# COGNITIVE CONTROL IN LOW PROFICIENT AND HIGH PROFICIENT YOUNGER AND OLDER BILINGUALS

ANITA. J

**Register Number: 17SLP003**

A Dissertation Submitted in Part Fulfilment for the Degree of Master of Science (Speech-Language Pathology)

University of Mysuru

Mysuru

**ALL INDIA INSTITUTE OF SPEECH AND HEARING**

**MANASAGANGOTHRI, MYSURU – 570 006**

**MAY- 2019**

## CERTIFICATE

This is to certify that this dissertation entitled "**Cognitive Control in Low Proficient and High Proficient Younger and Older Bilinguals**" is a bonafide work submitted in part fulfillment for the Degree of Master of Science (Speech-Language Pathology) of the student (Registration No: 17SLP003). This has been carried out under the guidance of a faculty of this institute and has not been submitted earlier for the award of any other Diploma or Degree to any other University.

Mysuru

May, 2019

**Dr. M. Pushpavathi**
**Director**
All India Institute of Speech and Hearing
Manasagangothri, Mysuru -570 006

## CERTIFICATE

This is to certify that this dissertation entitled "**Cognitive Control in Low Proficient and High Proficient Younger and Older Bilinguals**" has been prepared under my supervision and guidance. It is also certified that this has not been submitted earlier for the award of any Diploma or Degree to any other University.

Mysuru

May, 2019

**Dr. Abhishek B P**

***Guide***

Lecturer

Department of Speech-Language Sciences All India Institute of Speech and Hearing, Manasagangothri,

Mysuru - 570 006

## DECLARATION

This is to certify that this dissertation entitled "**Cognitive Control in Low Proficient and High Proficient Younger and Older Bilinguals**" is the result of my own study under the guidance of Dr. Abhishek B P, Lecturer, Department of Speech-Language Sciences, All India Institute of Speech and Hearing, Mysuru and has not been submitted earlier for the award of any Diploma or Degree to any other University.

Mysuru **Register No: 17SLP003**

May, 2019

## ACKNOWLEDGMENT

"Gratitude is the attitude of the heart"

At the outset, my deepest gratitude to God Almighty for His abundant blessings throughout this important venture.

My gratitude to the most inspiring and supportive guide Dr. Abhishek. B. P. Sir, I place on record the immense guidance and encouragement I received throughout this journey of the dissertation. Thank you for being there to clear all obstacles during this learning experience.

I would like to thank my beloved family, without whose unconditional love, support and constant encouragement I wouldn't have come this far.

My sincere thanks to all the learned teaching fraternity at AIISH, who were an enlightening and guiding source throughout my six years of study at AIISH.

Special thanks to Dr. Santhosha sir for his guidance in statistical analysis.

My thanks to all my friends and classmates throughout this wonderful journey of life and learning. I extend my sincere thanks to all my worthy seniors and loving juniors. A special thanks to Ranjitha di for all the support during data collection.

A special thanks to all the participants, young and old, who wholeheartedly participated in the study, without whom this venture wouldn't have been possible.

My sincere gratitude to one and all, who directly or indirectly were my well-wishers in this endeavor.

## TABLE OF CONTENTS

## LIST OF TABLES

## LIST OF FIGURES

*Chapter I*

# INTRODUCTION

## *1.1 Executive functions*

Executive functions refer to a variety of skills which help in making socially responsible, self-serving, independent and purposive behavior possible (Lezak, 1995). Executive functions include basic cognitive processes such as attentional control, cognitive inhibition, inhibitory control, working memory, and cognitive flexibility. Higher order executive functions require the simultaneous use of multiple basic executive functions and include planning and fluid intelligence (e.g., reasoning and problem solving).

## *1.2 Domains of executive functions*

Miyake and his colleagues (2000) claimed that executive function is not a unitary construct but includes many domains such as:

(i) Attention

(ii) Response inhibition

(iii) Cognitive flexibility

(iv) Memory

## *1.3 Executive functions in bilinguals*

Executive function is reported to be advantageous in bilinguals when compared to monolinguals as evident in the previous studies. It helps an individual to become more sensitive to finer distinctions between languages. Furthermore, it enhances the effective use of their first language and facilitates learning other/new languages.

Various studies conducted in this area have found that bilingualism enhances a bilingual's cognitive processes throughout life. This intern help develops better cognitive functions and this phenomenon is termed as "Bilingual Advantage" (Bialystok, Craik, Klein & Viswanathan, 2004).

The earlier studies have compared monolinguals and bilinguals. The present study is different compared to the previous studies as it compares bilinguals in terms of their proficiency.

### *1.4 Need for the Study*

1. Studies previously have compared bilinguals with monolinguals. Very few studies have compared high proficient and low proficient bilinguals. Though an earlier study was conducted, cognitive control was not tapped in that study.
2. The earlier studies on bilingualism have been done on younger bilinguals. In this study, older bilinguals will also be considered. Hence, the Bilingual Advantage in the cognitive domain would be viewed as a function of age.
3. Most of the studies on cognitive control have used non-linguistic tasks. The present study intends to use a variety of tasks with varying complexity.

### *1.5 Aim of the Study*

The aim of the study is to measure the effects of bilingualism on cognitive control in young and old, low proficient and high proficient bilinguals.

### *1.6 Objectives of the study*

1. To compare the reaction time and accuracy scores for high proficient young bilinguals and high proficient old bilinguals on the three tasks.
2. To compare the reaction time and accuracy scores for low proficient young bilinguals and low proficient old bilinguals on the three tasks.
3. To compare the reaction time and accuracy scores for low proficient and high proficient young bilinguals (in the age range of 18 to 30 years) on the three tasks.
4. To compare the reaction time and accuracy scores for low proficient and high proficient old bilinguals (in the age range of 55 to 70 years) on the three tasks.

*Chapter II*

# Review of Literature

## 2.1. Introduction on Bilingualism

### 2.1.1. Bilingualism - definition.

Bilingualism is a widespread phenomenon and it is approximated that half of the world's population speaks two or more languages (Grosjean, 2010). It is seen in almost all countries in the world, in all different classes of society and in all age groups. Bilinguals have various degrees of language abilities in different domains in both languages, such as 'those people who need and use two or more languages (or dialects) in their everyday lives' (Grosjean 2010). According to ASHA (2004), Bilingualism is defined as the usage and proficiency in at least two languages by an individual; subjected to change depending on the opportunities to use the languages and exposure to other users of the languages.

### 2.1.2. Classification and assessment of Bilingualism.

Reflecting the multidimensionality of bilingualism, a number of classifications focusing on different dimensions of bilingualism have been proposed.

Bilinguals can be classified on the basis of age of acquisition of the second language as early and late bilinguals (Beardsmore, 1986). In the case of early bilinguals, acquisition of two or more languages/L2 occurs in the pre-adolescent phase of life. These individuals are considered as attaining native-like linguistic competence in both languages. Early bilingualism can also be sub-grouped into simultaneous early bilingual i.e. when a child learns more than one language at the

same time; from birth. This usually produces strong bilingualism. On the other hand, successive early bilinguals, acquire L1 partially and then learns L2. Late bilinguals learn their second language (L2) after the critical period, particularly when L2 is learned during adulthood or adolescence. Most of the late bilinguals are considered as non-native speakers of L2. These bilinguals wouldn't have attained a complete competence of L2, and manifests as structural grammatical inadequacies and are unable to detect linguistic ambiguity (Baetens Beardsmore, 1986).

On the basis of functionality, they are classified as receptive bilinguals; who can't produce L2 either in oral and/or written domains but can understand and productive bilinguals who understand and produce L2. They can also be classified on the basis of mode of acquisition of the second language, i.e. whether there is a single lexicon moderating the activation of words in both the languages or if there is an independent lexicon for activation of words in each language.

On the basis of competency, bilinguals are classified as balanced and dominant types (Peal & Lambert, 1962). When L1 competence is equal to L2 competence, the condition is a balanced type. In a majority of the cases, balanced bilinguals are early bilinguals, who have acquired their languages simultaneously. On the other hand, in the dominant type, the L1 competence is greater than or less than the L2 competence. Bilinguals are also classified based on language status and learning environment as circumstantial /folk bilinguals and elective /elite bilinguals (Fishman, 1977). Folk bilinguals are regarded as a language minority group. Their language does not have a high status in the society with other dominant languages; where they reside. While, elite bilinguals speak the dominant language in the given society and also speak another language, giving them added value in the society.

Proficiency is a very important factor, based on which bilinguals are classified into high proficient and low proficient. Proficiency refers to the skill of an individual to use their second language more or less like a native or fluent speaker. Understanding, speaking, reading and writing forms the four core skills for the attainment of bilingual proficiency. Understanding would be the easiest to acquire followed by speaking, reading and then writing. Theoretically, there is no direct connection between the ability in one skill or the other. This, in fact, is true as a bilingual might have a good understanding of the language but may not be proficient enough while using the language for speaking.

Many different measures have been proposed to measure proficiency levels in the second language. The measures include self-rating scales, questionnaires, flexibility tests, fluency tests and dominance tests (McNamara, 1967). In a self- rating scale, individuals are asked to rate their proficiency for the different basic skills in each language. Flexibility tests include tests of synonyms, word associations and word frequency estimations in both L1 and L2. Whereas, fluency test includes; picture naming, oral reading, word completion, and following instructions. In the dominance tests, bilinguals are presented with stimuli that are either in L1 or L2 and would be asked to pronounce or interpret it. The test assesses the speed and efficiency in dealing with the stimuli presented in two languages in a variety of tasks. If the results of these tests indicate equal proficiency in both the language, two implications are possible. First would imply that the bilingual have native-like proficiency in both the languages. Other implication would be that the bilingual has poor/low proficiency in both the languages.

Out of these measures, the self-rating scale is a time economy measure to determine proficiency and has extensive usage. Rating scales such as the International

Second Language Proficiency Rating Scale (Ingram, 2000), Interagency Language Roundtable Scale, ACTFL Proficiency Scale are commonly used. Rating scales clubbed with questioners such as LEAP-Q developed by Flege and revised by Marian, Blumenfeld & Kaushanskaya, 2007 has been used. This has also been developed for the Indian context by Ramya & Goswami (2009). The Language Experience and Proficiency Questionnaire or commonly abbreviated as LEAP-Q is a tool for efficiently assessing the proficiency in the language of neurologically intact multilingual adults. It includes a total of 18 questions. Most of which determines the language history of the individual. Question number 10 in the questionnaire is meant for the assessment of an individual's proficiency in each of the languages. Here, the person is asked to rate his/her proficiency on a 4-point rating scale (1- zero proficiency, 2-low, 3-good, 4-native like/perfect) on the four domains; speaking, understanding, reading and writing.

### 2.1.3. Neuroanatomical changes in bilinguals.

Learning a second language increases the density and degree of structural reorganization of grey matter in the inferior parietal cortex of the left hemisphere. These changes are in turn regulated by the age of acquisition and proficiency attained in L2.

### 2.1.4. Advantages of Bilingualism.

- The well-known advantage of Bilinguals includes that of being able to speak in more than one language. Hence being able to converse with a larger group of people, making the migration to other places less troublesome. This is also an advantage in the job sector.

- Previous researchers have reported “Bilingual advantage”, where they demonstrate a superior performance relative to the monolinguals. This enhances bilingual’s cognitive processes across the lifespan and develops better cognitive functions (Bialystok et al, 2004).
- Some of the cognitive benefits of Bilingualism include:
  (a) Suppress irrelevant information and activate the relevant ones, despite adverse interference (Bialystok et al, 2008).
  (b) Shifting between mental sets (Garbin et al., 2010; Prior and MacWhinney, 2010).
  (c) Greater potential to store information in working memory (Bialystok et al., 2004).
  (d) A Slow decline of symptom onset of dementia in aging adults (Bialystok, 2010), Mild Cognitive Impairment (Bialystok et al, 2014) and Alzheimer’s disease (Alladi et al., 2013).
  (e) Better cognitive recovery (Alladi et al., 2016).

### 2.1.5. Reasons for the cognitive advantages seen in bilinguals.

Bilinguals share their knowledge or communicate in more than one language by code-switching (i.e. alternating between two or more languages, or dialects, in the circumstance of a single conversation) and/or language mixing; without impairing comprehension. Thus, there are instances that don't demand the exclusive use of one language and suppress the interference from the other one(s). Sometimes, complete language separation is even not desired as a certain pleasure often accompanies code-switching and language mixing. On the contrary, in many situations, where there are certain formal constraints or where communication has to be restricted to one

language, there is the necessity of rather pure monolingual language use. In such cases, the target language has to be selected and its activation has to be maintained during the communication while the (co-activated) non-target language(s) need to be inhibited (Dijkstra, 2005; Brysbaert, 2003; Green, 1998).

The bilingual advantage is due to relative inhibition i.e. facilitation of relevant information and not due to active inhibition, where there is active inhibition of irrelevant information. This selection process is part of the cognitive function called the executive control system. Thus, the bilingual advantage is not a result of inhibiting the irrelevant language constantly, but a better selection of the relevant/target language from the irrelevant competing language(s) (Colzato et al., 2008). Hence, language selection tends to have generalized cognitive benefits (Kroll, Dussias, Bice, & Perrotti, 2015). It is also assumed that as the number of years of experience of selecting and managing two language increases, an individual becomes more skilled across different aspects of executive functions and this skill would reduce with aging.

However, some disadvantages also accompany bilinguals. In general, bilinguals are prone to have smaller vocabularies in the languages they know (Oller & Eilers, 2002), they are slower at naming pictures (Kaushanskaya & Marian, 2007), and occurrences of tip-of-the-tongue errors are higher when compared to monolinguals (Gollan & Acenas, 2004).

### 2.2. Executive Function and Cognitive Control in Bilinguals

Bilingualism is regarded to have a favorable effect on the efficiency of Executive Functioning (EF) system. Executive functioning in bilinguals denotes higher cognitive processes that account for the conscious control of action and thought (Zelazo &

Muller, 2010). "Executive functions" (EFs), is an umbrella term consisting of many cognitive processes such as cognitive flexibility, response inhibition or resistance to interference, planning, sequencing, problem-solving, reasoning, ability to sustain attention, utilization of feedback, multitasking and the ability to deal with unfamiliarity (Chan , Shum & Chen, 2008). Bilinguals are assumed to have a higher executive function as stated by researchers.

On the other hand, Cognitive control is the ability to meet internal goals by shaping thoughts and behavior flexibly during continuously changing environmental demands (Miller & Cohen, 2001). Simon's task is usually used to assess cognitive control. Simon's effect refers to the increase in reaction time when the stimulus occurs in the same or relative location as the response.

Studies on Bilingualism and Bilingual advantages in executive function have been an area of interest for many researchers in the field of cognitive development. The various domains to be assessed include; response inhibition, cognitive flexibility, attention and working memory using tasks which could be verbal or nonverbal (Bialystok, 2001).

