BILINGUALISM AND COGNITIVE CONTROL: THE *ANT* IN A CANADIAN CONTEXT*

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1. Introduction

Cognitive control–a set of processes that include, but are not limited to, inhibition, attention, monitoring, conflict resolution, selection, and switching–has recently received much attention in not only the field of psychology, but also in the field of linguistics. These are processes that are also often referred to as "executive functions", but it is important to note that while the terms "cognitive control" and "executive control" are sometimes used interchangeably, they do not necessarily carry the same meaning in every instance. For the purpose of the current paper, "cognitive control" is a broad definition for the multitude of processes used by the cognitive system for the aforementioned information processing and management[1].

In recent literature, a growing number of studies link the ability to speak two (or more) languages with improved cognitive control (e.g. Bialystok, Craik, and Luk 2008, Costa, Hernández, and Sebastián-Gallés 2008, Coderre, Van Heuven, and Conklin 2013). While previously hypothesized to be improved only with respect to language processing, cognitive control abilities in bilinguals have been shown to be broader in nature (see overview in Bialystok, Craik, and Luk 2012). This may be due to the transfer of skills from the linguistic domain to the general domain.

While current models of bilingual language processing differ in the exact details regarding the organization of the mental lexicon, the nature of lexical access, and the degree of activation of the two languages, it is widely believed that lexical representations of both languages are active simultaneously (e.g. Green 1998). Strong evidence indicates that this simultaneous activation occurs during both comprehension (Marian and Spivey 2003) and production (Kroll, Bobb, and Wodniecka 2006) of the bilingual's two languages. This means that in any given discourse, the bilingual must resolve the conflict between these two competing languages to produce the one most suited for the situation. In other words, cognitive control skills must be used to pay attention to the language of conversation, select this target language, and inhibit the non-target language. In cases where both speakers are bilingual, rapid code-switching may also occur, requiring the speaker to seamlessly transition between the two languages. As a result of this language management experience, bilinguals may have increased domain-general ability to inhibit irrelevant information, to pay attention to relevant information, and to multitask.

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*Acknowledgements: We would like to thank Natalie Ho, Yu Ying (Joy) Li, and Sameer Ratti for help with recruiting and testing participants, the members of the ERPLing Lab at the University of Ottawa for invaluable discussion, and all of our participants for their time and enthusiasm. This research was supported by a SSHRC grant to the second author.

[1]"Executive Control" will be used strictly to discuss the attentional network as defined for the Attention Network Test (ANT) by Fan, McCandliss, Sommer, Raz, and Posner (2002).

Actes du congrès annuel de l'Association canadienne de linguistique 2015.
Proceedings of the 2015 annual conference of the Canadian Linguistic Association.

These bilingual advantages in cognitive control are, however, not without debate. Examining a number of studies, Hilchey and Klein (2011) note that the results pointing to an advantage for bilinguals are inconsistent, and particularly so when looking at the young adult population. In a large-scale investigation using both linguistic and non-linguistic tasks, Paap and Greenberg (2013) find that these bilingual advantages are also not consistent across experimental tasks. Furthermore, de Bruin, Treccani, and Della Salla (2014) suggest that the bilingual advantage hypothesis is in part due to a publication bias. In light of these inconsistencies, it would be beneficial to further investigate the connection between bilingualism and cognitive control. As Valian (2015) notes, the effects of bilingualism on cognitive control, when found, are generally positive. Thus, it is worthwhile to investigate when and under what circumstances the bilingual cognitive control advantage appears, and to identify factors that may modulate this advantage.

To investigate these issues, the current study examines cognitive control abilities in English-French bilinguals by using the Attention Network Test (ANT; Fan, McCandliss, Sommer, Raz, and Posner 2002) and asks 1) When and where does bilingualism improve cognitive control? and 2) Are any advantages modulated by the bilingual experience, i.e. earlier Age of Second Language (L2) Acquisition (AoA)? Importantly, we focus on bilinguals in the National Capital Region of Canada, where, unlike in a number of previous studies, both languages (English and French) are readily accessible and widely spoken.

