, participants slow down when striving to maintain accuracy. As a result, the bilingual advantage becomes impossible to detect in both cases (Costa, 2005). Based on these claims, it is possible that the Flanker Task was either too easy or too hard for participants, and as a result, the study failed to find significant differences between monolinguals and LLBBs. Since young adults are at the peak level of cognitive processing, it is more probable that they perform the Flanker task very efficiently and quickly because it is very easy for them. One could eliminate this problem by reducing breaks in between trials or by totally removing them.

The theory of Valian clearly explains why this study fails to find a difference between monolinguals and bilinguals despite of cognitively challenging task that was provided to them at the beginning of the experiment. The participants were college students who certainly engaged in many of the activities that were listed above. In addition as Valian emphasized, this group is unique because, as college students, they engage in many cognitively challenging activities on a daily basis (Valian, 2015).

One potential advantage of the current study was that the age was in the range of 18-25. In addition, the participants were very young, with a mean age of 19.6. The age is a very important factor in interference studies because cognitive processing starts to deteriorate gradually. For example, Miyake et., al. (2000) demonstrated that there are some age related changes in the three executive functioning components: working memory, shifting and inhibition. As one gets older, some impairment in executive functioning starts to manifest itself (Miyake et al., 2000). The Flanker Task requires all of these components. For example, one needs to be able to inhibit a response on no-go trials. Recent neuroimaging findings also suggest that “neural processes that support cognitive control of memory through inhibition differ between young and older adults” (Rizio, et al., 2014). According to Bialystok et al. (2009), usually young adults perform much better on interference tasks in comparison to older adults (Bialystok et al., 2009). It is possible that the difference in reaction time between monolinguals and bilinguals was not discovered due to strict age constraints that were implemented in the current study. Even in the blocks that were relatively challenging, bilinguals were not able to outperform monolinguals. Age was not so strictly controlled in other studies. A good example of this is a study conducted by Costa and colleagues where the mean age was 22 years and the oldest participants were 32 years old (Costa, 2006). Bialystok, Craik et al. ran an experiment using the Simon Task with young adult participants whose mean age was 29 years old (Bialystok et al., 2005). Bialystok, Martin et al., 2005 had young adults in the age range 20-30 years (Bialystok et al., 2005). In another study the mean for young adults was 23.8 (Bialystok & DePapa, 2009). It is reasonable to claim that the differences between the two groups would be larger if participants were be older as differences become larger with age.

Monolinguals and Trilinguals

There are not so many studies that investigate how trilinguals perform on the interference tasks. One study that is available attempted to compare monolingual, bilingual and trilingual children’s performance on the Simon Task. There were 20 monolinguals, 18 bilinguals and 18 trilinguals in the study. The age range was 5.2 to 7.8 with a mean age of 6.9 years. Based on a study by Poarch et al., it is known that trilingual (M = 69) children outperformed monolingual (98) and slightly bilingual (M = 74) children on the Flanker effect. Bilinguals and Trilinguals showed less interference than monolinguals in the incongruent condition of the Simon Task. As Poarch and colleagues claim, it indicates “that the language control continuously exercised by the bilinguals and trilinguals has a more general effect on attentional control mechanisms” (Poarch et al., 2012).

Unfortunately it is unknown whether these findings can be applied to young adults. Since they are at the peak level of cognitive functioning, benefits of being trilingual can become invisible during this period of time. There seem to be very few studies that investigated performance of young adults on interference tasks. One such a study was conducted by Madrazo and Bernardo. The researchers conducted a study that examined executive control of Bilinguals and Trilinguals. There were 104 bilingual participants and 106 trilinguals in their study. Participants received a version of go/no-go task. There were 13 practice trials before the actual test. There were three trials in the task: go trial, no-go trial and lure trial. In the go trial, there was a “go-shape” presented on the screen and participants were instructed to respond by pressing the spacebar on the keyboard. In the no-go trial, there were other “no-go shapes” presented on the screen and participants had to withhold their responses when they saw a shape different from a “go-shape”. In a lure trial, participants were instructed not to press the “go-shape” if it followed a previous go trial. The results of the study did not demonstrate a significant difference between monolinguals and trilinguals. As the authors of the study underline, many previous researchers have argued that speaking more than two languages does not enhance inhibitory control because the same mechanisms are involved in suppressing two or more languages (Madrazo and Bernardo, 2012). Unfortunately, this study examines only inhibition, and this is only one aspect of executive control.

As a result, more variables need to be investigated in order to gain a more extensive understanding of mechanisms responsible for executive control processes.

Another study was conducted by Valian and Humphrey in 2012. There were 24 trilingual participants in the study whereas the current study had 29 participants. However, for both studies, criteria for assignment to the trilingual group were not very strict, and there were few background restrictions that were required for membership in this group. It is also necessary to note that this group was much more diverse than any other group that participated in the study because they spoke more languages (2012).

Valian & Humphrey did not find a statistically significant difference between the three language groups. However trilinguals were numerically slower for every condition of the Flanker Task. Trilinguals appeared to be slower than other language groups. Nevertheless, these findings were not confirmed by the present study. Although, similar to the study from 2012, a statistical difference was not found (see Table 36); however, trilinguals were numerically faster than other groups in the control condition and in the mixed block on go and the incongruent condition and on the Flanker effect. Moreover, trilinguals were never the slowest in the present study. If one looks only at reaction time means, they were usually faster than monolinguals but slower than bilinguals. The current study seems to contradict previous findings from 2012, and as a result it is necessary to test more trilingual participants in order to gain a better understanding of this specific language group.

In addition, trilinguals were slower on average (although not significantly so) for every condition of the Flanker task, and the difference in the size of the Flanker effect for the mixed block approached significance. There appears to be an overall trend toward trilinguals being slower for all conditions. The fact that trilinguals appear slower in the control and go conditions when no conflicting, distracting information is present suggests that this group is simply slower. They are not differentially stumped by the conflict conditions. Future investigations should be conducted to determine whether this trend is indicative of an effect and what might be causing an overall slowing of reaction time in trilinguals.

Ego Depletion

The main purpose of this study was to examine if bilinguals could overcome a deprivation of their mental resources and as a result outperform other language groups on the Flanker Task. This indeed did not happen. It has been claimed that bilinguals should manifest differences when compared with monolinguals if they are being faced with a potentially demanding task. In one of the studies, experimenters used two versions of the Simon Task. In version one, Bialystok, presented on a screen a colored square in one of two possible positions (right or left) and participants had to respond with a relevant key. In version two, experimenters presented an arrow that pointed either to the right or left direction and appeared on the right or left side of the screen. Both versions were presented either in high or low switch conditions. The difference between these two conditions was due to the number of intertrial switches. The first version of the Simon Task examined working memory whereas the second version investigated inhibition (Bialystok, 2006a).

There were 96 undergraduate students in the study. There were 40 English speaking monolinguals and 57 bilinguals who spoke English and some other language. Moreover, some participants played video-games actively whereas others used a computer but did not play. Bialystok discovered that, in both versions of the Simon Task, video-game players had a faster reaction time in comparison to those participants who did not actively engage in video-gaming. This advantage was even seen in the control trials. However, what is more important, bilinguals performed better only for the high-switch condition in the second “arrows version” of the Simon Task. Indeed, this was the most cognitively challenging task in the experiment, and it took participants the longest time to complete (Bialystok, 2006a).