**(a) Response inhibition.**

It is the ability to suppress information that is unwanted and be able to focus on the rules of the task. There are many tasks to measure inhibition in bilinguals.

- One of them is the Stroop task, where color words in a particular color ink (e.g., red) in congruent or incongruent ink appears and the Stroop effect is calculated.

- Another task called Simon's task, in which arrows appear on either of the sides (left or right) of the computer screen. Participants have to indicate by pressing either the left or right shift keys depending on the direction of the arrow and Simon's effect is calculated.
- Flanker task is yet another task where the target and non-target stimuli appear either in the same direction as the target, usually left or right (congruent flankers), to the opposite direction (incongruent flankers), or to neither (neutral flankers). The participants have to respond to the direction of the target or the central stimulus. The stimuli most commonly used are letters and arrows.

**(b) Cognitive flexibility or set shifting.**

It refers to the ability to rapidly switch between varying response sets or in other words activation of a new criterion and inhibition of the previous one (Anderson, 2002).

- A local-global task is a nonverbal task used for measuring shifting, where a geometric, global, figure composed of much smaller, local, figures (i.e., Navon figures) are presented on a computer screen and congruent and incongruent trials are presented and the shifting effect is calculated.
- Also, tasks similar to the Simon task, Stroop task, Letter- number task can be used to test for set shifting.

**(c) Working memory.**

It involves both the storage capacity of working memory and also processing capacity and is considered as a core executive function (Zelazo, Muller, Frye, & Marcovitch, 2003).

- Corsi block test is used for bilinguals in which nine identical and spatially separated blocks appear on a black background of the computer screen. Participants are instructed to press on the blocks in the same order in which they were highlighted and the point at which participants got all three trials of a single length incorrect is calculated.
- Digit span tests (Forward and Backward) have also been used previously where participants are asked to recite numbers from 2-9 in the order as they appear and the point at which participants incorrectly repeated two lists of the same length, digit span was categorized.

## 2.3. Executive Function and Cognitive Control in Young Adults

Interference refers to the opposition offered by one language over the acquisition of other languages. The effect of interference was tested for a numerical Stroop task on young bilingual and monolingual adults by Costa, Hernandez, Faidella, and Sebastian (2009). They reported better interference suppression in bilinguals. This was associated with neural differences in areas responsible for executive control (Abutalebi, Della & Green, 2012).

Bilingual advantage on non-verbal working memory tasks using the backward Corsi block task on French- English bilinguals and monolinguals indicated equal

performance by both the groups in the simple condition but bilinguals performed significantly better than monolinguals on the difficult (backward) condition (Bialystok & Feng, 2009).

Bilingual advantages in shifting between mental sets were demonstrated by Prior & MacWhinney (2010). College students with a mean age of 19 years were recruited, among which 45 were monolinguals and 47 bilinguals. A non-linguistic task switching paradigm in English – Spanish bilinguals was carried out and results reveal that bilinguals had reduced switching costs when compared with monolinguals and performed better on task switching that required changing the criterion continuously.

The findings from the literature indicate that the performance of monolinguals and bilinguals is sensitive to the tasks. Bilinguals have shown advantages in nonverbal tasks. However, monolinguals outperform bilinguals on verbal tasks. Bialystok, Craik &Luk (2008) found monolinguals outperformed bilinguals on lexical retrieval tasks. Mindt, Arentoft, Germano, D'Aquila, Scheiner, Pizzirusso, Sandoval, & Gollan (2008) previously found that high L1 proficiency in a bilingual has a positive effect on the proficiency in L2. Also, high proficient bilinguals are predicted to have more cognitive advantages than low proficiency bilinguals in nonverbal tasks while the opposite pattern is predicted for verbal tasks.

In another study by Ivanova and Costa (2008), they recruited 37 monolinguals and bilingual college students. They were further grouped into Spanish monolinguals, Spanish -Catalan bilinguals and Catalan- Spanish bilinguals. They found that bilingual language proficiency resulted in slower word retrieval on a picture-naming

task. As inhibition of the second language is found to be important on verbal tasks, bilinguals find it difficult to suppress the other language. This may have resulted in poor performance. For non-verbal tasks, on the other hand, the other language known to the bilingual might not interfere much.

These results indicate the disadvantage of bilinguals on verbal tasks or tasks that require word generation for highly proficient bilinguals in comparison to monolinguals. However, this has not been tested on a wide sample to confirm these assumptions. Hence, these demonstrate the importance of assessing bilingual proficiency and carefully selecting tasks of varying complexity tapping both verbal and non-verbal skills.

Balanced bilingualism and early acquisition of L2 as determiners of the advantage seen in bilinguals was investigated by Yow and Li, 2015. For this, language proficiency, amount of usage of L1 and L2, and the age at which L2 was acquired were considered. Participants in the age range of 18 – 25 years old and English Mandarin bilinguals were included in the study. Tasks such as Stroop, Eriksen flanker, number-letter switching, and *n*-back task that measures: inhibition, shifting between mental sets, and updating information and monitoring were administered. Results show that the bilinguals performed significantly better on the Stroop and number-letter tasks, but no difference was seen for the flanker and *n*-back tasks. From this, it can be inferred that a bilingual's regular experience with controlling attention in using their two languages results in better performance on inhibition and global set-shifting.

The effects of bilingualism on executive functions in low and high proficient Kannada-English bilinguals were studied by Margaret and Abhishek (2017). Bilinguals in the age range of 18-25 years were recruited for the study. It included domains on response inhibition, cognitive flexibility, and attention. The findings showed that high proficient bilinguals performed better compared to low proficient bilinguals. However, this study did not include Cognitive Control, which is considered as another major cognitive function. Thus the present study will focus on the outcome of bilingualism on Cognitive Control.

The relationship between socio-economic status and cognitive control and higher-order executive functions was explored by Naeem, Filippi, Tomas, Papageorgiou, and Bright in 2018. Simon task and the Tower of London (TOL) task were administered on bilingual and monolingual young adults with low SES and high SES. Their performance was compared and the results showed that reaction time for bilinguals was faster on the Simon task. This was significant only in the lower SES group and no significant effect was seen in the higher SES group. Thus it can be concluded that SES can be considered as an important predictor of cognitive performance irrespective of whether a person is bilingual or not.

The influence of proficiency in L2 on cognitive control in unbalanced Chinese - English bilingual adults was carried out by Xie, 2018. They recruited 92 participants for the study and grouped them into 3 groups based on their L2 proficiency. For the test of proficiency in L1 and L2, a self-rating language proficiency Likert scale (1–10) (Marian et al., 2007) and a verbal fluency test (for the categories: jobs, sports, animals) were used. Two tasks were administered for assessing cognitive control; Flanker task (measures monitoring of conflict and inhibition), and Wisconsin Card

Sorting Test (WCST) (measures shifting of mental sets). Results revealed, no difference among any of the groups for inhibition, however, participants with the highest L2 proficiency performed faster for conflict monitoring. On the WCST, no differences were seen across all age. Therefore, it suggests that proficiency of L2 has a notable influence in monitoring conflict, not in inhibition or shifting between mental sets.

Consequences of bilingualism on inhibitory control in French–English bilinguals were studied by Martin and Bialystok (2008). 45 adults with a mean age of 47 years were grouped as English monolingual & French- English bilinguals. Bilinguals responded rapidly to both congruent and incongruent stimuli than monolinguals for inhibition and shorter reaction times on Simon's tasks. Enhanced interference suppression could be because of the ability to manage attention by inhibiting distracting spatial cues in rapidly changing contexts.

The effect of language switching frequency on the skills such as alerting, response inhibition and cognitive flexibility in bilinguals was studied by Barbu, Orban, Gillet & Poncelet (2018). Participants in the age range of 18 to 43 years and a mean age of 26 years were divided into two groups (21 LFHS and 21 HFLS). Tasks assessing response inhibition, cognitive flexibility and alerting from the Test of Attentional Performance (TAP) battery was administered. The results showed that for cognitive flexibility, faster reaction time was seen for high-frequency language switchers. The high frequency and low-frequency switchers performed equally for alerting and response inhibition tasks. These results indicate that the frequency of switching is a predictor of increased cognitive flexibility in bilinguals.

However conflicting results have also been reported in the literature. A study was carried out to see the consequences of bilingualism on inhibitory control by

Rodrigues & Zimmer (2016). They tested 40; of which 20 monolinguals and 20 bilinguals having L1- Brazilian Portuguese and L2- English. Simon's task was carried out and results indicated no significant statistical differences in the interference effect between the groups.

Earlier there was an idea that playing music or speaking a second language has a positive effect on the person's cognitive capacity. With this notion, many studies have been reported in the past. On similar lines, the added advantage of musical training in bilinguals was studied. Young adults were divided into the groups; monolingual musician; bilingual musician; bilingual non-musician; and monolingual non-musician and compared on the tasks of working memory and inhibitory control. Results showed that individuals who were musically trained, but not bilinguals, performed significantly better on working memory. Neither musically trained nor bilinguals had enhanced inhibitory control. The authors of this study; D'Souza, Moradzadeh, and Wiseheart in 2018 have concluded saying that the null bilingual effect could be due to the performance ceiling.

The effect of bilingualism on executive functioning abilities was investigated by Anton, Carreiras, and Dunabeitia in 2019, where they tested a large group of young bilingual and monolingual adults. A total of 180 young adults from Spain (90 bilinguals and 90 monolinguals) were recruited. A series of tasks i.e. Flanker's task, Simon's task, Verbal Stroop, Numerical Stroop and tasks for working memory (Corsi, Corsi inverse, Digit Span, Digit Span inverse) were administered. Results showed no significant difference across the age groups.

## 2.4. Executive Function and Cognitive Control in Older Adults

The effect of being a bilingual and the onset of Alzheimer's disease was studied in bilinguals and monolinguals. Total of 200 patients with Alzheimer's was recruited who were monolingual and bilinguals. It was found that the onset of symptoms of the disease in monolinguals was about 72.6 years and bilinguals at about 77.7 years of age i.e. 5.1 years later than monolinguals. Surprisingly, when the brain images were matched on the severity of the disease, the physical atrophy in the regions associated with AD were significantly higher for bilinguals than monolinguals. Yet bilinguals performed on par behaviourally.

Thus it can be assumed that bilingual advantage on tasks assessing cognitive functions also persists in older adults.

The effect of bilingualism on the performance of cognitive tasks in Spanish/English old bilinguals was studied by Rosselli, Ardila, Araujo, Weekes, Caracciolo, Padilla, & Ostrosky-Solís (2000). A total of 82 participants were recruited for the study with a mean age of 61 years. They were divided into three subgroups with 45 English monolinguals, 18 Spanish monolinguals, and 19 Spanish – English bilinguals. Two tests were administered; one was a verbal fluency test and the other a repetition test. Verbal fluency, where participants had to generate as many words as possible for the target phoneme and semantic category. A sentence repetition test was used to test repetition. Results reveal that both bilinguals and monolinguals performed equally in all the tasks except for the semantic verbal fluency. Among the bilinguals, significantly better performance was seen for bilinguals whose acquisition of L2 was before the age of 12 than those after the age of 12 years. Thus, it suggests that early acquisition of L2 has a significant influence on the performance of cognitive tests.

The bilingual advantage in older adults was explored also the attenuation of the negative effects of aging on cognitive control in older adults was studied by Bialystok, Craik, Klein, Viswanathan in 2004. Younger adults in the age range of 30 to 54 years with a mean age of 43.0 years and older adults in the age range of 60 to 88 years with a mean age of 71.9 years were recruited. Each group consisted of 10 monolingual English speakers living in Canada, and 10 Tamil–English bilinguals living in India. Peabody Picture Vocabulary Test-Revised, Raven's Standard Progressive Matrices, and Simon task were administered. It was found that all the groups had longer RT for the incongruent item when compared to the congruent one. Smaller Simon's effect was seen for bilinguals in the incongruent item. This was significantly smaller for younger adults. Thus, older adults were able to attenuate the negative effect of aging on cognitive functions only to a lesser degree. However, Simon's effect increased with age significantly more for monolinguals (1,178ms) than for bilinguals (708ms).

Planning and task management in young and older monolingual and bilingual adults was investigated by Craik & Bialystok, 2006. Younger adults in the age range of 18 -30 years with a mean age of 20.2 years and older adults in the age range of 60 - 80 years with a mean age of 69.6 years were recruited. Simulated "cooking breakfast" task was carried out in which participants had to finish cooking five foods at the same time, also remembering to start and stop cooking them. Participants also had to carry out a filler activity of "table-setting" between the start and stop of cooking. Results reveal that in both younger and older adults, the performance of monolinguals and bilinguals were equal on the main breakfast task measures of prospective memory and working memory. However, bilinguals performed better on table-setting measures of

planning and execution where they effectively used their time in the tasks. In older participants, these effects were larger.

The performance of executive functions based on the factors of (1) language switching frequency in daily life (2) age of acquisition of L2 (3) self-rated extent of use of the two languages in daily life was investigated by Soveri, Rodriguez-Fornells, and Laine, 2011. Finnish–Swedish bilinguals in the age range of 30 to 75-year-old were recruited and tasks that measure the different EF (inhibition, updating, and set shifting) were administered. Results showed that in the set-shifting task, individuals with high language switching frequency in daily life had smaller mixing cost. Set shifting is very similar to the situation faced by a bilingual; decisions of the relevant language and irrelevant language should be made in a conversation. This is based on the notion that some of the executive functions in bilinguals are determined by lifelong language switching experience.

The advantages and disadvantages of executive control in young and old English monolingual, French monolingual, and French/English bilinguals were studied by Kousaie, Sheppard, Lemieux, Monetta, and Taler, 2014. Stroop task, a Simon task, Sustained Attention to Response Task (SART), the Wisconsin Card Sort Test (WCST), and the digit span subtest of the Wechsler Adult Intelligence Scale, and language tasks; the Boston Naming Test (BNT), and category and letter fluency were administered. No significant advantage was seen for bilinguals on executive function tasks. Also for the language tasks, a disadvantage for bilinguals was not seen. Therefore, it suggests that the language environment could influence these results.

A bilingual advantage in dual-tasking and it's persistence across time (10 years follow up) was investigated by Soerman, Josefsson, Marsh, Hansson, and Ljungberg

in 2017. Participants (40-65 years) performed dual- task of free recall for a 12-item list and card sorting in three settings (1) encoding (2) retrieval or (3) both encoding and retrieval of the word-list. Reference for the dual task was when only a free recall without card sorting was carried out. Results revealed that bilinguals performed significantly better than monolinguals for the setting that demanded most executive function; card sorting during both encoding and retrieval. For bilinguals, dual-task costs increased across time when compared to monolinguals. This can be attributed to a reduction in cognitive abilities due to the decreased use of L2 after retirement.

