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Influence of gender and quality of sleep in cognitive impairment: A cross-sectional pilot study from Kerala, India

Rajeev A[1]*, Nair BP[2]

Corresponding author:

Akhil Rajeev, M. Sc (Applied Psychology), M. Phil (Clinical Psychology), Fellowship in Clinical Neuropsychology (NIMHANS), (Consultant Clinical Psychologist, Travancore Medical College Hospital) Kerala, India.

Email: akhilrajeev9099@gmail.com ORCID

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ABSTRACT

Background

Cognitive decline, a natural aging process, can lead to geriatric neurodegenerative diseases like dementia, which progresses rapidly, with memory complaints and deficits being particularly risky. Sleep is crucial for psychological functions and cognitive functions. The aim of this study was to investigate the connection between the sleep quality and cognitive function like working memory, reaction time (simple and choice reaction time), and attention (sustained/vigilant attention and divided attention) in the south Indian youth population.

Material and methods

A cross-sectional pilot study was carried out on the 30 participants. Pittsburgh Sleep Quality Index (PSQI) was used to assess the sleep quality, NIMHANS Neuropsychological Battery for adults was used to assess different neuro-cognitive domains and Computerized test of reaction time to assess the simple reaction time and choice reaction time.

Results

Participants with poor sleep quality showed impaired performance in the tests of attention (Sustained attention and Divided attention). No significant differences were observed between participants of good sleep quality and poor sleep quality in the test of working memory, N Back 1 test ($t=0.539$, $p>0.05$) and N Back 2 test of working memory ($t=0.306$, $p>0.05$).

Conclusion

Participants with poor sleep quality significantly differed from those with good sleep quality and committed more mistakes in the triad test of divided attention, spend longer time, and committed errors in the completion of the digit vigilance test of sustained attention. Sleep patterns are associated with cognitive test performance, and optimising sleep duration and quality should be an important consideration for cognitive functions.

Keywords

Attention, cognitive function, memory, reaction time, sleep.

Background

Cognitive decline, a natural ageing process, can indicate the development of geriatric neurodegenerative diseases like dementia. While some mild impairments remain stable, over half progress to dementia within 5 years, with memory complaints and deficits being particularly risky, leading to Alzheimer's disease. The presence of new infarctions in patients is associated with a more pronounced deterioration in cognitive function, hence elevating the likelihood of further infarctions. This cascade effect may further contribute to the progression of dementia [1]. Dementia represents a prevalent global affliction and stands as a significant health and societal concern. The prevalence of dementia is seeing a significant upward trend, with projections indicating a rise from approximately 47 million individuals in 2015 to 66 million in 2030 and a further escalation to 131 million by 2050. Due to its impact on an individual's daily life and social functioning, dementia poses a significant burden on individuals afflicted with the disease, their families, and society [2].

Subjective cognitive decline (SCD) is widely recognised as the first manifestation of dementia in individuals [3]. Hence, detecting cognitive decline can facilitate secondary prevention by enabling the adoption of interventions aimed at managing risk variables. Dementia is now recognised as a condition that is not necessarily an unavoidable outcome of the ageing process and can be both preventable and treatable. Various lifestyle-related factors have the potential to either decrease or elevate an individual's susceptibility to dementia [2].

Sleep impacts psychological functions, cognitive function, and overall health. Good sleep quality (GSQ) predicts wellness and overall vitality. Physical health issues, medication side effects, illness, neurodegenerative changes, and psychiatric disorders like depression, anxiety, and schizophrenia can all cause sleep disturbances. [2, 4]

Sleep is an essential physiological process crucial to maintaining alertness, enhancing cognitive function, bolstering the immune response, facilitating physical activity, and promoting bodily restoration. Sleep deprivation has been found to negatively affect various aspects of an individual's life, particularly academics. It is associated with diminished academic performance, an elevated likelihood of engaging in substance abuse such as drug and alcohol use, heightened irritability, and an increased propensity for aggressive behaviour. These consequences can significantly disrupt interpersonal interactions with classmates, parents, and teachers. Sleep patterns have been observed to exhibit a tendency to shift towards later times as individuals age, resulting in a reduction in the duration of nocturnal sleep. [5] Research in molecular genetics, behavioural neuroscience, sleep neurobiology, and cognitive neuroscience supports the crucial role of sleep in cognition. Insufficient sleep negatively impacts mood, cognitive performance, and motor function, impacting various mental processes like memory, problem-solving, and attention. Sleep deprivation has significant physiological and psychological consequences [6, 7].

