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Comparison of Cognitive Functions among Bilinguals and Multilinguals

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ABSTRACT

Background: *Language is one of the most fundamental aspects of any society. It is how individuals communicate with one another, form relationships and foster a feeling of community. Language processing is one of the most common, yet complex, tasks we perform regularly. Being multilingual facilitates effective communication and such people are better problem solvers. The benefits of multilingualism extend beyond the capacity to communicate in another language and provide individuals with a broader perspective of the world. This study aims to assess the cognitive functions of bilinguals and multilinguals and to compare the cognitive functions among bilingual and multilingual individuals.*

Materials and methods: *Nearly 115 members were screened for anemia, thyroid abnormalities, diabetes mellitus and other electrolyte imbalances to select the study participants in the age group of 30-50 years. Strub black mental status test was used for reading and writing, and controlled word association test for fluency. Depending on these observations, participants were divided into monolinguals, bilinguals, trilinguals and multilinguals. Stroop test was used to assess the cognitive function.*

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Results: *Mean scores and reaction time for color-to-word tests among monolingual and multilingual were 7.7±1.99, 21.65±3.68 and 9.9±0.29, 16.44±1.81, respectively. Mean scores and reaction time for word-to-color tests among monolinguals and multilinguals were and 7.65±1.12, 23.61±3.69 and 9.7±0.696, 13.80±3.14, respectively.*

Conclusion: *Inculcating multiple languages at a younger age might enhance cognitive skills and overall effectiveness.*

Keywords: cognitive function, bilingual, multilingual, Stroop test.

BACKGROUND

Language has the ability to influence cognition, behavior and even the structure and function of the brain. Technological and scientific advancements have recently resulted in a broader collection of tools for studying how language affects brain structures and activities (1). The specificity principle states that the acquisition of multiple languages is moderated by multiple factors, which include cultural cues, immigration and language similarity. Speaking in different languages is expected to be affecting the cognitive function. According to the previous literature, knowing multiple languages would influence only the verbal abilities basic cognitive processing speed. Whether it affects the cognition universally or certain components of cognition is still inconclusive. More than 6,000 languages are spoken in the world. This unique strength to learn more languages is possible through the neuroanatomical, neuron functional, biochemical, psychological functional changes in the brain (2). The manner of acquisition is influenced by various factors like age of second language acquisition, immigration status, country, education, occupational status, social activity and environmental factors (3). Multilingual brain induces the long-term neuroplasticity changes and enhanced cognitive persistence protects from the adverse cognitive effects of aging (4). Cognitive persistence among multilinguals will help them to perform at higher levels of cognition as compared with monolinguals. Cognitive persistence depends on age of language acquisition and language proficiency (5). A lot of research was done by Bialystok and colleagues, who observed that bilinguals showed symptoms of dementia four years later than monolinguals (6). There is also protection against the onset of symptoms of dementia in bilingualism (6). Practicing multilingualism from an early age and/or learning it quickly is even more efficient. This protection could be linked to increased cognitive reserve and brain plasticity, which would preserve brain functioning from aging-related changes (7). Seniors who spoke more than two languages were three times less likely to develop cognitive impairment not dementia (CIND) than bilinguals. A similar tendency was observed for three and four languages. Kavé *et al* discovered that cognitive performance in a non-demented Israeli senior population improved as the number of languages spoken increased (two, three or more), regardless of education level (8). Cognitive assessment are invaluable tools for understanding the role of specific brain functions across a range of disorders and syndromes, giving insight into underlying causes, identifying ways to detect the earliest symptoms and evaluating the effects of interventions designed to improve brain health. There are few cognitive function tests which can be used, with the computerized Stroop test being one of them (9). The Stroop color and word test (SCWT), an extensively neuropsychological test used for both experimental and clinical purposes, assesses the ability to inhibit cognitive interference, which occurs when the processing of a stimulus feature affects the simultaneous processing of another attribute of the same stimulus (10). This test was done among bilinguals and multilinguals. Strub black mental status test was helpful to classify the individuals as bilingual and multilingual (11).