As Bialystok suggests, participants need to activate two spatial codes in order to complete the arrows version of the Simon Task. One spatial code refers to the direction of the arrow and the second one to its positions. Bialystok indicates that “the arrows task presents a competition analogous to that created by two language systems; performance depends on attending more directly to one representation than to a similar competing representation” (Bialystok, 2006a). An advantage for bilinguals existed only under the high switching condition when the task was cognitively demanding and challenging (Bialystok, 2006a). Similar findings were discovered by Costa and colleagues on the Flanker task (Costa et al., 2009). The experimenters used two versions of the Flanker Task in the study. In the first version, they used two low monitoring conditions. In the second version, they used high-monitoring conditions. In the high monitoring context, there were either 48 congruent trials and 48 incongruent trials in each block or 72 congruent and 24 incongruent trials. The results of the study indicated that bilinguals were better than monolinguals only in high monitoring conditions that required more switching and monitoring. When the task was presented under the low switching condition, there was no significant difference between the two language groups (Costa et al., 2009).

Since generally in the studies the bilingual advantage is more evident in conditions that are cognitively demanding, the logic behind the present study was to design a task that was extremely challenging and could reveal differences between the three language groups. An ego depletion task seemed to be an excellent choice because previous studies demonstrated that participants who were deprived of their mental resources performed significantly worse on a subsequent task than those who were not ego depleted (Baumeister et al,. 1998; Baumeister 2002, Job 2010).

No known prior study has ever used the Flanker Task preceded by an ego depletion task in order to investigate the performance of bilinguals. Therefore, this study cannot be analyzed in the context of previous data.

All Language Groups and Ego Depletion

The current study showed a significant difference between control, mild and strong ego depletion conditions on Flanker Task reaction time means. The problem was that this significance was not in the direction that one would expect. Participants in the control condition were slower than those in mild and strong ego depletion condition. This difference was either statistically significant or approached significance for nearly every block except for the conflict effect and accuracy in every block. There was no significant difference in accuracy measures. There was no interaction of ego depletion with language groups, gender or handedness.

The data revealed that participants who were expected to actuallyshow poorer performance after being ego depleted, improved and got better for some reason. Perhaps, the ego depletion task that was presented to them actually improved their performance and equipped them with necessary skills which allowed them to succeed on the following Flanker task.

When two ego depletion conditions were combined into one and compared with the control condition (See Table 27), participants in the ego depletion condition performed significantly faster than those in the control condition, especially in the conflict block. This supports the idea that the ego depletion condition improved their performance on the subsequent task. It is also possible that performance of participants in the ego depletion condition successively decreased with time, and as a result, this difference was not visible in the mixed blocks that followed the control block.

The ego depletion tsk instructed participants to stay within a designated path even when the directions of the mouse were reversed. Therefore, the participants had to withhold their desire to move in the opposite direction in order to complete the task successfully. Similar processes occur in the Flanker Task, especially on the Go/no-go trials when participants need to inhibit their responses on the no-go portion of the trial. The ego depletion task also involved a great deal of monitoring. The difficulty of the task kept increasing and the designated path became smaller. As a result, participants had to concentrate and constantly monitor their progress. The Flanker Task also involved the same mechanisms. Participants had to be able to closely monitor and analyze every conflict.

Unfortunately, the ego depletion task closely resembled the Flanker Task. It is no wonder that participants in the control group were slower in comparison to those who were in one of the two ego depletion groups. If one takes into consideration only monolinguals and LLBBs, the same observation can be made. Although mean reaction times were not significant, participants in the control group were numerically slower than those in the mild and strong ego depletion groups for nearly every trial and block. There was no significant difference on accuracy measures between the three ego depletion groups. The three ego depletion conditions also did not interact with language groups, gender and handedness. Reaction time means indicate that Monolinguals and LLBBs were equally slower in the control condition in comparison to the two ego depletion conditions. This observation only confirms the hypothesis that participants in the two ego depletion groups performed better because they received extra practice before the Flanker Task.

Unfortunately, the same trend could not be observed for the trilingual group. The data for trilinguals is very inconsistent, therefore. However, numerically trilinguals in the control conditions were fastest on Go/No-Go Blocks, Control Block RT and slowest on Go RT in mixed blocks. There was no significant difference on accuracy measures. There was no interaction of ego depletion with language groups, gender and handedness. Since the data vary greatly for trilinguals, it is impossible to draw broad conclusions about this particular group. Therefore more studies need to be done.

The main disadvantage of the present study was a poor selection of the task that followed the ego depletion task. As the data from the current study suggests, the ego depletion task allowed participants to perform better on the Flanker Task and therefore distorted the results. Certainly, this issue needs to be taken under consideration when conducting another study.

Despite many studies, executive function and inhibitory control have not been well understood, especially in young adults. Hopefully, future studies will enhance our understanding of cognitive processes in this group.

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Tables

Table 1.

For males and females in the entire sample, means, standard deviations, and between group statistics for accuracy, reaction time and conflict effect for Flanker blocks and conditions.

	Females, n=134		Males, n=62				
	M	*SD*	*M*	*SD*	*F(1,193)*	*p*	*r*
Control Block ACC	.99	.06	1.00	.03	.60	.44	.06
Control Block RT	435	68	406	43	10	.00	-.22**
Go/no-go Block ACC	1.00	.03	.994	.04	.50	.48	-.05
Go RT	600	101	553	74	11	.00	-.23**
Conflict Block ACC	.99	.03	1.00	.03	.90	.34	-.07
Congruent RT	534	76	495	62	13	.00	-.25**
Incongruent RT	593	81	547	52	17	.00	-.28**
Conflict Effect	59	40	52	29	1.5	.22	-.09
Proportion	0.11	0.1	0.11	0.1	.13	.72	-.03
Mixed Block ACC	.99	0.5	1.00	0.4	.00	.98	.00
Go RT	606	94	561	78	10	.00	-.23**
Congruent RT	565	90	526	77	8.6	.00	-.21**
Incongruent RT	662	97	608	77	15	.00	-.27**
Conflict Effect	97	51	82	42	4.1	.05	-.14*
Proportion	0.18	0.1	0.17	0.1	1.4	.25	-.08
Flanker Overall ACC	1.00	.03	.99	.03	.65	.42	-.06
Flanker Overall RT	445	61	414	41	14	.00	-.26**

Table 2

Accuracy means and between group statistics (*F* and *p* values) for interactions between gender and three ego depletion groups: control, mild ego depletion, and strong ego depletion.

	Females n=134			Males n=62				
	C n=64	MED n=35	SED n=35	C n=13	MED n=25	SED n=24	*F*	*p*
Control Blocks ACC	1.00	.98	.98	1.00	1.00	.99		
Control Blocks RT	444	433	423	407	398	413	.83	.44
Go/nogo Blocks ACC	1.00	1.00	.99	1.00	.98	1.00	1.8	.16
Go/nogo Blocks RT	314	307	294	296	278	295	1.3	.27
Flanker-Conflict Blocks								
Conflict Block ACC	1.00	.99	.99	1.00	.98	1.00	.30	.74
Congruent RT	545	524	523	493	475	514	1.5	.22
Incongruent RT	600	580	592	547	632	561	.35	.71
Conflict Effect	55	56	69	54	56	47	1.5	.21
Proportion	0.11	0.11	0.13	0.11	0.12	0.10	1.6	.20
Flanker-Mixed Blocks								
Mixed Block ACC	1.00	.98	.99	1.00	.98	.99	.08	.92
GoRT	615	600	597	560	534	589	1.7	.18
Congruent RT	575	553	559	519	501	554	1.6	.21
Incongruent RT	674	646	657	615	578	634	.97	.38
Conflict Effect	99	93	99	96	77	80	.39	.68
Proportion	0.18	0.18	0.18	0.19	0.15	0.16	.83	.44
Flanker Overall ACC	1.00	.99	.99	1.00	.98	.99	.22	.80
Flanker Overall RT	453	439	437	415	398	427	1.4	.25

Note. C = control (no ego depletion), MED = mild ego depletion, SED = strong ego depletion, *F* = ANOVA statistic, *p* = alpha level for interaction between gender and ego depletion conditions

Table 3

For males and females in the monolingual and LLBB groups, mean reaction times, standard deviations, t-values and p-values for Flanker conditions.