A number of standardised measures of sleep quality are currently available. The Karolinska Sleep Diary, [8] Verran, and Snyder-Halpern Sleep Scale [9], and the Pittsburgh Sleep Quality Index (PSQI) [10] are currently in use. Among all, the Pittsburgh Sleep Quality Index (PSQI) is the most frequently employed self-administered questionnaire [11-13]. The PSQI is a pragmatic and concise assessment tool that yields a singular score encompassing several dimensions of sleep quality, including subjective and objective measures. A score beyond 5 is considered as symptomatic of a potential sleep-related issue. The PSQI incorporates open-ended inquiries that identify sleep disturbances' characteristics and potential origins to guide treatment strategies. [13] Additionally, it provides subscale scores that offer insights into various aspects of sleep problems, including sleep duration, latency, disturbances, quality, efficiency, daytime dysfunction, and utilisation of sleep medication. Furthermore, the questionnaire includes certain items pertaining to indicators of sleep apnea.

Although numerous ongoing studies on sleep duration have been actively conducted in the meantime, an insufficient number of studies about sleep quality have been performed in the South Indian population. We hypothesised that poor quality of sleep would be linked with the decline of cognitive function.

Therefore, our aim was to investigate the connection between sleep quality and cognitive functions like working memory, reaction time (simple and choice reaction time), and attention (sustained/vigilant attention and divided attention) in the South Indian youth population.

Material and methods

Study design and the participants

A cross-sectional pilot study was carried out on the 30 participants (13 males, 17 females) between 18 to 30 years hailing from different districts of Kerala reported to the Department of Psychology, University of Kerala, Thiruvananthapuram, Kerala. The participants were categorized into two groups of 15 members each based on the scores obtained in the PSQI.

Experimental procedure and data collection

At the beginning of the experiment, the quality of sleep of the individuals in this study was assessed using PSQI. Participants with scores of less than 6 (n=15) were categorised into the group of good sleep quality, and those with scores of 6 or greater (n=15) were categorised as poor sleep quality (PSQ). Based on the score obtained, the participants were divided into two groups: those with good sleep quality and those with poor sleep quality. Afterward, tests of cognitive functions were administered, namely the N Back Test (N Back 1 and N Back 2 test) for working memory, the triad test for divided attention, the digit vigilance test for sustained attention, and a computerised test for measuring reaction time (simple reaction time and choice reaction time). The scores were compared, and the impairment in cognitive functioning in subjects with poor sleep quality was examined, along with the gender differences in performance in these tests.

Pittsburgh Sleep Quality Index Scale (PSQI)

PSQI is a questionnaire that assesses sleep quality and quantity over a 1-month period [10]. The PSQI contains 19 items in seven component domains: subjective sleep quality, sleep latency, sleep duration, habitual sleep efficiency, sleep disturbances, use of sleep medication, and daytime dysfunction. The questionnaire requires the participant to describe sleep patterns, such as typical bedtime and wake time, length of time taken to fall asleep, and actual sleep duration. The participant then answers a series of questions relating to sleep habits and quality. Component scores are based on a four-point Likert scale that ranges from very good (0) to very bad (3). The component scores are combined to produce the Global Sleep Quality Score, which ranges from 0 to 21. Participants with scores of 6 or greater are considered to be poor sleepers. The authors report acceptable measures of internal homogeneity (0.83), consistency (test-retest reliability), and validity. A global PSQI score greater than 5 yielded a diagnostic sensitivity of 89.6% and a specificity of 86.5%. The seven component scores of the PSQI are reported to have an overall reliability coefficient of 0.83, indicating a high degree of internal consistency.

