Journal of Scientific & Industrial Research
Vol. 82, September 2023, pp. 983-988
DOI: 10.56042/jsir.v82i9.3551

Design and Implementation of Cognitive Assessment Tool for Working Memory and Attention based on PGI Memory Scale

Shilpa Walia[1,2]*, Neelesh Kumar[1,2], Praveen Kumar Khosla[3] & Sandeep Grover[4]

[1]Academy of Scientific and Innovative Research (AcSIR), Ghaziabad 201 002, Uttar Pradesh, India

[2]Biomedical Applications Group, CSIR-Central Scientific Instruments Organisation, Chandigarh 160 030, India

[3]Chitkara University Institute of Engineering Technology, Chitkara University, Punjab 140 401, India

[4]Department of Psychiatry, Postgraduate Institute of Medical Education and Research (PGIMER), Chandigarh 160 012, India

Received 26 July 2022; revised 17 June 2023; accepted 15 July 2023

Cognitive function is one of the most fundamental psychological functions that play a significant role in person's daily life. Impairment in cognitive function can impacts the daily functioning and overall performance of the person. A digital application could be an accessible and convenient method for the effective evaluation of cognition. The proposed Cognitive Assessment Digital Smart Tool (CADST) evaluates the Attention (ATT) and Working Memory (WM) parameters of cognition. The outcome measures of CADST were evaluated against PGI Memory Scale (PGIMS) and Montreal Cognitive Assessment (MoCA). Usability testing for the CADST tool was performed using the Post–Study System Usability Questionnaire (PSSUQ). A total of 30 healthy participants were recruited (women = 12, men = 18; age (M ± SD) = 35.6 ± 10.63 y. o.). The feasibility study analysis revealed a significant moderate to strong correlation between the total scores of CADST and PGIMS ($r = 0.75$; $p < 0.001$) and a low to moderate correlation between the total scores of CADST and MoCA ($r = 0.44$; $p < 0.001$). Subtests of CADST and PGIMS showed strong correlation for ATT ($r = 0.81$; $p < 0.001$) and moderate correlation for WM ($r = 0.51$; $p < 0.001$). Similarly, subtests of CADST and MoCA showed moderate correlation for ATT ($r = 0.63$; $p < 0.001$) and low correlation for WM ($r = 0.24$; $p = 1.82$). CADST showed a high correlation with PGIMS for evaluating ATT and WM symptoms of cognition provide evidence of convergent validity. CADST is the first digital smart screening tool based on PGIMS for ATT and WM using web–based technology. The overall usability ratings showed high acceptance for system usage, interface and information quality.

Keywords: Cognition, Digital screening, Evaluation, Memory, Mobile application

Introduction

Cognition refers to a wide range of mental processes and abilities, including perception, attention (ATT), memory, language, problem–solving, and decision–making. Cognitive impairments are observed in the majority of individuals diagnosed with psychosis and are present across a wide range of domains such as ATT, Working Memory (WM), executive function.[1] Impairments in these cognitive functions deteriorates the overall functionality of affected individuals.[2] There is good evidence that cognitive dysfunction strongly correlates with the social outcome, independent living, Quality of Life (QOL), and acquiring skills in psychosocial rehabilitation programs.[3]

Assessment of cognitive function is an essential component of the psychological, psychiatric, and neurological evaluation. A large number of cognitive assessment tools are available worldwide which are paper and pencil based screening tools such as Mini–Mental State Examination (MMSE) and Hindi version of MMSE (HMSE)[4], Montreal Cognitive Assessment (MoCA) and different versions of Addenbrooke's Cognitive Examination (ACE).[5] Recent technological advancements have created the opportunity for implementation of digital platforms for cognitive screening such as Mini Cog,[6] Brain Game,[7] electronic MoCA (eMoCA),[8] Cog State[9] and Cognistat.[10] These tools have been developed for populations in which they are intended to be used. The MMSE is one of the most widely used screening tools, but it has many shortcomings in terms of sensitivity, a prominent ceiling effect, and uneven sampling of cognitive domains.[11] The available cognitive screening tools are adapted and translated for varied populations with different educational levels.[12–13]

