World Journal of Education and Humanities
ISSN 2687-6760 (Print) ISSN 2687-6779 (Online)
Vol. 8 No. 1, 2026
www.scholink.org/ojs/index.php/wjeh

Original Paper

Cognitive Control in Low Proficient and High Proficient Younger and Older Bilinguals

Anita. J[1] & Abhishek B. P.[2]

[1] Speech language Pathologist, India

[2] Assistant professor in Language Pathology, India

Received: October 28, 2025 Accepted: January 02, 2026 Online Published: January 13, 2026

doi:10.22158/wjeh.v8n1p45 URL: http://dx.doi.org/10.22158/wjeh.v8n1p45

Abstract

Executive functions include basic cognitive processes such as attentional control, cognitive inhibition, inhibitory control, working memory, and cognitive flexibility. Executive function is reported to be advantageous in bilinguals when compared to monolinguals. The present study investigates the cognitive control in low and high proficient younger and older bilinguals. Kannada-English bilingual adults in the age range of 18-30 years and 55-70 years were recruited. Bilinguals were further divided into subgroups of high and low proficient bilinguals based on a self-rating proficiency questionnaire; LEAP-Q. 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. Reaction time and accuracy scores were computed. It was found that bilingual advantage of 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.

Keywords

Cognitive control, Bilingual advantage, L2 proficiency, Aging

1. Introduction

Bilingualism is a highly prevalent phenomenon, with estimates suggesting that around half of the world's population uses two or more languages in daily life (Grosjean, 2010). It cuts across national boundaries, social strata, and age groups, and has been defined as the use and proficiency in at least two languages, with relative skills in each language changing as a function of opportunities for use and exposure (ASHA, 2004). Within this broad phenomenon, bilinguals are typically described along multiple dimensions, including age and mode of acquisition, degree of dominance, and level of proficiency in each language (Beardsmore, 1986; Peal & Lambert, 1962).

Bilingualism has been characterized as dynamic and experience-dependent, with individuals' relative proficiency in their languages shifting over time as patterns of input and use change (ASHA, 2004; Grosjean, 2010). From a developmental perspective, bilinguals may be distinguished as early or late, depending on when the second language (L2) is acquired, and as possessing either a more integrated or more separate lexical–semantic organization across their two languages (Beardsmore, 1986).

In terms of competence, bilinguals are often described as balanced when their skills in L1 and L2 are comparable, and as dominant when one language is clearly stronger than the other (Peal & Lambert, 1962). Proficiency in L2 is a critical dimension and is commonly used to differentiate high- and low-proficient bilinguals, typically defined with reference to how closely their performance approximates that of native or fluent speakers.L2 proficiency is usually understood as the ability to use the second language efficiently and appropriately across modalities (listening, speaking, reading, and writing), and it is central to many experimental classifications of bilingual groups. A variety of procedures have been suggested to operationalize proficiency, including self-ratings, structured questionnaires, flexibility and fluency tasks, and dominance tests (McNamara, 1967).

Self-rating scales are widely employed because they are efficient and correlate reasonably well with objective measures, and several formal proficiency scales are in common use, such as the International Second Language Proficiency Ratings (Ingram, 2000), the Interagency Language Roundtable scale, and the ACTFL Proficiency Guidelines. Questionnaires that integrate rating scales with detailed language-history items, such as the Language Experience and Proficiency Questionnaire (LEAP-Q; Marian, Blumenfeld, & Kaushanskaya, 2007), have been adapted for different linguistic contexts, including an Indian version by Ramya and Goswami (2009). A widely discussed benefit of bilingualism is the so-called "bilingual advantage", wherein bilinguals show superior performance to monolinguals on tasks tapping aspects of executive control. Empirical work has linked bilingualism to advantages in suppressing irrelevant information while selecting goal-relevant representations (Bialystok et al., 2004, 2008), more efficient shifting between mental sets (Garbin et al., 2010; Prior & MacWhinney, 2010), and delayed onset of clinical symptoms in dementia, mild cognitive impairment, and Alzheimer's disease, along with better cognitive recovery following neurological insult (Bialystok, 2010; Bialystok et al., 2014; Alladi et al., 2013, 2016). These advantages have been linked to the demands of managing two active language systems, including frequent code-switching and language mixing in informal contexts, contrasted with situations where strict selection of a single target language is required (Green, 1998). Under such conditions, the target language must be kept sufficiently activated while the non-target language is constrained, and this constant need to select among competing language representations is proposed to strengthen core components of the executive control system (Colzato et al., 2008; Kroll, Dussias, Bice, & Perrotti, 2015). Executive functions refer to a constellation of higher-order processes that support purposeful, self-regulated behaviour, including attentional control, inhibitory control, working memory, cognitive flexibility, planning, and aspects of fluid intelligence (Lezak, 1995; Miyake et al., 2000). Miyake and colleagues demonstrated that

executive functions are related but separable, with distinct contributions from attention, response inhibition, cognitive flexibility, and memory to complex task performance. Evidence from bilingualism research suggests that lifelong management of two languages can enhance several of these executive components, making bilinguals more sensitive to subtle linguistic distinctions, supporting more efficient use of their first language, and facilitating the learning of additional languages (Bialystok et al., 2004). While many early studies contrasted bilinguals with monolinguals, more recent work, including the present study, has begun to examine how differences in L2 proficiency among bilinguals themselves modulate cognitive control, particularly in relation to aging.

