The Effect of Lifelong Bilingualism on Adulthood
Cognitive Control

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Language and Cognition

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1. Introduction

Bilingualism has been a subject of discussion and research for more than a century. It has received an immense attention from scholars in various disciplines since it is not only a linguistic but also a social, cultural, political and psychological phenomenon (Baker, 1988). Before the first half of twenty century, bilingualism was perceived as an interference to normal cognitive functioning, and a source of confusion that severely hampers the clarity of thinking (Bialystok, 2006). However, after a groundbreaking research by Peal and Lambert in 1962 which reported the advantage of bilingualism for the first time, there has been a paradigm shift in researches that have been conducted on bilingualism and in perception about bilingualism in general. Although there are still well recognized negative effects of bilingualism, for example, on verbal fluency (e.g. Sandoval & Gollan, 2010) and on lexical access in speech (e.g. Ivanova & Costa, 2008), a number of studies that have been conducted on bilingualism in the last six decades reported several advantages of bilingualism. To mention some, bilingualism is essential to enhance mental flexibility, metalinguistic awareness, superior concept formation and to develop executive control (Latham, 1998).

One of the advantages of bilingualism is enhancing cognitive control capabilities. Several studies have illustrated that bilinguals outperform monolinguals on various cognitive tasks (e.g. Bialystok et al., 2005; Bialystok & Craik, 2010; Craik & Bialystok, 2006; Gollan, Montoya, Cera, & Sandoval, 2008; Luk, Bialystok, Craik, & Grady, 2011; Salthouse, Atkinson, & Berish, 2003; Salvatierra & Rosselli, 2010). For instance, Salvatierra and Rosselli (2010) investigated the cognitive advantages of bilingualism using the Simon task, and reported that bilinguals are better than monolinguals on tasks that involve inhibition. Likewise, Luk, Sa and Bialystok (2011) examined the relationship between the onset of second language and the cognitive control using the Flanker task. Their study focused on young bilinguals who were around twenty years old. The result of their study showed that early bilinguals produce small flanker effects as compared to late bilinguals. Based on this finding, they concluded that more experience in being actively bilingual is associated with greater advantage in cognitive control.

Nonetheless, there are still issues that demand further scrutiny. One of the issues that need further inspection is the origin of the cognitive advantage and its sustainability. The commonly
reported explanation for the origin of the cognitive advantage is that bilinguals use two languages regularly (e.g. Blumenfeld & Marian, 2007; Bergmann, Speringer, & Schmid, 2015; Hatzidaki, Branigan, & Pickering, 2011). Controlling concurrent activations of the two language systems requires inhibiting the unwanted language and activating the language that is relevant in the given context. This persistent practice of selecting one language and suppressing another enhances the development of cognitive ability (Bialystok, Craik, & Luk, 2008; Bialystok, 2007; Christoffels, Firk, & Schiller, 2007; Luk et al., 2011). The development of executive control in turn enables bilinguals perform better than monolinguals on non-linguistic tasks (Bialystok et al., 2008; Bialystok, 2007; Christoffels et al., 2007; Luk et al., 2011).

Two concerns have remained unclear in this explanation. The first one is whether language processing and other cognitive tasks share the same neurological base (Abutalebi, 2008; Costa, Miozzo, & Caramazza, 1999; Genesee, 1989). The second issue is the permanency of the cognitive advantage. In previous studies, it has been consistently argued that once the cognitive advantage is acquired, bilinguals should use both languages on a daily basis throughout their lifespan to preserve this advantage for a later age (Bialystok et al., 2005; Bialystok, Craik, & Freedman, 2007; Craik & Bialystok, 2006; Gold, Kim, Johnson, Kryscio, & Smith, 2013). According to this account, the durability of the cognitive advantage is reliant on the amount of the two languages used throughout the bilinguals’ lifespan.

The claim indicates that the regular use of two languages is essential not just for the emergence of cognitive control, but also for the survival of the cognitive advantage. This means that using two languages just early on the continuum of the bilinguals’ life does not guarantee the continuity of cognitive advantages; the preservation of the cognitive advantage for late adulthood needs perpetual use of both first and second languages. Previous studies in which this claim has been made have not examined the bilinguals' lifelong language experience (e.g. Bialystok et al., 2007; Bialystok, Craik, Klein, & Viswanathan, 2004; Bialystok, Martin, & Viswanathan, 2005); rather they just compared bilinguals to monolinguals. For instance, Bialystok, Poarch, Luo and Craik (2014) studied the effect of bilingualism and aging on cognitive control using Strop task. They compared younger and older bilingual and monolingual. In both age classes bilinguals showed less interference than monolinguals. However, the larger bilingual advantage was found
among older bilinguals. To the best of my knowledge, previous studies did not measure the amount of first and second languages used throughout the bilinguals’ life and did not determine the association between the balance between the two languages and cognitive control. Therefore, the present study examined this association.

This investigation is particularly essential since, in reality, bilinguals do not always use both languages ‘on a daily bases’ throughout their life as indicated in (Bialystok et al., 2007; Bialystok et al., 2004; Bialystok et al., 2005). Bilinguals who use both first and second language ‘equally’ on the daily bases are very few. This is because, by its nature, bilingualism is a dynamic process; any change in a linguistic environment that bilinguals experience in their life can affect the magnitude of both languages they use (Bot, 2008; Grosjean, 1982). Therefore, it is unlikely that all bilinguals use both first and second languages in the same way and in the same amount throughout their life since the amount of language they use is dependent on the context. Even in a specific geographical setting, the amount of first and second language that the bilinguals use can vary due to various factors such as work place situations, language background of the family members and media influences (Mitchell, Myles, & Marsden, 2013).

Thus, there is a prospect that changes in the amount of languages that the bilinguals use throughout their life affect the bilinguals’ later age cognitive control. As indicated earlier, the perception about the cognitive advantage of bilingualism is that bilinguals 'regularly' use both first and second languages. This lifelong regular practices of the two languages enable them perform better than monolinguals on cognitive tasks, and protect them from rapid cognitive aging (Bialystok, Craik, & Ryan, 2006; Luk et al., 2011). Given that bilingualism is a dynamic process as indicated above, lifetime ‘regular’ practices of both first and second languages may not be possible for all bilinguals. Hence, if using both first and second languages 'regularly' throughout bilinguals’ lifespan is compulsory for the bilinguals’ later age cognitive control, it is likely that the changes in the amount of first and second languages that bilinguals experience at some point in their life can affect the magnitude of their performances on cognitive tasks during late adulthood.
To examine this effect, the participants’ lifelong language experience was assessed in two ways; first, by determining the amount of the first and second languages they used throughout their life, and second by assessing their speed of language processing in both languages. Then, the association between these measurements and the subjects’ performance in a cognitive inhibition task was examined. The Simon task was employed to assess the bilinguals' level of inhibition. The participants' speed of first and second language processing was assessed by means of picture naming task and by examining the number and duration of pauses in the participants' free speech. Simon task was employed in many previous studies (e.g. Bialystok et al., 2004; Bialystok et al., 2005). Picture naming was also previously to measure lexical access of bilinguals (e.g. Dell, Schwartz, Martin, Safran, & Gagnon, 1997; Gollan et al., 2008; Foygel & Dell, 2000; Scarborough, Gerard, & Cortese, 1984).

In addition to these, four confounding variables were included in the analysis. Working memory was one of these variables. It was included in the investigation since the bilinguals' degree of cognitive control is partly dependent on the bilinguals' working memory span capabilities (Bialystok et al., 2004). Forward and backward digit spans were employed to measure the participants' working memory span capabilities. Age of the participants was also a part of the investigation. It was included in the study to make sure that the relationship between the amount of lifelong language balance and cognitive control is not affected by the age of the participants. The participants’ age of the second language exposure was also included since age in which the participants began speaking the second language may have an effect on their later age cognitive control (e.g. Luk et al., 2011). Finally, the participants' education level was included since it may affect the bilinguals' performance on cognitive tasks. It was hypothesized that there is a positive relationship between the magnitude of balance between the first and the second languages used throughout the participants' life and cognitive control. Furthermore, a positive correlation was anticipated between participants’ speed of the first and second language processing and cognitive control.


2. Background

As indicated in the introduction, there are several researches that have reported the cognitive advantages of bilingualism. Regardless of some criticisms on the consistency of the findings on the cognitive advantage of bilingualism (e.g. Hilchey & Klein, 2011) and publication bias on studies that do not support the cognitive advantage of bilingualism (e.g. de Bruin, Treccani, & Della Sala, 2014), nowadays the cognitive benefits of bilingualism seems well recognized by many scholars.

2.1. Cognitive Advantage of Bilingualism

As pointed out above, the cognitive benefits of bilingualism have been attested by many scholars. In previous studies in which monolinguals were compared to bilinguals, the bilinguals outperformed the monolinguals on numerous cognitive tasks. For instance, Salvatierra and Rosselli (2010) investigated the effect of bilingualism on the inhibitory control by comparing monolinguals to bilinguals using the Simon task. The participants were English monolinguals and Spanish-English bilinguals. The participants performed the Simon task in two blocks: simple (two colored squares appeared either to the right or to the left of the computer screen) and complex (the number of colored square increased to four). In this study, 108 monolinguals and 125 bilingual participants who were classified into two age groups (older and younger) and to two language groups (bilinguals and monolinguals) were included. The average age of the older monolinguals was 63 whereas that of the older bilinguals was 65. The mean age of younger monolinguals was 26 while that of bilinguals was 27. The study identified the advantage of bilingualism in both age category in the simple block but not in the complex one. Based on this finding, they concluded that bilingualism increases selective attention when working memory demands are low.

In the same manner, Bialystok et al. (2004) investigated the relation between bilingualism, aging and cognitive control. They conducted two sequential studies. In their first study, the participants were 20 younger adults (30-54 years) and 20 older adults (60-88 years). All participants held a bachelor degree. The monolinguals were Canadians who were native English speakers whereas the bilinguals were Tamil-English speakers living in Canada. The researchers used the Simon task to measure the participants’ magnitude of cognitive control. The result of the study did not
show the cognitive advantage of bilingualism. Therefore, they conducted a second study with a relatively large number of participants; the number of participants increased from 40 to 96, and with some improvements of the Simon task design: they included a control condition (colored square appeared at the center of the screen). Besides, they added two more conditions to examine whether bilingual advantage reflect superior skill in ignoring the irrelevant information or in remembering the rules associating each color with the appropriate response key. They also increased the total number of trials from 28 to 192. The findings of their second study indicated that the inhibition costs are higher for monolinguals in both the young and the elderly categories; the bilinguals responded more rapidly to the incongruent condition. The reaction time difference between older monolingual and older bilinguals was larger than the reaction time difference between younger bilinguals and monolinguals. Based on these findings, Bialystok et al. (2004) hypothesized that bilingualism minimizes the deterioration of the cognitive performances due to aging. According to this hypothesis, though there is a natural decline in the cognitive performance due to aging, the rate of decline is slower among bilinguals as compared to their corresponding monolinguals.