*Author for Correspondence
E-mail: shilpa.walia@csio.res.in

To be used in India, the development of these tools requires adaptation and validation of the existing tests in the local language to improve the sensitivity or to search for measures with adequate cross–cultural validity.[14] Indians do not just differ by religion but also by culture and language. It is known that India is not a single language nation, but there are around 22 official languages in India[15] and unfortunately, the cognitive assessment tool is proving to be an enormous challenge among the Indian population. Some tools are available for use in the Indian population, but are adapted and translated versions of their original tools to ensure linguistic and cultural equivalence for other population. There are minimal numbers of Indian standard cognitive test paper and pencil batteries, such as Post Graduate Institute Memory Scale (PGIMS),[16] NIMHANS Neuropsychological Battery,[17] and AIIMS neuropsychological battery,[18] but a few are limited to the time of administration, language, and education. With advances in technology, electronic/digital assessments during clinical trials has a good potential for improving efficiency and reliability of testing cognitive parameters, also assisting integrating performance scores into digital health data record. By considering cultural factors and incorporating diverse perspectives, this study presents the Cognitive Assessment Digital Smart Tool (CADST) to evaluate the two major cognitive parameters such as ATT and Working Memory (WM) for promoting equity, accuracy, and fairness in cognitive evaluations.

Methods

Measures

After an extensive review of literature, two significant domains of cognition were selected, including ATT and WM.

Cognitive Assessment Digital Smart Tool (CADST)

The CADST tool, which was developed for this study, includes sections for assessment such as; a) the homepage that includes a login option, patient information (add/ open existing patient list), and open database; b) the verbal and audible instructions to the user for each test, option to choose assessment test and c) The third section of the CADST contains a set of 3 short cognitive assessment tests; Digit Forward Span (DFS) and Digit Backward Span (DBS) for ATT and Delayed Recall (DR) for WM assessment. These all tests were automated versions of PGIMS, including additional performance parameters such as correct and incorrect attempts, score of each test, reaction time, total time of assessment, and database storage for screening of cognitive parameters. The time taken to administer the CADST is 5–6 min. The CADST supports the English and Hindi language. The CADST tool framework is shown in Fig. 1.

A detailed description of each CADST test can be found in Table 1.

Standard Neuropsychological Tools

Two standardized neuropsychological assessment tools were used to investigate the correlation of CADST for ATT and WM. Tools included were: i)