Need for the study

Studies previously have compared bilinguals with monolinguals. Also, very few studies have compared the cognitive control across proficiency levels i.e. high proficient and low proficient bilinguals. Though an earlier study was conducted, cognitive control was not tapped in that study.The earlier studies on bilingualism have been done on younger bilinguals. In this study, older bilinguals were also considered. Hence, the Bilingual Advantage in the cognitive domain would be viewed as a function of age.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.

2. Method

2.1 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 (with 10 males & 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 L2 were 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. 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, two claims have been proposed by researchers; 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.

2.2 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. The first task was Simon's task where 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. The participant was instructed 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 the up key. The reaction time and accuracy scores for congruent and incongruent trials were considered. The second task was a Stroop task where color words were represented in the same color ink (congruent) or in different color ink (incongruent). Stimuli were presented in both L1 Kannada and L2 English. The participants were instructed to press the right key for a congruent condition and the left key for the incongruent condition. Reaction time and accuracy scores for congruent and incongruent trials in L1 and L2 were considered. The third task was a Conditioned naming task. Here, pictures of commonly occurring objects were chosen and they appeared on the computer screen accompanied by a red or a blue dot. Depending on the color of the dot the participant had 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. The stimulus was presented randomly, reaction time and accuracy were calculated.

3. Result

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. Four objectives were included in the study, where first and second objectives were to compare the reaction time and accuracy scores across different age groups (young and old adults) and third and fourth objectives were to compare the reaction time and accuracy scores across proficiency levels (high and low proficient bilinguals)

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 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

As shown in table 1, 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 T3 (Conditioned naming task), better for T2 (Stroop task) and highest for T1 (Simon's 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 were least for T3 (Conditioned naming task), then for T1 (Simon's task) and highest for T2 (Stroop task).

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 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

As shown in table 2, low proficient young bilinguals took the least time to respond for the T3 (Conditioned naming task) and then for T1 (Simon's task) and most time for T2 (Stroop task). However, their accuracy was the least for T3 (Conditioned naming task), better for T2 (Stroop task) and highest for T1 (Simon's 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 were least for T1 (Simon's task), better for T3 (Conditioned naming task) and highest for T2 (Stroop task).

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, $F(1, 36) = 5.264$, $p< 0.01$ 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.

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 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

As shown in table 3, 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, accuracy scores for high proficient bilinguals were the least for T3 (Conditioned naming task), better for T2 (Stroop task) and highest for T1 (Simon's task). Low proficient young bilinguals took the least time for T3 (Conditioned naming task) and then for T1 (Simon's task) and most time for T2 (Stroop task). Accuracy scores for low proficient bilinguals were the least for T3 (Conditioned naming task), better for T2 (Stroop task) and highest for T1 (Simon's task).

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. 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

As shown in table 4, 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 were 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 were least for T1 (Simon's task) better for T3 (Conditioned naming task) and highest for T2 (Stroop task).

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 for T1 (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. Similar trend was seen for accuracy scores. 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 T1 and had difficulty on T3 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 T3. 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.

4. 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 (T1) and was the fastest for the verbal response inhibition task (T3). 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 3rd objective was to examine if there was any difference in high proficient and low proficient young bilinguals on the three tasks. The 4th 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. 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 of 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.

In terms of implication 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.

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. 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.

References

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.

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.

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

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

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

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., 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., 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.

Colzato, L. S., Bajo, M. T., van den Wildenberg, W., Paolieri, D., Nieuwenhuis, S., La Heij, W., & Hommel, B. (2008). How does bilingualism improve executive control? A comparison of active and reactive inhibition mechanisms. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *34*(2), 302.

Garbin, G., Sanjuan, A., Forn, C., Bustamante, J. C., Rodríguez-Pujadas, A., Belloch, V., ... & Ávila, C. (2010). Bridging language and attention: Brain basis of the impact of bilingualism on cognitive control. *Neuroimage*, *53*(4), 1272-1278.

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.

Gollan, T. H., & Acenas, L. A. R. (2004). What is a TOT? Cognate and translation effects on tip-of-the-tongue states in Spanish-English and tagalog-English bilinguals. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *30*(1), 246.

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

Green, D. W. (1998). Mental control of the bilingual lexico-sematic system. *Bilingualism: Language and Cognition*, *1*, 67-81

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

Kaushanskaya, M., & Marian, V. (2007). Bilingual language processing and interference in bilinguals: Evidence from eye tracking and picture naming. *Language Learning*, *57*, 119-163.

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

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.

McNamara. (1967).The Bilingual's Linguistic Performance- A Psychological Overview. *Journal of social issues*, *23*(2).

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 the evaluation of bilingual individuals. *Neuropsychology review*, *18*(3), 255-268.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive psychology*, *41*(1), 49-100.

Oller, D. K., & Eilers, R. E. (2002). Language and Literacy in Bilingual Children. Clevedon, UK: Multilingual Matters

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*.

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.