Bialystok et al. (2008) also investigated cognitive control and lexical retrieval in younger and older bilinguals. They used the Simon task to examine the participants’ degree of cognitive control. The young participants were bachelor university students (mean = 20 years) whereas the older bilinguals (M = 68 years) were voluntary participants. The second languages of the bilinguals include wide range of languages (around 28 languages were listed as second language of the participants). According to this study, younger bilinguals performed better than older bilinguals in all tasks. Monolinguals performed better in lexical retrieval task whereas bilinguals performed better than monolinguals in cognitive task with a large difference between older bilinguals and monolinguals. Evidence which supports the cognitive advantage of bilingualism also comes from neuroimaging studies. For instance, Gold et al. (2013) investigated lifelong bilinguals (20) and monolinguals (20). They compared the white matter integrity (WM) and gray matter (GM) volumetric pattern of the participants using high structural imaging to measure the grey matter volume and diffusion tensor imaging (DTI) to assess the white matter integrity. The result of this study indicated that lifelong bilingualism contributes to cognitive reserve against white matter integrity decline due to aging.
Bak, Nissan, Allerhand and Deary (2014) also investigated the effect of bilingualism on later age cognition. They examined 853 participants at two different years. They first tested the participants in 1947 (age = 11) to examine the effect of childhood intelligence and then re-tested the same participants later in between 2008 and 2010. They used different cognitive tasks: Letter-Number Sequencing, Matrix Reasoning, Block Design, Digit Symbol and Symbol Search, and Backward Digit span. They also tested the participants’ level of memory using Logical Memory, Spatial Span Verbal Paired Association, Backward Digit span and Letter Number Sequencing. The result of their study shows that the bilinguals performed better than predicted from the baseline cognitive ability with strong effect on general intelligence and reading. They concluded from this finding that bilingualism has a positive effect on later-life cognition.

In addition to enhancing cognitive performances and reducing the rate of cognitive aging, several studies have suggested that bilingualism increases the onset of cognitive diseases such as dementia and Alzheimer. For instance, Bialystok et al. (2007) investigated the roles of bilingualism in reducing the onset of dementia. The participants were patients with cognitive complaints who were referred to a memory clinic. Only the participants who were diagnosed with dementia (184) were included in the study. Among these participants, 54 were bilinguals while the rest were monolinguals. It was found that, on average, the bilinguals showed symptoms of dementia four years later than the monolinguals. However, the rate of decline was the same (measured by means of Mini-Mental State Examination) both for the monolinguals and the bilinguals. Based on this finding, the authors concluded that bilingualism delays the age of onset of dementia, but it does not affect the rate of progression. Similarly, Craik, Bialystok and Freedman (2010) investigated the association between bilingualism and dementia. They studied case records of 648 bilingual and monolingual patients. They examined various factors related to the patients: language, education, occupation and other variables. According to the result of the study, bilinguals were diagnosed for dementia four years later than the monolinguals.

Although many scholars have reported the cognitive advantages of bilingualism, there are scholars who have been critical of these advantages. For instance, de Bruin et al. (2014) examined the chance of publication of abstracts whose results support the cognitive advantage of
bilingualism and those whose results oppose the cognitive advantage of bilingualism. The result of the study indicated that studies whose findings support the cognitive advantage of bilingualism are more likely to be published than studies whose results oppose the theory of cognitive advantage. Based on this finding, they argued that the cognitive advantage of bilingualism is not the accurate reflection of all studies on the area. Similarly, Hilchey and Klein (2011) reviewed empirical data obtained from studies which were conducted on cognitive advantage of bilingualism using non-linguistic tasks. Their review result indicated that the bilingual advantage in conflict resolution which have been reported in many studies varies significantly and in some cases the advantage is completely absent. However, the result of the review showed that bilinguals enjoy wide spread advantage; they perform better than monolinguals on both compatible and incompatible trials.

2.2. Possible Explanations for the Cognitive Advantages of Bilingualism

Though the cognitive advantages of bilingualism have been reported in many studies, there has not been a precise explanation for the process that leads speaking two languages to the enhancement of cognitive control. Nevertheless, there are suggestions which have been proposed by some scholars. The postulation of an inhibitory mechanism has been one of the most prominent explanations. The inhibition hypothesis suggests that the inhibition of one language while another language is being used leads to the development of task-independent skills which can be employed to control non-linguistic tasks (Bialystok et al., 2005).

There are two important models that explain how the inhibitory control operates. One of the models is the Bilingual Interaction Activation model (BIA) (Dijkstra & Heuven, 1998). According to this model, hierarchically organized representations of words from both first and second languages are activated by the language input in a certain context, and the two representations compete for selection. The representation that is linked more strongly to the language input wins the competition by inhibiting the adjacent less active representation. Though this proposal is crucial in explaining how bilinguals switch between two languages, it has its own flaws in depicting the relation between bilingualism and cognitive control. The pitfall of this proposal is that it suggests the local (language-specific) mechanism as a fundamental process that underlies the association between bilingualism and cognitive control. It is not clear how the
two language presentations are eventually converted to the higher level cognitive ability which is also used for the management of non-linguistic tasks.

Hence, Green (1998) proposed an alternative model which is called Inhibitory Control model. According to this model, there are supervisory attention systems which control the activation of competing schemes. In other words, the activation of the two language system is controlled by higher level cognitive process. According to Bialystok et al. (2005), the difference between interactive and inhibitory control processes is that the former makes local language system responsible for the management of the activation of the two languages representation while the latter gives this responsibility to the higher level cognitive processing. According to the Inhibitory Control model, the inhibition originates from higher centers such as frontal lobes. As the representations of the two language systems should receive order from higher level cognitive processing, continuous use of two or more languages means continuous exercise of higher level cognitive processing which is also used for the management of non-linguistic tasks.

The claim of the second proposal seems stronger than the first as it defines the relationship between executive control and the language presentations. Neuroimaging studies which was conducted to investigate the underpinning brain system that leads to cognitive control also seem to support the second proposal. For instance, in addition to Gold et al. (2013) which was presented earlier, Bialystok et al. (2005) employed magneto-encephalography to investigate the neural correlates of the bilingual advantages which were claimed in previous behavioral studies. The correlation between the activated areas and the reaction time showed that the bilingual groups demonstrated faster reaction time with greater activity in superior and middle temporal cingulate cortex, and in superior and inferior frontal regions largely in the left hemisphere. The monolingual demonstrated faster reaction times with the activation in middle frontal region. Based on this, they concluded that the management of two language system leads to systematic changes in frontal executive functions. Thus, it seems that a frequent switch between two language systems enhances the frontal capability which eventually enables bilinguals perform better than monolinguals on non-linguistic tasks. Though this explanation is convincing, it does not provide a detailed account about the lifelong interaction between speaking two languages and the executive control.
2.3. The Association between Lifelong Bilingualism and Cognitive Control

Although the inhibitory control model provides a reasonable description about the process which leads bilingualism to the cognitive advantage, there are, at least, two important issues that have not been adequately addressed in the previous studies. These are the amount of first and second language exposure needed for the origin of cognitive control and the durability of the cognitive advantage once it is acquired. The amount of two language exposure which is required for the bilinguals to get an access to the advantage of bilingualism was not adequately discussed in the previous studies.

Though, in the majority of the studies, it has been argued that fluency in both first and second language is a precondition for the boost of the cognitive advantage, there are also studies which indicate that exposure to two languages can lead to the cognitive control without achieving equal proficiency in both languages. For instance, Kovacs and Mehler (2009) studied bilingual and monolingual preverbal 7 month bilinguals (raised in two languages from birth) and monolingual infants. They presented the infants with meaningless sound stimuli (trisyllable sounds) and visual reward (looming puppets). In pre-switch task, the infants were provided with sound stimuli followed by the reward which appeared on the same side of the screen. In post switch task, the appearance of the reward was shifted to the opposite side of the screen. At this point, the infants were expected to gaze at the opposite side of the screen following the sound stimuli. They used eye-tracking to measure the direction of the gaze. Their finding indicated that bilingual infants rapidly suppressed looking at the first location. According to this result, it is likely that a short period exposure to two languages is sufficient for the enhancement of the cognitive advantage at early childhood. Similarly, Poulin-Dubois, Blaye, Coutya and Bialystok (2011) used Stroop task to examine the cognitive control ability of 63 bilingual and monolingual children of around 2 years. The result of their study showed that the bilinguals perform significantly better than monolingual children on the Stroop task.

Contrary to the above two studies, Luk et al. (2011) compared early and late bilinguals. In their study, young bilinguals whose ages were around twenty were classified into early (before 10) and late (after 10) starters depending on their age of second language exposure. They found the cognitive advantage only among the early bilinguals which shows that cognitive advantage of
bilingualism does not appear at late starters though they used the two languages for at least 10 years. Therefore, it seems that the amount of the two languages needed for the enhancement of the cognitive advantage is determined by the age in which the bilinguals are exposed to the two languages.

Another interesting, but less investigated, issue is the continuity of the cognitive advantage of bilingualism. Regarding this, a widely held view is that, once the cognitive benefit is acquired, both first and second languages should be used regularly and persistently to ensure the continuity of the cognitive advantage. Hence, a regular use of two languages has been viewed as a requirement for the sustainability the cognitive benefit (e.g. Bialystok et al., 2005; Bialystok, 2007; Bialystok et al., 2007; Craik & Bialystok, 2006; Salvatierra & Rosselli, 2010). This implies that cognitive advantage of bilingualism can vanish at any time in the bilinguals' lifetime if it is not nurtured by a sustainable use of both first and second languages. This suggests that the dependency between bilingualism and the cognitive control continues throughout the bilinguals' life. If a bilingual stops using one of the languages at some point in his life, there is a possibility for the cognitive advantage to disappear.

However, this lifelong relationship between bilingualism and cognitive control has not been examined by a proper study. For instance, previous studies did not thoroughly investigate what exactly happens to the bilinguals who began speaking second language early, but used one of the languages less frequently due to various reasons. In the same manner, previous studies did not consider the effect of the amount of the first and second languages used at different ages of bilinguals. The lifelong association between bilingualism and cognitive advantage which was claimed in the previous studies largely comes from a comparison between monolinguals and bilinguals. For instance, Bialystok, Martin, et al. (2005) studied the effect of bilingualism across the bilinguals’ lifespan. They conducted a series of studies by examining the bilinguals at different age levels: children, young and elders by using Simon task. The result of their studies showed that the bilinguals perform better than monolinguals during childhood and adulthood. However, they did not find a significant difference between the young bilinguals and young monolinguals. Based on this result, they concluded that during adolescence the cognitive performance is at its peak of efficiency; as a result, bilingualism does not offer further boost.
Gold et al. (2013) also used perceptual task switching paradigm in two experiments. In the first experiment, older bilinguals showed better perceptual switching performance than their corresponding monolinguals. In the second experiment, the same participants performed the perceptual task switching task in fMRI. The result of the study showed that bilingual older adults outperformed their monolingual friends and displayed a decreased activation in the left lateral frontal cortex and cingulate cortex.