A study was carried out to see the performance of young and old monolingual and bilinguals on cognitive and executive functions task (Bialystok, Craik, and Luk, 2008). A total of 96 participants, young with a mean age 20 years and old adults with a mean age 68 years; monolingual and bilinguals were recruited for the study. Tasks measuring working memory, lexical retrieval, and executive control were administered. Results reveal that the performance of monolinguals and bilinguals was similar on working memory tasks, whereas for lexical retrieval task, monolinguals performed better and for executive control task, bilinguals performed better. These results were consistent in the younger age group, but not for the older group on the executive task, suggesting an increased heterogeneity in older participants.

The influence of bilingualism on a dual-task was examined by Hsieh in 2015. In this, monolingual and bilinguals were subjected to dual - task of talking over the phone and attending simulated driving events. 20 monolingual and 13 bilingual adults were recruited. Reaction times for 2 conditions; i.e. only driving and driving and attending

phone conversation were calculated. Results revealed that bilingual advantage was significant for the multitasking condition and not when only driving.

Persistence of a lifelong advantage of cognitive control abilities in bilinguals was investigated by Gold, Kim, Johnson, Kryscio & Smith, 2013. In this, 80 right-handed participants were recruited. They were further sub-grouped into young monolingual and bilingual adults (20 each), and older monolingual and bilingual adults (20 each). Two experiments conducted were, 1st was using a perceptual task switching paradigm only and the 2nd same perceptual task-switching experiment while fMRI was performed. Results showed that, in experiment 1, perceptual switching performance was better in older bilingual adults. In Experiment 2, a decline in the performance that can be attributed to aging and increased activation of fMRI was observed. Younger adults performed better than their monolingual counterparts. This was also the case in older bilingual adults yet they displayed reduced activation in the left lateral frontal cortex and cingulate cortex. Therefore, it implies that a long term experience of being a bilingual counteracts the changes that are related to aging for cognitive control processes at the level of neural efficiency.

The effect of executive control in the development of lexical retrieval and the influence of bilingualism on the same was investigated by Friesen, Luo, Luk & Bialystok, 2015. For this bilinguals and monolinguals in four age groups were recruited; 7 years, 10 years, young and old adults with mean ages 20 and 70 respectively. Verbal fluency tasks i.e. a category fluency and letter fluency task was administered on all the participants. Results revealed that the performance in verbal fluency showed improvement from early childhood to younger adults and remained relatively unchanged in older adults. The efforts for letter fluency was less for bilinguals than for monolinguals right at the beginning of 10 years and an evident

bilingual advantage started off in adulthood. Therefore it can be concluded that both age and vocabulary knowledge influenced category fluency, on the other hand, bilingualism influenced the performance in letter fluency.

The extent of the bilingual advantage in EF was determined by Bialystok, Poarch, Luo, & Craik, 2014. Two experiments were carried out in monolingual and bilingual young adults with a mean age of 20 years and old adults with a mean age of 70 years. In experiment 1, the Stroop task was administered on 130 participants and in experiment 2, complex working memory task was administered on 108 participants. In experiment 1, less interference was exhibited by young and old bilinguals, with greater advantage for older adults. In experiment 2, less interference was exhibited by bilinguals than monolinguals, with a greater bilingual advantage in the older adults and in the nonverbal task. Hence, these suggest that the advantage seen in bilinguals on executive function is influenced by the participants and the tasks involved. These results were evident for older adults than compared to younger adults and for tasks that are complex involving nonverbal stimuli.

The effect of inhibitory control on executive functioning in French – English bilinguals was investigated by Bialystok and colleagues (2008). A total of ninety-six monolingual and bilinguals, where the mean age of younger adults was 20 years and older adults 68 years. Tasks that assessed the participant's working memory, lexical retrieval, and executive control were administered. They reported that reaction time was faster for both younger and older bilinguals on the conflict condition compared to their monolingual peers on the Stroop test. Also, younger adults were significantly faster compared to older adults indicating that older and monolingual participants had larger Stroop effect. This finding, in addition, suggests that bilinguals did better on tasks measuring interference suppression.

The existence of advantage in bilingual older adults and to determine whether language use and bilingual type (dominant vs. balanced) are predictors of the same was studied by Goral, Campanelli & Spiro, 2015. Total of 106 bilinguals who spoke Spanish–English in the age range of 50 - 84 years participated in the study. Three tasks, targeting different cognitive domains were administered; Simon task (inhibition), Trail Making test (alternating attention), and Month Ordering (working memory). A negative correlation was seen for age and performance on the 3 domains. Bilingual type is a predictor of the performance and varied with age on Simon's task that measures inhibition. Age-related decline in inhibition was seen in balanced bilinguals. However, the dominant bilinguals did not show any age-related changes. Therefore, it suggests that cognitive advantages seen in older adults are significant only for a subset of bilinguals.

The effect of Simon's task on younger and older monolinguals and bilinguals (Tamil- English) was investigated by Bialystok and Viswanathan (2004). Individuals in the age range of 30 to 54 and 60 to 88 were recruited for the study. They reported less Simon effect for bilinguals when compared to monolinguals. Also, larger response time for incongruent trials for both age and language groups. However, this difference was smaller for young adults and bilinguals.

Most of the studies carried out earlier uses only verbal task or a non-verbal task to tap cognitive control. The present study aims to study cognitive control, not a much-explored domain in high and low proficient bilinguals. The study also aims to compare cognitive control in younger and older individuals by employing a variety of verbal and non-verbal tasks.

*Chapter III*

# Method

## 3.1. Participants

The study involved a total of 40 participants. The participants were divided into two groups. Each group was further divided equally into two subgroups (10 males and 10 females) based on proficiency. The first group comprised of 20 individuals in the age range of 18 to 30 years while the second group comprised of 20 individuals in the age range of 55 to 70 years. Further, the subgrouping of participants was done. Young bilinguals were divided into subgroups i.e. high and low proficient same as the older group.

Participants who are successive bilinguals having Kannada as L1 and English as L2were recruited for the study. Participants exposed to L2 (English) right from their childhood with a minimum of 10 years were included. Individuals with normal/corrected vision were included in the study. Participants with a history of any communication, psychological and other sensory impairments were excluded from the study. Informed consent was taken before enrolment.

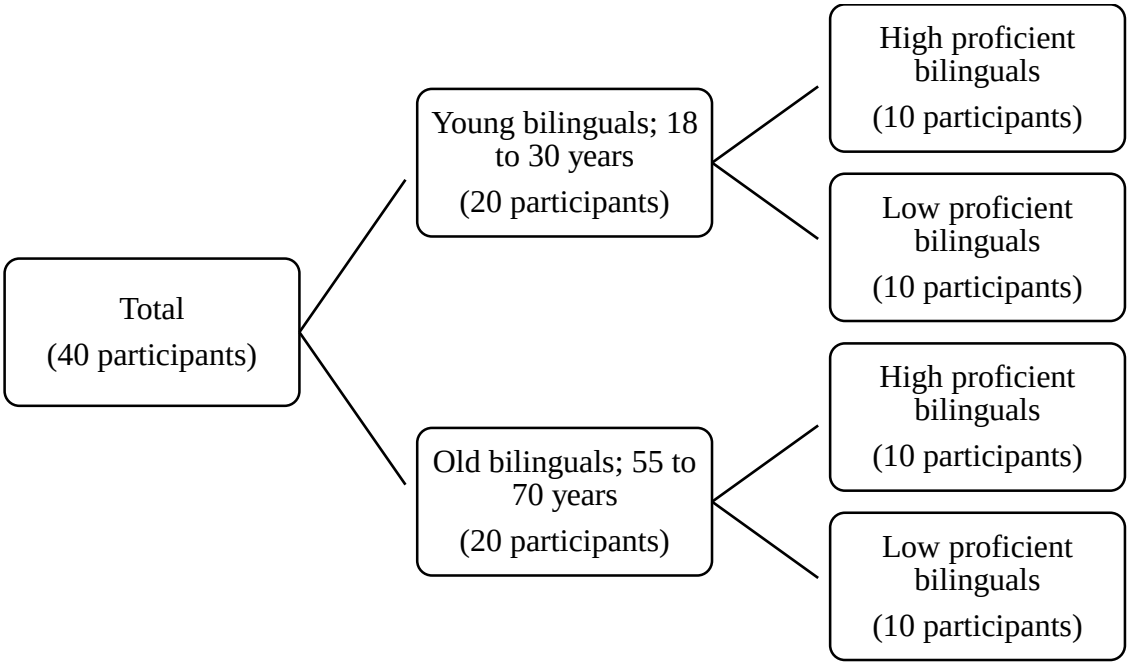



*Figure 3.1: Depiction of the grouping of participants*

### 3.2. Administration of LEAP-Q

Based on the LEAP- Q findings, participants were divided into high proficient and low proficient bilinguals. The questionnaire contains 18 questions pertaining to language acquisition and usage which was used to determine bilingual proficiency. Question 10 of the questionnaire, participants had to rate their proficiency on four domains: understanding, speaking, reading and writing using a four-point rating scale (where, 1-Zero Proficiency, 2-Low, 3-Good, and 4-Perfect Proficiency).

Based on LEAP-Q:

- Hayward (2013) claimed that if a bilingual has a score of 3 or 4 on the speaking domain of L1 they can be classified as high proficient bilinguals
- Whereas Hickey (2010) claimed that a bilingual should receive a score of 4 in the understanding domain and a minimum score of 3 on all the other domains (speaking, reading and writing) in order to be classified as a high proficient bilingual.

Based on the ratings by the participants they were classified as high proficient or low proficient bilinguals and were assigned into group 1 and group 2 respectively. In the present study, Hickey's criteria were used.

*Table 3.1: Participants included in the study- young bilinguals*

| Group | Sl. No. | Age/Gender | Qualification |
|---|---|---|---|
| Group 1 | 1. | 30/F | Homemaker |
| | 2. | 24/F | Student |
| | 3. | 27/M | IT employee |
| | 4. | 22/F | Student |
| | 5. | 20/M | Student |
| | 6. | 18/F | Student |
| | 7. | 23/M | Student |
| | 8. | 24/F | Homemaker |
| | 9. | 19/M | Student |
| | 10. | 28/M | IT employee |
| Group 2 | 11. | 27/F | Tuition teacher |
| | 12. | 20/M | Student |
| | 13. | 19/F | Student |
| | 14. | 22/M | Student |
| | 15. | 30/F | Singer |
| | 16. | 18/M | Student |
| | 17. | 25/M | Student |
| | 18. | 28/F | Homemaker |
| | 19. | 23/F | Homemaker |
| | 20. | 26/M | Call center employee |

*Table 3.2: Participants included in the study-old bilinguals*

| Group | Sl. No. | Age/Gender | Qualification |
|---|---|---|---|
| Group 3 | 1. | 62/F | Retired lecturer |
| | 2. | 56/M | Engineer |
| | 3. | 70/M | Retired bank employee |
| | 4. | 66/F | Homemaker |
| | 5. | 59/M | Doctor |
| | 6. | 62/F | Homemaker |
| | 7. | 68/M | Retired headmaster |
| | 8. | 55/M | Engineer |
| | 9. | 65/F | Rtd postal assistant |
| | 10. | 57/F | Homemaker |
| Group 4 | 11. | 60/F | Homemaker |
| | 12. | 64/F | Homemaker |
| | 13. | 70/M | Private shop owner |
| | 14. | 68/M | Retired PT teacher |
| | 15. | 56/F | Homemaker |
| | 16. | 57/F | Homemaker |
| | 17. | 59/M | Kannada teacher |
| | 18. | 69/F | Homemaker |
| | 19. | 70/M | Retired postman |
| | 20. | 63/M | Shop owner |

### 3.3. Tasks

Three tasks i.e. Simon's task, Stroop task, and a Conditioned naming task were administered on all the participants. The stimuli for all the tasks were presented in visual mode on a 15.6-inch laptop through the DMDX software. The participants were seated at a distance of 50cm from the laptop screen and the testing was carried out in a silent room. Instructions varied with respect to each task. Practice trials were presented for all the tasks before the presentation of the actual stimuli.

**Task 1: Simon's task.**

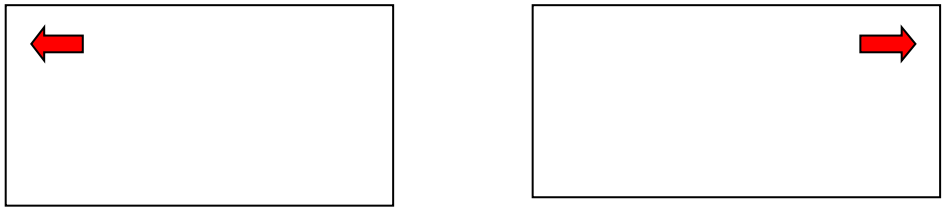
***Stimulus****:* The stimulus here is arrow marks.

***Task description****:* An arrow appeared on the top corners of the screen facing either to the right or left direction. The participant was required to look for the direction of the arrow and press keys based on the alignment of the arrow, irrespective of the location of the stimulus. Neutral stimulus, i.e. the arrow appearing in the middle of the screen was also displayed.

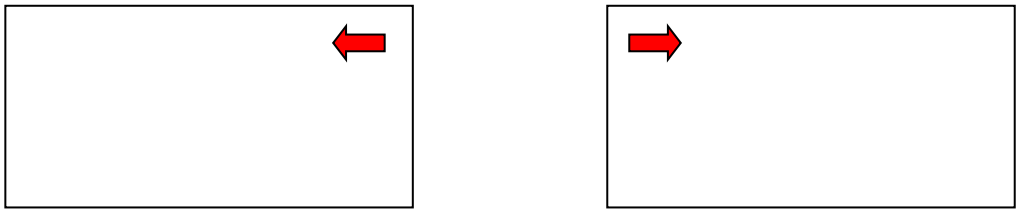
***Instruction & Procedure****:* The participant was required to press the right key when the arrow was in the right direction and left key when the arrow was in the left direction, ignoring the location of the arrow. For the neutral stimulus, the participant was asked to press up key.

***Analysis****:* The reaction time and accuracy for congruent and incongruent trials were considered.

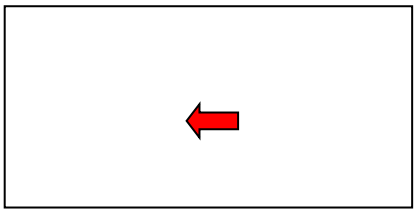
***Example**:*



*(i) Examples of congruent stimulus*



*(ii) Examples of incongruent stimulus*



*(iii) Example of the neutral stimulus*

*Figure 3.2: Depiction of stimulus used in Simon's task*

**Task 2: Stroop task.**

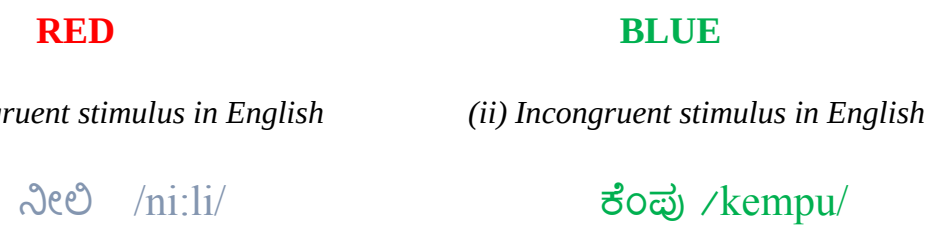
***Stimulus**:* The stimuli were in L1: Kannada and L2: English with congruent or incongruent color ink.