Objectives

This study aims to assess the cognitive functions of bilingual and multilingual people and to compare the cognitive functions among bilinguals and multilinguals.

Methodology

We conducted a cross sectional study in the faculty of All India Institute of Medical Sciences

(AIIMS), Bibinagar, Hyderabad, India, which was started after obtaining the Ethical committee clearance (AIIMS/BBN/IEC/SEP/2021/96-AM). Also, the informed written consent was obtained from all participants. Sample size calculation was done by referring the previous studies accordingly (8). Nearly 115 members were screened to select the study participants in the age group of 30-50 years. Screening for anemia, thyroid abnormalities, diabetes mellitus and other electrolyte imbalances was done, which included the following tests: complete hemogram to rule out anemia, HbA_{1c} to rule out diabetes mellitus, thyroid profile to exclude thyroid disorders and serum electrolytes (Na^+, K^+, Ca^{2+}) to exclude electrolyte imbalances. Among 115 participants, 15 were excluded from the study.

Grouping of the subjects

After screening, the remaining 100 participants were divided into five groups of 20 each. By using the Strub black mental status test and controlled word association test (COWAT-FAS), participants were grouped into monolinguals (Group V), bilinguals (Group IV), trilinguals, (Group III), quadrilinguals (Group II) and multilinguals (Group I). Strub black mental status test was used for reading and writing (11), and COWAT-FAS for fluency (12). Depending on these observations, participants were divided into monolinguals, bilinguals, trilinguals and multilinguals. Stroop test was used to assess the cognitive function.

Reading – Subjects were asked to read a given paragraph and questions related to it were asked.

Writing – In the beginning, letters and numbers for dictation were given to subjects. Later, participants were instructed to write the names of common objects or body parts. Lastly, they were asked to write single words, then a short sentence describing the weather, their job or a picture from a magazine.

Fluency – COWAT-FAS (12) requires the individual to name as many words as possible that begin with a given letter (*i.e.* F, A and S). Sixty seconds are allotted for each letter. The test measures the phonemic word fluency, which is a type of verbal fluency. It assesses phonemic fluency by requesting an individual to orally produce as many words as possible that begin with the letters F, A and S within a prescribed time frame, usually one minute (13). Depending upon the reading, writing and fluency in each language, participants were divided into five groups: Group I comprising multilinguals (five languages); Group II, quadrilinguals (four languages); Group III, trilinguals (three languages); Group IV, bilinguals (two languages); and Group V, monolinguals (one language).

Statistical analysis

Results on continuous measurements were presented as mean ± standard deviation (SD) and categorical measurements as numbers or percentages. Data was analyzed using the statistical package for social sciences version 25.0 (SPSS Inc., Chicago, IL, USA). Significance was assessed at 5% level of significance. Data was entered into MS excel vs.2019 and statistical analyses was performed using unpaired t test; p value less than or equal to 0.05 was considered statistically significant.

RESULTS

The total number of 100 subjects included in the present study were divided into five groups of 20 each. Gender wise distribution across the study groups is depicted in Figure 1. The mean of scores and the reaction time for color to word test in all groups is summarized in Table 1, similarly for word to color test in Table 2. Comparisons of scores and reaction time between Groups I and IV