Three crucial points can be inferred from the studies presented above. First, the findings of Luk et al. (2011), Kovacs and Mehler (2009), and Poulin-Dubois et al. (2011) suggest that the age in which the bilinguals are exposed to the two languages is indispensable for the emergence of the cognitive advantage. This means that the magnitude of both languages that a bilingual encounter at different age levels can have a different magnitude of cognitive effect. Second, from the finding of Bialystok, Martin, et al. (2005), it is apparent that there are falls and rises of the cognitive advantage; it became noticeable at childhood, disappeared during adolescence and then reappeared during adulthood. Finally, as presented earlier, there has been a repeated claim that bilinguals should use both first and second languages regularly throughout their life to preserve the cognitive advantage for the later age.

Regardless of the claims, the amount of first and second languages used at different ages of the participants was not thoroughly examined in previous studies. The studies did not also directly investigate changes in the amount of both languages used throughout the bilinguals' life and find out its association with the cognitive advantage. The current study, therefore, examined the magnitude of both languages used at different ages of the bilinguals and illustrated its relationship with the magnitude of the participants’ cognitive control during adulthood.

2.4. Association between Speed of Language Processing and Cognitive Control

According to inhibitory control model, inhibition of one language while other is being used leads to the development of cognitive control. As also discussed in Section 2.3, lifelong regular practices of both first and second language is essential for the enhancement of later age cognitive control. This shows a direct link between the bilinguals’ language fluency and cognitive control during adulthood. Several studies have reported that bilingual are slower than monolinguals in lexical retrieval and speech processing (Colomé, 2001; Costa et al., 1999; Green, 1986) since
they should control one language while using another. They are slower than monolinguals even when they use their first language since they have to suppress the parallel activation of the second language. However, the amount of inhibition that the bilinguals require is reliant on the bilinguals’ level of proficiency in a particular language. For instance, when bilinguals speak in the first language, more inhibition of the second language may not be required since the baseline activation of the second language is lower than the base line activation of the first language (Ivanova & Costa, 2008). Accordingly, as bilinguals practice two languages and become equally fluent in both languages, the suppression effort that they require to inhibit the activation of the unwanted language decreases.

Some previous studies support this perspective. For instance, Costa and Santesteban (2004) studied the switching cost of the Spanish learners of Cataln and Korean learners of Spanish. The participants performed language switching task. The finding of this study indicated that the switching cost from the second language (weaker) to the first language was difficult than the vice versa for less balanced bilinguals. However, this switching cost was not found among balanced Spanish-Catalan bilinguals. Moreover, highly proficient bilinguals showed faster reaction time in their weaker languages than their dominant languages. Based on this finding, they concluded that the switching performance of proficient bilinguals is different from the non-proficient L2 learners’ language processing mechanism. Similarly, Gollan et al. (2008) examined the effect of increased word use associated with bilingualism and age. They compared the lexical retrieval speed of bilinguals and monolinguals using more frequent and less frequent words in picture naming task. The result of their study indicated that the bilinguals’ reaction time was slower for less frequent names than for more frequent names. This shows that frequent use of two languages is vital for the enhancement of speed of lexical retrieval.

Moreover, Bialystok et al. (2008) investigated cognitive control and lexical access in young and old bilinguals. They assessed working memory, lexical retrieval and executive control. They used backward and forward corsi blocks, and self-ordered pointing to measure the participants’ working memory. Peabody picture vocabulary test and Boston naming task were employed to measure the lexical access. Simon arrow task was employed to measure the participants’ degree of cognitive control. The result of their study indicated that monolinguals are better than
bilinguals in the speed of lexical retrieval. The two groups are different in terms of working memory, but bilinguals are better than monolinguals on executive control tasks. Costa (2009) conducted the same study on younger and older bilinguals and reported the same result. Therefore, there are evidences that bilinguals always inhibit the activation of one language when the other is being used. However, the balanced bilinguals employ less effort to control the intrusion of one language while other is being used. Given that constant control over one language while another is being used leads to the development of a general cognitive control ability according to Green (1998) inhibitory control model, and considering the fact that constant practice of switching between the two languages enhances the bilinguals’ speed of lexical and speech processing, it is plausible to assume that there is a positive association between the degree of control over the activation of two language system and general cognitive performance during adulthood.
3. Research Questions

The present study examined the relationship between lifelong language experiences and the cognitive control at the later age. The study has been conducted to test the hypothesis that the lifelong variability in the magnitude of balance between the first and second languages that the bilinguals use throughout their lifetime affects the magnitude of their cognitive control at later age. It was hypothesized that the higher the magnitude of balance between the two languages used by the participants and the more consistent of this magnitude of balance, the more likely that the bilinguals maintain their cognitive advantage at later age. Besides, if the cognitive advantage that the bilinguals maintain at later age is the outcome of the lifelong language experiences, it is plausible that the amount of the two language exposure that the bilinguals face at different age levels can have a different effect on the bilinguals' adulthood cognitive performance. In the same manner, if bilingualism and cognitive control have a lifelong relationship, and the cognitive advantage which the bilinguals maintain at later age is the outcome the lifelong language experience, it is probable that participants' speed of first and the second languages processing positively correlates with the later age cognitive control. This assumption is based on the fact that ease of language processing which is achieved at later age is the result of the lifelong language practices. Specifically, the current study was conducted to answer the following questions.

1) *Is there an association between the lifelong balance between first and second languages and cognitive control?*

As indicated in Bialystok (1999), Bialystok (2007) and Bialystok et al. (2007), both first and second languages should be used 'regularly' throughout the bilinguals' lifespan for the cognitive advantage to continue till later age. This means that after the bilinguals acquire the cognitive advantage, there is a possibility for this benefit to fade at some point in the bilinguals' life unless the first and the second languages are used frequently. However, as explained in 2.3, though this view has been widely held in the previous studies, it has not been thoroughly examined. As a result, in the present study, the extent to which the first and the second languages have been used throughout the bilinguals’ life has been determined by means of an exploratory investigation of the participants’ lifelong language exposure. Subsequently, the extent of language exposure across the life span has been correlated with the extent of cognitive control at later age. The
amount of the first and the second languages used by the bilinguals in different contexts has been measured by means of self-rating scales. The participants' magnitude of cognitive control has been measured by means reaction time to the Simon task.

2) Does the amount of first and second languages use at different ages differently affect the bilinguals' cognitive control abilities during adulthood?

If the lifelong exposure of the two languages has an enduring effect on the bilinguals' cognitive control as indicated in Bialystok et al. (2005), Bialystok et al. (2007), Craik and Bialystok (2006), and Salvatierra and Rosselli (2010), it is probable that the amount of the two languages used at the different ages of the bilinguals has different effects on the cognitive control. The results of the studies which were conducted by Luk et al. (2011), Kovacs and Mehler (2009) and Poulin-Dubois et al. (2011) support this claim. In these studies, early and late language exposure showed different effects on the participants' cognitive control though the researchers did not measure the amount of the first and the second languages the participants used. Furthermore, as bilinguals often do not get an equal amount of two language exposure throughout their lives due to various factors such as moving home, work place language condition and parents’ language background; it was expected that the magnitude of balance between the two languages that the participants come across at different age levels can have a different degree of effect on their cognitive performance during later age.

In the current study, to examine this effect, the participants' age has been classified into three age categories: ‘Childhood and Adolescence’, ‘Early and Middle Adulthood’ and ‘Mature Adulthood’. ‘Childhood and Adolescence’ age category includes the participants’ language experience before the age of 20 (inclusive) while ‘Early and Middle Adulthood’ exposure covers the participants' two language experience between the age of 21 and 40. The ‘Mature Adulthood’ category covers the participants’ language exposure after the age of 40. The classification between ‘Childhood and Adolescence’ and ‘Early and Middle Adulthood' was theoretically motivated. According to Birdsong (2006), the acquisition of second language declines rapidly around the age of twenty. Therefore, it was assumed that the amount of language exposure before the age of twenty and the amount of exposure after twenty can have a different effect on the bilinguals' cognitive control. The classification between the last two age categories was
purposeful though not supported by theoretical ground. As the average age of the participants was 64, it was assumed that classifying the remaining ages at the age of 40 provides fair age length coverage in both ‘Early and Middle Adulthood’ and ‘Mature Adulthood’ age categories.

3) Does the speed of first and second language processing have an association with cognitive control?

As presented in section 2.4, balanced bilinguals face smaller difficulty in controlling the intrusion of one language when other is being used (Ivanova & Costa, 2008). Furthermore, studies which previously examined the association between language fluency and cognitive control reported that the cognitive advantage may not be accessible unless the bilinguals become fluent in both first and second languages (e.g. Abutalebi, 2008; Kharkhurin, 2008; Luk et al., 2011). Moreover, as presented in Bialystok et al. (2005), Bialystok et al. (2007), and Salvatierra and Rosselli (2010), bilinguals should use both first and second languages regularly throughout their life to preserve the cognitive advantage for the later age. In other words, lifelong and regular practice of controlling one language over another is required for the later age cognitive control. In order to examine this claim, the relationship between the participants’ speed of language processing in both first and second languages and cognitive control has been examined. As indicated in the introduction, picture naming task and storytelling were employed to measure the participants’ speed of first and second language processing. It was expected that the participants who are fast in speech and lexical retrieval perform better on the cognitive task than bilinguals who have slower lexical and speech processing speed.
4. Methods

In the present study, five types of data gathering methods were employed. Questionnaires, Picture naming task, Digit span task, Simon task, and storytelling. Two types of questionnaire were designed: background assessment questionnaire and language history questionnaire. The background assessment questionnaire was employed to collect general information about participants’ age, age of second language acquisition, educational level, work experiences, medical history, and other demographic information. The language history questionnaire was used to assess the magnitude of first and second languages used throughout the participants’ life. Picture naming task was used to measure the participants’ speed of lexical retrieval in the first and second languages. The speed of first and second language processing was measured by counting the number of pauses and by estimating the duration of pauses in the participants' free speech during storytelling while Simon task was employed to measure the bilinguals' degree of cognitive control.

Prior to the data collection, a manual for data collection procedures was prepared to ensure that all experimenters followed the same procedures (see Appendix I for summary of the procedure). The first step in data collection process was finding the participants. Once a voluntary participant was found, the next step was administering a background questionnaire. This was followed by the language history questionnaire. The questionnaire administration was followed by forward and backward digit span tasks. For all participants, forward digit span was administered before backward just to begin from the simple! This was followed by Dutch storytelling. The participants watched a short Charlie Chaplin movie (Coming Home Drunk) and narrated the story in the movie. This was followed by Dutch picture naming task. Then, the Simon task was administered. After the Simon task, Frisian storytelling was administered. In this case, the participants' watched another short Charlie Chaplin movie (The Lion's Cage) and narrated the story in the movie. This was followed by the Frisian picture naming task. Tests on Dutch picture naming and storytelling were separated from that of the Frisian by Simon task to alleviate the priming effect.