2. Investigating Bilingual Cognitive Control

2.1 The Attention Network Test

While it was initially suggested that bilinguals have superior inhibitory control abilities (for overview, see Bialystok et al. 2012), the studies reviewed by Hilchey and Klein (2011) show that advantages in interference tasks are not common and that bilinguals and monolinguals perform similarly on tasks requiring pure inhibition. Thus, inhibitory control may not be the main mechanism responsible for the observed bilingual advantages. A second cognitive control mechanism that has been implicated in the bilingual advantage is attention. In contrast with monolinguals, bilinguals have considerably more practice in using attentional mechanisms to focus on the target language and inhibition mechanisms to suppress the non-target language (Bialystok and Craik 2010). Attention in this case becomes an assisting process to inhibition, since by focusing attention on the relevant dimension (i.e. the target language), the irrelevant dimension (i.e. the non-target language) can be inhibited. But is "attention" a single mechanism?

Posner and Petersen (1990) proposed that attention consists of three networks. These networks are alerting, which is the achieving and maintaining of an alert state; orienting, which is the selection of specific elements of the input; and executive control, which is involved in monitoring and conflict resolution (Fan et al. 2002). Furthermore, these networks have been shown to be relatively independent and linked to separate brain regions (Fan et al. 2005). This demonstrates that attention is not a single mechanism, but rather, it is made up of several components.

To test these attentional components, the ANT (Fan et al. 2002) has been developed. Not only does it allow for an examination of specific attentional processes, but also it provides a non-linguistic measure of cognitive control. To test these networks, the ANT combines timing and four cue conditions in addition to a flanker task originally developed by Eriksen and Eriksen (1974), in which the target is surrounded by distractors.

In a typical trial, before the onset of the arrow stimuli, a fixation cross appears with either a cue or no cue. In the case of a cue, an asterisk may appear in the centre, as a spatial cue above or below the fixation cross, or two asterisks may simultaneously appear above or below the fixation cross as a double cue. This is followed by arrows in a neutral, congruent, or incongruent condition. In the neutral condition, a single arrow pointing left or right with two dashes on either side appear either above or below the fixation cross. In the congruent condition, the arrow appears with flankers pointing in the same direction as the central arrow, while in the incongruent condition, the flankers point in the opposite direction of the central arrow, thus creating a conflict situation. Participants respond by indicating the direction of the central arrow. From this combination of cues and targets, the three aforementioned networks (Alerting, Orienting, and Executive Control) can be calculated, and results can be compared across groups.Thus, the ANT provides a good measure of the networks associated with attention, and has been used widely used in studies of bilingual cognitive control.

2.2 ANT and the Bilingual Advantage

Observed bilingual cognitive control advantages have been said to be the result of an improved executive control network (Costa et al. 2008, 2009; Hernández, Costa, Sebastián-Gallés, Fuentes, and Vivas 2010, Marzecová, Asanowicz, Krivá, and Wodniecka 2013). Indeed, various findings appear to support this view. Hernández et al. (2010) found greater executive control efficiency for bilinguals, and using the ANT, Costa et al. (2008, 2009) also revealed significant executive control network differences between monolinguals and bilinguals. Bilinguals outperformed monolinguals on all tasks of executive control. Thus, it appears that language management experience may contribute to executive control advantages in bilinguals.

Any advantages for the alerting and orienting networks, however, still remain unclear. Improved alerting efficiency was shown by Costa et al. (2008), who reasons that due to having to pay attention to two different language systems and switch between them, bilinguals are able to maintain a better state of alertness. Alerting allows them to prepare the executive control network for monitoring and conflict resolution. An alerting advantage, however, is not present in their 2009 study. Both studies also fail to find a significant orienting advantage.

Similarly, a lack of an orienting advantage is noted by Hernández et al. (2010) and Marzecová et al. (2013). This contradicts findings by Colatzo et al. (2008) that do show a significant orienting advantage. However, the orienting advantage in Colatzo et al.'s (2008) study comes about only under very specific experimental conditions. Whether these inconsistent findings are the result of methodological differences or other factors, it is clear that much work remains to be done in this area.

In particular, the inconsistencies noted for the young adult population by Hilchey and Klein (2011) suggest an avenue for continuing research. A study by Paap and Greenberg (2013) examined this population using a variety of methods, including flanker tasks, and found not only inconsistent advantages, but also a complete lack of a bilingual advantage altogether. Does this mean that the bilingual advantage is a myth? Such a conclusion would seem too extreme, especially in light of studies that continue to find these advantages. A critical factor here appears to be the conditions under which advantages appear in the young adult population.