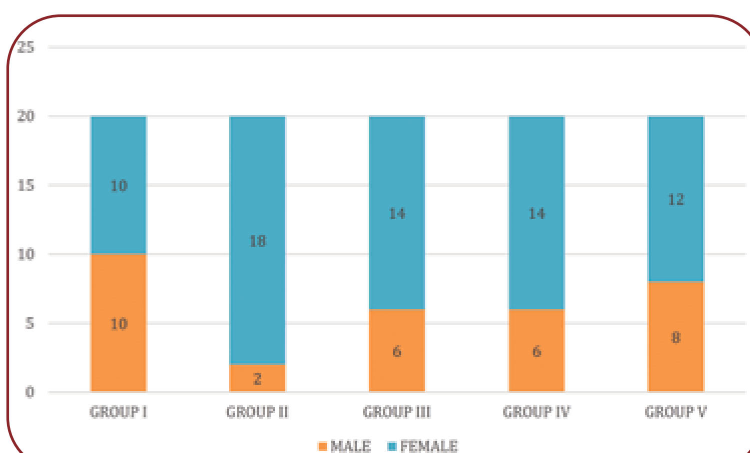

FIGURE 1. Gender wise distribution across the various groups of the study

TABLE 1. Mean scores and reaction time for color to word test

Groups	Scores (mean±SD)	Reaction time in seconds (mean±SD)
Group I	9.9±0.29	16.44±1.81
Group II	9.65±0.70	16.70±2.44
Group III	9.60±0.64	18.73±4.77
Group IV	9.5±0.84	19.55±5.04
Group V	7.7±1.99	21.65±3.68

TABLE 2. Mean scores and reaction time for word to color test

Groups	Scores (mean±SD)	Reaction time in seconds (mean±SD)
Group I	9.7±0.696	13.80±3.14
Group II	9.75±0.52	17.30±3.04
Group III	8.95±2.23	18.05±4.18
Group IV	9.45±0.89	16.55±4.89
Group V	7.65±1.12	23.61±3.69

TABLE 3. Scores and reaction time comparison between multilinguals (Group I) and bilinguals (Group IV) for color to word test

Parameters	Group I	Group IV	t value	P value
Scores (mean ±SD)	9.9±0.29	9.5±0.84	2.013	0.004*
Reaction time in seconds (mean ±SD)	16.4±1.81	19.55±5.04	2.631	0.001*

*Statistically significant

TABLE 3. Scores and reaction time comparison between multilinguals (Group I) and bilinguals (Group IV) for word to color test

Parameters	Group I	Group IV	t value	P value
Scores (mean ±SD)	9.7±0.69	9.45±0.89	1.19	0.23
Reaction time in seconds (mean ±SD)	13.80±3.14	16.55±4.81	2.142	0.001*

*Statistically significant

are summarized in Tables 3 and 4, showing a significant score reduction in Group IV in comparison with Group I; also, the reaction time is significantly higher in Group IV than Group I. ❑

DISCUSSION

In order to enhance comprehension of the feasibility of bilingual and consequently multilingual, advantage hypothesis, the current study examined the differences in executive functioning performance between mono- and multilinguals in the age group of 30–50 years.

The Stroop test in mono- and multilingual individuals were investigated in this study. Our findings indicate that while Group V (monolingual people) scored higher on the Stroop test for both the color to word and word to color tests, Group I (multilingual people) scored higher. With significant differences in reaction times in both the color to word and word to color tests, as well as significant differences in scores in the color to word test, Group I's multilingual individuals generally outperform Group IV's bilinguals in both tests. The mean reaction time scores are higher for Group V and lower for Group I. Among all groups, Group V consistently performs the lowest in both tests. This implies that, in comparison to other groups, members of Group V can experience difficulties with cognitive processing or language understanding.

A comparison between multilinguals (Group I) and bilinguals (Group IV) provides insight into how language competency affects cognitive activities. Group I performs much better than Group IV in the color-word test in terms of both mean scores and reaction times. This suggests that, when it comes to the ability to associate words with colors, being bilingual may offer benefits in terms of cognitive flexibility and processing speed.

Nonetheless, there is no significant difference in mean scores between Groups I and IV in the word-color test, even though Group I still exhibits quicker reaction times than Group IV. This implies that multilingualism may not be as beneficial in word-color association tasks as it is in color-word association tasks.

Numerous reasons could be responsible for the performance differences that have been found. Firstly, the experience of managing many languages may have improved cognitive control and executive function in multilingual individuals, which could lead to faster responses in activities demanding cognitive flexibility. Secondly, performance could be impacted by variations in linguistic processing techniques. People who speak more than one language could have a larger semantic network, which would allow them to more quickly access and associate color-word information. On the other hand, bilingual people can encounter language competition or interruption, which could potentially slow down their cognitive speed.