	Females, n=43		Males, n=19				
	M	*SD*	*M*	*SD*	*t(60)*	*P*	*Cohen's d*
Flanker-Separate Blocks							
Control	446	52	418	41	2.1	.04	0.6
Go	617	101	573	89	1.6	.11	0.5
Congruent	550	71	515	69	1.8	.08	0.5
Incongruent	608	81	567	56	2.0	.05	0.6
Flanker-Mixed Block							
Go	628	96	573	89	2.1	.04	0.6
Congruent	586	93	544	96	1,6	.11	0.4
Incongruent	684	98	616	87	2.6	.01	0.7

Table 4.

For participants in the monolingual and LLBB groups, accuracy means, reaction times and between group statistics (*F* and *p* values) for interactions between gender and three ego depletion groups: controls, mild ego depletion, and strong ego depletion.

	Females n=43			Males N=19				
	C n=22	MED n=9	SED n=12	C n=3	MED n=6	SED n=10	*F(2,56)*	*p*
Control Blocks ACC	1.00	.98	.99	1.00	1.00	.98	.87	.43
Control Blocks RT	453	435	443	417	433	394	.51	.60
Go/nogo Blocks ACC	1.00	1.00	1.00	1.00	1.00	1.00	--	--
Go/nogo Blocks RT	325	305	313	287	284	306	.32	.73
Flanker-Conflict Blocks								
Conflict Block ACC	1.00	.98	.98	1.00	1.00	.99	.39	.68
Congruent RT	558	531	549	486	486	541	.84	.45
Incongruent RT	610	589	620	546	539	589	.18	.83
Conflict Effect	51	58	72	61	53	48	.48	.62
Proportion	.09	.12	.13	.13	.11	.10	.51	.60
Flanker-Mixed Blocks								
Mixed Block ACC	1.00	.99	.98	1.00	1.00	.99	.15	.86
GoRT	647	604	612	546	520	613	1.5	.23
Congruent RT	589	570	590	533	488	581	.68	.51
Incongruent RT	691	668	682	591	567	653	.84	.44
Conflict Effect	102	98	91	58	79	72	.20	.81
Proportion	.18	.18	.16	.12	.16	.14	.17	.85
Flanker Overall ACC	1.00	.99	1.00	1.00	1.00	.99	1.5	.23
Flanker Overall RT	465	446	459	406	403	448	.83	.44

Note. C = control (no ego depletion), MED = mild ego depletion, SED = strong ego depletion, *F* = ANOVA statistic, *p* = alpha level for interaction between language status and ego depletion condition.

Table 5.

For participants in the monolingual and LLBB groups, correlation between age, highest SES score, average SES score, and accuracy & correlation between age, highest SES score, average SES score and reaction times.

	Age n=44		Highest SES Score		Average SES score	
	r	*p*	*r*	*p*	*r*	*p*
Flanker - Separate Blocks						
Control RT	-.08	.54	-.12	.38	-.06	.66
Control ACC	-.17	.19	-.18	.20	-.21	.12
Go RT	.13	.30	-.05	.70	-.06	.67
Go ACC	---	---	---	---	---	---
Congruent RT	-.13	.32	-.09	.50	-.03	.83
Congruent ACC	---	---	---	---	---	---
Incongruent RT	-.15	.26	-.13	.34	-.17	.21
Incongruent ACC	-.09	.49	-.18	.19	-.14	.30
Conflict Effect RT	-.04	.75	-.07	.59	-.25	.07
Proportion RT	.02	.88	-.07	.62	-.24	.08
Flanker - Mixed Block						
Go RT	-.20	.11	-.12	.37	-.07	.60
Go ACC	-.22	.09	-.01	.96	.00	.97
Congruent RT	-.15	.24	-.16	.25	-.07	.59
Congruent ACC	-.20	.12	.13	.36	.20	.14
Incongruent RT	-.22	.09	-.12	.40	-.08	.58
Incongruent ACC	-.20	.12	-.15	.27	-.11	.42
Conflict Effect RT	-.13	.33	.06	.66	-.01	.93
Proportion RT	-.06	.63	.08	.55	-.00	.98
Flanker Overall ACC	.14	.27	-.18	.20	-.14	.31
Flanker Overall RT	-.22	.09	-.12	.38	-.11	.44

Table 6.

For participants in the monolingual and LLBB groups, means, standard deviations and between group statistics for age, education, socio-economic status, computer use, handedness, gender and MTELP.

	Monolingual n=38		LLBB n=15				
	M	*SD*	*M*	*SD*	*t*	p	Cohen's *d*
Age	19	1.4	19	. 92	1.6	.29	0
Education	2.8	.44	2.8	.41	.32	.01	0
Highest SES	7.2	1.6	6.0	2.0	2.3	.11	0.67
Average SES	6.4	1.5	5.2	1.9	2.4	.37	0.70
Computer Frequency	4.8	.37	5.0	.00	-1.7	.98	-0.76
Computer Proficiency	4.7	.53	4.7	.59	-.45	.65	0
Handedness	1.0	.16	1.1	.35	-1.5	.00	-0.48
Gender	1.2	.44	1.4	.49	-.50	.36	-0.42
MTELP	43	2.9	43	1.2	-1.0	.38	-0.18

Table 7.

For males and females in the monolingual and trilingual groups, mean reaction times, standard deviations, t-values and p for Flanker conditions.

	Females, n=47		Males, n=26				
	M	*SD*	*M*	*SD*	*t(71)*	*p*	*Cohen's d*
Flanker-Separate Blocks							
Control	444	60	406	41	3.2	.00	.74
Go	614	84	556	79	2.9	.01	.71
Congruent	545	72	504	63	2.4	.02	.61
Incongruent	607	86	555	52	2.8	.01	.73
Flanker-Mixed Block							
Go	615	86	564	77	2.5	.01	.62
Congruent	582	89	527	64	2.8	.01	.71
Incongruent	680	99.9	611	74	3.1	.00	.78

Table 8.

For participants in the monolingual and trilingual group, accuracy means, reaction times and between group statistics (*F* and *p* values) for interactions between gender and three ego depletion groups: control, mild ego depletion, and strong ego depletion.

	Females n=47			Males n=26				
	C n=21	MED n=15	SED n=11	C n=4	MED n=11	SED n=11	*F(2,56)*	*p*
Control Blocks ACC	1.00	.95	1.00	1.00	1.00	.98	1.5	.23
Control Blocks RT	438	438	464	419	387	419	.39	.68
Go/no-go Blocks ACC	1.00	.99	1.00	1.00	1.00	1.00	.59	.56
Go/no-go Blocks RT	308	324	321	284	272	302	.92	.40
Flanker-Conflict Blocks								
Conflict Block ACC	1.00	.97	.99	1.00	1.00	.99	1.0	.37
Congruent RT	541	534	569	524	538	464	.88	.42
Incongruent RT	597	594	643	576	528	575	.48	.62
Conflict Effect	57	60	74	52	65	37	1.3	.29
Proportion	11	12	13	11	14	7	1.2	.30
Flanker-Mixed Blocks								
Mixed Block ACC	1.00	.99	.98	1.00	1.00	.99	.31	.74
Go RT	608	608	639	567	522	604	.65	.53
Congruent RT	567	575	619	531	487	566	.56	.57
Incongruent RT	671	661	723	615	572	648	.15	.86
Conflict Effect	104	86	104	84	85	82	.27	.77
Proportion	.19	.15	.17	.16	.18	.15	.41	.67
Flanker Overall ACC	1.00	.99	1.00	1.00	1.00	.99	1.9	.16
Flanker Overall RT	447	452	477	420	392	440	.56	.57

Note. C = control (no ego depletion), MED = mild ego depletion, SED = strong ego depletion, *F* = ANOVA statistic, *p* = alpha level for interaction between gender and ego depletion condition

Table 9.