It appears that the conditions do have an impact on observed advantages in attentional efficiency. This was shown by Costa et al. (2009), who varied the proportion of congruent and incongruent trials in their study of young adult monolinguals and bilinguals. In the low-conflict version of the task, where most of the trials were either congruent or incongruent and thus the need for monitoring was low, the groups were fairly evenly matched. However, in the higher conflict version, where both types of trials were more in proportion thus creating a situation where the need for monitoring was high, the bilingual group surpassed the monolingual one. It has been suggested that since young adults are already at the peak of cognitive control, the boost given by bilingualism is not as large as that of children and older adults. Still, while not as robust, even young adults appear to enjoy processing advantages that are not available to their monolingual counterparts, particularly in challenging environments.

Experimental conditions may not be the only contributing factor to observed differences in cognitive control ability between monolinguals and bilinguals. Just as various experiences shape our cognitive development and functions, the experience of being bilingual and the circumstances under which one became bilingual may be further factors in the development of cognitive control. The first of these factors is AoA.

2.3 AoA Effects on Cognitive Control

Many studies of bilingual cognitive control have predominantly used early bilinguals as participants (see review in Tao, Marzecová, Taft, Asanowicz, and Wodniecka 2011). What might be the consequences of acquiring an L2 early in life? It is possible that the prolonged practice of being bilingual alters anatomical structures (Bialystok et al. 2012; Abutalebi and Green 2008), which in turn appears to have consequences for behaviour. Becoming bilingual early in life also has another obvious advantage: namely, early bilinguals have spent a greater amount of time being bilingual, and therefore have much more practice and experience in managing two language systems. However, thorough investigations of AoA effects on cognitive control remain sparse.

In a study focusing specifically on AoA effects, Tao et al. (2011) used the ANT to examine early and late English-Chinese bilinguals living in Australia. Two possibilities were suggested as a result of becoming bilingual early or later in life. The first was that early bilinguals would enjoy a greater advantage as a result of a longer length of bilingual exposure, and the second, that older bilinguals would enjoy a greater advantage due to needing to use executive control networks to suppress interference from their weaker second language, as suggested by Abutalebi and Green (2007).

Supporting the bilingual cognitive control advantage, this study revealed better efficiency across all networks for bilinguals compared to monolinguals, but when the AoA groups were compared, another finding emerged. While early bilinguals had faster overall RTs, it was the late bilingual group that showed improved alerting and executive control (once again, no orienting advantage was found.) A subsequent study of a mix of Polish-L2 and Slovak-L2 bilinguals (where L2 could be Czech, Ukrainian, Russian, or Belarussian) by Marzevocá et al. (2013), however, found quite the opposite. While still finding an executive control advantage for all bilinguals, it was the early bilinguals who showed the greatest alerting network efficiency. Furthermore, no global RT advantages were found; an RT advantage only became apparent on conflict trials. The authors suggest that bilingualism does impact both conflict resolution and monitoring, but possibly in an independent manner. This suggests that while becoming bilingual at any age confers an executive advantage, there are differences in the type of advantage. Results were interpreted as dissociating the conflict resolution advantage (for late bilinguals) from a monitoring advantage (for early bilinguals, as evidenced by faster RTs).

A different approach to the AoA issue was taken by Luk, de Sa, and Bialystok (2011), who examined the onset age of active bilingualism in young adults using a flanker task. Onset age of bilingualism is defined as the age at which a bilingual started using both languages daily, with earlier onset resulting in a greater length of bilingual experience. Once again, while an overall bilingual advantage was found, the early bilingual group showed the greatest ability to suppress interference in the flanker task, demonstrating their increased cognitive control ability. Interestingly, the flanker task used revealed no differences in cognitive control ability between the late bilingual and monolinguals groups. For the late bilingual group, this finding could be the result of less experience in managing two languages- a possibility confirmed by a correlation analysis which showed that becoming bilingual earlier and a longer timespan of being bilingual results in greater proficiency and cognitive control for the individual. While earlier AoA may contribute to more positive outcomes for bilingual cognitive control, there is a second factor that cannot be ignored: this factor is the bilingual environment.