***Task description***: Randomized presentation of the pictures were carried out, with a few items shown in different color ink and few in congruent ink. This was carried out in both L1 Kannada and L2 English.

***Instruction & Procedure**:* The participants were instructed to press the right key for a congruent condition and the left key for the incongruent condition.

***Analysis**:* Reaction time and accuracy for congruent and incongruent trials in L1 and L2 were considered.

***Example**:*




*(i)Congruent stimulus in English* *(ii) Incongruent stimulus in English*

*(iii) Congruent stimulus in Kannada* *(iv) Incongruent stimulus in Kannada*

Figure 3.3: Depiction of the stimulus used in the Stroop task

**Task 3: Conditioned naming task.**

***Stimulus**:* Pictures of commonly occurring objects were chosen accompanied by a blue or red dot.

***Task description**:* A picture appeared on the computer screen with the presence of a red or a blue dot. Depending on the color of the dot the participant had to name the picture. The stimulus was presented randomly and reaction time and accuracy were calculated.

***Instruction & Procedure**:* The participant had to name the item in Kannada if the picture was accompanied by a blue dot and in English if the picture was accompanied by a red dot.

***Analysis**:* 1. The number of correct responses named in Kannada (L1)

2. The number of correct responses named in English (L2)

***Example:***

ಮನೆ /mane/

House

*Figure 3.4: Depiction of the stimulus used in Conditioned naming task*

### 3.4. Test-Retest Reliability

To check for the reliability of the data, 10% of the samples from the two groups i.e. young and older bilinguals was carried out.

### 3.5. Overall Analysis

**Task 1.**

(i) Reaction time and accuracy for congruent trials and incongruent trials for low proficient and high proficient young bilinguals were considered.

(ii) Reaction time and accuracy for congruent trials and incongruent trials for low proficient and high proficient old bilinguals were considered.

**Task 2.**

(i) Reaction time and accuracy for congruent and incongruent trails in L1for low and high proficient, young bilinguals were considered.

(ii)Reaction time and accuracy for congruent and incongruent trails in L1for low and high proficient, old bilinguals were considered.

(iii) Reaction time and accuracy for congruent and incongruent trails in L2 for low and high proficient, young bilinguals were considered.

(iv) Reaction time and accuracy for congruent and incongruent trails in L2 for low and high proficient, old bilinguals were considered.

**Task 3.**

(i) Reaction time and accuracy of correct responses named in Kannada for low and high proficient young bilinguals were considered.

(ii) Reaction time and accuracy of correct responses named in English for low and high proficient old bilinguals were considered.

*Chapter IV*

# Results

The primary aim of the study was to measure the effects of bilingualism on cognitive control in young and old, low proficient and high proficient bilinguals. 40 Participants in the age range of 18-30 and 55-70 years were considered for the study. They were divided into two groups based on their age as young bilinguals and old bilinguals, comprising of 20 participants each. Each group was further divided into two subgroups based on proficiency as high proficient and low proficient bilinguals, comprising of 10 participants each. Each of the group included an equal number of both males and females.

Three tasks i.e. Simon's task, Stroop task, and a Conditioned naming task were administered on all the participants. The stimulus for all the tasks was presented in visual mode through the DMDX software.

## 4.1 Simon's Task

In Simon's task, an arrow appeared on the top corners of the screen facing either to the right or left direction. The participant was asked to look for the direction of the arrow and press keys (right/left) based on the alignment of the arrow, irrespective of the location of the stimulus. For neutral stimulus, the arrow appeared in the middle of the screen and the participant was asked to press up key.

## 4.2 Stroop Task

For the Stroop task, the stimuli were in L1: Kannada and L2: English with congruent or incongruent color ink. The participants were instructed to press the right key for a congruent condition and the left key for the incongruent condition.

### 4.3 Conditioned Naming Task

In the Conditioned naming task, pictures appeared on the computer screen with either a red or a blue dot. The participant was asked to name the picture in Kannada if the picture was accompanied by a blue dot and in English if the picture was accompanied by a red dot.

### 4.4 Objectives of the study

1. To compare the reaction time and accuracy scores for high proficient young bilinguals and high proficient old bilinguals on the three tasks.
2. To compare the reaction time and accuracy scores for low proficient young bilinguals and low proficient old bilinguals on the three tasks.
3. To compare the reaction time and accuracy scores for low proficient and high proficient young bilinguals (in the age range of 18 to 30 years) on the three tasks.
4. To compare the reaction time and accuracy scores for low proficient and high proficient old bilinguals (in the age range of 55 to 70 years) on the three tasks.

#### 4.4.1 Objective 1

**To compare the reaction time and accuracy scores for high proficient young and old bilinguals on the three tasks.**

The aim was to compare and look for any significant difference in reaction time and accuracy measures in high proficient bilinguals as an effect of aging on the three tasks.

**Table 4.1**

*Descriptive values for reaction time and accuracy scores of high proficient young and old bilinguals on the three tasks*

| Reaction time (ms) | Young bilinguals | | | Old bilinguals | | |
|---|---|---|---|---|---|---|
| | Task 1 | Task 2 | Task 3 | Task 1 | Task 2 | Task 3 |
| Mean | 1121.94 | 1165.44 | 1211.85 | 1338.58 | 1498.07 | 1410.01 |
| Median | 957.64 | 1107.90 | 1236.38 | 1293.95 | 1452.75 | 1386.53 |
| SD | 397.48 | 210.14 | 202.31 | 542.10 | 311.58 | 213.94 |
| Accuracy Scores (%) | | | | | | |
| Mean | 94.99 | 96.83 | 95.31 | 86.65 | 94.34 | 87.64 |
| Median | 100.00 | 96.80 | 96.60 | 91.65 | 96.80 | 90.00 |
| SD | 8.06 | 2.95 | 4.21 | 17.22 | 6.89 | 11.78 |

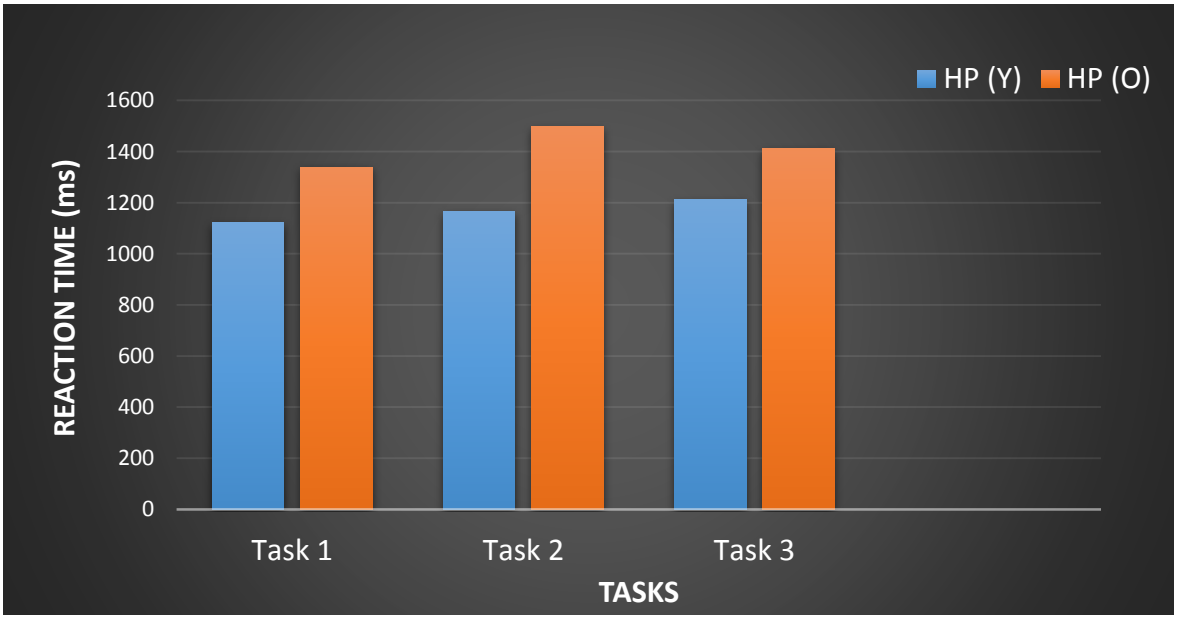



*Figure 4.1.1: Mean of the reaction time for tasks 1, 2 and 3 in high proficient young and old bilingual adults.*

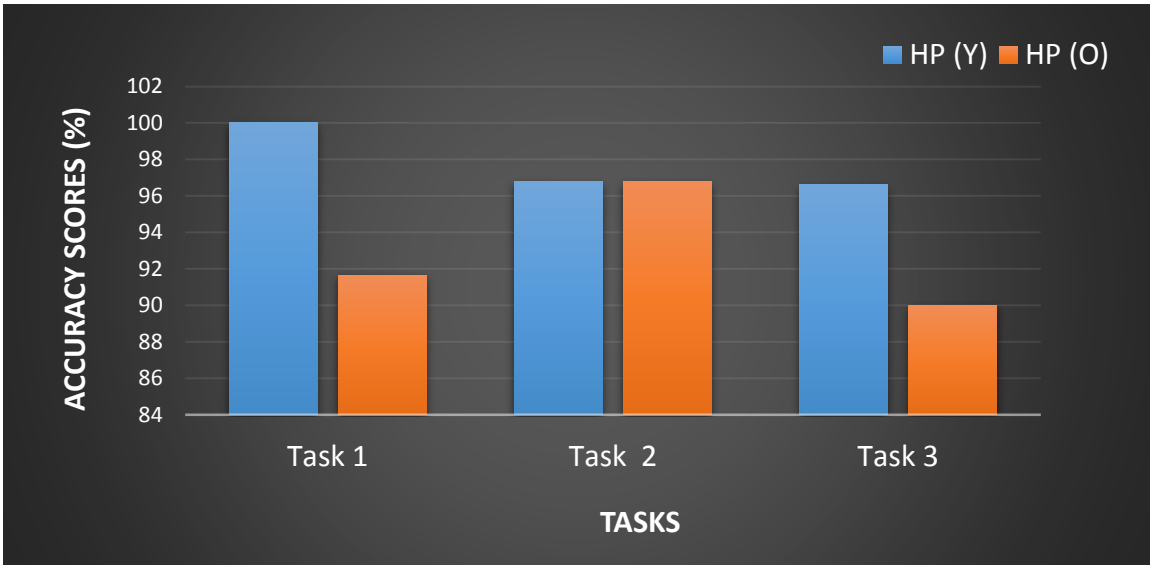



*Figure 4.1.2: Median of the accuracy for tasks 1, 2 and 3 in high proficient young and old bilingual adults.*

As shown in table 4.1, the mean reaction time for high proficient young bilinguals on task 1, 2 and 3 are 1121.94 ms, 1165.44 ms, and 1211.85 ms respectively whereas, for high proficient old bilinguals on task 1, 2 and 3 are 1338.58 ms, 1498.07 ms, and 1410.01ms respectively. The mean reaction time was better for task 1 (Simon's task), followed by task 2 (Stroop task) and then task 3 (Conditioned naming task) for high proficient young bilinguals. Whereas, for high proficient old bilinguals, the mean reaction time was better for task 1 (Simon's task), followed by task 3 (Conditioned naming task) and then task 2 (Stroop task). The median for the reaction time of high proficient young bilinguals was the least for task 3 (Conditioned naming task), followed by task 2 (Stroop task) and highest for task 1(Simon's task). In the case of old bilinguals, the median was least for task 1 (Simon's task), followed by task 3 (Conditioned naming task) and highest for task 2 (Stroop task). The SD for the reaction time was the least for task 3 (Conditioned naming task), followed by task 2 (Stroop task) and highest for task 1 (Simon's task), for both young and old bilinguals.

However, the SD was slightly higher for old bilinguals when compared to young bilinguals.

The mean accuracy scores of high proficient young bilinguals for T1, T2, and T3 are 94.99%, 96.83%, and 95.31% respectively whereas, for high proficient old bilinguals for T1, T2 and T3 are86.65%, 94.34%, and 87.64% respectively. The mean accuracy scores for high proficient young bilinguals were the least for task 1 (Simon's task), followed by task 3 (Conditioned naming task) and highest for task 2 (Stroop task). The same trend was followed by old bilinguals. The median for the accuracy scores of high proficient young bilinguals was the least for task 3 (Conditioned naming task), followed by task 2 (Stroop task) and highest for task 1 (Simon's task). In the case of old bilinguals, the median was least for task 3 (Conditioned naming task), followed by task 1 (Simon's task), and highest for task 2 (Stroop task). The SD for the accuracy scores was the least for task 2 (Stroop task), followed by task 3 (Conditioned naming task) and highest for task 1 (Simon's task), for both young and old bilinguals. However, the SD was slightly higher for old bilinguals when compared to young bilinguals.

In summary, high proficient young bilinguals took the least time to respond for the T1 (Simon's task) and then for T2 (Stroop task) and most time for T3 (Conditioned naming task). However, their accuracy was the least for T1 (Simon's task), better for T3 (Conditioned naming task) and highest for T2 (Stroop task). In the case of high proficient old bilinguals, they responded the fastest for T1 (Simon's task), slower for T3 (Conditioned naming task) and took the most time for T2 (Stroop task). Their accuracy scores also followed the same trend.

### 4.4.2 Objective 2:

**To compare the reaction time and accuracy scores for low proficient young and old bilinguals on the three tasks.**

The aim was to compare and look for any significant difference in reaction time and accuracy measures in low proficient bilinguals as an effect of aging on the three tasks.