For participants in the monolingual and trilingual groups, means, standard deviations and between group statistics for age, education, socio-economic status, and computer use.

	Monolingual n=44		Trilinguals n=29				
	M	*SD*	*M*	*SD*	*t*	p	Cohen's *d*
Age	19	1.3	20	2.1	-1.3	.19	-.57
Education	2.8	.45	3.0	.50	-1.9	.06	-.42
High SES	7.3	1.5	6.3	2.4	1.9	.06	.50
Average SES	6.4	1.5	5.7	2.2	1.4	.18	.37
Computer Frequency	4.9	.35	4.7	.70	.97	.34	.36
Computer Proficiency	4.7	.51	4.4	.91	1.3	.19	.41

*Levene's test for age was significant $F=9.76$, $p<0.01$ therefore equal variances were not assumed.
*Levene's test for average SES score was significant $F=4.93$, $p<0.05$ therefore equal variances were not assumed
*Levene's test for computer frequency was significant $F= 5.4$, $p<0.05$ and computer proficiency was significant $F=6.0$, $p<0.05$ therefore equal variances were not assumed

.

Table 10.

For monolinguals and trilinguals, correlation between age, high SES score, average SES score and accuracy means & correlation between age, high SES score, average SES score and reaction time means.

	Age n=73		High SES Score n=69		Average SES score n=69	
	r	*p*	*r*	*p*	*r*	*P*
Flanker - Separate Blocks						
Control RT	-.17	.15	.04	.74	.03	.84
Control ACC	.14	.22	-.19	.13	-.22	.07
Go RT	-.18	.14	.11	.37	.09	.46
Go ACC	-.12	.32	.11	.36	.14	.25
Congruent RT	-.11	.35	.11	.38	.07	.59
Congruent ACC	-.02	.87	-.01	.92	-.04	.77
Incongruent RT	-.14	.23	-.02	.88	-.09	.47
Incongruent ACC	.04	.74	-.16	.18	-.16	.19
Conflict Effect RT	-.07	.54	-.21	.09	-.27*	.03
Proportion RT	-.02	.84	-.22	.07	-.26*	.03
Flanker - Mixed Block						
Go RT	-.13	.27	-.01	.91	-.01	.95
Go ACC	-.12	.32	-.01	.94	.01	.95
Congruent RT	-.18	.12	.05	.69	.03	.82
Congruent ACC	-.21	.08	.02	.87	.11	.37
Incongruent RT	-.15	.19	-.01	.93	-.04	.76
Incongruent ACC	.01	.91	-.09	.48	-.09	.48
Conflict Effect RT	.01	.93	-.01	.43	-.11	.36
Proportion RT	.06	.60	-.09	.44	-.11	.38
Flanker Overall ACC	.16	.18	-.19	.11	-.20	.10
Flanker Overall RT	-.22	.06	.03	.80	-.02	.91

Table 11.

For monolingual, bilingual, and trilingual participants, number of left and right handed participants, number of females and males.

	Gender		Handedness	
	Female n=134	Male n=62	Right n=182	Left n=14
Monolingual n= 44	30	14	43	1
Bilingual n=123	87	36	112	11
Trilingual n= 29	17	12	27	2

Table 12.

Means, standard deviations and between group statistics for Flanker accuracy for monolinguals, all bilinguals and trilinguals.

	Monolingual n=44		Bilingual n=123		Trilingual n=29				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*(2,193)	*p*	*r*
Control Blocks	.99	.04	1.00	.05	.98	.09	.62	.54	-.03
Go/no-go Blocks	1.00	.00	.99	.04	1.00	.02	.52	.59	-.04
Conflict Blocks	.99	.04	.99	.03	.99	.04	.20	.82	.03
Mixed Blocks	.99	.03	.99	.05	1.00	.02	.18	.84	-.03
Flanker Overall	1.00	.02	.99	.03	1.00	.02	.17	.86	.01

Table 13.

For all language groups, Linear Regression for Mixed Block Flanker effect with predictors: highest SES, education level, Peabody accuracy, English adult proficiency average, childhood proficiency, gender, age, ego depletion, language group.

$F(9,173) = 1.16, p>0.05; r^2=.06$ adjusted $r^2=.02$

	B	*SEB*	Β	*T*	*p*	*M*	*SD*	N
Constant	145	82		1.8	.08			
Higher SES	.21	2.0	.01	.10	.92	6.3	2.0	183
Education level	1.1	8.8	.01	.13	.90	2.9	.46	183
Peabody accuracy	2.7	1.9	.13	1.4	.15	33	2.4	183
English Adult Proficiency Average	-18	10	-.17	-1.7	.09	4.8	.49	183
English Child proficiency Average	-1.6	3.8	-.04	-.41	.68	3.8	1.2	183
Gender	-13	8.2	-.12	-1.6	.11	1.3	.46	183
Age	-1.2	2.5	-.04	-.50	.62	19	1.6	183
Ego depletion	-3.2	4.5	-.05	-.71	.48	.95	.83	183
Language Groups	-6.9	6.3	-.09	-1.1	.28	1.9	.61	183

Table 14.

Correlations between Flanker accuracy and reaction time and conflict effect measures for the monolingual, all bilingual, LLBB and trilingual groups.

	Monolingual n=44		Bilingual n=123		LLBB n=18		Trilingual n=29	
	r	*p*	*r*	*p*	*r*	*p*	*r*	*P*
Flanker - Separate Blocks								
Control[b]	.02	.92	.30 **	.00	.39	.11	-.51**	.00
Go[c]			.25*	.01			-.25	.19
Congruent[d]			.16	.078			-.02	.93
Incongruent[d]	.24	.12	.24**	.01	.25	31	.03	.90
Conflict Effect[d]								
Flanker - Mixed Block								
Go[e]								
Congruent[e]	.14	.35	-.01	.94	.05	.85	-.12	.54
Incongruent[e]	.20	.20	.01	.91	.27	.27	.08	.69
Conflict Effect[e]								
Flanker Overall[a]	.07	.36	.08	.37			-.01	.90

[a]Flanker overall reaction time was correlated with overall Flanker accuracy.

[b]Flanker control reaction time was correlated with control accuracy.

[c]Flanker Go reaction time was correlated with go accuracy.

[d]Flanker conflict block reaction time measures were correlated with conflict block accuracy.

[e]Flanker mixed block reaction time measures were correlated with mixed block accuracy.

Table 15.

For monolinguals, all bilinguals and trilinguals, means, standard deviations and between group statistics for reaction time and conflict effect measures.