4.1. The Participants

The participants were 20 native Frisian speakers for whom Dutch is their second language. All of them acquired their second language before the age of seven. They were between 54 and 77
years old (mean = 64), and all of them had been using both Frisian and Dutch throughout their life. There were equal number of males and females (10 in each group). Among these participants, two are MA degree holders, three of them are bachelor degree holders while the rest non-degree holders. Their year of onset of second language exposure was between zero and seven (mean = 2.93). The participants did not have symptoms of stroke, color vision deficiency, muscular dystrophy, and dementia according to their responses to the background questionnaire (see Appendix II). All participants live in the same geographical area, and have the same cultural background. The participants were residents of Drachten, Groningen and Leeuwarden. These locations were chosen due to their proximity. The participants were contacted via fellow students who have Frisian families and via the Frisian Library in Leeuwarden.

4.2. Questionnaires

As indicated above, two types of questionnaires were employed to gather data from the participants. The questionnaires were first designed in English and then translated to Dutch by a native Dutch speaker. The first questionnaire was used to determine the participants’ eligibility for the task (see appendix II). This questionnaire contained items about the participants’ health conditions, their language background and general demographic information which were used to determine the participants’ eligibility for the study. After collecting the questionnaire responses from each participant, the responses were examined. Then, participants who fit the requirements were approached for the actual data gathering phase. Based on the questionnaire, only participants who were speaking Frisian and Dutch starting from childhood, had normal vision and did not have medical record of neurological disease were recruited. The questionnaire was administered by the researcher and two assistant bachelor degree students.

The second questionnaire (language history questionnaire) (see appendix III) was designed to make a retrospective exploration of the amount of the first and the second languages that the participants’ used throughout their life. Three language contexts were included in the questionnaire design: home, school and social. These contexts were included since people normally use language regularly in these situations, and their language use can differ between these contexts.
The questionnaire contained three components: lists of basic questions about events that could affect the magnitude of the first and the second languages the participants used (for example, moving home and changing work places), list of the age of the participants (from 4-80) and self-rating scale (100% Frisian-100% Dutch) to measure the amount of the first and the second languages the participants used in each age and context. Each context was presented in separate section to explore in depth the amount of first and second languages used in the three contexts. The amount of the first and the second language that the participants used between the age of 4 and 80 was included in the questionnaire. This age interval was considered since the participants' are unlikely to remember the amount of the first and the second languages they used before the age of four, and bilinguals whose ages are above 80 may have serious cognitive problems due to aging.

From structure perspective, the items in each context began with the instruction, followed by questions about the amount of the first and second languages the participants used at different age and context in their life. As an explanatory approach was considered, only a few core questions were included in the questionnaire to enable the experimenters generate their own similar questions and probe in depth the participants’ lifelong language experiences. It was also believed that providing these questions minimizes subjectivity among the experimenters. Then a response sheet with self-rating scale (100% Frisian -100% Dutch) at the top and lists of the participants’ age (4-80) on the first column (see appendix III) was designed. During the data collection, the participants were asked to mention the magnitude of first and second languages they used in different contexts (e.g. if they change the work place, the amount of language they used in each place and for how long they used the language in each context), and to rate (out of 100 %) the amount of first and second languages they used in each context. The participants' responses were filled on the response sheet by the experimenters. The responses were also recorded for further revision.

4.3. Picture Naming Task
Picture naming task was employed to measure the participants' Frisian and Dutch lexical retrieval capabilities. For this task, one hundred twenty (60 for Frisian and 60 for Dutch) pictures of various types (animals, plants, insects...etc.) were randomly taken from a picture manual which has been used by researchers at the University of Groningen. The pictures were scanned
and adjusted to 600 x 600 pixel size using picture paint. E-Prime 2.0 was employed to present the stimuli.

The stimuli were presented by using a laptop. The task began with an instruction which remained on the computer screen until a shift key was pressed. This followed by a fixation at the center of the screen which remained on the screen for 1000ms. The fixation was followed by a tone which was audible for 110ms. Following the tone, a picture appeared for 2000ms on the screen. Each picture was followed by a tone which was audible for 110ms. The participants were requested to name the pictures as fast as and as accurately as they can. Their responses were recorded using a Sony Digital Voice Recorder. The response time of 2000ms (2s) was determined based on Costa et al. (1999). He used 1.9 seconds. As the current participants were elderly bilinguals, the time was increased slightly. The participants’ lexical retrieval ability was determined based on their reaction time. The time between the onset of the tone and the onset of the naming sound was considered as the reaction time. The reaction time was measured using Praat.

Furthermore, as initially the pictures were included in the experiment randomly, after the experiment their frequency and length were measured. SUBTLEX-NL was used to measure the frequency of the names of the picture while CELEX was used to measure the length of the names of the pictures. For the detailed procedure of SUBTLEX-NL application, Keuleers, Brysbaert and New (2010) were consulted. For CELEX application Burnage (1990) and König, Luetgert, & Dannwolf (2006) were consulted. The length of the names of the pictures was measured in terms of the number of syllables. Though CELEX could be used to measure the frequency of words, SUBTLEX-NL was preferred since it is based on oral, and contains more recent data. The accuracy of the respondents’ responses was checked by the native speakers. The Frisian names were translated to Dutch and Dutch frequency and length were used instead of Frisian since Frisian does not have a corpus to be used for computing the frequency and length. Among 120 pictures initially included in the experiment, only 80 pictures (40 from each language) were included in the analysis after balancing for syllable and frequency in both languages.

4.4. Storytelling
Since the picture naming task mainly measures the participants’ lexical retrieval ability, the participants’ first and second language speed of speech processing was also examined. The
speech processing speed was measured in terms of the number and duration of pauses in the participants' free speech. The participants watched two short silent Charlie Chaplin movies and narrated the story of the movies. To measure the number and duration of pauses in the Frisian speech, a Charlie Chaplin movie—‘The Lion’s Cage’ (length = 3.25 minutes), was employed. To assess the number and duration of pauses in the Dutch free speech, another movie—‘Coming Home Drunk’ (length = 4.07 minutes) was employed. Three factors were considered in the selection of the movies: length, entertainment and the content of the movies; movies which are relatively short, entertaining and content wise inoffensive were selected.

The participants first watched the silent (sound was off) movies, and then retold the story in the movies. Their responses were recorded using a Sony Digital Voice Recorder. During the story telling, the experimenters were not allowed to make any interference except using facial expressions and body movement to indicate to the participants’ that they were following the stories. The two movies were administered at a different time (separated by Simon task) to minimize the priming effect. The recorded speeches were analyzed using Praat. Two types of pauses were considered in the analysis: empty (silent) pauses and filled (e.g. 'eh' and 'euhm'). Silent gaps which are more than 250ms were considered as pauses based on Jong & Bosker (2013) recommendation. The number of pauses per minute and the average duration of pauses were used to measure the participants' speed of speech processing. The sum of both types of pauses was used to measure the participants’ speed of speech processing. A positive correlation was expected between the speed of speech processing and reaction time in Simon task; the higher the speed of speech processing, the longer the reaction time in the Simon task was anticipated.

4.5. Working Memory

Backward and forward Digit span tasks were employed to assess the participants’ working memory. In the forward span task, series of digits sequentially appeared in the middle of the computer screen. Each digit was written in font size 40. Following the sequence of digits, the instruction which says ‘Name the numbers in the correct order!’ appeared on the computer screen and stayed on the screen till the participants orally respond to the instruction. To proceed to the next trial, the participants should press a computer shift key. The first trial began with two digits and then increased by one digit until the participants made a mistake. Each digit stayed on
the screen for 500ms. The participants were asked to remember the numbers in the correct order in the forward digit span task.

The procedure was the same for the backward digit span except that the participants were requested to remember the digits in the reverse order. The working memory span score was defined as the longer sequence of digits that each participant could remember in the correct order. The respondents’ responses were noted on an answer sheet which was provided for this purpose. Though both digit span (forward and backward) may measure the same variable which is working memory, both digit spans were used, and the average of the two measures were taken as working memory measure since in some of the previous studies the measure of the two tasks showed slight difference (e.g. Conklin, Curtis, Katsanis, & Iacono, 2000). It was assumed that combining the two scores may help to have a better assessment of the participants' working memory. Digit span was preferred to other memory tasks such as word span and semantic span to minimize the burden of translating from English to Dutch or Frisian that the researcher could face since he is the speaker of neither Frisian nor Dutch.

4.6. The Simon Tasks
These tasks were designed to measure the participants' level of cognitive control. In previous studies, three tasks were commonly used to examine the cognitive advantage of bilingualism; Standard Simon Task (e.g. Bialystok et al., 2004 and Salvatierra & Rosselli, 2010), Spatial Stroop task (e.g. Bialystok, 2006) and Flanker Task (e.g. Carlson & Meltzoff, 2008). Among these three tasks, the Standard Simon task was chosen for the current study since previous works show that the majority of studies in which the advantage of bilingualism was reported employed Simon task (see Hilchey & Klein, 2011, p.630-631).

a) Stimuli
The Simon task which was employed for the current study contains two blocks: Simple and Complex. These two blocks were included in the experiment based on the recommendation of Bialystok et al. (2004) that the complexity of the task can have its own effect on determining the relationship between bilingualism and cognitive control. The first block (simple) contains two squares: red and green squares which appeared either to the right or to the left of the computer
screen while the second block (complex) consists of four squares with different colors: blue, purple, yellow and black squares. Each square had a size of 200 x 200 pixel and 96 DPI resolution. The experiment was presented on a laptop. The sequencing of events and the data collection was controlled using E-Prime 2.0. Each trial began with fixation cross at the center of the screen, that remained visible for 250 ms followed by the squares of different colors which appeared on the left (x = 290 pixel, y = 340 pixel) or the right (x = 1090 pixel, y = 340 pixel) of the screen and remained on the screen for 3000ms if there was no response. The timing began with the onset of the stimulus and the response terminated the stimulus.

b) Procedure
The participants were instructed to press 'Q' when the red square appeared and press 'P' when the green square appeared in the first block. In the second block, they were instructed to press ‘Q’ when either a blue or yellow square appeared, and press ‘P’ when either a purple or black square appeared. The orders of the conditions were randomized in both blocks. There were an equal number of congruent and incongruent conditions in both blocks. Each block consisted of the total of 48 trials; 24 trials in the congruent condition and another 24 trials in the incongruent condition; in total there were 96 trials: 48 congruent and 48 incongruent conditions. The experiment began with 16 practice trails for each block. Each participant practiced at least once before beginning the actual experiment. The participants were allowed to practice once or twice depending on their interest, and their level of confidence.