Similar results were obtained in a study by Den Noort *et al*, who found that bilingual adults and children performed better on cognitive control tasks than monolinguals (14). When Bialystok *et al* tested groups of adult monolinguals and bilinguals in their twenties and older (roughly 60–70 years) on the Stroop task, measuring interference suppression, and found that both bilingual groups outperformed their monolingual peers, with the older group exhibiting the most pronounced bilingual advantage (15). Another study by Massa *et al* found that young bilinguals performed better than monolinguals on the Stroop test, which indicated that the advantage of bilinguals increased with the amount of executive control needed for the language-based activity (16). When compared to monolinguals, bilinguals and multilinguals had better cognitive function, as indicated by greater scores on the Addenbrooke's cognitive examination (ACE-III). The scores were higher in bilinguals with no cognitive impairment and also in bilinguals with mild cognitive impairment. Similar findings of better cognitive performance by multilinguals were reported by Venugopal *et al* (17). Gallo F *et al* demonstrated that bilingualism encourages healthy aging and guards against dementia and cognitive decline, maybe as a result of extra cognitive advantages associated with bilingual speakers (19), the underlying mechanism of which may be improved cognitive reserve and enhanced neural plasticity as a result of lifelong language practice (18).

Comparing healthy bilingual older persons to age-matched monolinguals, additional studies have also found higher results on the mini-mental state examination, which measures general cognitive function (19, 20). A different study revealed that early bilingual students had faster reaction times than monolingual students on the Stroop color word test. This indicated that early bilingual students had an advantage in executive function, which may be attributed to the benefits of learning a second language sooner or to having been bilingual for a longer period of time (21). In a study conducted by Achaa-Amankwaa *et al*, the multilingual group outperforms the monolingual group in interference suppression, which is the fundamental process of Stroop test (20). According to comparable findings from a number of previous studies, bilinguals outperform their monolingual counterparts on tasks involving executive skills, including inhibition and cognitive flexibility (22-25). The management of languages probably reinforces these networks and raises the degree of general cognitive functioning if language control and executive control share similar mechanisms and brain networks. When Kave *et al* examined the cognitive capabilities of older persons (aged 83–91) who were bilingual, trilingual and multilingual, they discovered that multilinguals did better on tests of general cognitive ability than trilinguals, and the latter performed better than bilinguals (8).

Bilingualism and multilingualism may serve as a sort of cognitive training, with trained functions resulting in improved performance on executive function tests. Language learning programs may thus serve as an essential supplemental alternative for developing cognitive reserve, as language acquisition involves an extensive neural network that is otherwise susceptible to age-related cognitive loss, as well as delaying the development of dementia (26). Our findings are consistent with prior meta-analyses (24, 27). Though the benefits of multilingualism may not be evident in enhanced cognitive tasks in daily life, the changes caused by it have been proven to transfer into practically important differences in neuroplasticity as a result of the bi- or multilingual experience (28).

Estanga *et al* found that bilingualism had a favorable impact on CSF t-tau levels in Alzheimer's disease, as well as a lower proportion of preclinical Alzheimer's disease among early bilingual participants, indicating that intellectual achievements may also contribute to brain reserve (29). Thus, multilingualism not only improves cognitive capabilities but also helps to delay the start of age-related cognitive decline and the occurrence of disorders like Alzheimer's (30).

Limitations of the study

It is vital to recognize the limitations of the present study. Firstly, sample sizes and group characteristics are not disclosed, limiting the generalizability of our findings. Furthermore, characteristics such as age, education and cognitive ability were not controlled for, which potentially confounded the results.

Future research should include larger and more diverse populations to validate these findings. Furthermore, neuroimaging approaches could shed light on the brain mechanisms that underpin language and cognitive functioning in various linguistic communities. ❑

CONCLUSION

In conclusion, the data highlights the complex interplay between language proficiency and cognitive performance. While multilingual individuals demonstrate advantages in certain cognitive tasks, such as associating colors with words, the extent of these advantages may vary depending on the specific cognitive demands of the task. Inculcating multiple languages at a young age might enhance cognitive skills and overall effectiveness. ❑

Conflicts of interest: none declared.

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