	Monolingual n=44		Bilingual n=123		Trilingual n=29				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*(2,193)	*p*	
Flanker - Separate Blocks									
Control	437	55	424	66	420	58	.87	.42	-.09
Go	595	89	580	101	592	83	.44	.66	-.02
Congruent	537	73	516	76	520	69	1.4	.26	-.08
Incongruent	596	80	572	73	578	79	1.6	.21	-.09
Conflict Effect (Incongruent -Congruent)	58	51	56	31	58	39	.06	.94	-.01
Proportion	0.1	0.1	0.1	0.1	0.1	0.1	.00	1.0	.01
Flanker - Mixed Blocks									
Go	603	90	590	95	587	80	.41	.66	-.06
Congruent	569	91	547	90	553	88	.98	.38	-.07
Incongruent	667	100	639	93	638	91	1.5	.23	-.10
Conflict Effect (Incongruent -Congruent)	98	56	92	47	85	45	.60	.55	-.08
Proportion	0.2	0.1	0.2	0.1	0.2	0.1	.57	.57	-.07
Flanker Overall	449	56	431	59	431	50	1.6	.21	-.10

Means and standard deviations are reported in milliseconds.

Table 16.

Repeated measures ANOVA that compares overall reaction times for control, go/no-go and conflict trials.

	All language groups N=196			
	M	*SD*	*F*	*p*
Control Bl.	426	62	605	0.01
Go/NoGo Bl.	301	52		
Conflict Bl.	549	73		

Table 17.

For participants in the monolingual and LLBB groups, means, standard deviations and between group statistics for reaction time and conflict effect measures.

	Monolingual n=44		LLBB n=18		t(60)	p	Cohen's d
	M	*SD*	*M*	*SD*			
Flanker - Separate Blocks							
Control	437	55	440	38	3.1	.83	-0.1
Go	595	89	624	120	-1.1	.29	-0.3
Congruent	537	73	543	70	-.29	.78	-0.1
Incongruent	596	80	597	68	-.00	1.00	-0.0
Conflict Effect	58	51	52	32	.44	.66	0.1
Flanker - Mixed Block							
Go	603	90	631	111	-1.0	.31	-0.3
Congruent	569	91	583	107	-.53	.60	-0.1
Incongruent	667	100	654	98	.46	.65	0.1
Conflict Effect	98	56	71	44	1.8	.07	0.5

Table 18.

Reaction Time means and between group statistics (*F* and *p* values) for three ego depletion groups: control, mild ego depletion, and strong ego depletion.

	Control n=77		Mild Ego Depletion n=60		Strong Ego Depletion n=59				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*(2, 193)	*p*	*r*
Flanker - Separate Blocks									
Control	438	71	418	55	419	57	2.2	.11	-.13
Go	605	106	566	92	579	83	3.0	.05	-.17*
Congruent	536	80	504	64	520	73	3.3	.04	-.18*
Incongruent	591	78	560	59	579	84	2.8	.06	-.17*
Conflict Effect	55	41	56	28	60	40	.32	.73	.02
Proportion	0.1	0.7	0.1	0.6	0.1	0.7	.37	.69	.05
Flanker - Mixed Block									
Go	606	94	573	94	594	85	2.1	.12	-.15*
Congruent	566	88	532	80	557	93	2.6	.07	-.16
Incongruent	664	98	618	85	648	94	4.0	.02	-.20**
Conflict Effect	98	54	87	44	91	45	.97	.38	-.10
Proportion	0.2	0.1	0.2	0.1	0.2	0.1	.27	.76	-.05
Flanker Overall	447	59	422	51	433	58	3.1	.05	-.18*

Note. C = control (no ego depletion), MED = mild ego depletion, SED = strong ego depletion, *F* = ANOVA statistic, *p* = alpha level for ego depletion condition.

Table 19.

Reaction time means and interactions between three ego depletion conditions and language groups.

	Monolinguals, n=44			Bilinguals, n=123			Trilinguals, n=29				
	C n=15	SED n=16	MED n=13	C n=52	SED n=38	MED N=33	Control n=10	SED n=6	MED n=13	F(4,193)	p
Flanker-Separate Blocks											
Control	453	440	414	439	405	420	407	445	418	1.5	.20
Go	622	599	558	605	562	562	577	535	582	1.1	.35
Congruent	548	544	516	536	500	504	522	579	492	1.7	.15
Incongruent	604	603	576	590	562	555	579	625	557	.91	.46
Conflict Effect	56	59	60	54	63	52	56	46	64	.54	.70
Proportion	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.1	.35
Flanker-Mixed Blocks											
Go	619	609	578	608	578	575	576	655	565	1.3	.29
Congruent	573	584	544	568	536	527	542	615	532	1.3	.26
Incongruent	683	673	640	665	626	615	630	719	606	1.6	.16
Conflict Effect	110	89	96	97	90	88	88	104	74	.49	.74
Proportion	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.1	.44	.78
Flanker Overall	454	455	434	449	418	419	426	467	419	1.6	.18

Note. C = control (no ego depletion), MED = mild ego depletion, SED = strong ego depletion, *F* = ANOVA statistic, *p* = alpha level for interaction between language status and ego depletion condition.

Table 20.

Means, standard deviations and between group statistics for accuracy measures for control group, mild ego depletion group and strong ego depletion group

	Control n=77		Mild Ego Depletion N=60		Strong Ego Depletion N=59				
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*(2,193)	*p*	*r*
Flanker-Separate Blocks									
Control ACC	1.00	.00	.99	.07	.99	.07	1.4	.28	-.10
Go ACC	1.00	.00	1.00	.02	.99	.07	.85	.43	-.04
Congruent ACC	1.00	.00	.99	.02	1.00	.01	2.2	.11	-.15
Incongruent ACC	1.00	.00	.97	.08	.99	.04	6.9	.00	-.25**
Flanker-Mixed Blocks									
Go	1.00	.00	.98	.09	1.00	.01	1.7	.19	-.12
Congruent	1.00	.00	.99	.04	1.00	.02	1.9	.16	-.14
Incongruent	1.00	.00	.97	.11	.99	.03	3.9	.02	-.19**
Flanker Over all ACC	1.00	.00	.99	.04	1.00	.04	3.8	.03	-.19**

Table 21.

Accuracy means and between group statistics (*F* and *p* values) for interactions between language group and three ego depletion groups: control, mild ego depletion, and strong ego depletion

	Monolinguals n=44			Bilinguals n=123			Trilinguals n=29				
	C n=15	MED n=13	SED n=16	C n=52	MED n=33	SED n=38	C n=10	MED n=13	SED n=6	*F*	*p*
Flanker-Separate Blocks											
Control	1.00	.99	.98	1.00	1.00	.98	1.00	.96	1.00	1.0	.40
Go	1.00	1.00	1.00	1.00	1.00	.99	1.00	.99	1.00	.33	.86
Congruent	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.98	1.00	1.6	.19
Incongruent	1.00	.97	.97	1.00	1.00	.99	1.00	.97	1.00	.58	.68
Flanker-Mixed Blocks											
Go	1.00	1.00	.99	1.00	.97	1.00	1.00	1.00	1.00	.80	.53
Congruent	1.00	.99	.99	1.00	.99	1.00	1.00	.99	1.00	.07	.99
Incongruent	1.00	.99	.99	1.00	.96	.99	1.00	.98	1.00	.45	.77
Flanker Overall ACC	1.00	.99	.99	1.00	.98	.99	1.00	.99	1.00	.33	.86

Note. C = control (no ego depletion), MED = mild ego depletion, SED = strong ego depletion, *F* = ANOVA statistic, *p* = alpha level for interaction between language status and ego depletion condition.

Table 22

Reaction Time means and between group statistics (*F* and *p* values) for interactions between language group (Monolinguals and LLBBs) and three ego depletion groups: control, mild ego depletion, and strong ego depletion.