4.7 Analysis
To determine the participants’ lifelong magnitude of the first and second language experience, first the amount of each language used in each age of the participants was computed. This was achieved by calculating the mean of each language used in the three contexts. For example, if someone used 90% Frisian in school, 80% Frisian at home and 70% Frisian in social interaction at the age of four, the average amount of Frisian used during this specific year would be (90+80+70)/3  = 80%. For every year, the average amount of Frisian which the participants used was computed in the same manner. The average amount of Frisian used during the three age classes (childhood and adolescence, early and middle adulthood and mature adulthood) was obtained by computing the average of the amount of Frisian used within the duration of each age
class. For instance, the amount of Frisian used by a participant during early and middle adulthood was obtained by computing the mean of the amount Frisian used from age of 21 to age 40. The same procedure was followed to compute the amount Frisian used in the remaining two age classes. To determine the amount of each language used throughout the participants’ life, the mean of the amount of Frisian and Dutch used throughout the participants' lifetime was computed.

After computing the amount of Frisian and Dutch used throughout the participants’ life and at the three age levels, the magnitude of balance between the two languages was determined. This was achieved by computing the absolute difference between the amount of both language used by the participants and the amount of two language that is believed to be used by perfect balanced bilinguals. Perfect balanced bilinguals are expected to use equal amount of first and second languages, for instance 50% Frisian and 50% Dutch. The same procedure was followed to compute the magnitude of balance at the three age classes. Therefore, on the scale that ranges from 100% Frisian - 100% Dutch, it is assumed that the ideal balanced bilinguals rate themselves at 50%. Hence, the absolute difference between the amount of two languages used by the ideal balanced bilinguals (50%) and the amount the two languages that each of the current participants used was computed to determine the magnitude of participants’ language balance. For instance, if a participant used 80% Dutch and 20% Frisian throughout his/her life, the absolute difference between this amount and the amount which is assumed to be used by perfect balanced bilinguals would be |50-80| or |50-20| which is 30 in both cases. For the participants who used both Frisian and Dutch equally throughout their life, the absolute difference would be zero, |50-50| = 0. Therefore, the greater the deviation from zero, the less likely that both languages are used equally throughout the participants’ life. Hence, it is crucial to notice that as deviation from zero increases the magnitude of balance between Frisian and Dutch decreases.

As presented in section 3, in addition to the lifelong magnitude of balance, the participants' level of lexical retrieval and the number and duration of pauses in the participants' free speech were included in the analysis to measure the participants' first and second language speed of processing. Furthermore, there are four important confounding variables which might influence the relationship between the amount of language balance and cognitive control. One of these
variables is the age of second language exposure. Though all the participants in the current study began acquiring their second language starting from early childhood (before 7), age of second language exposure was included in the analysis since early childhood is critical as far as language acquisition and cognitive development are concerned, and a small difference in the age of second language exposition can have a substantial effect on the bilinguals’ later cognitive performance. Similarly, as there is a wide gap among the ages of the current participants (54-77), this age range could have an effect on the magnitude of the participants’ cognitive performance. As a result, the age of the participants was included in the analysis. Furthermore, in many of the previous studies, working memory was considered as one of the factors which determine the bilinguals’ cognitive control (e.g. Bialystok et al., 2004). Hence, the participants' working memory span was included in the analysis. Education level of the participants was also included in the analysis since it may affect the participants' degree of cognitive control.

In general, in the current study, eleven predictor variables were examined: age of the participants, age of second language onset, working memory, the participants' education level, the balance between the first and second languages during childhood and adolescence (before 20), the magnitude balance between the two languages during early and middle adulthood (21-40), the magnitude of balance between the two languages during mature adulthood (after 40), the magnitude of balance between the two languages throughout the bilinguals’ life, first and second language speed of speech processing and first and second language speed of lexical retrieval. The participants' reaction time to the conditions in the Simon task was dependent variable. The association between the predictor variables and the participants’ reaction time in the Simon task was analyzed using Linear Mixed Effect Model. According to Baayen (2008), Linear Fixed Effect Model has three functions; it helps to manage systematic dependence within the observation; it allows more flexible modeling for additional source of variation. Finally, it is vital when the effects of the coefficients can be random, or distributed according to probability distribution.

The analysis generally involved three steps. It began with checking for the assumptions of regression. This was followed by model selection. Finally, the eleven predictor variables outlined above were examined using the best model. The magnitude of balance between the first and
second languages at the three age levels was examined separately to reduce the effect of multicollinearity. All continuous predictor variables were centered before the analysis. The outcome variable (Simon task reaction time) was log transformed. Furthermore, since Mixed Effect Model does not provide p-value, Test-lmer was used to estimate the p-value and the degree of freedom. Forced entry method of regression was employed to fill the models.
5. Results

Based on the selection parameters which were specified in the background questionnaire, 28 participants took part in the experiment. Among these participants, eight of them were excluded. Four participants were excluded since they made more than 25% of errors while performing the Simon task. Additional two participants were left out since the experimenters made procedural errors while testing the participants; they did not turn the computer speaker on; as a result, the tone was not included in the recorded picture naming responses. The remaining two participants were excluded since they committed many errors (more than 30%) in the picture naming task. As a result, data from twenty participants were included in the analysis. As Table 1 indicates, two participants are MA degree holders, three participants are bachelor degree holders whereas the remaining participants do not have an academic degree.

Table 1

<table>
<thead>
<tr>
<th>Education level</th>
<th>Sex</th>
<th>Age</th>
<th>Age of L2 Onset</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-degree</td>
<td>15</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Bachelor</td>
<td>3</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Master</td>
<td>2</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>

Note: ‘non-degree’ participants are those who did not join a college or university and did not receive an academic degree.

5.1. Participants’ First and Second Language Lifelong Experiences

As Figure 1 depicts, the assessment of the participants’ lifelong language experience shows that the amount of Frisian and Dutch that the participants have used throughout their life has shown changes from age to age. The average amount of Frisian used by the participants has decreased across the participant age; it is higher during childhood and adolescence. However, it declined during early and middle adulthood, and during mature adulthood. As the participants speak only the Frisian and Dutch, a decline in the amount of Frisian used by the participants automatically mean an increase in the amount of Dutch used by the participants.

Paired-sample t-test was employed to compare the amount of Frisian and Dutch used at the three age classes. There was a significant difference between the amount of Frisian (M = 68.52, SD =
and the amount of Dutch ($M = 31.48$, $SD = 13.60$) used during childhood and adolescence, $t(19) = 5.95, p < .001$. However, there was no significant difference between the amount of Frisian ($M = 54.39$, $SD = 24.16$) and the amount of Dutch ($M = 45.61$, $SD = 24.16$) used during early and middle age, paired-sample t-test, $t(19) = .79, p = .439$. Likewise, there was no a significant difference between the amount of Frisian ($M = 54.20$, $SD = 24$) and the amount of Dutch ($M = 45.80$, $SD = 24$) used during mature adulthood, paired sample t-test, $t(19) = .798, p = .435$. However, there is a significant difference between the amount of Frisian ($M = 59$, $SD = 22$) and the amount of Dutch ($M = 41$, $SD = 22$) used throughout the participants' life, paired-sample t-test, $t(19) = 3.182, p = .002$. Though the difference between the amount of Frisian and Dutch used during the latter two ages was not statistically significant, the difference between the amount of Frisian and Dutch used throughout the bilinguals' life became significant due to the effect of the Frisian dominance during childhood and adolescence.

**Figure 1.** The amount of Frisian and Dutch used in the three age classes and throughout the bilingual's life
Figure 2 also illustrates that the average magnitude of balance between the first and the second language slightly increases across the participants' age. It is relatively low during childhood and adolescence, and increases somehow during early and middle adulthood. Overall, the results indicate that Frisian was the dominant language before the age 20. Nonetheless, after the age of 20, the dominance of Frisian has declined. However, it should be noted that the participants are not balanced bilinguals even during mature adulthood since for balanced bilinguals, the balance line should be close to zero.

![Graph showing changes in balance across age](image.png)

**Figure 2.** Changes in the magnitude of balance across the participants' age (note: the magnitude of balance increases as the line declines).

### 5.2. Speed of First and Second Language Processing

As presented in Section 3, the speed of lexical retrieval during picture naming and the number and duration of pauses in the participants' speech were employed to measure the participants'
speed of first and second language processing. With regard to the picture naming, the comparison between the names of the pictures in the two languages shows that the length (measured in terms of syllables) of the names of the Dutch pictures (M =1.78, SD = .80) and that of the names of the Frisian pictures (M =1.53, SD = 0.78) are not significantly different; independent-sample t-test, t(78) = 1.411, p = .742. Correspondingly, there was no a significant difference between the frequency of the names of Frisian pictures (M = 19.88, SD = 22.76) and that of Dutch pictures (M =19.17, SD = 32.67); independent-sample t-test, t(78) = -.113, p = .911. The results show that the names of the pictures in both languages are not statistically different both in terms of length and frequency.

Only the correct responses were included in the picture naming reaction time analysis as presented in section 4.3 There were two types of response errors: responses which were provided after 3000 ms (the maximum time allotted for the response), and responses whose meanings were different from the meanings of the pictures which had been provided by the native rater. According to these parameters, the participants’ response accuracy was between 70% to 95%. A paired-sample t-test was conducted to compare the participants’ Frisian picture naming reaction time and the Dutch picture naming reaction time. There was no a significant difference between the participants' Frisian picture naming reaction time (M = 871ms, SD = 85) and the Dutch picture naming reaction times (M = 862ms, SD = 153); t(19) =.295, p = .771. This shows that participants' speed of lexical retrieval is the same for both first and second languages.

Regarding the speed of speech processing, as presented in section 4.4, both empty (silence) and filled pauses (e.g. 'eh' and 'euhm’) were included in the analysis. Empty pauses which are longer than 250 ms were considered based on Jong & Bosker (2013). All filled pauses were included in the analysis irrespective of their duration of pauses. The pauses in the participants' free speech were measured in two ways: in terms of the number of pauses per minute in speech and in terms of duration of pauses in millisecond. The average number of pauses per minute in Dutch free speech was higher (M = 16.47, SD =7.21) than the average number of pauses in Frisian free speech (M = 15.13, SD = 7.27); paired-sample t-test, t(19) = -2.173, p = .05. The result shows that the participants produced more pauses in Dutch speech than in Frisian speech. In addition to the number of pauses, the average duration of pauses in Frisian and in Dutch free speech was
examined. A paired-sample t-test was employed to compare the participants’ mean duration of pauses in the speeches of the two languages. There was marginally a significant difference between the duration of pauses in Dutch speech (M = 792ms, SD = 204) and the duration of pauses in Frisian speech, (M = 711ms, SD = 176); t(19) = -1.81, p = .086. The result shows that duration of pauses in Dutch free speech is slightly longer than the pauses in Frisian free speech.