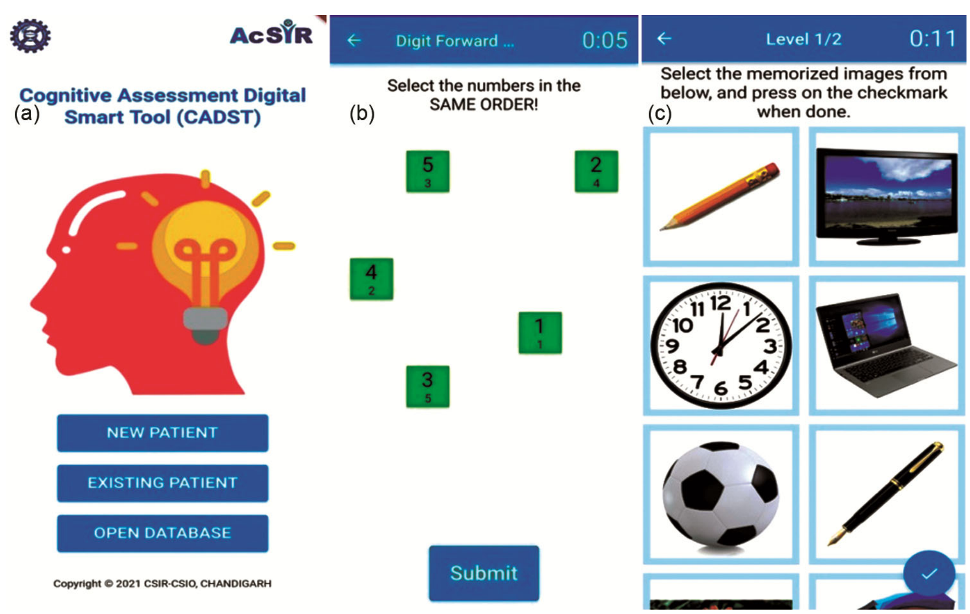

Fig. 1 — The user interface of CADST tool: (a) home page, (b) ATT (c) WM test

Table 1 — Description of the CADST subtests

Test features	Test 1: DFS[a]	Test 2: DBS[b]	Test 3: DR[c]
Measure	ATT		WM
Scoring criteria	Total No. of correctly recalled digits	Total No. of correctly recalled digits	Total No. of correctly recalled words
Maximum score	08	08	10
Practice Test	No	No	No

Note: [a]A set of digit sequences will be displayed onscreen (1 digit/second). The user has to select the digits in the same sequence.
[b]A set of digit sequences will be displayed on screen (1 digit/second). Following that, the user has to select the digits in opposite sequence.
[c]An audio and a visual file containing a list of 5 words will be displayed on screen (1 image/second). Following that, the user has to recall and select as many words as possible (distraction of 1min). This test is repeated 1 more time (2 trials in total) using the different word lists.

PGIMS, consists of ten subtests of cognition i) remote memory, ii) recent memory, iii) mental balance, iv) ATT/ concentration, v) DR, vi) immediate recall, vii) retention for similar pairs viii) retention for dissimilar pairs, ix) visual retention and x) recognition.[19] In this study, ATT and DR subtests were included for assessment and total time to administer the PGIMS was 5–7 min. It is applicable for individuals with varying educational and language backgrounds and considers being a valid tool for Indian multicultural society; ii) MoCA, to detect the cognitive impairments in clinical settings.[20] Various cognitive parameters are assessed in MoCA such as WM, DR, ATT, language and other cognitive parameters.[21] In this study, 3 subtests of ATT: taping task, backward series subtraction task, DFS, DBS and DR for WM were included for assessment. Total time to administer the MoCA was 6–8 min and score was scaled for ATT (0–16) and WM (0–10) for data analysis.

Technical Specifications and Apparatus

The CADST tool was developed in the Android Studio Integrated Development Environment (IDE) (version 3.5.3) developed by Google and JetBrains company.[22] Program was written in Kotlin language. The CADST data was stored and synchronized over the Firebase cloud.

Participant Recruitment

Participants were recruited from 12th August 2021 to 08th September 2021. A total of 30 healthy participants, without any visual or auditory impairment, which cannot be corrected by aids, 18–60 years, able to comprehend the English or Hindi language were recruited for this study. The participants with any mental illness or neurological disorder were excluded from this study.

Procedure

The experimental procedure was done into different stages. At the beginning, the participants introduced about the detailed description of the study and instruments/tools used. Then, with the signing up of the consent form, the participant's demographic details were recorded. In 1st stage, the participants were evaluated on CADST tool for ATT and WM assessment as shown in Table 1. In 2nd stage, same participants were evaluated on PGIMS and MoCA with a gap of XX minutes between the different batteries. After assessment part, survey questionnaire was filled by each participant to measure their perceived satisfaction of using CADST tool.

Usability Testing

The CADST tool usability was assessed using the Post–Study System Usability Questionnaire (PSSUQ) questionnaire.[23] It is 16 item post–test survey questionnaire that calculates 3 crucial metrics to rate the usefulness of a system, information quality and interface equality. The PSSUQ rating scale ranged from 1–7 for each question. The higher score corresponds to disagree strongly.

Ethical Approval

The Organization Ethical Committee approved the study at the CSIR–Central Scientific Instruments Organisation (CSIR–CSIO), Chandigarh (letter no. IEC/CSIO/2021/11).