	Monolinguals n=44			LLBB N=18				
	C n=15	MED n=13	SED n=16	C n=10	MED n=2	SED n=6	*F*	*p*
Control Blocks ACC	1.00	.98	.99	1.00	1.00	.98	.16	.85
Control Blocks RT	453	414	440	443	445	433	.46	.64
Go/nogo Blocks ACC	1.00	1.00	1.00	1.00	1.00	1.00	-	-
Go/nogo Blocks RT	312	303	312	334	253	304	1.39	.26
Flanker-Conflict Blocks								
Conflict Block ACC	1.00	.98	.99	1.00	1.00	,98	.97	.39
Congruent RT	548	516	544	551	490	548	.120	.89
Incongruent RT	604	576	603	599	523	615	.44	.65
Conflict Effect	56	60	59	48	33	67	.37	.69
Proportion	0.1	0.1	0.1	0.1	0.1	0.1	.46	.63
Flanker-Mixed Blocks								
Mixed Block ACC	1.00	.99	.98	1.00	1.00	1.00	.74	.48
GoRT	619	578	609	660	518	620	.76	.47
Congruent RT	573	544	584	598	492	590	.41	.66
Incongruent RT	683	640	673	673	549	657	.47	.63
Conflict Effect	110	96	89	76	57	67	.09	.92
Proportion	0.2	0.2	0.1	0.1	0.1	0.1	.21	.81
Flanker Overall ACC	1.00	.99	.99	1.00	1.00	1.00	.21	.81
Flanker Overall RT	454	434	455	464	393	451	.58	.56

Note. C = control (no ego depletion), MED = mild ego depletion, SED = strong ego depletion, *F* = ANOVA statistic, *p* = alpha level for interaction between language status and ego depletion condition.

Table 23.

For participants in the monolingual and LLBB groups, Linear Regression for Mixed Block Flanker effect with predictors: highest SES, education level, Peabody accuracy, English adult proficiency average, childhood proficiency, gender, age, ego depletion, language group. $F(9,45) = 1.18$, $p>0.05$; $r^2=.19$, adjusted $r^2= .03$.

	B	*SEB*	*β*	*T*	*P*	*M*	*SD*	*N*
Constant	389	268.		1.5	.16			
High SES	-1.47	4.80	-.05	-.31	.76	6.9	1.8	55
Education level	6.43	20.1	.05	.32	.75	2.8	.43	55
Peabody accuracy	3.41	5.02	.12	.68	.50	34.1	1.9	55
English Adult Proficiency Average	-29.2	49.1	-.09	-.59	.56	4.96	.18	55
English Child proficiency Average	1.18	11.8	.02	.10	.92	4.6	.73	55
Gender	-29.1	17.4	-.24	-1.7	.10	1.3	.47	55
Age	-10.2	6.9	-.23	-1.5	.15	18.9	1.3	55
Ego depletion	-6.54	10.4	-.09	-.63	.53	.89	.79	55
Language Groups	-35.1	18.1	-.29	-1.9	.06	1.3	.45	55

Table 24.

For participants in the monolingual and LLBB groups, accuracy means, standard deviations and between group statistics for reaction time and conflict effect measures.

Condition	Monolingual (n = 44)		LLBB (n = 18)				
	M	*SD*	*M*	*SD*	*t*(60)	*p*	Cohen's *d*
Control blocks	.99	.04	1.00	.02	-.33	.74	-0.3
Go/no-go blocks	1.00	.00	1.00	.00	-	-	-
Conflict Blocks	.99	.04	.99	.02	-.38	.70	0
Mixed Blocks	.99	.03	1.00	.00	-1.3	.19	-0.4
Flanker overall ACC	1.00	.02	1.00	.00	-.91	.37	0

Table 25.

Accuracy means and between group statistics (*F* and *p* values) for interactions between two language groups (monolinguals and LLBBs) and three ego depletion groups: control, mild ego depletion, and strong ego depletion

	Monolinguals n=44			LLBB N=18				
	C n=15	MED n=13	SED n=16	C n=10	MED n=2	SED n=6	*F*	*P*
Control blocks								
Go/no-go blocks	1.00	1.00	1.00	1.00	1.00	1.00	-	-
Conflict Blocks	1.00	.98	.99	1.00	1.00	.98	.21	.81
Mixed Blocks	1.00	.99	.98	1.00	1.00	1.00	.74	.58
Flanker overall ACC	1.00	.99	.99	1.00	1.00	1.00	.21	.82

Note. C = control (no ego depletion), MED = mild ego depletion, SED = strong ego depletion, *F* = ANOVA statistic, *p* = alpha level for interaction between language status and ego depletion condition.

Table 26.

For monolinguals and all bilinguals, Linear Regression for Mixed Block Flanker effect with predictors: highest SES, education level, Peabody accuracy, English adult proficiency average, childhood proficiency, gender, age, ego depletion, language group.

$F(9,144) = 1.13$, $p>0.05$; $r^2=.066$, adjusted $r^2= .02$

	B	*SEB*	Β	*t*	*p*	*M*	*SD*	*n*
Constant	195	97		2.02	.05			
High SES	-.37	2.3	-.02	-.16	.87	6.2	1.9	154
Education level	-.51	9.9	-.01	-.05	.96	2.9	.45	154
Peabody accuracy	2.68	2.2	.12	1.2	.22	33.6	2.2	154
English Adult Proficiency Average	-13.3	11.8	-.12	-1.1	.26	4.8	.46	154
English Child proficiency Average	-.70	4.4	-.02	-.16	.87	3.9	1.2	154
Gender	-18.2	9.3	-.17	-1.95	.05	1.2	.46	154
Age	-4.2	3.0	-.12	-1.4	.17	18.99	1.4	154
Ego depletion	-2.07	5.2	-.03	-.40	.69	.92	.82	154
Language Groups	-9.1	9.9	-.08	-.93	.36	1.74	.44	154

Table 27.

Reaction time means and interactions between two ego depletion conditions and two language groups.

	Monolinguals, n=44		Bilinguals, n=123				
	C n=15	ED n=29	C n=52	ED n=71	F(3,163)	*p*	
Flanker-Separate Blocks							
Control	453	429	439	412	2.9	0.39	
Go	622	581	605	562	2.8	0.04	
Congruent	548	532	536	502	3.2	0.02	
Incongruent	604	591	590	559	2.9	0.04	
Conflict Effect	56	59	54	57	0.1	0.94	
Proportion	0.1	0.1	0.1	0.1	0.3	0.86	
Flanker-Mixed Blocks							
Go	619	595	608	576	1.6	0.20	
Congruent	573	566	568	532	2.3	0.80	
Incongruent	683	658	665	621	3.4	0.19	
Conflict Effect	110	92	97	89	.83	0.48	
Proportion	0.2	0.2	0.2	0.2	0.4	0.79	
Flanker Overall	454	446	449	418	3.9	0.10	

Table 28.

For participants in the monolingual and trilingual groups, means, standard deviations and between group statistics for reaction time and conflict effect measures.

	Monolinguals n=44		Trilinguals n=29		t(71)	p	Cohen's d
	M	*SD*	*M*	*SD*			
Flanker - Separate Blocks							
Control	437	55	420	58	1.2	.22	0.30
Go	595	89	592	83	.15	.88	0.03
Congruent	537	73	520	69	1.0	.32	0.24
Incongruent	596	80	578	79	.90	.37	0.23
Conflict Effect	58	51	58	39	.02	.98	0
Proportion	.11	.09	.11	.07	-.08	.94	0
Flanker - Mixed Block							
Go	603	90	587	80	.78	.44	0.19
Congruent	569	91	553	74	.79	.43	0.19
Incongruent	667	100	638	91	1.2	.22	0.30
Mixed Effect	98	56	85	43	1.0	.31	0.26
Proportion	.18	.10	.16	.08	.94	.35	0.22

Table 29.

For participants in the monolingual and trilingual groups, accuracy means, standard deviations and between group statistics for reaction time and conflict effect measures.