5.3. The Simon task

As presented in Table 2, the responses which were obtained from the Simon task shows that the respondents responded correctly to 937 trials out of the total 960 possible responses in the first block. This shows that the number of errors was 23 (2.4%) in the first block. The participants’ reaction time was higher in the incongruent condition than in the congruent condition; 575 ms (SD = 197) in the congruent condition, and 586 ms (SD = 228) in the incongruent condition. This difference was expected as the participants need to inhibit the mismatch between the location of the response keys and the location of the stimuli when they respond in the incongruent condition. Similarly, in the second block, the participants’ mean reaction time was 680 ms (SD = 273) in the congruent condition while the mean response reaction time was 690 ms (SD = 244) in the incongruent condition. Similar to the first block, the result shows that the participants took more time in the incongruent condition than in the congruent condition. In the second block, the participants correctly responded to 911 trials out of the total of 960 trials. This means that the number of errors was 49 (5.1%). There were more errors in the second block than in the first block. This was not surprising since the second block was more demanding than the first block.

<table>
<thead>
<tr>
<th></th>
<th>Block I</th>
<th></th>
<th>Block II</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Congruent</td>
<td>575 (197)</td>
<td></td>
<td>680 (273)</td>
<td></td>
</tr>
<tr>
<td>Incongruent</td>
<td>586 (228)</td>
<td></td>
<td>690 (244)</td>
<td></td>
</tr>
<tr>
<td>No. of Error</td>
<td>23 (2.39%)</td>
<td></td>
<td>49 (5.1%)</td>
<td></td>
</tr>
<tr>
<td>RT Accuracy</td>
<td>937 (97.61%)</td>
<td></td>
<td>911 (94.8%)</td>
<td></td>
</tr>
</tbody>
</table>

*Note: ‘No. of error ’ refers to the number of error.*
5.4. Exploring Random Variations and Regression Assumptions

The exploration of the participants’ reaction times in Simon task has shown that some of the initial Simon task responses were extremely high due to the effect of the participants’ lack of familiarity with the Simon task (see Appendix IV, Figure 3). Hence, out of 1848 correct responses of the initial data set, 129 (7%) extreme values which are greater than 3 (log transformed) were removed. Since further visual inspection of the normality plot indicated a deviation of the standard residuals from the normality line, absolute standard residuals exceeding 2.5 were excluded. This resulted in the loss of an additional 31 (1.67%) responses. In total, 160 (8.67%) of the responses were excluded from the analysis. After the inspection of the assumption of regression: normality of residual distribution, homoscedasticity, and influential values (see appendix IV, Figure 5), the best fitting Simon task model was selected. As indicated in section 3, linear mixed effect models were fit using the lmer function of lme4, R version 3.2.0. The p-value was estimated using lmerTest.

Since the participants were randomly selected from the population, and tested repeatedly in all conditions of the Simon task, their reaction times were affected by the individual differences and by the repeated measurements (see appendix V, Figure 6). In addition to the variations due to the individual differences, the participants’ reaction times have also varied due to the effect of the experimental design (see appendix V, Figure 7). Hence, a model which contains a by-subject random intercept and a random slope of the factor trial was initially fitted using log transformed reaction time data. The examination of the correlation between the by-subject random intercept and the random slope for the factor trial indicated a moderate correlation between the two random factors, $r^2 = -.58$ (see appendix V, Figure 8). Thus, a comparison was made between a model that contains the correlated random intercept and the random slope for the factor trial and a model that contains an uncorrelated random slope and a random intercept. The result indicated that the latter model was the better one ($\chi^2(1) = 6.34, p = .01$). To further investigate the importance of the random slope of the factor trial, a comparison was made between a model that contains an uncorrelated a random intercept and random slope and the one that contains only the random intercept. The model comparison confirmed that the latter mode was the better model ($\chi^2(1) = 43.629, p < .001$). Hence, the by-subject random intercept model was selected to examine the effects of the variables of interest.
The model comparisons have shown that the variation in the random slope for the factor trial was not a significant source variation among the participants' reaction time. The results, however, illustrate that there was a significant effects of trial (β = -.0008, t = -6.155, p < .001) on the participants’ inhibition reaction time. This means that as the participants continued responding to the task, their reaction times decreased. Furthermore, the participants’ reaction time was faster in the first block than in the second block (β = -.090, t = -12.372, p < .001) which confirms that the second block was more demanding than the first block. In the same manner, the participants’ reaction time was slower in the incongruent condition than in the congruent conditions (β = .011, t = 2.985, p = .01).

5.5. The Effect of Lifelong Two Language Experiences on Cognitive Control

In this section, the effect of the lifelong magnitude of balance between the first and second languages on cognitive control is analyzed. The amount of the first and the second language that the participants used throughout their lives was classified into three age classes: childhood and adolescence, early and middle adulthood and mature adulthood. The effect of the magnitude of balance at each age class on cognitive control was analyzed separately to avoid the effect of multicollinearity. In addition to the magnitude of balance at the three age classes, the effect of the lifelong magnitude of balance on cognitive control was examined to inspect the overall impact of the lifelong participants' language experience on cognitive control. As fixed factors, the magnitude of balance at the three age classes, lifelong magnitude of balance, working memory, age of the second language exposure, age of the participants and the participants’ education level were entered; as random effect the by-subject random intercept was entered. Forced entry method of regression was employed to fill the model.

5.5.1 The Effect of the Magnitude of Balance during Childhood and Adolescence (<20)

The main question to be answered in this section was whether the balance between the first and second languages during childhood and adolescence shows a significant relationship with the participants' cognitive control abilities. To answer this question, the effects of language balance during childhood and adolescence as well as the effects of the confounding variables: working memory, age of the second language exposure, age of the participants and the participants’ education level on the participants' reaction time in the Simon task were examined. The outcome of the analysis revealed that there was a significant negative effect of the magnitude of balance
during childhood and adolescence on the participants' reaction time ($\beta = -0.004$, $t = -3.799$, $p = .01$). A model containing the magnitude of balance during childhood and adolescence and other three significant fixed effect factors (block, trial and congruency) and the random effect factor (intercept) explained approximately 50.7% of the variance in the inhibition response time data. However, when the effect size of the magnitude of balance during childhood and adolescence is computed separately, it explained 0% of the variance in the inhibition reaction time. This shows that the significant association which is found between the magnitude of balance during childhood and adolescence and cognitive control was due to noises in the participants' language background data.

Therefore, the result of the analysis did not confirm the effect of early age bilingualism on cognitive control which was reported in Luk et al. (2011) and Poulin-Dubois et al. (2011). The result also indicated that working memory had a marginally significant effect on the participants’ magnitude of cognitive control ($\beta = -.027$, $t = -1.837$, $p = .087$). However, there was no significant effect of the age of the participants on the cognitive control ($\beta = 0.001$, $t = 0.203$, $p = .842$). Also, no significant association was found between the education level of the participants and the inhibition reaction time ($\beta = 0.029$, $t = 0.965$, $p = .346$). Moreover, the participants’ cognitive control was not significantly affected by the participants' age of second language exposure ($\beta = .004$, $t = .615$, $p = .454$). The results show that none of the confounding variables had a significant effect on the participants' magnitude of cognitive control.

5.5.2 The Effect of the Magnitude of Balance during Early and Middle Adulthood (21-40)

The relationship between the magnitude of balance during early and middle adulthood and cognitive control was also examined to illustrate whether the magnitude of balance during this age has a different effect from the remaining age classes. The result of the analysis shows that there was a significant negative effect of the magnitude of balance during early and middle adulthood on the participants’ later age degree of cognitive control ($\beta = -0.003$, $t = -2.42$, $p = .05$). A model containing the magnitude of balance during early and middle adulthood and three significant fixed effect factors (block, trial and congruency) and the random effect factor (intercept) explained approximately 50.7% of the variance in the inhibition RT data. Similar with the magnitude of balance during childhood and adolescence, the magnitude of balance during early and middle adulthood explained 0% variance in the Simon task reaction time. This also
shows that the significant association which was found between early and middle age magnitude of balance and cognitive control was due to the subjectivity in the participants' language history responses. Therefore, the result of the analysis did not verify the cognitive advantage of bilingualism among adult bilinguals which was reported in previous studies (e.g. Bialystok et al., 2004; Bialystok, Martin, et al., 2005).

None of the confounding variables has a significant effect on the participants' reaction time. There were no statistically significant effects of working memory ($β = -0.031$, $t = -1.753$, $p = .101$), age of second language exposure ($β = 0.009$, $t = 1.210$, $p = .247$), age of the participants ($β = 0.004$, $t = .767$, $p = .455$) and the participants' education level ($β = 0.022$, $t = .624$, $p = .538$) on the participants' later age cognitive control. In order to determine which of the two age classes (childhood and adolescence or early and middle adulthood) has a stronger effect on the participants' reaction time, the corresponding two models were compared. The result of the comparison between the two models indicated that the language balance during early and middle adulthood was the better predictor of the participants' level of cognitive control (AIC: 3878.9 < 3885.9). However, as presented above neither the magnitude of balance during childhood and adolescence nor the magnitude of balance during early and middle adulthood had effect of a significant size.

5.5.3 The Effect of the Magnitude of Balance during Mature Adulthood (> 40)
The effect of the magnitude of balance during mature adulthood on the participants' cognitive control was also examined. The result of the analysis showed that there was no significant effect of the magnitude of balance during this age on the participants' degree of cognitive control ($β = -0.001$, $t = -0.331$, $p = .475$). Likewise, no significant association was found between working memory and cognitive control ($β = -0.021$, $t = -1.039$, $p = .316$). In the same manner, there was no significant effect of the age of the participants ($β = -0.001$, $t = -0.231$, $p = .820$) on the cognitive control. Moreover, the effect of age of the second language exposure on the participants' inhibition reaction time was not statistically significant ($β = 0.006$, $t = 0.654$, $p = .524$). The participants' education level did not also have a significant effect on the cognitive control ($β = 0.019$, $t = 0.437$, $p = .665$). Similar with the preceding two ages, the cognitive benefit of bilingualism which was reported in the previous studies (e.g. Bialystok et al., 2006; Bialystok et al., 2007) could not be replicated by the analysis of the association between the magnitude of balance during mature adulthood and the bilinguals' later age cognitive performance.
5.5.4 The Effect of Lifelong Magnitude of Balance on Cognitive Control

The effect of the lifelong balance between the first and the second languages on the participants' degree of cognitive control was also examined to investigate the impact of lifetime two language experience on the bilinguals' later age degree of cognitive control. Contrary to the expectation, no significant effect of the lifelong magnitude of balance on the bilinguals’ cognitive control was found ($\beta = -.002, t = -1.514, p = .147$). Based on, for example, Bialystok et al. (2004), Bialystok et al. (2005), Bialystok et al. (2006) and Craik et al. (2010), it was expected that the magnitude of balance between the two languages across the participants' age positively associate with the bilinguals degree of cognitive control. The results obtained from the analysis of the confounding variables also indicated that none of the variables had a significant effect on the participants' later age cognitive control (see Appendix VI).

5.6. The Effect of Speed of Language Processing on Cognitive control

In addition to the effects of the participants’ lifelong language balance, the relationship between the participants’ speed of language processing in the first and second languages and cognitive control was examined. The speed of first and second language processing was measured in two ways: by examining the participants' speed of lexical retrieval in both first and second languages and by determining the number and duration of pauses in the participants' speech in both languages. The effects of speed of lexical retrieval, number of pauses and speed of pauses were examined separately to reduce the effect of multicollinearity.