Statistical Analysis

The data was analysed using SPSS tool (ver. 20.0). All the quantitative variables' results were reported either as mean, standard deviation, or frequency (percentage). The continuous variables were compared by using a two–tail T–test. The correlation between two variables was measured using the Pearson Correlation test. The p–value ≤ 0.05 was considered to be significant.

Results and Discussion

Participants Statistics

The study included 30 healthy participants. The participants' mean age was 35.6 (SD: 10.63) years, with 13% of them aged 46 years or above. Out of all

Table 2 — Cognitive functioning in the study sample based on age differences

Variables	Whole Sample N= 30	Age group		Comparison statistics T–*test (p–value)*
		Age 18–45 year (*n* = 24)	> 45 years (n = 06)	
Age(mean, SD)	35.6 (10.63)	31.3 (6.03)	53 (5.96)	<0.001*
Mean CADST score (%)				
ATT WM	10.66(67)	11.5 (72)	7.33 (46)	0.004467*
	9.66 (97)	9.79 (98)	9.16 (92)	0.012844*
Mean PGIMS score (%)				
ATT WM	10.36 (65)	11.08 (69)	7.5 (47)	0.0031*
	9.03(90)	9.45 (95)	7.33 (73)	0.0155*
Mean MoCA score (%)				
ATT WM	5.33 (89)	5.58 (93)	4.33 (72)	0.0503
	3.13(63)	3.41 (68)	2 (40)	0.0612

Note: *Statistically significant

Table 3 — Correlation analysis between performance measures of CADST, PGIMS, and MoCA

Variables	Pearson *r*	*P*–value
CADST & PGIMS		
ATT	0.80	< 0.001*
WM	0.51	0.004*
CADST & MoCA		
ATT	0.24	0.82
WM	0.64	< 0.001*
PGIMS & MoCA		
ATT	0.34	0.16
WM	0.64	0.003*

Note: *Statistically significant

Table 4 — Usability evaluation of the CADST

Factor	(N= 30), Score[a] for each factor, mean (SD)
Overall score	1.36 (0.25)
System usage	1.24 (0.19)
Information squality	1.53 (0.58)
Interface quality	1.33 (0.29)

Note: [a]Scores ranged from 1 (strongly agree) to 7 (strongly disagree)

participants, 40% were women, and 60% were men. All participants were educated for at least 10 years with diverse occupational backgrounds such as computer science, electronics, physics, biomedical engineering, and accounts. When those aged up to 45 years and those aged above 45 years were compared, it was seen that those who were younger had better performance on CADST and PGIMS subtests mean scores (Table 2).

When the correlation between CADST and PGIMS tool for ATT and WM was evaluated, there was a moderate and strong correlation between both tools for WM and ATT test, respectively. When the association of CADST and MoCA was evaluated, there was a low and moderate correlation between both tools for WM and ATT test, respectively. Correlation analysis between

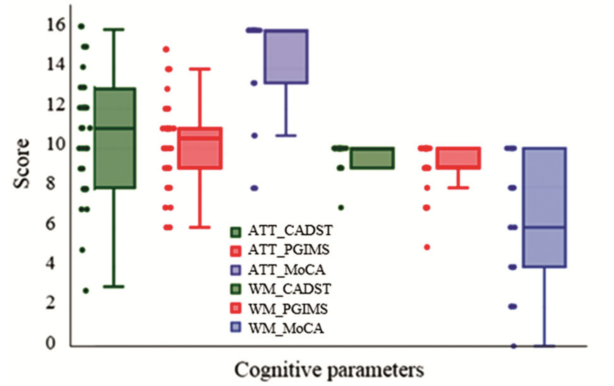

Fig. 2 — Box plots of participants' scores in CADST, PGIMS, and MoCA

performance on PGIMS and MoCA tool for ATT and WM was evaluated; there was a low and moderate correlation between both the tools for WM and ATT test, respectively (Table 3, Fig. 2).