Condition	Monolingual (n = 44)		Trilingual (n =29)				
	M	*SD*	*M*	*SD*	*t*(71)	*p*	Cohen's *d*
Control blocks	.99	.04	.98	.09	.51	.61	0.1
Go/no-go blocks	1.00	.00	1.00	.02	1.0	.33	0
Conflict Blocks	.99	.04	.99	.04	-.25	.80	0
Mixed Blocks	.99	.03	1.00	.02	-.93	.36	-0.4
Flanker overall ACC	1.00	.02	1.00	.02	-.23	.82	0

Table 30.

Accuracy means and between group statistics (*F* and *p* values) for interactions between two language groups (monolinguals and trilinguals) and three ego depletion groups: control, mild ego depletion, and strong ego depletion.

	Monolinguals n=44			Trilinguals N=29				
	C n=15	MED n=13	SED n=16	C n=10	MED n=13	SED n=6	*F*	*p*
Control blocks	1.00	.98	.99	1.00	.96	1.00	.40	.68
Go/no-go blocks	1.00	1.00	1.00	1.00	.99	1.00	.86	.43
Conflict Blocks	1.00	.98	.99	1.00	.98	1.00	.19	.83
Mixed Blocks	1.00	.99	.98	1.00	.99	1.00	.89	.42
Flanker overall ACC	1.00	.99	.99	1.00	.99	1.00	.15	.86

Note. C = control (no ego depletion), MED = mild ego depletion, SED = strong ego depletion, *F* = ANOVA statistic, *p* = alpha level for interaction between language status and ego depletion condition.

Table 31.

Correlations between adulthood English proficiency self-report scores and performance on English proficiency assessments for all multilinguals.

	N	English Adult Proficiency Scores				MTELP		IMAGE NAMING	
		M	*SD*	*Low*	*High*	*r*	*p*	*r*	*p*
Speaking	196	4.76	.56	2	5	.36**	.001	.52**	.001
Hearing	196	4.80	.48	3	5	.33**	.001	.50**	.001
Reading	194	4.79	.49	3	5	.32**	.001	.50**	.001
Writing	195	4.41	.86	2	5	.29**	.001	.42**	.001

***Significant at $p < .001$.

Table 32.

Comparison of means, standard deviations and between group statistics for the conflict block of the Flanker task reported in the present study and the 50:50 (congruent to incongruent) version of the ANT for Costa et al. (2009).

	Researchers	Monolinguals		LLBBs			
		N		**N**		***Df***	
	Present study (2014)	44		18		60	
	Costa et al. (2009)	31		31		60	
		M	***SD***	***M***	***SD***	***T***	***P***
Congruent	Present Study (2014)	537	73	543	70	-.29	.78
	Costa et al. (2009)	581	64	536	38	3.3	.00
Incongruent	Present Study (2014)	596	80	596	60	-0.0	1.0
	Costa et al. (2009)	672	75	633	52	2.4	.02
Flanker Effect	Present Study (2014)	58	51	52	32	0.4	.66
	Costa et al. (2009)	92	35	97	37	0.6	.59

Table 33.

Comparison of means, standard deviations and between group statistics for the go, congruent, and incongruent conditions of the Flanker task mixed block for the current study (2014) and the Flanker task for Luk et al. (2010).

	Researchers	Monolinguals		LLBBs			
		n		n			
	Current Study (2014) Luk et al. (2010)	44 9		18 9			
		M	*SD*	*M*	*SD*	*T*	*P*
Control	Current Study (2014) Luk et al. (2010)	437 552	55 25	440 551	38 44	3.1 0.1	.83 .95
Go	Current Study (2014) Luk et al. (2010)	603 587	90 42	631 585	111 47	-1.0 0.1	.31 .89
Congruent	Current Study (2014) Luk et al. (2010)	569 561	91 42	583 547	107 47	-.53 0.7	.60 .51
Incongruent	Current Study (2014) Luk et al. (2010)	667 636	100 47	654 616	98 41	.46 1.0	.65 .35
Flanker Effect	Current Study (2014) Luk et al. (2010)	98 75	56	71 69	44	1.8	.07

Table 34.

Comparison of means, standard deviations and between group statistics for control and conflict blocks of the Flanker task reported in the present study (2014) and the Flanker task in Luk et al. (2011).

	Researchers	Monolinguals		LLBBs			
		N		**N**		df	
	Current Study (2014) Luk et al. (2011)	44 38		18 43		60 79	
		M	***SD***	***M***	***SD***	***T***	***P***
Control	Current Study (2014) Luk et al. (2011)	437 397	55 52	440 416	38 76	3.1 1.3	.83 .20
Congruent	Current Study (2014) Luk et al. (2011)	537 503	73 61	543 513	70 83	-.29 .62	.78 .54
Incongruent	Current Study (2014) Luk et al. (2011)	596 565	80 70	596 558	60 81	-.00 .44	1.0 .66
Flanker Effect	Current Study (2014) Luk et al. (2011)	58 62*	51	52 45*	32	.44	.66 <.05

All means and standard deviations are reported in milliseconds.

Table 35.

Comparison of means, standard deviations and between group statistics for conflict blocks of the Flanker task reported in the present study (2014) and the Flanker task in Abutalebi et al. (2011).

	Researchers	Monolinguals		LLBBs			
		n		**n**		***Df***	
	Present study (2014)	44		18		60	
	Abutalebi et al. (2011)	14		17		29	
		M	***SD***	***M***	***SD***	***T***	***P***
Congruent	Present Study (2014)	537	73	543	70	-.29	.78
	Abutalebi et al. (2011)	558	101	594	106	1.0	.35
Incongruent	Present Study (2014)	596	80	596	60	-0.0	.78
	Abutalebi et al. (2011)	682	121	705	100	0.6	.56
Flanker Effect	Present Study (2014)	58	51	52	32	0.4	.66
	Abutalebi et al. (2011)	124		111			

All means and standard deviations are reported in milliseconds.

Table 36

Comparison of means, standard deviations and between group statistics for conflict, mixed blocks of the Flanker task reported in the present study (2014) and in the Humphrey study (2012).

	Researchers	**Monolingual**		**Bilingual**		**Trilingual**				
		N		n		n		df		
	Present Study	44		123		29		213		
	A. Humphrey	49		143		24		213		
Condition		*M*	*SD*	*M*	*SD*	*M*	*SD*	$F(2,213)$	*p*	*r*
Flanker Overall	Present Study	449	56	431	59	431	50	1.6	.21	.07
	A.Humphrey2012	551	69	544	66	566	74	1.1	.33	.10
Separate Bl.										
Control	Present Study 2014	437	55	424	66	420	58	0.9	.42	.05
	A.Humphrey 2012	425	60	423	59	438	68	0.7	.52	.08
Go	Present Study 2014	595	89	580	101	592	83	0.4	.66	.20
	A.Humphrey 2012	576	73	565	69	590	73	1.5	.23	.18
Congruent	Present Study 2014	537	73	516	76	520	69	1.4	.26	.09
	A.Humphrey 2012	523	78	516	69	527	72	0.3	.71	.06
Incongruent	Present Study 2014	596	80	572	73	578	79	1.6	.21	.19
	A.Humphrey 2012	575	72	570	68	590	78	0.9	.40	.09
Conflict Effect	Present Study 2014	58	51	56	31	58	39	0.1	.94	1.0
	A.Humphrey 2012	52	30	54	27	63	37	1.3	.26	.11
Mixed Block										
Go	Present Study 2014	603	90	590	95	587	80	0.4	.66	-.06
	A.Humphrey 2012	591	83	585	85	606	97	0.7	.51	.08
Congruent	Present Study 2014	569	91	547	90	553	88	1.0	.38	.07
	A.Humphrey 2012	553	82	546	82	557	84	0.3	.77	.05
Incongruent	Present Study 2014	667	100	639	93	638	91	1.5	.23	.04
	A.Humphrey 2012	637	87	632	87	662	77	1.3	.29	.11
Conflict Effect	Present Study 2014	98	56	92	47	85	45	0.6	.55	.06
	A.Humphrey 2012	83	44	85	39	104	57	2.3	.10	.15

Table 37 Age, Highest SES, Language Proficiency, Picture Naming.