**Table 4.2**

*Descriptive values for reaction time and accuracy scores of low proficient young and old bilinguals on the three tasks*

| **Reaction time (ms)** | Young bilinguals | | | Old bilinguals | | |
|---|---|---|---|---|---|---|
| | Task 1 | Task 2 | Task 3 | Task 1 | Task 2 | Task 3 |
| Mean | 1327.25 | 1525.72 | 1206.64 | 1229.62 | 1817.46 | 1386.31 |
| Median | 1209.43 | 1493.31 | 1137.84 | 1131.84 | 1846.20 | 1362.99 |
| SD | 484.29 | 417.21 | 199.92 | 409.88 | 290.56 | 186.48 |
| **Accuracy Scores (%)** | | | | | | |
| Mean | 91.65 | 94.35 | 86.63 | 74.98 | 90.58 | 78.30 |
| Median | 100.00 | 95.25 | 83.30 | 74.95 | 93.70 | 78.30 |
| SD | 11.8 | 6.3 | 7.8 | 25.16 | 9.78 | 12.20 |

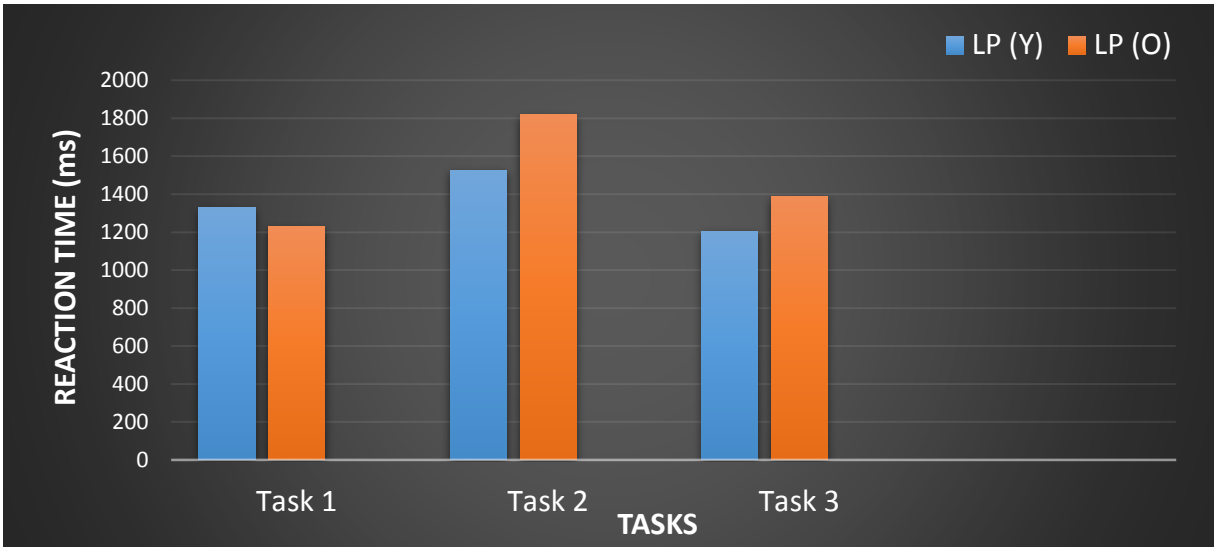



*Figure 4.2.1: Mean of the reaction time for tasks 1, 2 and 3 in low proficient young and old bilingual adults.*

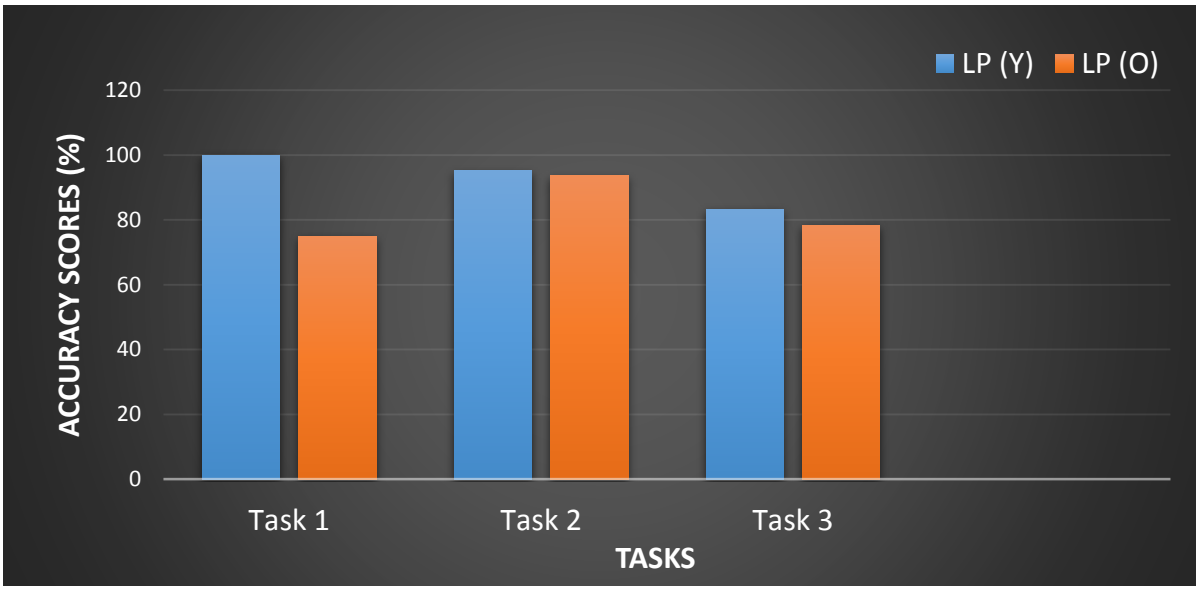



*Figure 4.2.2: Median of the accuracy for tasks 1, 2 and 3 in low proficient young and old bilingual adults*

As shown in table 4.2, the mean reaction time for low proficient young bilinguals on task 1, 2 and 3 are1327.25 ms, 1525.72 ms and 1206.64 ms respectively whereas, for low proficient old bilinguals on task 1, 2 and 3 are1229.62 ms, 1817.46 ms and 1386.31 ms respectively. The mean reaction time was better for task 1 (Simon's task),

followed by task 2 (Stroop task) and then task 3 (Conditioned naming task) for low proficient young bilinguals. Whereas, for low proficient old bilinguals, the mean reaction time was better for task 1 (Simon's task), followed by task 3 (Conditioned naming task) and then task 2 (Stroop task). The median for the reaction time of low proficient young bilinguals was the least for task 3 (Conditioned naming task), followed by task 1 (Simon's task), and highest for task 2 (Stroop task). In the case of old bilinguals, the median was least for task 1 (Simon's task), followed by task 3 (Conditioned naming task) and highest for task 2 (Stroop task). The SD for the reaction time was the least for task 3 (Conditioned naming task), followed by task 2 (Stroop task) and highest for task 1 (Simon's task), for both young and old bilinguals.

The mean accuracy scores of low proficient young bilinguals for T1, T2, and T3 are 91.65%, 94.35%, and 86.63% respectively whereas, for low proficient old bilinguals for T1, T2 and T3 are74.98%, 90.58%, and 78.30% respectively. The mean accuracy scores for low proficient young bilinguals were the least for task 3 (Conditioned naming task), followed by 1(Simon's task) and highest for task 2 (Stroop task). In the case of old bilinguals, it was least for task 1 (Simon's task), followed by task 3 (Conditioned naming task) and task 2 (Stroop task). The same trend was seen for the median. The median for the accuracy scores of low proficient young bilinguals was the least for task 3 (Conditioned naming task), followed by task 2 (Stroop task) and highest for task 1 (Simon's task). The SD for the accuracy scores was the least for task 2 (Stroop task), followed by task 3 (Conditioned naming task) and highest for task 1 (Simon's task), for both young and old bilinguals. However, the SD was slightly higher for old bilinguals when compared to young bilinguals.

In summary, low proficient young bilinguals took the least time to respond for the T1 (Simon's task) and then for T2 (Stroop task) and most time for T3

(Conditioned naming tsk). However, their accuracy was the least for T3 (Conditioned naming task), better for T1 (Simon's task) and highest for T2(Stroop task). In the case of low proficient old bilinguals, they responded the fastest for T1 (Simon's task), slower for T3 (Conditioned naming task) and took the most time for T2 (Stroop task). Their accuracy scores followed the same trend.

***Statistical Analysis***

*Objective 1 & 2:*

The objective was to compare the reaction time and accuracy measures of high proficient and low proficient bilinguals as an effect of age (young and old).

In order to verify any significant difference in the performance between the two groups - young and old bilinguals (between-group comparisons), statistical analysis was carried out. The data were subjected to test of normality using Shapiro Wilk test and it was observed that it follows a normal distribution ($p>0.05$) for reaction time for both young & old and high & low proficient bilinguals. Whereas for accuracy scores, it was found that the data was not normally distributed ($p<0.05$) for both young & old and high & low proficient bilinguals.

***Reaction time***

A parametric test, Mixed ANOVA was carried out for the reaction time measures to check for the main effect of groups (young or old), proficiency (high or low), and tasks (Simon's task or Stroop task or conditioned naming task). Also, the interaction effects between the following were checked for: group and task, group and proficiency, proficiency and task, group- proficiency and task. The results revealed a main effect for group, $F (1, 36) = 1104.206$, $p< 0.01$ and main effect for task, $F (2, 72)$

= 8.849, $p < 0.01$, but not for proficiency. An interaction effect was only seen for proficiency and task.

Since there was an effect of group, as the main effect further, independent 2 sample t-test was carried out to check for significant difference between the groups in each of the tasks. A significant difference was found for T2 – Stroop task ($t_{38} = 2.79$, $p < 0.01$), and T3- Conditioned naming task ($t_{38} = 3.052$, $p < 0.01$) but not for T1- Simon's Task ($p > 0.01$).

Since a main effect for the task was observed, further Bonferroni alpha correction was carried out, where reaction times of T1 (Simon's task), T2 (Stroop task) and T3 (Conditioned naming task) were subjected for pairwise comparison to check for a significant difference. It was found that there was a significant difference between T1- Simon's task & T2- Stroop task ($p < 0.05$) and T2- Stroop task & T3- Conditioned naming task ($p < 0.05$).

***Accuracy Scores***

Since accuracy was not normally distributed, a non-parametric Mann Whitney-U test was performed for the comparison of young and old adults:

(i) Irrespective of proficiency- it was found that T3- Conditioned naming task had significant difference ($z = 2.111$, $p < 0.05$) but not for T1- Simon's task and T2- Stroop task ($p > 0.05$).

(ii) With respect to proficiency- similar result was found for high proficient i.e. significant difference for T3- Conditioned naming task ($z = 2.049$, $p < 0.05$) but not for T1- Simon's task and T2- Stroop task. For low proficient bilinguals, no significant difference was found for any of the tasks.

Comparison of T1, T2, and T3, Friedman's test was carried out to see the significant difference between the tasks and further, if present, Wilcoxon's signed rank test was carried out to see the pairwise significant difference.

(i) Irrespective of groups and proficiency- Friedman's test rendered a chi-square value of 9.00, $p<0.05$. Wilcoxon's signed rank test revealed significant difference for T1- Simon's task & T2- Stroop task ($z= 2.192$, $p< 0.05$) and for T2- Stroop task & T3- Conditioned naming task ($z= 4.037$, $p<0.05$).

(ii) With respect to group irrespective of proficiency- for young adults, Friedman's test rendered a chi-square value of 4.750, $p> 0.05$, hence further Wilcoxon's signed rank test was not carried out. For old adults, Friedman's test rendered a chi-square value of 6.811, $p< 0.05$ and Wilcoxon's signed rank test revealed significant difference for T2- Stroop task & T3- Conditioned naming task ($z= 3.180$, $p<0.05$).

(iii) With respect to groups and proficiency- for high and low proficient young bilinguals, Friedman's test rendered a chi-square value of 2.457, $p> 0.05$ and 2.649, $p> 0.05$. Also for high and low proficient old bilinguals, Friedman's test rendered a chi-square value of 3.059, $p> 0.05$ and 3.800, $p> 0.05$ respectively. Hence, further Wilcoxon's signed rank test was not carried out.

To summarize, Main effect was seen for group. The mean reaction time between younger and older adults was statistically significant for T2 (Stroop task) and T3 (Conditioned naming task), but not for T1 (Simon's task). This holds good for high

proficient (high proficient young v/s high proficient old) and low proficient bilinguals (low proficient young v/s low proficient old).

The accuracy scores between younger and older adults (irrespective of proficiency) were statistically significant for T3 (Conditioned naming task) but not for T1 (Simon's task) and T2 (Stroop task). Further, the performance of younger high proficient and older high proficient bilinguals was compared. Statistically, significant difference was seen for T3 (Conditioned naming task). For low proficient young v/s old, a statistically significant difference was not seen for any of the tasks.

In addition to the pre-set objectives, for each group, the performance across the three tasks was compared, using Wilcoxon's signed rank test and no significant difference was seen.

### 4.4.3 Objective 3

**To compare the reaction time and accuracy scores for high and low proficient young bilinguals (in the age range of 18 to 30 years) on the three tasks.**

The aim was to compare and look for any significant difference in reaction time and accuracy measures in young bilinguals as an effect of their proficiency in L2 on the three tasks. Based on the rating of participants for question 10 on LEAP- Q, they were divided into high proficient and low proficient bilinguals. The rating included their proficiency on four domains: understanding, speaking, reading and writing using a four-point rating scale (where, 1-Zero Proficiency, 2-Low, 3-Good, and 4-Perfect Proficiency). A participant was classified as a high proficient bilingual if they received a score of 4 in the understanding domain and a minimum score of 3 on all the other domains i.e. speaking, reading and writing (Hickey, 2010).