2.4 The Bilingual Environment and Cognitive Control

The Adaptive Control Hypothesis (Green and Abutalebi 2013) states that control processes adapt themselves to the demands placed upon them by the interactional context. In other words, the type of language use by a community of speakers determines the development of these control processes. While this applies to both monolinguals and bilinguals, it is particularly the bilingual situation which is of greatest interest. Green and Abutalebi (2013) identify 3 such interactional contexts- single language, dual-language, and dense code-switching.

The first context, single language, is characterized by the use of one language in one environment. In the case of bilinguals, this means that each of the languages is used in a separate environment, with no overlap in use. For a family who has immigrated to Canada from a non-English or non-French speaking country, for example, the native language may be used at home, while English or French is used with the outside community. Here, the languages are not mixed.

The second context, dual-language, is characterized by the use of two languages in the same environment, but each language is used with a different interlocutor. For example, an English-French bilingual in the workplace may use English with a colleague whose first language (L1) is English, but switch to French with a L1 French colleague. In this context, there is switching between languages, but this switching is dependent on the speaker, and does not occur within sentences.

The final context, dense code-switching, is characterized by frequent switching between the two languages, both within a conversation and within sentences, and with the same interlocutor. This may be the case for two English-French bilinguals who are aware of each other's bilingual status. In such instances, both English and French words are intermixed, and words from one language may be adapted into the other (Green and Abutalebi 2013).

Some of the inconsistencies in the bilingual cognitive control literature may be due in part to the type of environment of the bilingual participant sample, as each of the aforementioned environments have been hypothesized to result in the development of different cognitive control skills. Particularly, it is the dual-language environment which requires the greatest use of cognitive control skills, while the single-language and dense code-switching environments are less demanding. Therefore, it is not only one's status as 'monolingual' or 'bilingual' that should be taken into account in bilingual cognitive control studies, but also factors such as the AoA and the bilingual environment.

3. The Current Study

The current study aims to examine the efficiency of attentional networks in a bilingual Canadian setting. As the young adult population has been shown to be the most inconsistent with respect to general cognitive control abilities (Hilchey and Kelin 2011), we seek to explore the circumstances under which advantages, if any, are present, and to examine which specific attentional networks are at an advantage for this population.

The AoA has been suggested to impact cognitive control abilities (Tao et al. 2011); therefore, we examine the differences between Simultaneous, Early, and Late bilinguals in the non-linguistic ANT. Based on previous studies in our lab (Sabourin, Brien, and Burkholder 2014; Sabourin and Vīnerte 2015), we operationalize the AoA as the Age of Immersion (AoI). Furthermore, we draw our participant sample from the National Capital Region of Canada, a region where both English and French are largely available. We believe that this environment can be classified, according to the Adaptive Control Hypothesis, as a dense code-switching environment. With this in mind, we hypothesise that as in much of the literature, our bilinguals will exhibit advantages in cognitive control, although effects may not be as large as those previously reported. Furthermore, a greater degree of bilingualism (i.e. earlier AoI) may lead to greater efficiency of attentional networks. While we predict improved executive control network efficiency for bilinguals, we take a more exploratory approach to the alerting and orienting networks. If these networks are impacted by bilingualism, we may see improved efficiency.

4. Methods

4.1 Participants

A total of 65 participants (6 male) between the ages of 18 and 27 (mean age = 19.14 years) took part in this study. All participants were English-French bilinguals or learners of second language French. All had normal or corrected-to-normal vision and no known attentional disorders (i.e. Attention Deficit Disorder or Attention Deficit Hyperactivity Disorder). Participants were recruited through the University of Ottawa's Integrated System for Participation in Research (ISPR) and received 1 point credit for their psychology class. Light refreshments were also provided during the study.

Participants gave a detailed account of the context of English/French/other language acquisition using the lab's Language Background Questionnaire (Sabourin et al. 2009).

Based on the questionnaire, participants were divided into three groups based on when they became immersed in their L2. Simultaneous bilinguals (SM; n=24) were individuals who were immersed in both English and French from birth (e.g. one parent spoke one language, while the other spoke the other language), while Early Sequential bilinguals (ES; n=21) were individuals who were immersed in their L2 between the ages of 1 and 6. Furthermore, a Functional Monolingual (FM; n=20) group was included for comparison. It is important to note that the latter group was not truly monolingual; these participants have received core French classes in school, but were never immersed in their L2. Their 'functional monolingual' status was reflected in their self-rated proficiency (M=9.67/20, SD=3.5) and their L2 Cloze test scores (M=10%).