	Monolingual N=44	Lifelong Balance Bilinglual N=18	Late Balanced Bilingual (NE1) N=17	Late Balanced Bilingual (Eng) N=6	English Dominant (Lifelong or Late) N=65	Unassigned Bilingual N=6	Trilingual N=29
Age	19	19	19	19	19	18	20
SES	6.9	5.2	5.2	7.1	5.2	3.8	5.7
MTELP	95	97	94	96	95	96	94
Picture naming	95	93	91	95	93	87	90

Table 38

Reaction Time means and between group statistics (*F* and *p* values) for interactions between language group: monolinguals and trilinguals and three ego depletion groups: control, mild ego depletion, and strong ego depletion.

	Monolinguals n=44			Trilinguals N=29				
	C n=15	MED n=13	SED n=16	C n=10	MED n=13	SED n=6	*F*	*p*
Control Blocks ACC	1.0	.98	.99	1.0	.96	1.0	.40	.60
Control Blocks RT	453	414	440	407	418	445	1.2	.31
Go/nogo Blocks ACC	1.0	1.0	1.0	1.0	.99	1.0	.86	.43
Go/nogo Blocks RT	312	303	312	292	301	308	.27	.76
Flanker-Conflict Blocks								
Conflict Block ACC	1.0	.98	.99	1.0	.98	1.0	.19	.83
Congruent RT	548	516	544	522	492	579	1.2	.31
Incongruent RT	604	576	603	579	557	625	.51	.60
Conflict Effect RT	56	60	59	56	64	46	.17	.84
Proportion RT	.11	.12	.11	.11	.13	.7	.46	.63
Flanker-Mixed Blocks								
Mixed Block ACC	1.0	.99	.98	1.0	.99	1.0	.89	.42
Go RT	619	578	609	576	565	655	1.4	.25
Congruent RT	573	544	584	542	532	615	.69	.51
Incongruent RT	683	640	673	630	606	719	1.5	.23
Conflict Effect RT	110	96	89	88	74	104	.82	.45
Proportion RT	.20	.18	.16	.17	.14	.17	.38	.68
Flanker Overall ACC	1.0	.99	.99	1.0	.99	1.0	.15	.86
Flanker Overall RT	454	434	455	426	419	467	.73	.48

Note. C = control (no ego depletion), MED = mild ego depletion, SED = strong ego depletion, *F* = ANOVA statistic, *p* = alpha level for interaction between language status and ego depletion condition.

Appendix

Figure 1. Incongruent condition of the Flanker Task

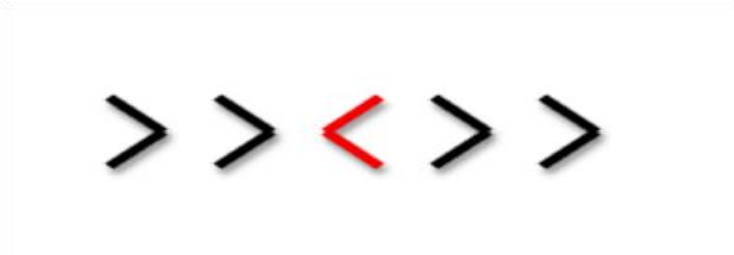

Figure 2. The no-go signal of the go/no-go task

Figure 3. Mirror tracing game

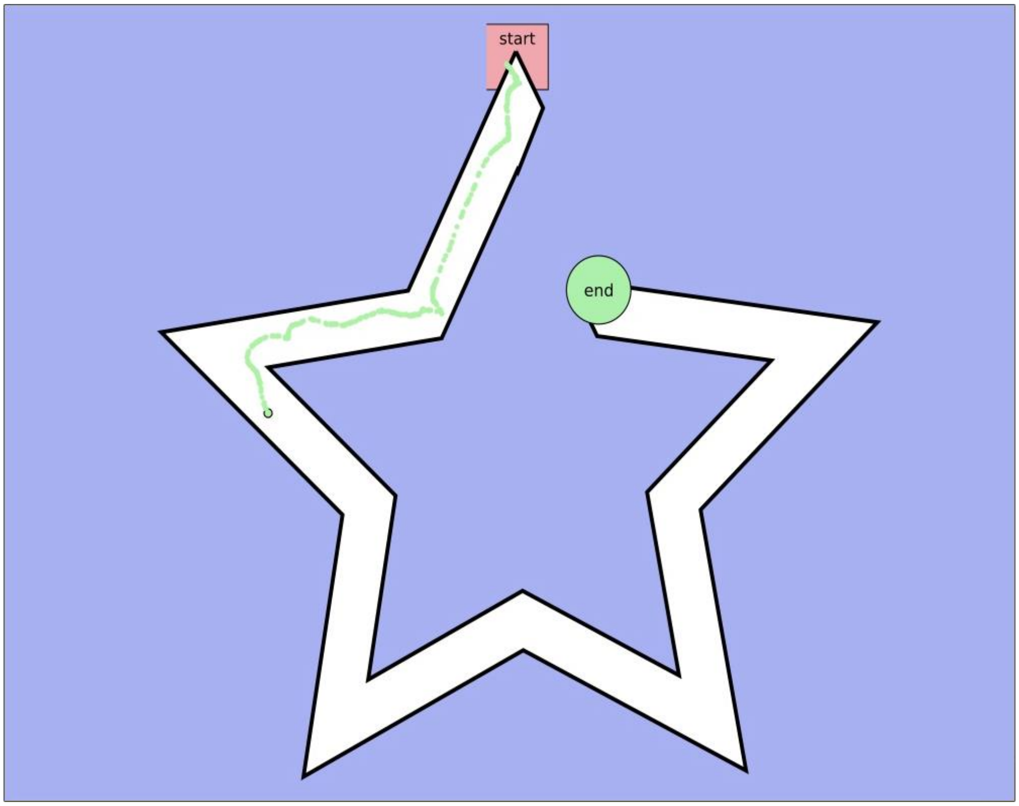

Figure 4. An example of the image naming task

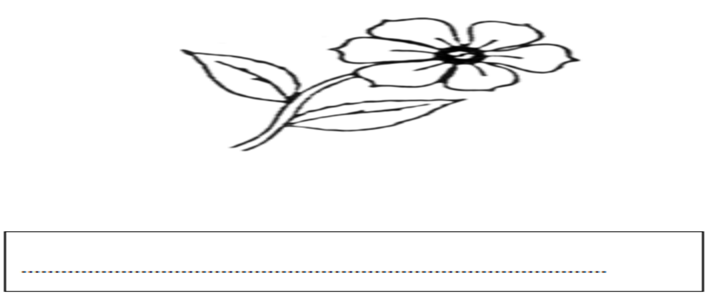

Figure 5. An example of the MTELP task

This is a test of your ability to understand spoken English. The examiner will either ask a question or make a statement. To show that you have understood what was said, you are to select the ONE answer choice you think is correct, and mark that choice on the separate answer sheet.

Here is an example. Listen carefully to the question, then choose one of the answers given below.

<u>Example A.</u> a. I am.
b. Tomorrow.
c. At home.