Reaction time (RT) test

Reaction time (RT) which was performed, is a measure of the quickness with which an organism responds to some sort of stimulus. RT is defined as the interval of time between the presentation of the stimulus and the appearance of an appropriate voluntary response in the subject. [14] In the test of reaction time, the subject's simple and choice reaction time was assessed using software. Simple reaction time is defined as the minimal amount of time needed to respond to a single stimulus. Complex reaction time is the minimal time needed to respond to multiple stimuli, which requires different responses. The test was administered as follows: After a beep sound, the subject was shown a green patch of colour in the middle of the screen. In the first 5 trials, the subject was asked to press the button labelled 'L' as fast as possible with the right hand immediately after seeing the green patch of colour. In the next five trials, the subject was shown a red patch of colour and was asked to press the button labelled 'A' as fast as possible with the left hand. For the next 20 trials, the subject was shown either a red colour or a green colour. The subject needs to react with the left hand immediately after seeing the red colour and with the right hand after the presentation of the green colour. After the completion of 20 trials, the subject was shown a red patch of colour for the next 5 trials and asked to react with the left hand. Again, for the next five trials, the subject was shown with a green patch of colour for which the subject needed to react with the right hand. After completing the test, the average reaction time (both simple and complex reaction times) was obtained in milliseconds.

NIMHANS Neuropsychological Battery

The neuropsychological tests used in the present study were taken from the NIMHANS neuropsychological battery. The battery consists of 21 different neuropsychological subtests, which were originally developed by different authors and standardised in the Indian population on an age range of 16 to 65, on samples of both males and females and education ranging from illiteracy to college education by Rao *et al*. in 2004 [15]. The factor analysis was carried out on different neuropsychological domains (with a ratio of variables to the number of subjects at 1:5) and established the factorial validity of the tests for literate subjects. This battery is extensively used in research on neuropsychological assessments for a wide variety of groups, including normal and clinical populations, and hence has proven validity and applicability. The different areas of functions covered in the test battery are attention and concentration, motor speed, executive functions such as planning ability, category fluency, phonemic fluency, working memory, set-shifting and response inhibition, verbal learning and memory, visual learning and memory, and visuo-constructive ability. The following tests from the NIMHANS Neuropsychological Battery were used in the present investigation, namely the N Back test, the Triad test, and the Digit vigilance test.

N Back test

Visual working memory was tested using 1 back and 2 back versions. It consists of 36 cards, each of which has one black dot placed randomly along a circle imagined to be on the card. The dimensions and location of the imagery circle on each card remained constant on all cards. Each card was individually presented to the subject. The subject was told to respond whenever the location of the dot repeated itself. In the 1 back test, the subject was told to respond when the location of the dots was consecutively repeated, and in the 2 back test, the subject was told to respond whenever the location of the dot was repeated after one intervening card. The number of hits and errors in each test formed the score.

The Triad test

The Triads test combines a tactual number identification problem with a verbal triads task. The stimulus modality and nature of stimulus processing differ between the two tasks. Both tasks demand a vocal answer; hence, the nature of the response is identical. As a result, the attention resource pool tapped by the two tasks is thought to be partially distinct. This partial overlap of the nature of response within the attention resource pool necessitates the division of attention. In this test, the individual is blindfolded. There are 48 concrete nouns in the verbal triads task, which are organised into 16-word triads. Two terms in each triad belong to one category, while the third does not. The odd term is named after the subject. Because spoken auditory processing is required, this task primarily engages the left-hemisphere attention resource. A single- or double-digit Arabic numeral is inscribed on the subject's non-dominant hand in the tactual number identification task. The subject calls out the number to identify it. Because the stimulus is tactual and written on the non-dominant hand, it necessitates the use of the right or non-dominant hemisphere's attention resource. Because both tasks demand verbal responses, it is expected that according to Kinsbourne's (1978) multiple attention resource pool model, the subject will find combining the two tasks somewhat difficult because they tap into partially overlapping attention resource pools. On each task, the number of errors made was counted. A mistake can also be defined as omitting to pronounce a word or a number. There are two categories of errors that are counted: word and number errors. Because there are 16 trials in the test, the maximum errors in any category are 16.

Digit vigilance test
The digit vigilance test was used to examine sustained attention. The test consists of numbers 1 to 9 randomly ordered and placed in rows on a page. There are 30 digits per row and 50 rows on the sheet. The digits are closely packed on the sheet. The same level of mental effort or attention deployment is required over a period of time. The subject has to focus on the target numbers '6' and '9' amongst other distracter digits. The inability to maintain and focus attention leads to both increased times to complete the test as well as errors.

Inclusion criteria
Participants within the age group of 18 to 30 years who can understand residing in Kerala and who speak English and Malayalam.

Exclusion criteria
Participants who have any physical or psychological comorbidities and who have any dependence on any substances are excluded from the study.