**Table 4.3**

*Descriptive values for reaction time and accuracy scores of high and low proficient young bilinguals on the three tasks*

| **Reaction time (ms)** | High proficient | | | Low proficient | | |
|---|---|---|---|---|---|---|
| | Task 1 | Task 2 | Task 3 | Task 1 | Task 2 | Task 3 |
| Mean | 1121.94 | 1165.44 | 1211.85 | 1327.25 | 1525.72 | 1206.64 |
| Median | 957.64 | 1107.90 | 1236.38 | 1209.43 | 1493.31 | 1137.84 |
| SD | 397.48 | 210.14 | 202.31 | 484.29 | 417.21 | 199.92 |
| **Accuracy Scores (%)** | | | | | | |
| Mean | 94.99 | 96.83 | 95.31 | 91.65 | 94.35 | 86.63 |
| Median | 100.00 | 96.80 | 96.60 | 100.00 | 95.25 | 88.30 |
| SD | 8.06 | 2.95 | 4.21 | 11.8 | 6.39 | 7.85 |

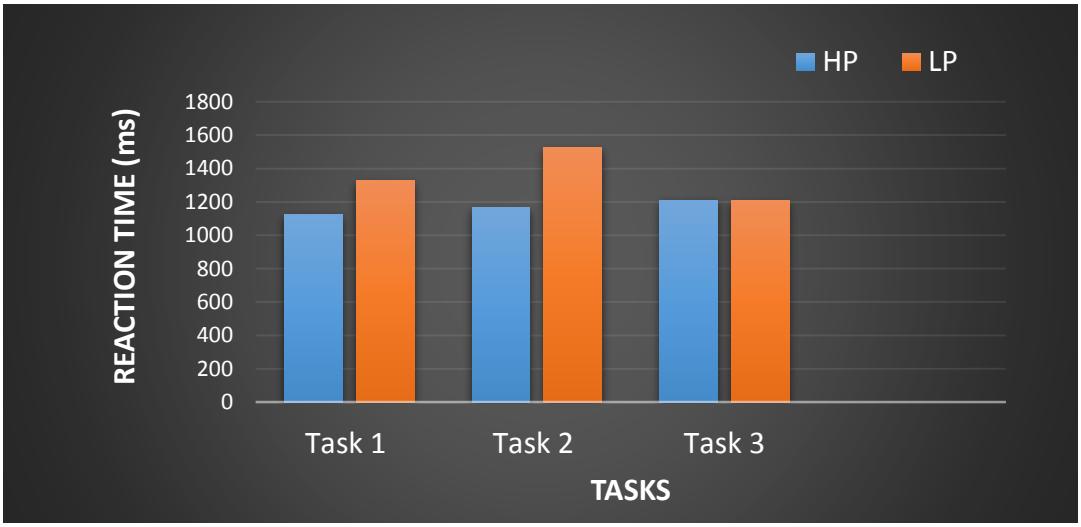



*Figure 4.3.1: Mean of the reaction time for tasks 1, 2 and 3 in young bilingual adults.*

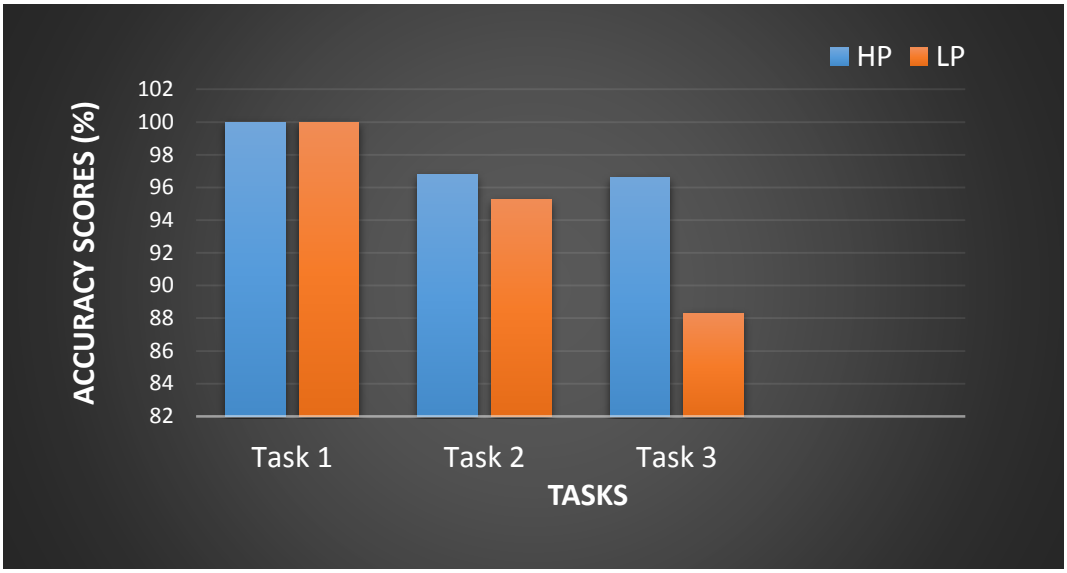



*Figure 4.3.2: Median of the accuracy scores for tasks 1, 2 and 3 in young bilinguals.*

As shown in table 4.3, the mean reaction time for high proficient young bilinguals on task 1, 2 and 3 are 1121.94 ms, 1165.44 ms, and 1211.85ms respectively. Whereas, the mean reaction time for low proficient young bilinguals on task 1, 2 and 3 are 1327.25 ms, 1525.72 ms, and 1206.64 ms respectively. The mean reaction time was better for task 1(Simon's task), followed by task 2 (Stroop task) and then task 3 (Conditioned naming task) for high proficient young bilinguals. For low proficient young bilinguals, reaction time was better for task 3 (Conditioned naming task), followed by task 1 (Simon's task) and then for task 2 (Stroop task). The same trend was seen for median scores for both high and low proficient bilinguals. The SD for the reaction time of high proficient young bilinguals was the least for task 3 (Conditioned naming task), followed by task 2 (Stroop task) and highest for task 1 (Simon's task). The same was followed for low proficient young bilinguals.

The mean accuracy scores of high proficient young bilinguals for T1, T2, and T3 are 94.99%, 96.83%, and 95.31% respectively whereas, for low proficient young bilinguals for T1, T2 and T3 are 91.65%, 94.35%, and 86.63% respectively. The mean

accuracy scores of high proficient young bilinguals were least for task 1 (Simon's task), followed by task3 (Conditioned naming task), and highest for task 2 (Stroop task). On the other hand, for low proficient young bilinguals, accuracy was lowest for task 3 (Conditioned naming task), followed by task 1 (Simon's task) and greatest for task 2 (Stroop task). The median for the accuracy scores was the least for task 3 (Conditioned naming task), followed by task 2 (Stroop task) and highest for task 1 (Simon's task) for both high and low proficient bilinguals. The SD for the accuracy scores for high and low proficient bilinguals was the least for task 2 (Stroop task), followed by task 3 (Conditioned naming task) and highest for task 1 (Simon's task).

In summary, high and low proficient young bilinguals took the least time to respond for the T1 (Simon's task) and then for T2 (Stroop task) and most time for T3 (Conditioned naming task). However, accuracy scores for high proficient bilinguals were the least for T1 (Simon's task), better for T3 (Conditioned naming task) and highest for T2 (Stroop task). Accuracy scores for low proficient bilinguals were the least for T3 (Conditioned naming task), better for T1 (Simon's task) and highest for T2 (Stroop task).

### 4.4.4 Objective 4

**To compare the reaction time and accuracy scores for high and low proficient old bilinguals (in the age range of 55 to 70 years) on the three tasks.**

The aim was to compare and look for any significant difference in reaction time and accuracy measures in old bilinguals as an effect of their proficiency in L2 on the three tasks.

Old bilinguals were also classified as high proficient based on the rating of participants for question 10 on LEAP- Q. Similar to that of young bilinguals, Hickey's, 2010 criteria were used.

**Table 4.4**

*Descriptive values for reaction time and accuracy of high and low proficient old bilinguals on the three tasks*

| **Reaction time (ms)** | High proficient | | | Low proficient | | |
|---|---|---|---|---|---|---|
| | Task 1 | Task 2 | Task 3 | Task 1 | Task 2 | Task 3 |
| Mean | 1338.58 | 1498.07 | 1410.01 | 1229.62 | 1817.46 | 1386.31 |
| Median | 1293.95 | 1452.75 | 1386.53 | 1131.84 | 1846.20 | 1362.99 |
| SD | 542.10 | 311.58 | 213.94 | 409.88 | 290.56 | 186.48 |
| **Accuracy Scores (%)** | | | | | | |
| Mean | 86.65 | 94.34 | 87.64 | 74.98 | 90.58 | 78.30 |
| Median | 91.65 | 96.80 | 90.00 | 74.95 | 93.70 | 78.30 |
| SD | 17.22 | 6.89 | 11.78 | 25.16 | 9.78 | 12.20 |

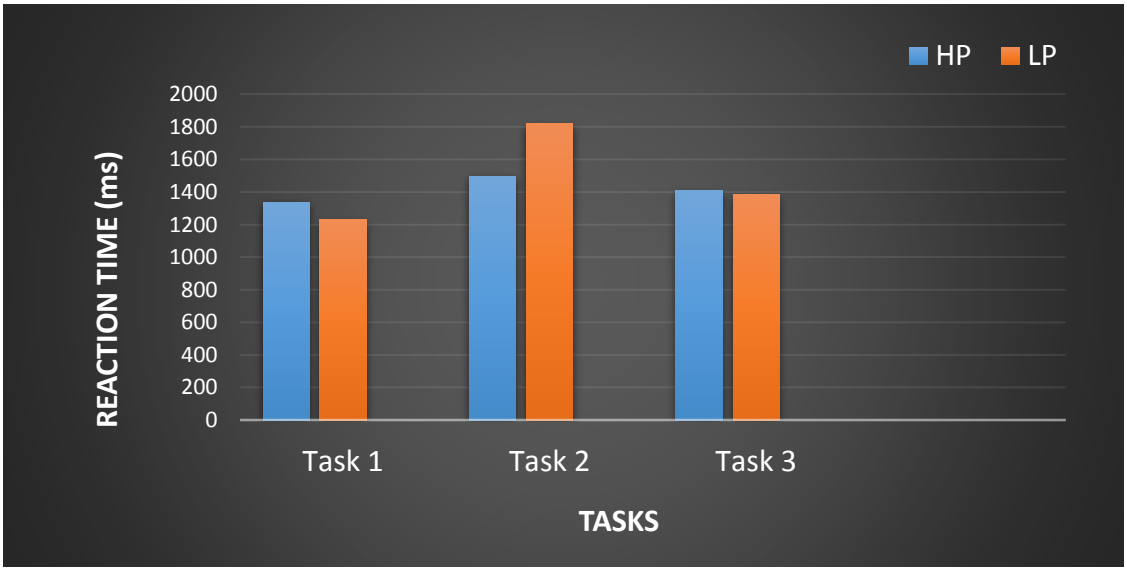



*Figure 4.4.1: Mean of the reaction time for tasks 1, 2, and 3 in old bilingual adults.*

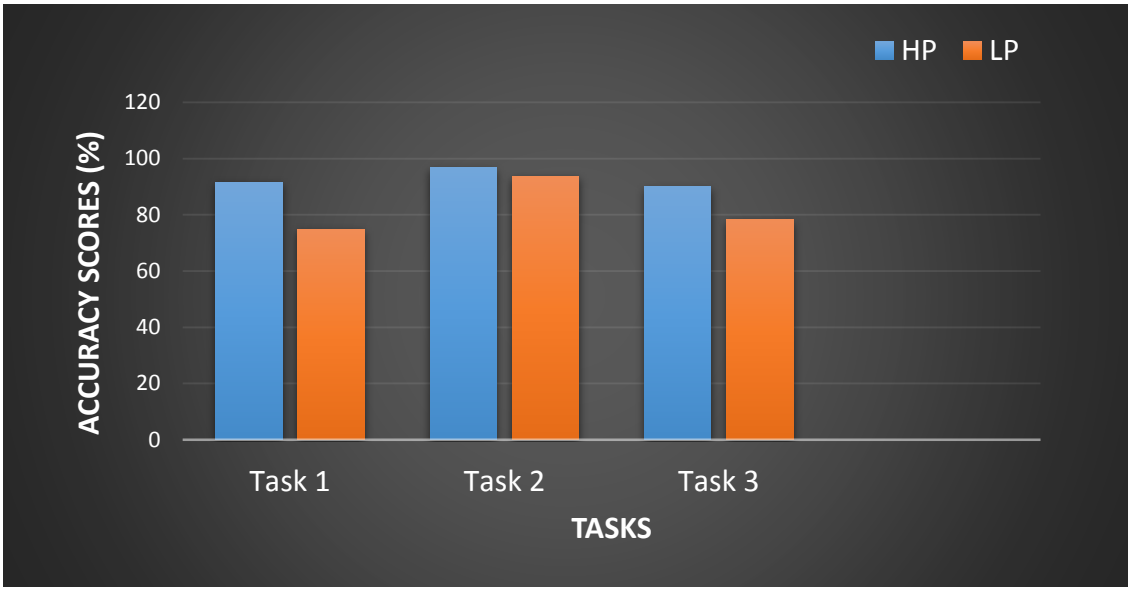



*Figure 4.4.2: Median of the accuracy for tasks 1, 2 and 3 in old bilingual adults.*

As shown in table 4.4, the mean reaction time for high proficient old bilinguals on task 1, 2 and 3 are 1338.58 ms, 1498.07 ms, and 1410.01 ms respectively. Whereas, the mean reaction time for low proficient old bilinguals on task 1, 2 and 3 are 1229.62 ms, 1817.46 ms, and 1386.31msrespectively. The mean reaction time was better for task 1 (Simon's task), followed by task 3 (Conditioned naming task) and then task 2 (Stroop task) for high proficient old bilinguals. Similar results were seen for low proficient old bilinguals. The median also followed the same trend. The SD for the reaction time of high proficient old bilinguals was the least for task 3 (Conditioned naming task), followed by task 2 (Stroop task) and highest for task 1 (Simon's task). Similar results were seen for low proficient old bilinguals.

The mean accuracy scores of high proficient old bilinguals for T1, T2, and T3 are 86.65%, 94.34%, and 87.64% respectively whereas, for low proficient old bilinguals for T1, T2 and T3 are 74.98%, 90.58%, and 78.30% respectively. The mean accuracy scores of high and low proficient old bilinguals were the least for task 1 (Simon's task), followed by 3(Conditioned naming task), and highest for task 2

(Stroop task). The median for the accuracy scores was the least for task 3 (Conditioned naming task), followed by task 1 (Simon's task) and highest for task 2 (Stroop task) for high proficient bilinguals. On the other hand, the median for the accuracy scores was the least for task 1 (Simon's task), followed by task 3 (Conditioned naming task), and highest for task 2 (Stroop task) for low proficient bilinguals. The SD for the accuracy scores for high and low proficient bilinguals were the least for task 2 (Stroop task), followed by task 3 (Conditioned naming task) and highest for task 1 (Simon's task).

In summary, high proficient old bilinguals responded the fastest for T1 (Simon's task), slower for T3 (Conditioned naming task) and took the most time for T2 (Stroop task). Their accuracy scores followed the same trend. In the case of low proficient old bilinguals, they responded the fastest for T1 (Simon's task), slower for T3 (Conditioned naming task) and took the most time for T2 (Stroop task). Their accuracy scores also followed the same trend.

***Statistical analysis***

*Objective 3 & 4:*

The objective was to compare the reaction time and accuracy measures of young and old bilinguals as an effect of proficiency (high and low).

In order to verify any significant difference in the performance between the high and low- proficient bilinguals (within-group comparisons), statistical analysis was carried out. As mentioned in the previous objectives, the data were subjected to test of normality using Shapiro Wilk test and it was observed that it follows a normal distribution ($p>0.05$) for reaction time for both young & old and high & low proficient bilinguals. Whereas for accuracy scores, it was found that the data was not

normally distributed ($p<0.05$) for both young & old and high & low proficient bilinguals.

***Reaction Time***

A parametric test, Mixed ANOVA was carried out to check for the main and interaction effects. The results revealed a main effect for the task, $F(2, 72) = 8.849$, $p< 0.01$ but not for proficiency. Also, a positive interaction effect between the proficiency and task was found to be present, not for the other interactions tested.

As mentioned in the previous objectives, since a main effect for task was observed, further Bonferroni alpha correction was carried out and it was found that there was a significant difference between T1- Simon's task & T2- Stroop task ($p< 0.05$) and T2- Stroop task & T3- Conditioned naming task ($p< 0.05$).