Usability Outcomes

When the usability of CADST was evaluated, in terms of system usage, interface, and information for the CADST usability, the mean scores on PSSUQ were in the acceptable range (Table 4).

Existing digital cognitive assessment tools are developed and validated in Western countries. However, most of these tools are not validated in the Indian socio–cultural context. Many studies have reported that the available cognitive assessment instruments differ widely in the population intended for use, administration time, interpretation of results, and the assessment of certain cognitive domains, and little guidance is available for selection among these instruments for clinical trials.[24] Some of the studies have reported that there are translated and adapted tools for cognitive assessment.[25–27] Clinicians from developing countries use translated and adapted cognitive assessment tools to suit their culture and language.[28] However, there is a lack of information about digital tools developed in India to assess various cognitive functions.

This study aimed to assess the feasibility of using CADST in the Indian population, which is the first automated cognitive assessment tool based on PGIMS; a gold–standard tool to assess cognition. The results from this study reveal that adult group showed significantly higher mean score than old group for ATT and WM. Old population, presumably at higher risk to cognitive decline. It was also observed that the CADST tool correlated well with PGIMS and MoCA for ATT and WM assessment. There was a moderate to strong correlation between CADST and PGIMS total scores for ATT and WM subtests. There was a low to moderate level of correlation between total scores of CADST and MoCA total scores for ATT and WM subtests. The CADST's usability evaluation by participants revealed high acceptability of tool with scores less than 2 (strongly agree) for overall usage, system usage, interface, and information quality. Based on these findings, it can be said that CADST is well suited for the Indian population and is feasible to assess ATT and WM parameters of cognitive function.

Conclusions

The introduced CADST is a smart digital tool for cognitive assessment which is evaluated against globally available PGIMS and MoCA tools and applied to a limited number of participants in order to understand its potential as a useful tool. A strong correlation was observed between the scores of CADST and PGIMS and moderate correlation between scores of CADST and MoCA. The outcome of this study demonstrates the adequate feasibility and usability between well–established PGIMS and CADST. Utilizing digital version of PGIMS for WM and ATT in research settings has a potential in terms of improving efficiency and reliability of this tool. The CADST's usability evaluation reveals high acceptability of CADST tool by participants. The majority of the participants feel CADST is an easy and comfortable tool for assessment.

Despite promising results, there are some limitations in this study. The evaluation of the CADST is limited to sample size, English or Hindi–speaking and well–educated participants only. Two major parameters of cognitive function such as ATT and WM are evaluated in CADST tool. In future, other cognitive parameters can be included in this tool for overall screening of cognitive dysfunction among various neurological and psychiatric conditions. The use of this tool can be explored not only in the clinical population but can be used in screening for cognitive impairment or in tracking changes that occur in a healthy population. Overall, digital smart tool based cognitive testing has the potential to revolutionize cognitive assessment by making it more accessible, convenient, and ecologically valid for population– level screening and clinical practice.

Acknowledgment

We sincerely thank all the participants who contributed to the research.

Conflicts of Interest

The authors declare no conflicts of interest.

References

1 Khalil M, Hollander P, Raucher–Chene D, Lepage M & Lavigne K M, Structural brain correlates of cognitive function in schizophrenia: A meta–analysis, *Neurosci Biobehav Rev*, **132** (2022) 37–49, https://doi.org/10.1016/j.neubiorev.2021.11.034.

2 Zoupa E, Bogiatzidou O, Siokas V, Liampas I, Tzeferakos G, Mavreas V, Stylianidis S & Dardiotis E, Cognitive rehabilitation in schizophrenia–associated cognitive impairment: A review, *Neurol Int*, **15(1)** (2022) 12–23, https://doi.org/10.3390/neurolint15010002.

3 Song D, Yu D S, Li PW, He G & Sun Q, Correlates of health–related quality of life among Chinese older adults with mild cognitive impairment, *Clin Interv Aging*, **16** (2019) 2205–2212, https://doi.org/10.2147/CIA.S227767.