4.2 Materials

An ANT task was programmed using Neurobehavioural Systems' Presentation v.14.9 software. Stimuli were presented using a PC desktop computer with a Windows Vista operating system, on a 19-inch screen. Participants used a Cedrus RB-830 button box equipped with 3 active buttons to respond. To minimize cognitive demand of responses, the left and right response buttons were placed on the left and right side, respectively.
In the current study, as in the original test, the stimuli used were left-pointing and right-pointing arrows and asterisks (*) as spatial cues. Four cue conditions and three different arrow conditions were created for this task. Arrow stimuli pointed either left or right. Cue and Arrow conditions are given in Tables 1 and 2, respectively.

Table 1. ANT Cue Conditions.

Cue	Example
None	No cue appears; only fixation cross
Central	Cue over fixation cross
Double	Cue above and below fixation cross
Spatial	Cue above or below fixation cross

Table 2. ANT Arrow Conditions.

Arrow	Example
Neutral	Single arrow flanked by 4 dashes; two dashes on each side
Congruent	5 arrows pointing in same direction
Incongruent	Central arrow; flankers point in opposite direction of central arrow

4.3 Procedure

Once participants had completed the questionnaire and cloze tasks, they were invited into a sound-attenuated room to begin the experiment. Participants were told that they would see arrows in the conditions described in the Materials section, and were asked to press the white, left-hand-side button if the central arrow pointed to the left, or the red, right-hand-side button if the central arrow pointed to the right. Participants were asked to keep their gaze fixed on the fixation cross in the middle of the screen. These instructions also appeared on the screen in front of the participant.

The participant then began the practice trials. The researcher remained in the room during the practice trials to give the participant an opportunity to ask any further questions. Once the practice trials were over and the participant had no further questions, the researcher left the room and the experiment began.

The ANT trial began with a fixation cross at the centre of the screen for 250-1500ms, followed by a 100ms presentation of the spatial cue. The cue disappeared, and 250ms later the target appeared. Participants responded by pressing either the white or the red button of the button box to indicate the direction of the arrow they had seen. The next trial began immediately following the button press. Once the ANT block had been completed, a self-timed break screen appeared. Once they were ready to continue, participants were invited to press a button on the button box.

The experiment consisted of two blocks of ANT, separated by an interspersed linguistic task. Each block consisted of 144 randomized trials, for a total of 288 trials across the experiment. An equal number of cue conditions and congruency conditions appeared in each block, with 1/3 of the trials being neutral, 1/3 being congruent, and 1/3 being incongruent. Neutral trials were used to obtain a baseline reaction time. A sample trial is shown in Figure 1.

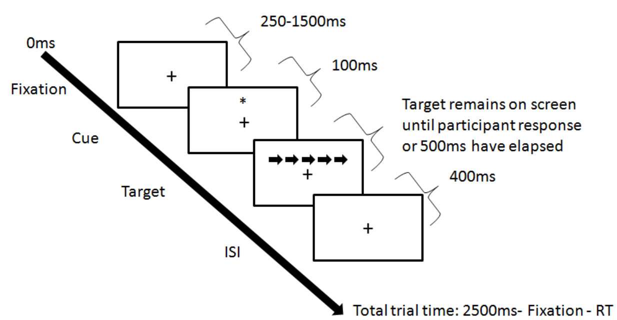

Figure 1. Sample ANT trial.

5. Results

Data were coded for reaction time (RT) and accuracy. RTs to incorrect responses were removed from the analysis, and RTs that were 2 standard deviations above or below the mean for each participant were also excluded as outliers. Using the cues and targets of the ANT, the mean network effects for Orienting, Alerting, and Executive Control networks were calculated. Following Fan et al. (2002), network efficiencies were calculated as shown in (1).

(1) $\text{Orienting} = RT_{(\text{spatial cue})} - RT_{(\text{central cue})}$
$\text{Alerting} = RT_{(\text{double cue})} - RT_{(\text{no cue})}$
$\text{Executive Control} = RT_{(\text{incongruent trials})} - RT_{(\text{congruent trials})}$

5.1 Orienting

A one-way ANOVA was conducted to compare Orienting effect magnitudes using AoI as the between-subjects factor. Results revealed a trend toward AoI effects on Orienting (p =.08), with the ES group showing an advantage in Orienting ability over the FM group

(p=.04; M=31.76ms, SD=19.59ms vs. M=20.76ms, SD=12.97 for ES and FM groups, respectively) and a trend toward an advantage compared to the SB group (p=.07; M=22.25ms, SD=16.93ms). There were, however, no differences between the FM and the SB group (p=.77), as seen in Figure 2.