Since there was an interaction effect for proficiency and task, further tasks were compared with respect to proficiency. Results revealed that for high proficient bilinguals no significant ($p>0.05$) task effect was observed. For low proficient bilinguals, a significant task effect was seen, $F(2, 38) = 9.718$, $p< 0.05$. When data was subjected for pairwise comparison to check for the significant difference between the tasks, similar results i.e. a significant difference between T1- Simon's task & T2- Stroop task ($p< 0.05$) and T2- Stroop task & T3- Conditioned naming task ($p< 0.05$) were observed.

***Accuracy Scores***

Since accuracy was not normally distributed, a non-parametric Mann Whitney-U test was performed for the comparison of high and low proficient bilinguals:

(i) Irrespective of groups- T1- Simon's task and T2- Stroop task had no significant difference, T3- Conditioned naming task was significantly different with $z= 3.126$, $p< 0.05$

(ii) With respect to groups- it was found that for young adults, T3- Conditioned naming task had significant difference ($z= 2.817$, $p< 0.05$), however no significant difference for T1- Simon's task and T2- Stroop task. For old adults, none of the tasks were significantly different.

Comparison of T1, T2, and T3, Friedman's test was carried out to see the significant difference between the tasks and further, if present, Wilcoxon's signed rank test was carried out to see the pairwise significant difference.

(i) Irrespective of groups and proficiency- Friedman's test rendered a chi-square value of 9.00, $p< 0.05$. Wilcoxon's signed rank test revealed significant difference for T1- Simon's task& T2- Stroop task ($z= 2.192$, $p< 0.05$) and for T2- Stroop task& T3- Conditioned naming task ($z= 4.037$, $p<0.05$).

(ii) With respect to groups and proficiency- for high and low proficient young adults, Friedman's test rendered a chi-square value of 2.457, $p> 0.05$ and 2.649, $p> 0.05$. Also for high and low proficient old bilinguals, Friedman's test rendered a chi-square value of 3.059, $p> 0.05$ and 3.800, $p> 0.05$ respectively. Hence, further Wilcoxon's signed rank test was not carried out.

To summarize, an interaction effect was seen for proficiency and task. It was found that for high proficient bilinguals no significant task effect was seen. For low proficient bilinguals, a significant task effect was seen and pairwise comparison

between the tasks revealed a significant difference between T1- Simon's task & T2- Stroop task and T2- Stroop task & T3- Conditioned naming task.

The mean reaction time was statistically significant forT1 (Simon's task) & T2 (Stroop task) and for T2 (Stroop task) & T3 (Conditioned naming task) for young (high v/s low proficient) and old (high v/s low proficient) bilinguals.

The accuracy scores between high and low proficient bilinguals (irrespective of the group) were statistically significant for T3 (Conditioned naming task) but not for T1 (Simon's task) and T2 (Stroop task). Further, the performance of high proficient young & low proficient young bilinguals was compared and statistically significant difference was seen for T3 (Conditioned naming task). For high proficient old v/s low proficient old bilinguals, a statistically significant difference was not seen for any of the tasks.

Additionally, the performance across the three tasks was compared for high proficient young adults and it was found that they performed well on T1 and had difficulty on T3 in terms of reaction time. In terms of accuracy scores, they performed well on T2 and had difficulty on T1. For low proficient young bilinguals, they performed well on T3 and had difficulty on T2 in terms of reaction time while they performed well on T2 and had difficulty on T1 in terms of accuracy scores.

Similarly, the performance across the three tasks was compared for high proficient old bilinguals and it was found that they performed well on T1 and had difficulty on T2 in terms of reaction time. In terms of accuracy scores, they performed well on T2 and had difficulty on T1. For low proficient old bilinguals, they performed well on T1 and had difficulty on T2 in terms of reaction time while they performed well on T2 and

had difficulty on T1 in terms of accuracy scores. However, a statistically significant difference was not observed.

In addition to the pre-set objectives, within each group (high proficient and low proficient), the performance across the three tasks was compared, using Wilcoxon's signed rank test and no significant difference was seen.

In the present study, the output was in terms of reaction time and accuracy scores. The reaction time and accuracy were computed through the software used automatically.

In addition to the investigator, the reaction time and accuracy scores were verified by two other examiners. Since reaction time would not vary for each examiner, statistical analysis was not carried out for the same. Thus, in order to verify the reliability, a manual check of 10% of the data was carried out. It was observed that the other examiners opined that the reaction time and accuracy measures were appropriate.

## *Chapter V*

## Discussion

The aim of the present study was to compare the cognitive control in younger and older, high and low proficient bilinguals. Executive function was tested through Simon's task, Stroop task and Conditioned naming task. Two of the tasks i.e. Simon's task and Conditioned naming task measured response inhibition in non-verbal and verbal situations respectively. While the Stroop task measured cognitive flexibility. The output for all the tasks was measured in terms of reaction time and accuracy scores.

The 1st objective was to examine if there was any difference in high proficient young and old bilinguals on the three tasks. The 2nd objective was to investigate if there was any difference in low proficient young and old bilinguals on the three tasks. The results revealed that the mean reaction time for T2 (Stroop task) and T3 (Conditioned naming task) were greater and also showed a statistically significant difference for young v/s old high proficient bilinguals. This suggests that, as the complexity of the task increased, the participants took a long time to respond to the task. This result was evident in both high proficient young and high proficient old bilinguals. However, the reaction time was quicker in all the tasks for high proficient young bilinguals when compared to high proficient old bilinguals. Thus, high proficient young bilinguals outperformed high proficient old bilinguals on reaction time measures for tasks assessing cognitive flexibility and verbal response inhibition.

In the case of low proficient young bilinguals, greater reaction time was seen for the task assessing cognitive flexibility (T2), relatively faster reaction time for non-verbal response inhibition task (T3) and was the fastest for the verbal response

inhibition task (T1). For low proficient young bilinguals, reaction time was faster when compared to low proficient old bilinguals. Greater reaction time was seen for the task assessing cognitive flexibility (T2), relatively faster reaction time for verbal response inhibition task (T3) and was the fastest for the non-verbal response inhibition task (T1). Also, the mean reaction time was statistically significant for T2 (cognitive flexibility task) and T3 (verbal response inhibition task) for young adults v/s old adults low proficient bilinguals. Thus, low proficient young bilinguals outperform low proficient old bilinguals on reaction time measures for tasks assessing cognitive flexibility and verbal response inhibition.

In the case of accuracy scores, T3 (verbal response inhibition task) was statistically significant between younger and older adults (irrespective of proficiency). When younger and older adults were compared with respect to proficiency, T3 (verbal response inhibition task) was statistically significant for high proficient bilinguals while none of the tasks were statistically significant for low proficient bilinguals. Thus, younger adults outperformed older adults on accuracy measures; predominantly the high proficient bilinguals.

The above discussion is with respect to between-group comparisons (young and old bilinguals). Considering within-group comparisons (high and low proficient bilinguals), two objectives were considered in the study. The 3$^{rd}$ objective was to examine if there was any difference in high proficient and low proficient young bilinguals on the three tasks. The 4$^{th}$ objective was to investigate if there was any difference in high proficient and low proficient old bilinguals on the three tasks. In high proficient young bilinguals, the mean reaction time was the fastest for T1 (non-verbal response inhibition task), followed by T2 (cognitive flexibility task) and then for T3 (verbal response inhibition task). For low proficient young bilinguals, the mean

reaction time was fastest for T3 (verbal response inhibition task), followed by T1 (non-verbal response inhibition task) and then T2 (cognitive flexibility task). The mean reaction time in the case of high proficient old bilinguals was the fastest for T1 (non-verbal response inhibition task), followed by T3 (verbal response inhibition task), and then for T2 (cognitive flexibility task). Low proficient old bilinguals also followed the same trend, however, the values were higher for low proficient old bilinguals when compared to high proficient old bilinguals. Statistically, a significant difference was seen for T1 (non-verbal response inhibition task) & T2 (cognitive flexibility task) and for T2 (cognitive flexibility task) & T3 (verbal response inhibition task) for high proficient v/s low proficient, young and old adults. Thus, high proficient young bilinguals outperformed low proficient young bilinguals on reaction time measures for T1 (non-verbal response inhibition task) & T2 (cognitive flexibility task) and for T2 (cognitive flexibility task) & T3 (verbal response inhibition task). In older adults, high proficient bilinguals outperformed low proficient bilinguals on for reaction time measures for T1 (non-verbal response inhibition task) & T2 (cognitive flexibility task) and for T2 (cognitive flexibility task) & T3 (verbal response inhibition task).

In the case of accuracy scores, high proficient young bilinguals had better accuracy scores when compared to low proficient young bilinguals on all the tasks. A similar trend was seen in older bilinguals. A statistically significant difference was seen for T3 (irrespective of groups). When compared with respect to groups, T3 was statistically significant for high proficient v/s low proficient young bilinguals and none of the tasks were statistically significant for high proficient v/s low proficient old bilinguals. Thus, high proficient young bilinguals outperformed low proficient

young bilinguals, also a similar trend was seen in high proficient old and low proficient old bilinguals.

In a nutshell, young bilinguals outperform old bilinguals on both the reaction time and accuracy score measures. For the reaction time measures, high proficient young bilinguals outperform high proficient old bilinguals on T2 and T3 similarly, low proficient young bilinguals outperform low proficient old bilinguals on T2 and T3. In the case of accuracy scores, high proficient young bilinguals outperform high proficient old bilinguals only on T3, while, low proficient young bilinguals did not outperform low proficient old bilinguals on any of the tasks.

High proficient bilinguals outperform low proficient bilinguals on both reaction time and accuracy score measures. For reaction time measures, high proficient young bilinguals outperform low proficient young bilinguals on T1 &T2 and for T2 & T3. Similar findings were seen for older adults' i.e. high proficient old bilinguals outperform low proficient old bilinguals on T1 & T2 and for T2 & T3. In the case of accuracy scores, high proficient young bilinguals outperform low proficient young bilinguals only on T3 whereas, high proficient old did not outperform low proficient old bilinguals on any of the tasks.

This is in line with the findings from the past where researchers have found that young bilinguals outperformed old bilinguals on executive functions. Bialystok and colleagues (2008) reported that younger adults were significantly faster compared to older adults indicating that older adults had larger Stroop effect.

Another support for this fact comes from a study by Goral, Campanelli &Spiro, 2015, whereas a negative correlation was seen with an increase in age and performance on domains of executive functions. Also, the age-related decline in

inhibition was seen. Bialystok and Viswanathan (2004) in their study reported less Simon effect for bilinguals when compared to monolinguals. Also, larger response time for incongruent trials for both age and language groups. However, this difference was smaller for young adults and bilinguals.

Barbu, Orban, Gillet & Poncelet (2018) reported that faster reaction time was seen for high-frequency language switchers for cognitive flexibility. The high frequency and low-frequency switchers performed equally for alerting and response inhibition tasks. These results indicate that the frequency of switching is a predictor of increased cognitive flexibility in bilinguals.

Bialystok, Craik, Klein, and Viswanathan in 2004 also reported similar findings, longer RT was seen for the incongruent item when compared to the congruent one. Smaller Simon's effect was seen for bilinguals in the incongruent item. This was significantly smaller for younger adults. Thus, older adults were able to attenuate the negative effect of aging on cognitive functions only to a lesser degree.

The present study also matches with a dissertation carried out earlier by Margaret and Abhishek (2017). They included domains on response inhibition, cognitive flexibility, and attention. The results revealed that high proficient bilinguals performed better compared to low proficient bilinguals.

## *Chapter VI*

## Summary and Conclusion

Bilingualism is a widespread phenomenon and is seen in almost all countries in the world. Researchers in the past have reported of bilingual advantage on cognitive domain which is due to the facilitation of relevant information and active inhibition of irrelevant information. This is the exact situation confronted by bilinguals in their ongoing conversation when it is restricted to a particular language. This language selection tends to have generalized cognitive benefits. Since it's rare to get monolinguals in the current scenario as almost every individual would have some exposure to another language apart from their native language, the current study has considered high and low proficient bilinguals.

The aim of the present study was to measure the effects of bilingualism on cognitive control in young and old, low proficient and high proficient bilinguals. Young and old Kannada-English bilinguals were recruited, while young adults were in the age range of 18-30 years, the older adults in the age range of 55-70 years. Bilinguals were further divided into subgroups of high and low proficient bilinguals based on a self-rating proficiency questionnaire; LEAP-Q. Question 10 on LEAP-Q was considered for the same which included rating their proficiency on four domains: understanding, speaking, reading and writing on a four-point rating scale. A participant was classified as a high proficient bilingual if they received a score of 4 in the understanding domain and a minimum score of 3 on all the other domains i.e. speaking, reading and writing (Hickey, 2010).

Three tasks assessing different domains of cognitive control i.e. Simon's task, Stroop task, and Conditioned naming task were administered on all the subjects. The reaction time and accuracy scores were measured for each of the tasks. These scores were tabulated and analyzed statistically using SPSS version 20.0. Statistical analysis was carried out in terms of between-group (young and old adults) and within group (high and low proficient) comparisons.

The 1st objective was to examine if there was any difference in high proficient young and high proficient old bilinguals on the three tasks. The 2nd objective was to investigate if there was any difference in low proficient young and low proficient old bilinguals on the three tasks. As the reaction time measures followed a normal distribution, parametric Mixed ANOVA was carried out to check for main and interaction effects. The results revealed a main effect for group and task, but not for proficiency. An interaction effect was only seen for proficiency and task. Since there was a main effect of group, further, independent 2 sample t-test was carried out to verify any significant difference between the groups in each task. A significant difference was between younger and older adults was found for T2 – Stroop task, and T3- Conditioned naming task but not for T1- Simon's Task.

The same objective was studied accounting for accuracy scores. Since accuracy scores were not normally distributed, a non-parametric Mann Whitney-U test was performed between groups. The accuracy score was statistically significant for T3 (Conditioned naming task) but not for T1 (Simon's task) and T2 (Stroop task) between younger and older adults (irrespective of proficiency). Further, a statistically significant difference was seen for T3 (Conditioned naming task) in high proficient bilinguals between younger and older adults. However, a statistically significant

difference was not seen for any of the tasks in low proficient bilinguals between younger and older adults.

In addition to the pre-set objectives, for each group, the performance across the three tasks was compared within the low proficient and high proficient group, using Wilcoxon's signed rank test and no significant difference was seen for both the groups.

Similarly in the case of within-group comparisons, as reaction time followed a normal distribution, parametric Mixed ANOVA was carried out to check for the main and interaction effects. The results revealed a main effect for the task, but not for proficiency. Also, a positive interaction effect between the proficiency and task was found, but not for the other interactions tested. Since a main effect for the task was observed, further Bonferroni alpha correction was carried out and it was found that there was a significant difference for T1- Simon's task v/s T2-Stroop task and T2-Stroop task v/s T3-Conditioned naming task. As there was an interaction effect for proficiency and task, further tasks were compared with respect to proficiency. Results revealed that for high proficient bilinguals no significant task effect was observed. For low proficient bilinguals, a significant task effect was seen. Hence, the data was subjected for pairwise comparison to check for the significant difference between the tasks, similar results i.e. a significant difference for T1- Simon's task v/s T2- Stroop task and T2- Stroop task v/s T3- Conditioned naming task was observed.