Ethical committee approval and informed consent
The Ethical Committee of the Department of Psychology, University of Kerala approved the study. Consent was obtained from the participants prior to the study. This study was done according to the declaration of Helsinki.

Data interpretation and statistical analysis
A t-test was used to find out if there was any significant difference based on participants' sleep quality (good sleeper-poor sleeper) on various cognitive functioning tests meant to measure working memory, divided attention, sustained attention, and reaction time.

Results

Table 1: Comparison of the scores of various cognitive tests based on the sleep quality

Variables	Sleep Quality	n	Mean	SD	df	t-value	P value
NB1_H	GSQ	15	5.87	1.50	28	0.539	0.297$^{\times}$
	PSQ	15	5.60	1.18			
	TOTAL	30					
NB1_E	GSQ	15	2.73	1.71	28	-1.264	0.108$^{\times}$
	PSQ	15	3.47	1.45			
	TOTAL	30					
NB2_H	GSQ	15	0.884	0.88	28	0.539	0.297$^{\times}$
	PSQ	15	3.93	1.43			
	TOTAL	30					
NB2_E	GSQ	15	3.60	1.50	28	-1.104	0.139$^{\times}$
	PSQ	15	4.27	1.79			
	TOTAL	30					
DA_ES	GSQ	15	2.533	1.68	28	-2.444	0.10$^{\times}$
	PSQ	15	4.067	1.75			
	TOTAL	30					
SA_TT	GSQ	15	384.333	63.45	28	-3.937	0.000*
	PSQ	15	485.733	76.97			
	TOTAL	30					
SA_TE	GSQ	15	2.000	1.46	28	-4.141	0.000*
	PSQ	15	4.267	1.53			
	TOTAL	30					
RT_SRT	GSQ	15	389.5733	59.49	28	-1.122	0.135$^{\times}$
	PSQ	15	417.9920	68.65			
	TOTAL	30					
RT_CRT	GSQ	15	545.6967	114.25	28	-0.439	0.332$^{\times}$
	PSQ	15	565.8947	136.50			
	TOTAL	30					

$^{\times}$p>0.05, statistically not significant, *p<0.05, statistically significant NB1_H – N Back 1 Test Hits, NB2_H – N Back 2 Hits, NB1_E – N Back 1 Errors, NB2_E – N Back 2 Errors, DA_ES – Divided Attention Error Score, SA_TT – Sustained Attention Total Time, SA_TE – Sustained Attention Total Error, RT_SRT – Simple Reaction Time, RT_CRT – Choice Reaction Time

A significant mean differences between good sleepers and poor sleepers in the number of errors committed in the test of divided attention (t=2.444; p<0.05), total time taken in the test of sustained attention (t=3.937; p<0.001) and in the total number of errors committed in the test of sustained attention (t=4.14; p<0.001) was observed. Poor sleepers showed impaired performance in all the above-mentioned tests of attention. No significant difference was observed between good sleepers and poor sleepers in the N Back 1 test (t=0.539, p>0.05) and N Back 2 test of working memory (t=0.306, p>0.05). On comparing the scores of reaction time based on sleep quality, it can be seen that there is no statistically significant difference between good sleepers and poor sleepers in either simple reaction time (t= 1.212, p>0.05) or choice reaction time (t= 0.439, p>0.05). (Table 1)

Table 2 represents the details of 2-Way ANOVA of the scores of cognitive tests based on the gender and sleep quality groups. It shows that significant gender difference exists in the number of correct responses (hits) in N Back 1 test (F=6.145, p<0.05), number of errors committed in the N Back 1 test (F=17.191, p<0.001), the number of correct responses made in the N back 2 test (F=5.36, p<0.05), the

Table 2: Details of the scores of cognitive tests based on gender and sleep quality groups