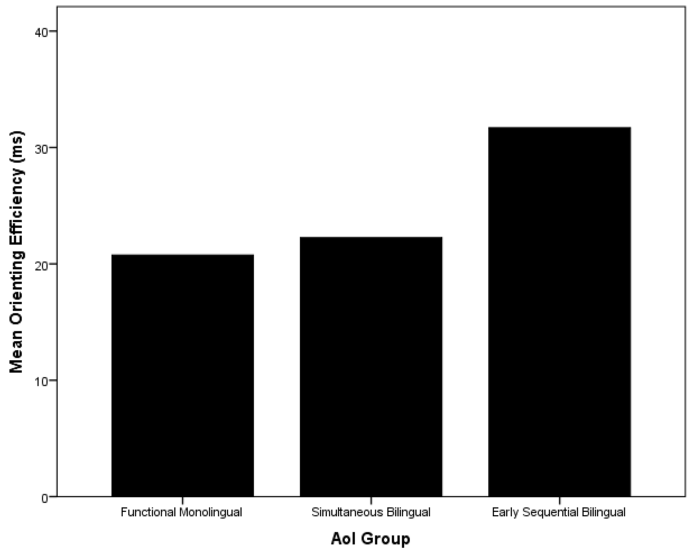

Figure 2. Orienting network analysis. Larger effect indicates greater efficiency.

5.2 Alerting

A one-way ANOVA was conducted to compare Alerting effect magnitudes, and results revealed no significant effect of AoI on Alerting (p =.84), with no group showing a network advantage (M=45.63ms, SD=22.51ms; M=43.96ms, SD=23.62ms; and M=41.40ms, SD=22.86ms, for the FM, SB, and ES groups, respectively.) This is seen in Figure 3.

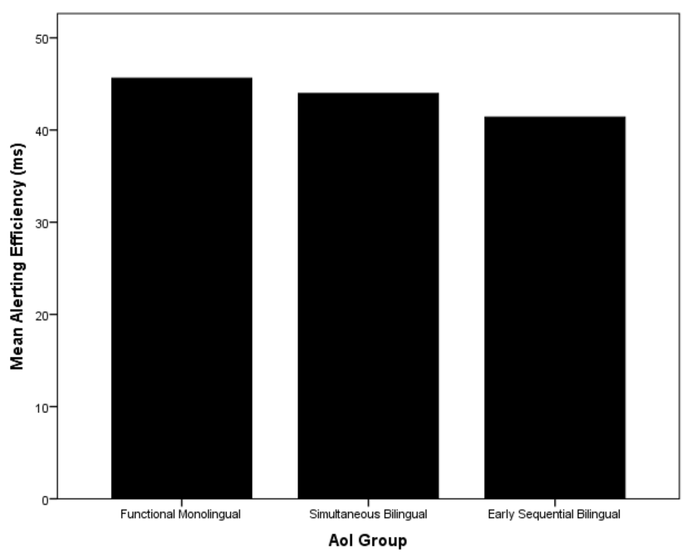

Figure 3. Alerting network analysis. Larger effect indicates greater efficiency.

5.3 Executive Control

A one-way ANOVA comparing Executive Control effect magnitudes between the groups revealed no effect of AoI (p =.547), with the FM, SB, and ES groups performing similarly (M=62.57ms, SD=33.70 ms; M=54.08ms, SD=19.14ms; and M=58.50ms, SD=23.03ms, respectively). This is shown in Figure 4.