As accuracy scores didn't follow a normal distribution, non- parametric Mann Whitney-U test was performed between high and low proficient bilinguals. It was found that T3- Conditioned naming task was statistically significant but not for T1-Simon's task and T2- Stroop task for high and low proficient bilinguals (irrespective

of groups). When high proficient and low proficient were compared with respect to proficiency, T3 was statistically significant for young adults and none of the tasks were significant for older adults.

In addition to the pre-set objectives, within each group (high proficient and low proficient), the performance across the three tasks was compared, using Wilcoxon's signed rank test and no significant difference was seen.

Hence the overall results show that young bilinguals outperform old bilinguals on both the reaction time and accuracy score measures. For the reaction time measures, high proficient young bilinguals outperform high proficient old bilinguals on T2 and T3 similarly, low proficient young bilinguals outperform low proficient old bilinguals on T2 and T3. In the case of accuracy scores, high proficient young bilinguals outperform high proficient old bilinguals only on T3, while, low proficient young bilinguals did not outperform low proficient old bilinguals on any of the tasks.

High proficient bilinguals outperform low proficient bilinguals on both reaction time and accuracy score measures. For reaction time measures, high proficient young bilinguals outperform low proficient young bilinguals on T1 & T2 and for T2 & T3. Similar findings were seen for older adults' i.e. high proficient old bilinguals outperform low proficient old bilinguals on T1 & T2 and for T2 & T3. In the case of accuracy scores, high proficient young bilinguals outperform low proficient young bilinguals only on T3 whereas, high proficient old did not outperform low proficient old bilinguals on any of the tasks.

Therefore it can be concluded that bilingual advantage on cognitive control was seen for both reaction time and accuracy scores in young and high proficient

bilinguals. However, high proficient bilinguals were able to persist this advantage with increasing age.

***Implications of the study***

1. The study will aid in understanding the cognitive control in neurotypical young and old, low proficient and high proficient bilinguals. It was found that young bilinguals outperformed old bilinguals on reaction time and accuracy measures. Also, high proficient bilinguals outperformed low proficient bilinguals on reaction time and accuracy measures, predominantly on the accuracy measures.
2. Task assessing verbal response inhibition or T3 (conditioned naming task) in the study is sensitive to demarcate younger and older adults on cognitive control advantage for accuracy measures.
3. Similarly, task assessing verbal response inhibition or T3 (conditioned naming task) in the study is also sensitive to demarcate high proficient and low proficient bilinguals on cognitive control advantage for accuracy measures.
4. For high proficient young adults, it was found that they performed well on T1 and had difficulty on T3 in terms of reaction time. In terms of accuracy scores, they performed well on T2 and had difficulty on T1. For low proficient young bilinguals, they performed well on T3 and had difficulty on T2 in terms of reaction time while they performed well on T2 and had difficulty on T1 in terms of accuracy scores. However, a statistically significant difference was not observed.
5. Similarly, high proficient old bilinguals performed well on T1 and had difficulty on T2 in terms of reaction time. In terms of accuracy scores, they performed well on T2 and had difficulty on T1. For low proficient old bilinguals, they performed well on T1 and had difficulty on T2 in terms of reaction time while they performed well on

T2 and had difficulty on T1 in terms of accuracy scores. However, a statistically significant difference was not observed.

6. Similar tasks can be further extended to study the extent of cognitive control in disordered individuals like MCI.
7. The results of the present study can be used to design an intervention procedure in language disordered individuals, where tasks assessing cognitive flexibility and response inhibition can be used to work on increasing executive functions.

***Limitations of the study***

1. The study was carried on a smaller group of bilinguals.
2. The tasks were behavioural, and thus may be prone to false positive responses.
3. The reaction time measures are subjected to variability as the participants were required to speculate the responses.

## References


Abutalebi, J., Della Rosa, P. A., Ding, G., Weekes, B., Costa, A., & Green, D. W. (2013). Language proficiency modulates the engagement of cognitive control areas in multilinguals. *Cortex*, *49*(3), 905-911.

Alladi, S., Bak, T. H., Duggirala, V., Surampudi, B., Shailaja, M., Shukla, A. K., & Kaul, S. (2013). Bilingualism delays age at onset of dementia, independent of education and immigration status. *Neurology*, 10-1212.

Alladi, S., Bak, T. H., Mekala, S., Rajan, A., Chaudhuri, J. R., Mioshi, E., & Kaul, S. (2016). Impact of bilingualism on cognitive outcome after stroke. *Stroke*, *47*(1), 258-261.

Antón, E., Carreiras, M., & Duñabeitia, J. A. (2019). The impact of bilingualism on executive functions and working memory in young adults. *PloS one*, *14*(2), e0206770.

Beardsmore, H. B. (1986). *Bilingualism: basic principles* (Vol. 1). Multilingual Matters.

Barbu, C., Orban, S., Gillet, S., & Poncelet, M. (2018). The Impact of Language Switching Frequency on Attentional and Executive Functioning in Proficient Bilingual Adults. *Psychologica Belgica*, *58*(1), 115.

Bialystok, E. (2001). *Bilingualism in development: Language, literacy, and cognition.* New York: Cambridge University Press.

Bialystok, E., Craik, F. I. M., Klein, R., & Viswanathan, M. (2004). Bilingualism, aging and cognitive control: Evidence from the Simon task. *Psychology and Aging*, *19*, 290-303.

Bialystok, E., Craik, F. I., Grady, C., Chau, W., Ishii, R., Gunji, A., & Pantev, C. (2005). Effect of bilingualism on cognitive control in the Simon task: Evidence from MEG. *NeuroImage*, *24*(1), 40-49.

Bialystok, E., Craik, F., & Luk, G. (2008). Cognitive control and lexical access in younger and older bilinguals. *Journal of Experimental Psychology: Learning, memory, and cognition*, *34*(4), 859.

Bialystok, E. (2009). Bilingualism: The good, the bad, and the indifferent. *Bilingualism: Language and cognition*, *12*(1), 3-11.

Bialystok, E., Craik, F. I., Binns, M. A., Ossher, L., & Freedman, M. (2014). Effects of bilingualism on the age of onset and progression of MCI and AD: Evidence from executive function tests. *Neuropsychology*, *28*(2), 290.

Bialystok, E., Poarch, G., Luo, L., & Craik, F. I. (2014). Effects of bilingualism and aging on executive function and working memory. *Psychology and aging*, *29*(3), 696.

Chan, R. C., Shum, D., Toulopoulou, T., & Chen, E. Y. (2008). Assessment of executive functions: Review of instruments and identification of critical issues. *Archives of clinical neuropsychology*, *23*(2), 201-216.

Costa, A., Hernández, M., Costa-Faidella, J., & Sebastián-Gallés, N. (2009). On the bilingual advantage in conflict processing: Now you see it, now you don't. *Cognition*, *113*(2), 135-149.

Craik, F. I., & Bialystok, E. (2006). Cognition through the lifespan: mechanisms of change. *Trends in cognitive sciences*, *10*(3), 131-138.

D'Souza, A. A., Moradzadeh, L., & Wiseheart, M. (2018). Musical training, bilingualism, and executive function: working memory and inhibitory control. *Cognitive research: principles and implications*, *3*(1), 11.

Friesen, D. C., Luo, L., Luk, G., & Bialystok, E. (2015). Proficiency and control in verbal fluency performance across the lifespan for monolinguals and bilinguals. *Language, cognition and neuroscience*, *30*(3), 238-250.

Gold, B. T., Kim, C., Johnson, N. F., Kryscio, R. J., & Smith, C. D. (2013). Lifelong bilingualism maintains neural efficiency for cognitive control in aging. *Journal of Neuroscience*, *33*(2), 387-396.

Goral, M., Campanelli, L., & Spiro, A. (2015). Language dominance and inhibition abilities in bilingual older adults. *Bilingualism: Language and Cognition*, *18*(1), 79-89.

Grosjean, F. (2010). *Bilingual*. Harvard University Press

Hsieh, L. (2015). Effect of bilingualism on multitasking: A pilot study. *Perspectives on Communication Disorders and Sciences in Culturally and Linguistically Diverse (CLD) Populations*, *22*(3), 94-101.

Ivanova, I., & Costa, A. (2008). Does bilingualism hamper lexical access in speech production?. *Acta psychologica*, *127*(2), 277-288.

Kousaie, S., Sheppard, C., Lemieux, M., Monetta, L., & Taler, V. (2014). Executive function and bilingualism in young and older adults. *Frontiers in Behavioral Neuroscience*, *8*, 250.

Kroll, J. F., Dussias, P. E., Bice, K., & Perrotti, L. (2015). Bilingualism, mind, and brain. *Annu. Rev. Linguist.*, *1*(1), 377-394.

Kroll, J. F., Gollan, T. H., Goldrick, M., Ferreira, V., & Miozzo, M. (2014). Speech planning in two languages: What bilinguals tell us about language production. *The Oxford handbook of language production*, 165-181.

Margaret, V., & Abhishek, B. P. (2017).Effect of Bilingualism on Executive Functioning. *Unpublished master's Dissertation: University of Mysore, Mysore*.

Marian, V., Blumenfeld, H. K., & Kaushanskaya, M. (2007). The Language Experience and Proficiency Questionnaire (LEAP-Q): Assessing language profiles in bilinguals and multilinguals. *Journal of Speech, Language, and Hearing Research*, *50*(4), 940-967.

Miller, E. K., & Cohen, J. D. (2001). An integrative theory of prefrontal cortex function. *Annual review of neuroscience*, *24*(1), 167-202.

Mindt, M. R., Arentoft, A., Germano, K. K., D'Aquila, E., Scheiner, D., Pizzirusso, M., ... & Gollan, T. H. (2008). Neuropsychological, cognitive, and theoretical considerations for evaluation of bilingual individuals. *Neuropsychology review*, *18*(3), 255-268.

Naeem, K., Filippi, R., Periche-Tomas, E., Papageorgiou, A., & Bright, P. (2018). The importance of socioeconomic status as a modulator of the bilingual advantage in cognitive ability. *Frontiers in psychology*, *9*, 1818.

Peal, E. & Lambert, W. (1962). The relation of bilingualism to intelligence. *Psychological Monographs*, *76*(Whole No. 546), 1–23.

Prior, A., & MacWhinney, B. (2010). A bilingual advantage in task switching. *Bilingualism: Language and Cognition, 13*, 253-262.

Ramya, M., & Goswami, S. P. (2009). Language Proficiency questionnaire: An adaptation of LEAP Q to Indian context. *Unpublished master's Dissertation: University of Mysore, Mysore*.

Rodrigues, L., & Zimmer, M. (2016). Inhibitory and attentional control: the interaction between "professional activity" and bilingualism. *Psicologia: Reflexão e Crítica*, 29:36
DOI 10.1186/s41155-016-0034-8

Rosselli, M., Ardila, A., Araujo, K., Weekes, V. A., Caracciolo, V., Padilla, M., & Ostrosky-Solí, F. (2000). Verbal fluency and repetition skills in healthy older Spanish-English bilinguals. *Applied neuropsychology*, *7*(1), 17-24.

Roselli, M., & Ardilla, A. (2015). The effect of language proficiency on executive functions in balanced and unbalanced Spanish–English bilinguals. *Bilingualism: Language and Cognition*; doi:10.1017/S1366728915000309

Sörman, D. E., Josefsson, M., Marsh, J. E., Hansson, P., & Ljungberg, J. K. (2017). Longitudinal effects of bilingualism on dual-tasking. *PloS one*, *12*(12), e0189299.

Soveri, A., Rodriguez-Fornells, A., & Laine, M. (2011). Is there a relationship between language switching and executive functions in bilingualism? Introducing a within group analysis approach. *Frontiers in Psychology*, *2*, 183.

Viswanathan, M. & Bialystok, E. (2009). Exploring the bilingual advantage in executive control: The role of expectancies. Poster presented at the 6th International Symposium on Bilingualism, Hamburg, Germany.

Xie, Z. (2018). The Influence of Second Language (L2) Proficiency on Cognitive Control Among Young Adult Unbalanced Chinese-English Bilinguals. *Frontiers in psychology*, *9*, 412.

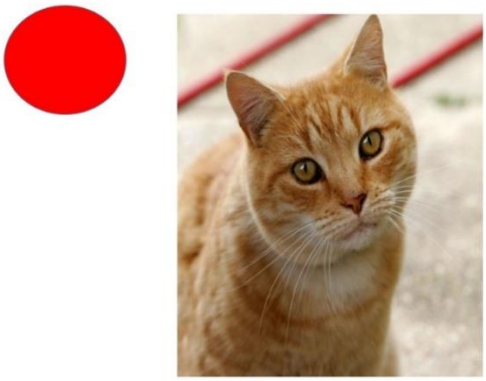
Yow, W. Q., & Li, X. (2015). Balanced bilingualism and early age of second language acquisition as the underlying mechanisms of a bilingual executive control advantage: why variations in bilingual experiences matter. *Frontiers in psychology*, *6*, 164.

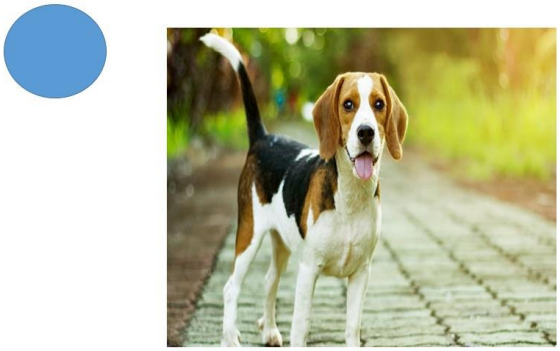
Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. *Blackwell handbook of childhood cognitive development*, 445-469.

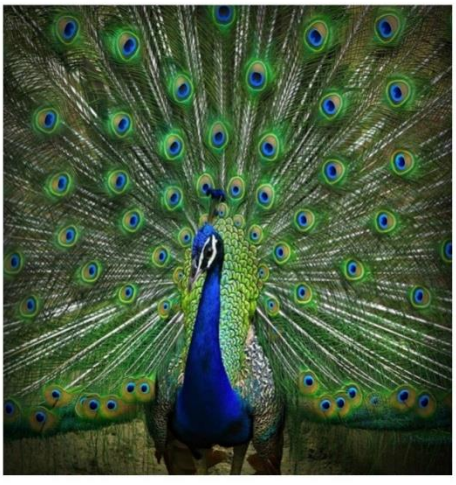
Zelazo, P. D., Müller, U., Frye, D., Marcovitch, S., Argitis, G., Boseovski, J., ... & Carlson, S. M. (2003). The development of executive function in early childhood. *Monographs of the society for research in child development*, i-151.

## APPENDIX

***Stimuli used for the study- conditioned naming task***








© arvindkatoch.com