Variables	Gender	Group	Mean	Std.	N	F, P value
NB1_H	Male	GSQ	5.00	1.789	6	
		PSQ	5.14	0.900	7	
		Total	5.08	1.320	13	
	Female	GSQ	6.44	1.014	9	
		PSQ	6.00	1.309	8	6.145
		Total	6.24	1.147	17	(p=0.020)*
	Total	GSQ	5.87	1.506	15	
		PSQ	5.60	1.183	15	
		Total	5.73	1.337	30	
NB1_E	Male	GSQ	4.00	1.789	6	
		PSQ	4.43	0.976	7	
		Total	4.23	1.363	13	
	Female	GSQ	1.89	1.054	9	
		PSQ	2.63	1.302	8	17.191
		Total	2.24	1.200	17	(p=0.000)*
	Total	GSQ	2.73	1.710	15	
		PSQ	3.47	1.457	15	
		Total	3.10	1.605	30	
NB2_H	Male	GSQ	3.83	1.169	6	
		PSQ	3.14	0.690	7	
		Total	3.46	0.967	13	
	Female	GSQ	4.22	0.667	9	5.360
		PSQ	4.63	1.598	8	(p=0.029)*
		Total	4.41	1.176	17	
	Total	GSQ	4.07	0.884	15	
		PSQ	3.93	1.438	15	
		Total	4.00	1.174	30	
NB2_E	Male	GSQ	3.67	1.966	6	
		PSQ	5.43	1.718	7	
		Total	4.62	1.981	13	
	Female	GSQ	3.56	1.236	9	
		PSQ	3.25	1.165	8	4.251
		Total	3.41	1.176	17	(p=0.049)$^{\times}$
	Total	GSQ	3.60	1.502	15	
		PSQ	4.27	1.792	15	
		Total	3.93	1.660	30	
DA_ES	Male	GSQ	2.000	1.265	6	
		PSQ	5.000	1.155	7	
		Total	3.615	1.938	13	0.517
	Female	GSQ	2.889	1.900	9	(p=0.479)$^{\times}$
		PSQ	3.250	1.832	8	
		Total	3.059	1.819	17	
	Total	GSQ	2.533	1.685	15	
		PSQ	4.067	1.751	15	
		Total	3.300	1.860	30	
SA_TT	Male	GSQ	404.333	42.117	6	
		PSQ	522.429	58.844	7	
		Total	467.923	78.900	13	
	Female	GSQ	371.000	73.743	9	
		PSQ	453.625	79.732	8	4.225
		Total	409.822	85.483	17	(p=0.050)*
	Total	GSQ	384.333	63.456	15	
		PSQ	485.733	76.974	15	
		Total	435.033	86.391	30	
SA_TE	Male	GSQ	1.500	0.837	6	
		PSQ	4.286	1.380	7	
		Total	3.000	1.826	13	
	Female	GSQ	2.333	1.732	9	
		PSQ	4.250	1.753	8	0.502
		Total	3.235	1.954	17	(p=0.485)$^{\times}$
	Total	GSQ	2.000	1.464	15	
		PSQ	4.267	1.534	15	
		Total	3.133	1.871	30	
RT_SRT	Male	GSQ	396.2450	48.048	6	
		PSQ	422.7314	34.605	7	
		Total	410.5069	41.828	13	
	Female	GSQ	385.1256	68.525	9	
		PSQ	413.8450	91.417	8	0.166

		Total	398.6406	78.882	17	(p=0.687)[×]
	Total	GSQ	389.5733	59.494	15	
		PSQ	417.9920	68.650	15	
		Total	403.7827	64.752	30	
RT_CRT	Mal	GSQ	581.4933	131.806	6	
		PSQ	663.1386	126.841	7	
		Total	625.4562	130.652	13	
	Female	GSQ	521.8322	101.908	9	
		PSQ	480.8063	75.802	8	9.098
		Total	502.5259	90.288	17	(p=0.006)[*]
	Total	GSQ	545.6967	114.255	15	
		PSQ	565.8947	136.505	15	
		Total	555.7957	124.109	30	

×p>0.05, statistically not significant, *p<0.05, statistically significant

number of errors committed in the N back 2 test (F=4.25, p<0.05), the total time taken in the test for sustained attention (F=4.225, p<0.05), and in the time taken in the test of choice reaction time (F=9.09, p<0.01).

Discussion

We found a significant mean difference between good sleepers and poor sleepers in the number of errors committed in the test of divided attention, total time taken in the test of sustained attention, and the total number of errors committed in the test of sustained attention. All the specific tests indicated above revealed decreased performance in those who had difficulties sleeping. The present finding is in line with a previous study, which found a strong correlation between poor sleep quality and decreased sustained attention [16]. Another study by Alvaro *et al* in 2013 stated that sleep latency positively correlates with attention [17].

An essential component of general cognitive functioning is working memory. Working memory refers to our capacity to retain knowledge in our brains for shorter periods of time and use it for tasks like doing math problems mentally, paying attention to spoken instructions, memorising directions, etc. So good sleep is required for the improvement of memory functions, and sleep deprivation deteriorates memory, which we observed in our study.