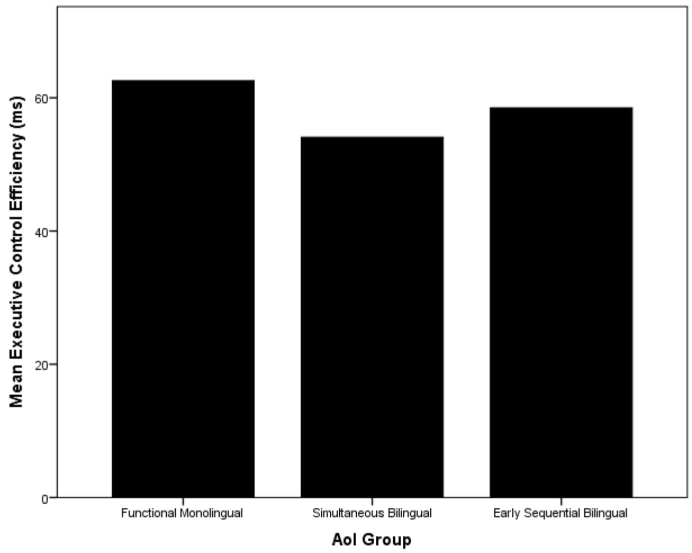

Figure 4. Executive Control analysis. Smaller effect indicates greater efficiency.

6. Discussion

The current study investigated the effects of AoI on the attentional networks of Orienting, Alerting, and Executive Control in the ANT task, and revealed a trend toward better Orienting network efficiency for early sequential bilinguals compared to functional monolinguals and simultaneous bilinguals, and no differences between the functional monolingual and simultaneous bilingual groups. The expected Executive Control network advantage for bilinguals, however, was absent, with all groups performing similarly. Also absent were any effects on the attentional network of Alerting. These findings will be discussed with respect to the experimental task, participant grouping, and importantly, the bilingual environment.

Looking at the experimental task, the current study uses a standard ANT task. In this task, there is an equal proportion of congruent and incongruent trials, as well as neutral trials to establish a baseline RT. It is possible that our Executive Control, Alerting, and Orienting results come about as a result of the design of the experimental task itself. As has been shown in tasks of linguistic cognitive control, there are strong cognitive control advantages for children (Bialystok and Barac 2012) and for older adults (Bialystok et al. 2008), but advantages for the young adult population on tasks such as the ANT are not as clear (Hilchey and Klein 2011). Furthermore, in some cases, these advantages are entirely absent (Kousaie and Phillips 2012).

Using linguistic and a non-linguistic tasks, including a flanker task similar to the ANT in the current study, both Kousaie and Phillips (2012) and Paap and Greenberg (2013) fail to find any cognitive control advantages for the young adult population. Similarly, the current study finds no distinct advantage for our young adult participants in any of the three attentional networks. In contrast, Costa et al. (2009), also testing the young adult population and using the ANT, do find significant advantages for the bilingual group. However, this advantage is seen only when the proportion of congruent and incongruent trials is varied, thereby creating a more challenging tasks and increasing the need for monitoring the situation. The authors suggest that it is particularly when monitoring needs are high that bilinguals outperform monolinguals. Furthermore, the authors note that the young adult population is at a life stage where their cognitive control abilities are already at a peak, and this population therefore requires additional challenge to make any effects apparent. Applying this reasoning to our current study, it is possible that we do not find significant results due to an insufficiently challenging task.

If the boost given by bilingualism is minimal to a group that is already at the peak of executive control (i.e. the young adult population), it is reasonable to expect that any advantages observed are not as robust as those that would be seen in children and older adults. These two groups, whose cognitive control abilities are not yet fully developed or are in decline, respectively, may show greater effects due to a greater boost from bilingualism. Therefore, to elicit the same type of effects from young adults, the task difficulty must be increased. This could be done by varying the proportion of congruent and incongruent trials, as was done by Costa et al. (2009), or by further increasing the task difficulty by adding more challenging interspersed tasks. By modifying tasks to make them suitably challenging for young adults, it may be possible to better identify the minute effects on different attentional networks. The trend towards better Orienting in the present study does suggest that bilinguals may be controlling information differently from their monolingual counterparts, and particularly that there are differences even between the bilingual groups themselves.

Earlier studies such as Costa et al.'s (2008, 2009) differentiate only between monolingual and bilingual groups, without taking into consideration the differences that may exist within the bilingual group itself. Our finding that there are differences between simultaneous and early sequential bilinguals with respect to the Orienting network suggests a need for a fine-grained distinction among bilinguals themselves. Here, while simultaneous and early sequential bilinguals are both "bilingual" groups, the former patterns more closely to the monolingual group, while the second shows signs of a bilingual advantage. These Orienting network results mirror the results of a previous linguistic study with the same young adult group (Sabourin and Vīnerte 2015), where there were no differences between the functional monolingual and simultaneous bilingual groups, but these differences were found in the early sequential group. We suggest that these differences may be the result of how the bilinguals' two language systems develop: while simultaneous bilinguals may develop only one system, similar to the monolinguals, but with two integrated languages, the early sequential bilinguals develop two competing languages systems (see Sabourin and Vīnerte 2015 for full discussion). These differences could be reflected in both linguistic and non-linguistic cognitive control tasks.