5.6.1. Effects of the First and Second Language Speed of Lexical Retrieval

The analysis of the effect of the first and the second language speed of lexical retrieval on the participants' cognitive control has shown that there was neither a significant effect of the first language speed of lexical retrieval ($\beta = .447, t = 1.262, p = .233$) nor of the effect of speed of second language lexical retrieval ($\beta = -.091, t = -.484, p = .637$). Furthermore, no significant association was found between the interaction between the first and second language speed of lexical retrieval and cognitive control ($\beta = -.314, t = -.137, p = .894$). To add more, none of the control variables found statistically significant (see appendix VI). These results are contrary to what was expected. Based on Costa & Santesteban (2004), Luk et al. (2011) and Kharkhurin (2008), it was expected that the speed of lexical retrieval in the first and the second languages positively correlate with the participants' degree of cognitive control.
5.6.2. The Effect of Speed of Speech Processing on Cognitive Control

Similar with the first and the second language speed of lexical retrieval, the effect of the number of pauses in the participants' first and second language free speech on the participants' cognitive control abilities was examined. The result of the examination indicated that, contrary to the expectation based on Ivanova and Costa (2008), Luk et al. (2011) and Kharkhurin (2008), there was no significant effect of the number of pauses in the first language speech on cognitive control ($\beta = .0003$, $t = .037$, $p = .971$). In the same manner, no significant effect of number of pauses in second language speech was found ($\beta = .002$, $t = .216$, $p = .832$). Furthermore, the interaction between the number of pauses in first and in the second language did not have a significant effect on the participants' reaction time ($\beta = .0001$, $t = .138$, $p = .891$). Similarly, neither of the confounding variables had a significant effect on the participants' later age cognitive control (see Appendix VI).

The analysis of the relationship between the duration of pauses in the participants' free speech and cognitive control has also shown that there was no significant effect of the duration of pauses in the first language ($\beta = -.0002$, $t = -1.772$, $p = .095$) on the participants' later age cognitive control. Similarly, no significant effect of the duration of pauses in the second language was found ($\beta = -.0001$, $t = -1.201$, $p = .247$). Moreover, the interaction between the duration of pauses in the first and in the second languages did not have a significant effect on the participants' cognitive control ($\beta = .001$, $t = .138$, $p = .892$). All control variables: working memory, the participants' education level, age of the participants and the participants' age of second language exposure did not have a significant effect on the participants later age cognitive control (see Appendix VI).
6. Discussion

Previous studies on the cognitive advantages of bilingualism have compared bilinguals to monolinguals and reported the cognitive advantages of bilingualism at various ages of bilinguals (e.g. Bialystok et al., 2005; Gold et al., 2013). According to these studies, once the cognitive advantage has been acquired, bilinguals should use both first and second languages regularly throughout their life in order to preserve the cognitive advantage for later age. However, these studies have not determined the extent to which the first and the second languages have been used throughout the bilinguals' life and have not examined the relationship between the lifelong balance between the two languages and the bilinguals' adulthood cognitive control.

Hence, in the current study, the participants' lifelong magnitude of balance between the first and the second languages has been explored using a semi-structured questionnaire. In addition, the bilinguals' speed of first and second language processing was examined by computing the number and duration of pauses in the participants' speech and by measuring the participants' speed of lexical retrieval using picture naming. Then, the effects of the bilinguals' lifelong language balance and that of the speed of the first and second language processing on Simon task reaction time were analyzed by means of a series of linear mixed effect models. It was hypothesized that the degree of balance between the first and second languages that the bilinguals experience throughout their life associates positively with the participants' degree of cognitive control at a later age. Furthermore, it was predicted that the bilinguals' speed of first and second language processing positively correlate with their levels of cognitive control since previous studies have reported a positive relationship between fluency in both languages and cognitive control (e.g. Luk et al., 2011; Kovacs & Mehler, 2009 and Poulin-Dubois et al., 2011).

The assessment of the participants' language experience across the three age classes shows that there have been differences in the extent to which the first and second languages has been used. A comparison between the amount of Frisian and Dutch used across the three age classes indicated that there is a significant difference between the magnitude of Frisian and Dutch used during childhood and adolescence (paired-sample t-test, \( p < .001 \)). However, the difference between the amount of the two languages used during the latter two age categories is not statistically significant. This means that the participants were unbalanced during childhood and adolescence since they used Frisian more frequently than Dutch. During early and middle
adulthood, however, their frequency of use of Frisian declined which in turn resulted in an increase in the magnitude of balance between the two languages. During mature adulthood, the predominance of the Frisian language remained almost the same with that of during early and middle adulthood (see Figure 1). Furthermore, the assessment of the between subject variation shows that, comparatively, there is higher variation among the participants during early and middle adulthood and during mature adulthood (see Figure 1) than during childhood and adolescence.

The results illustrate that the amount of first and second languages used across the participants' lifespan is characterized by Frisian dominance during childhood and adolescence and by relatively a high level of variation during the latter two ages. Thus, in contrast to what has often been claimed for bilingual populations in the literature (Bialystok, Martin, et al., 2005; Bialystok et al., 2007; Christoffels et al., 2007 and Luk et al., 2011), the assessment of the participants’ lifelong language experience in general shows that the participants have not been using both the first and the second language ‘regularly’ and ‘consistently’ throughout their life.

6.1. The Effects of Across Age Magnitude of Balance on Cognitive Control

The analysis of the relationship between the magnitude of language balance at the three age classes and cognitive control has shown similar outcomes since no significant effect of language balance is found in all age classes. The magnitudes of balance between first and second languages used during childhood and adolescence and during early and middle adulthood apparently significantly associated with the participants’ later age magnitude of cognitive control. As presented in section 5.5.1, the associations between the magnitude of balance during these two age classes and cognitive control are not due to the real effect of the amount of languages used. Rather, they are due to the noises in the language history data since the effect size of the magnitude of balance in both age classes is zero. No significant association is also found between the magnitude of balance during mature adulthood and cognitive control. Hence, the results obtained from the analysis of the association between the magnitude of balance at the three age classes and the bilinguals' later age cognitive performance did not approve the claims in previous studies (e.g. Bialystok et al., 2004; Bialystok, Martin, et al., 2005; Bialystok et al., 2006) In these studies, the cognitive advantage of bilingualism was found among bilinguals who are in different age levels.
6.2. The Relationship between Lifelong Language Balance and Cognitive Control

The analysis of the relationship between lifelong magnitude of balance and cognitive control shows that the lifelong balance between the two languages has no significant association with the bilinguals’ later age cognitive control. This result is not surprising given that the participants are not balanced bilinguals. The comparison between the magnitude of Frisian and Dutch used throughout the participants' age shows that there is a significant difference between the amount of the two language used; Frisian used more frequently than Dutch. Furthermore, the number of pauses in Dutch free speech is higher than the number of pauses in the Frisian free speech. Similarly, the length of pauses on Dutch free speech is longer than the length of pauses in Frisian free speech. These show that the participants are not balanced bilinguals. Therefore, it is likely that the absence of a significant relationship between lifelong language balance and cognitive control is due to lack of regular and daily base exposure of two languages as indicated in Bialystok et al. (2005), Bialystok et al. (2007), Gold et al. (2013).

6.3. The Association between Speed of L1 and L2 Processing and Cognitive Control

The analysis of the association between the first and the second language speed of lexical retrieval and cognitive control shows that there is no significant relationship between the two variables. In the same manner, the participants' speed of first language speech processing does not have a significant effect on the participants' later age degree of cognitive control. Likewise, there is no a significant association between the interaction of speed of the first language speech processing and second language speech processing and cognitive control. Contrary to the expectation based on Costa and Santesteban (2004) and Ivanova and Costa (2008), no significant effect of speed of language processing is identified in the current study. In general, in present study, no association was found between the participants' language experience and cognitive control.

There are two points that can be inferred from the results of the analysis of the effects of lifelong language balance and the speed of language processing on the bilinguals' later age degree of cognitive control. To begin with, the results indicate that lifetime consistency in the amount of first and second language is essential for the sustainability of cognitive advantage as indicated in, for example, Bialystok, Martin, et al. (2005), Bialystok et al. (2007) and Christoffels et al. (2007). Although the balance between the first and second language has increased from age to
age for the current bilinguals (see Figure 2), parallel increase was not observed in the participants' later age cognitive performance. This means that the bilinguals' degree of cognitive performance during the later age is determined by the absence of balance between the two languages during childhood and adolescence. This implies that the preservation of cognitive advantage for the later age requires consistent and regular use of both languages throughout the bilinguals' life. Moreover, results hint that the amount of the first and second language which is used at different ages of the participants is not equally important. Though the magnitude of balance has shown an increase across the ages of the bilinguals, the association between the magnitude of balance and cognitive control remained the same across the three age classes (absent in all age classes). This further suggests that two language exposure during the early age is crucial for the preservation of the cognitive control for the later age. This is consistent with the finding of Luk,Sa, et al. (2011).

In general, based on the above findings, it can be argued that the absence of a significant relationship between the participants' language experiences and cognitive control in the present study is mainly due to four reasons; the lack of lifelong balance between the two language, the absence of consistency in the magnitude of balance across the participants' ages, the involvement of various confounding variables and methodological concerns. As presented above, the assessment of the participants’ lifelong language experience shows that the participants in the current study are not balanced bilinguals. The absence of the balance is mainly due to the more frequent use of Frisian during childhood and adolescence. The results obtained from the assessment of the participants' free speech also confirm this assertion. The number of pauses in the participants' Dutch free speech is greater than the number of pauses in the participants Frisian free speech. Moreover, the duration of pauses in the Dutch free speech is longer than the duration of pauses in Frisian free speech. These indicate that the participants in the current study are not balanced bilinguals; rather they are Frisian dominant. Thus, the absence of the cognitive advantage is due to the imbalance between the amount of the two languages used since ideally the two languages should be used regularly throughout the bilinguals’ life to preserve the cognitive advantage for later age (Bialystok, Martin, et al., 2005; Bialystok, 2007; Bialystok et al., 2007; Craik & Bialystok, 2006; Salvatierra & Rosselli, 2010).

In addition to the absence of balance between the two languages, inconsistency in the amount of both languages used throughout the participants’ life may have also contributed to the absence of
the cognitive advantage; as illustrated above, the participants' have not used equal amount of languages throughout their life. They were less balanced during childhood and adolescence, but the magnitude of balance between the two languages increased during the later age. This shows that there is lack of consistency which is mentioned in Bialystok, Martin, et al. (2005), Bialystok et al. (2007), Craik and Bialystok (2006) and Gold et al. (2013). These studies, though they did not measure the participants' lifelong language experience, suggested that unless both first and second languages are used consistently on the daily bases throughout the participants' life, the cognitive advantage may not appear at the later age of the bilinguals.