No significant difference was found between good sleepers and poor sleepers in the N Back 1 test (t=0.539, p>0.05) and the N Back 2 test of working memory (t=0.306, p>0.05). Our findings are contrary to another study in which sleep reduction produced a decrease in the phonological and visuospatial storage components of working memory, which may interfere with processing verbal information and solving problems that require spatial analysis [18]. Miyata *et al*. (2013) have also attested that working memory via the n-back test (1-back) was correlated with age and sleep efficiency [19].

Reaction time refers to the time elapsing between the beginning of the application of a stimulus and the beginning of an organism's reaction to it. On comparing the scores of reaction time based on sleep quality, we didn't observe a statistically significant difference between good sleepers and poor sleepers in either simple reaction time (t= 1.212, p>0.05) or choice reaction time (t= 0.439, p>0.05). However, contradictory results have been reported by previous studies, which maintained that loss of sleep can have a major impact on dynamic changes in mental attention and reaction time [20]. Other researchers reported that total sleep time, age, and sleep efficiency were correlated with reaction time performance [19]. One plausible reason for no difference in reaction time between good sleepers and poor sleepers in the present study could be that there was not much difference in the age of the participants, and hence they were more or less similar in their agility towards reacting to stimuli.

Although no single finding has unanimous support, conclusions from multiple studies suggest that females, on average, score higher on tasks that require rapid access to and use of phonological and semantic information in the long-term memory, production, and comprehension of complex prose, fine motor skills, and perceptual speed. Males, on average, score higher on tasks that require transformations in visual-spatial working memory, motor skills involved in aiming, spatiotemporal responding, and fluid reasoning, especially in abstract mathematical and scientific domains. In addition to the analysed differences in performance in the cognitive functioning tests based on sleep quality (table 1), it was therefore considered worthwhile to explore the possibility of gender differences in performance based on sleep quality.

Conclusion

Participants with poor sleep quality significantly differed from those with good sleep quality and committed a greater number of errors in the triad test of divided attention, took more time, and committed more errors in the completion of the digit vigilance test of sustained attention. A gender advantage favouring females was seen on the test of working memory, the test for sustained attention, and the test for choice reaction time. Sleep patterns are associated with cognitive test performance, and optimising sleep duration and quality should be an important consideration for cognitive functions.

Limitation and future scope of the study

This is a cross-sectional pilot study with a limited sample size. The study design does not consider other variables that could affect cognitive functioning like educational qualification, intelligence quotient, socio-adaptive functioning, etc. Subjective complaints of the participants about sleep in their day-to-day functioning were not evaluated. Future research with a large sample size and overcoming all the above-mentioned issues is recommended. Future study designs can include both quantitative and qualitative analysis for a better understanding of cognitive functions. Considering more cognitive variables like processing speed, planning abilities, response inhibition, and visuospatial abilities may strengthen future research in this field.

Relevance of the study

This pilot study explored the association between gender and quality of sleep in cognitive impairment. Findings suggest large-scale research is required to explore more domains of cognitive impairment and sleep deprivation.

Abbreviations

Good sleep quality (GSQ), Pittsburgh Sleep Quality Index (PSQI), Poor Sleep quality (PSQ), Reaction time (RT), Subjective cognitive decline (SCD)

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None.

Authors' contribution

a. Study planning: AR, BPN
b. Data collection: AR, BPN
c. Data analysis/ interpretation: MMH, MSM
d. Manuscript writing: AR, BPN
e. Manuscript revision: AR, BPN
f. Final approval: AR, BPN
g. Agreement to be accountable for all aspects of the work: AR, BPN

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Availability of data and materials

All data underlying the results are available as part of the article.

Competing interests

The authors declare that there are no conflicts of interest to disclose in relation to this manuscript.

Author information

[1]Akhil Rajeev, M. Sc (Applied Psychology), M. Phil (Clinical Psychology), Fellowship in Clinical Neuropsychology (NIMHANS), Consultant Clinical Psychologist, Travancore Medical College Hospital, Kerala, India. ORCID
[2]Dr. Bindu P. Nair, M.A (Psychology), PhD (Psychology), Associate Professor, Department of Psychology, University of Kerala, Thiruvananthapuram, Kerala, India. ORCID

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