Furthermore, these differences may be caused not only by the differing development of the language systems, but also in part by the bilingual environment in which our participants were immersed. It may be specifically the environment which contributes to the lack of observed Alerting and Executive Control effects.

Kroll and Bialystok (2013) suggest that the experience of being bilingual has profound effects on the development of our general cognitive abilities. Green (2013) also discusses the brain's ability to adapt to a task over the course of a single experiment. If there is such rapid adaptation over the timecourse of a single experiment, it is clear that experiences shape cognitive function and development. Therefore, it is necessary to examine the bilingual experience when looking at cognitive control. The bilingual environment and context are a large part of this bilingual experience, and context has recently been linked to cognitive control (Wu and Thierry, 2013). This leads to an interesting question: could the bilingual environment account for the observed differences in findings between the current study and previous studies (e.g. Costa et al. 2009)?

As with playing a musical instrument or practicing a sport, the constant practice of the task is what leads to improvement. The same could be true for language. According to the bilingual advantage hypothesis, cognitive control abilities in bilinguals are improved as a result of language experience (e.g. inhibiting the non-target language). In a sense, because bilinguals are constantly inhibiting one language to produce the target language, and because they have to control their language switches, they have more experience with these types of tasks and are therefore better at them. However, what would happen if bilinguals did not need to inhibit or control their language switching?

As discussed in the Introduction, Green and Abutalebi (2013) identify three distinct bilingual environments- single language, dual language, and dense code-switching. These different types of environments, the authors suggest, may lead to processing differences. Particularly, it is the dual-language bilinguals who may benefit the most, with a lesser effect for dense code-switching bilinguals. Indeed, studies showing strong bilingual advantages have included bilinguals from a dual-language environment (e.g. Costa et al., 2008; Spanish-Catalan bilinguals, in an environment where Spanish and Catalan are spoken with different interlocutors). Our participants, however, may be different.

Being the National Capital region, the Ottawa-Gatineau area is highly bilingual. As such, both English and French are constantly available, and all of our participants have had both formal (e.g. Core French classes) and informal (e.g. Francophone friends) exposure to their L2. Furthermore, the area can be considered a dense code-switching environment, as both languages are heard and mixed frequently, especially at the University of Ottawa. Therefore, it may be that our participants do not have to inhibit either language, as both are readily available in their environment and they may speak one, the other, or both in any given situation. Thus, as a result of not needing to use attentional processes to control the switches between their two languages, the bilingual experience of our participants does not include extensive practice in executive control, which may be a reason why we find no differences between our groups in Executive Control.

Furthermore, when looking at the results of Kousaie and Phillips (2012), another Canadian study which fails to find an advantage for bilinguals, we notice similarities between their environment and ours. Kousaie and Phillips (2012) conducted their study in Montreal, a Canadian city where, just like in Ottawa, both English and French are readily available. Thus, participants do not have to constantly inhibit and control both of their languages, thereby decreasing the amount of executive control they must engage to manage language switching. Given these similar environments and similar lack of positive results and comparing them to studies that do find positive results and their respective language environments, it is possible that the bilingual environment is in part responsible for the differences found among studies of cognitive control.

7. Conclusions

While the current study does not find significant differences between groups for the attentional networks of Alerting and Executive Control, and only a trend towards Orienting differences, we do not interpret this as demonstrating a lack of a bilingual cognitive control advantage, as has been suggested by authors such as Paap and Greenberg (2013). Instead, we believe that factors such as the experimental task, participant grouping, and particularly the environment contribute to the observed results. Environmental effects on cognitive control are still a largely unexplored area of research, and while we are unable to say with certainty that our results reflect a dense code-switching environment, we do believe that environmental factors should be taken into consideration in studies of both cognition and language. Thus, we urge researchers not to take this factor for granted when conducting studies with bilinguals.

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