Furthermore, previous studies have reported the cognitive advantages of bilingualism by comparing monolinguals to bilinguals. This comparison assumes that the two groups are the same except in the some variables of interest. However, there may be a lot of uncontrolled variables that determine the association between language experience and cognitive control. In the current study, rather than comparing individuals, major variables which are related to the cognitive control are examined using mixed model linear regression. Hence, it can be the case that many other uncontrolled variables interplay with the magnitude of balance to determine the cognitive advantage; as a result, the magnitude of balance alone may not be able to predict the degree of cognitive control.

Moreover, there are methodological concerns that are likely to affect the outcomes the current study. As the lifelong magnitude of balance was measured based on the participants' opinion about their past language experiences, the subjectivity of their responses can affect the outcome. Besides, the computation of the participants' first and second language magnitude of exposure was made by adding the amount of each language which was used by the participants in different contexts. This addition pretends as if the amount of each language used in different contexts had equal weight and effect. For instance, 80% Frisian exposure at home was considered as if it were equal with 80 % Frisian exposure at school. In reality, however, the two figures may not have equal weight and effect.

In addition to the above three possibilities, it is also probable that bilingualism may not lead to the cognitive advantage if the first and the second languages are closely related. With regard to the current languages, there is a close similarity between Frisian and Dutch. Studies which have been conducted on the mutual intelligibility between the two languages shows that Dutch
speakers can understand Frisian to some extent. For instance, Bezooijen and Gooskens (2005) studied the mutual intelligibility between Frisian, Dutch and Afrikaans. The finding of their study showed that though Afrikaans is easier than Frisian for the native Dutch speakers, Dutch speakers can understand Frisian to certain extent. Therefore, it can be the case that the absence of the cognitive advantage among the current participants is due to the close similarity between the two languages. Future studies should investigate the effect of the similarity between first and second languages on the cognitive advantage of bilingualism.

6.4. The Effect of Age, Working Memory, Education and Age of L2 Onset

The analysis of the effect of the age of the participants, working memory, age of second language exposure and the level of education of the participants' shows that none of them has a significant effect on the participants' later age cognitive control. With regard to the second language exposure, since all participants began speaking both languages before the age of seven, the result is expected. It shows that exposure to a second language from birth to the age of 7 has similar effect on the bilinguals’ later age cognitive control. Furthermore, since all the participants are elderly bilinguals (54-77), the absence of the effect of the age of the participants on the inhibition reaction time is expected. The result just shows that the age variation among the elderly bilinguals does not have a significant effect on their inhibition reaction time.

The participants are different in terms of their level of education; many of them attended junior and secondary school whereas some of them hold BA and MA degrees. The examination of the association between the participants' level of education and cognitive control shows, however, that the participants’ cognitive control capability is not affected by the differences in their education levels. It shows that the level of expertise and length of education are not related to cognitive control. It may be the case that this relationship is affected by the small sample size and difference in the scale between non-degree and the degree holder categories. Comparison between illiterate and literate bilinguals can be an interesting area of future studies. There was also no significant effect of working memory on the bilinguals' later age cognitive control. Furthermore, no significant association of working memory is found during the examination of the relationship between the first and second language speed of processing and the participants' later age cognitive control. In general, all the control variables included in the current study do not have significant relationships with the participants' later age cognitive control.
7. Conclusion and Recommendations

In this study, no cognitive advantage of bilingualism has been found. The association between lifelong bilingualism and cognitive control that has been claimed in previous studies has not been confirmed by the current study. Moreover, no association was found between the magnitude of language balance at different ages of the bilinguals and the bilinguals' later age cognitive control. The bilinguals' speed of first and second language processing and adulthood cognitive control did not also show a significant relationship with the participants' later age degree of cognitive control. Three plausible assumptions are provided for the absence of these associations.

First, the current participants are not balanced bilinguals. Thus, the magnitude of their balance is not able to predict the bilinguals' degree of cognitive control. Second, the bilinguals in current study have not used both languages consistently as stated in previous studies. Their early age language experience was dominated by Frisian. Thus, it is likely that due to the lack of equal access to the two languages during childhood and adolescence, their cognitive control ability was not enhanced from the beginning. It is also the case that many other uncontrolled variables interplay with the magnitude of balance to determine the cognitive advantage; as a result, the magnitude of balance alone may not be able to predict the degree of cognitive control. Two more probable causes for the absence of cognitive advantage has also been suggested: the similarity between the first and the second language and the subjectivity within the participants' lifelong language experience.

Future studies should consider higher number of participants since only twenty participants are included in the current study. Furthermore, since only picture naming and the number and the duration of pauses in the participants’ free speech were employed to measure the participants’ speed of first and second language processing, a detailed assessment of the participants’ language fluency ought to be considered in future studies. The current study has taken an initial step towards applying a retrospective exploration of the bilinguals’ lifelong language experience. However, the responses obtained via this method are likely to be affected by subjectivity since the participants may not precisely remember their language-related past experiences. Researchers who are interested in similar theme may consider follow up study.
References


Appendices

Appendix I : Experiment check list
Each assistant who participate in this project will fill this check list and make sure that the data are gathered according to the guidelines/procedures. Use the confirmation column to indicate that the experiment is done according to the guideline!

<table>
<thead>
<tr>
<th>No</th>
<th>Activities</th>
<th>For confirmation use (x)</th>
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<tbody>
<tr>
<td>A</td>
<td>Background Questionnaire and Language History</td>
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</tr>
<tr>
<td>1</td>
<td>All parts of the questionnaire are filled</td>
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<tr>
<td>2</td>
<td>Orientation and explanation are given</td>
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<tr>
<td>3</td>
<td>The questionnaires are collected from the respondents</td>
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<tr>
<td>B</td>
<td>Digit Span Task</td>
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<tr>
<td>1</td>
<td>Appropriate instructions are used</td>
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<tr>
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Appendix II: Eligibility Questionnaire

This questionnaire is prepared to make sure that you are a candidate to participate in our study before we take up too much of your time. Go through the question and check if you fulfill our requirements.

1. Are you a native speaker of Frisian?
   a. Yes   b. No
2. Have you used Dutch as a second language starting from early childhood?
   a. Yes   a. No
3. Are you older than 50?
   a. Yes   b. No

If the answer to all of these questions is ‘yes’, you are a potential candidate and we would ask you to fill in the following questions. These concern some other issues that are relevant to your suitability to participate.

Personal Background

1. What is your date of birth (DD/MM/YY)? ……………………………………………
2. Are you a. Male b. Female (circle one)
3. Where is your place of birth (country and city/town)? ……………………………………..
4. Where is your present address (Street and house number)? ……………………………………

5. Healthy Condition: Do you have or have you ever been diagnosed for
   a disease affecting the brain such as dementia (a decline in mental ability such as memory loss) or
   multiple sclerosis?
      a. Yes       b. No
   b. stroke or other vascular problems affecting brain function?
      a. Yes     b. No
   c. concussion with a loss of consciousness longer than 15 minutes ?
      a. Yes     b. No
   d. color blindness (decreased ability to perceive color differences)?
      a. Yes   b. No
   e. eye problem leading to loss of ability to read even with support of sight glass
      a. Yes   b. No

6. What is your level of education? (Circle best choice)
   a. Kindergarten       b. Elementary school
   c. Secondary school   c. Vocational Training
   d. bachelor degree  e. Master degree
   f. PhD

7. What is your present occupation or, if not working now your last position? .................
8. At what age were you first exposed to Frisian? .................................................................
9. At what age did you first expose to Dutch? .................................................................

If you don’t understand a certain question, please do not hesitate to contact us via my email (hitakeleg@gmail.com)
Appendix III: Language History Questionnaire

ID____________________

Part I: Personal Information

1. What is your date of birth (DD/MM/YY)? .................................................................
2. Sex □ male □ female
3. Place of birth (country and city/town)? ..............................................................................

Instruction
In your life, you may have experienced various changes such as moving home, learning in
different schools, having different friends…etc. Here we are interested in how much these
changes have affected your exposure to Frisian and Dutch languages. We provide you below
some changes, list of ages and scales on which you indicate the effect of the changes on your
exposure to Frisian and Dutch languages. Your task is remembering age on which these changes
happened in your life, and showing on the scale provided (100%-100%) how much these
changes affected the amount of your exposure to Frisian and Dutch. Only some of the changes
are provided for you; you can think of as many other changes as you can! Please note that the
more you move towards the middle across the scales, the more you indicate equal use of both
Frisian and Dutch (e.g. if you select 50%, you mean that you used 50% Frisian and 50% Dutch).

A) Home Experience

a) Which language did your parents speak when you were a kid (1-3 years)?
b) Did something happen in the family then? For instances, when did a new member joined
your family? How did this affect your use of Frisian/Dutch?
c) When did your parents move home? Which language was spoken more often in the
community you moved to?
d) When did you leave your parents’ home and had your own house? How much did this
affect your use of Frisian/Dutch?
e) When did you move your home after that? How did these changes affect your use of
Frisian and Dutch?
f) When did you have a girl/boyfriend? How much did this affect your use of
Frisian/Dutch?
g) When did you retire from the work? How much did this affect you use of Frisian/Dutch?
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### B. School-Related language Experience

1. When did you attend kindergarten? How often did you use Frisian/Dutch to talk to your school friends and teachers?
2. Did you attend elementary education in different schools? Which language (Frisian/Dutch) did you frequently use when you communicate with classmates, teachers and friends in each school?
3. When did you attend secondary/high schools? How often did you use the two languages to communicate with your classmates, teachers and friends?
4. When did you attend colleges/universities? Which language did you use more often when you talk to your classmates, teachers and friends?

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C. Changes Related to Social Interaction

1. Which language did you use to tell stories and jokes to your friends?

2. Did you enjoy teenage hangouts? Which language was usually used?

3. Did you enjoy parties with your friends when you were young? Which language was dominantly used?

4. Think of memorable events you have spent with friends or partners. Which language was more frequently used at that time?

5. When did you often participate in festivals and various celebrations? Which language did you commonly use on the celebrations?

6. When did you make a change of work places? Which language was often used in each place?

7. Did you retire from work? Which language was more frequently used after retirement?

Social Language Use History Summary

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Appendix IV: data distribution and normality assessment

Figure 3: Quantile-quantile plot for log transformed time in inhibition reaction time grouped by subject, before the exclusion of extreme values
Figure 4: Quantile-quantile plot after trimming (more than 3), for log transformed reaction time in inhibition grouped by subject
Figure 5, model diagnostic graph showing the normality of distribution, cooks distance and leverage
Appendix V: variations due to subject difference and experimental design

Figure 6: participants’ reaction time adjustment to the mean
Figure 7 the effect the task design on the participants’ reaction time
Figure 8: correlation between by subject random intercept and the slope of the effect of trial
Appendix VI

Estimated coefficients, standardized error, t-value and p-value of the mixed effect regression model for the control variables

**Lifetime**

<table>
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<tr>
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<th>Estimate</th>
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<th>p-value</th>
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**Lexical retrieval**

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**Number of pauses**

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**Duration of pauses**

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