4 Tiwari S C, Tripathi R K & Kumar A, Applicability of the Mini–Mental State Examination (MMSE) and the Hindi Mental State Examination (HMSE) to the urban elderly in India: A pilot study, *Int Psychogeriatr*, **21(1)** (2009) 123–128, https://doi.org/10.1097/00005053-198610000-00005.

5 Julayanont P, Phillips N, Chertkow H & Nasreddine Z, in *Cognitive screening instruments*, 2nd edn, edited by Larner A J, (Springer) 2017.

6 Borson S, Scanlan J M, Chen P & Ganguli M, The Mini–Cog as a screen for dementia: Validation in a population–based sample, *J Am Geriatr Soc*, **51(10)** (2003) 1451–1454, https://doi.org/ 10.1046/j.1532-5415.2003.51465.x.

7 Strobach T & Huestegge L, Evaluating the effectiveness of commercial brain game training with working–memory tasks, *J Cogn Enhanc*, **1(4)** (2017) 539–558, https://doi.org/10.1007/s41465-017-0053-0.

8 Berg J L, Durant J, Leger G C, Cummings J L, Nasreddine Z & Miller J B, Comparing the electronic and standard versions of the Montreal cognitive assessment in an outpatient memory disorders clinic: A validation study, *J Alzheimers Dis: JAD*, **62(1)** (2018) 93–97, https://doi.org/10.3233/JAD-170896.

9 Mielke M M, Machulda M M, Hagen C E, Edwards K K, Roberts R O, Pankratz V S, Knopman D S, Jack C R &

Petersen R C, Performance of the CogState computerized battery in the Mayo Clinic Study on Aging, *Alzheimers Dement*, **11(11)** (2015) 1367–1376, https://doi.org/10.1016/j.jalz.2015.01.008.

10 Melgar M I, Ramos Jr M A, Cuadro C K, Yusay C T, King E K & Maramba D H, A translating COGNISTAT and the use of the cognitive interview approach: Observations and challenges, *Madridge J Behav Soc Sci*, **5(1)** (2022) 89–95.

11 Srinivasan S, The concise cognitive test for dementia screening: Reliability and effects of demographic variables as compared to the mini mental state examination, *Neurol India*, **58(5)** (2010) 702–707, https://doi.org/10.4103/0028-3886.72167.

12 Rosli R, Tan M P, Gray W K, Subramanian P & Chin A V, Cognitive assessment tools in Asia: A systematic review, *Int Psychogeriatr*, **28(2)** (2016) 189–210, https://doi.org/10.1017/S1041610215001635.

13 Ng K P, Chiew H J, Lim L, Rosa–Neto P, Kandiah N & Gauthier S, The influence of language and culture on cognitive assessment tools in the diagnosis of early cognitive impairment and dementia, *Expert Rev Neurother*, **18(11)** (2018) 859–69, https://doi.org/10.1080/14737175.2018.1532792.

14 Chopra S, Kaur H, Pandey R M & Nehra A, Development of neuropsychological evaluation screening tool: An education–free cognitive screening instrument, *Neurol India*, **66(2)** (2018) 391–399, https://doi.org/10.4103/0028-3886.227304.

15 Porrselvi A P & Shankar V, Status of cognitive testing of adults in India, *Ann Indian Acad Neurol*, **20(4)** (2017) 334–340, https://doi.org/10.4103/aian.AIAN_107_17.

16 Karim M & Venkatachalam J, A randomized pilot study of a cognitive intervention for the elderly with mild cognitive impairment, *ECS Trans*, **107(1)** (2022) 8383, https://doi.org/10.1149/10701.8383ecst.

17 Botta R, Keshav K J, Kutty B, Mahadevan A, Pal P K & Yadav R, NIMHANS Neuropsychological battery for elderly in parkinson's disease patients: Validation and diagnosis using MDS PD-MCI task force criteria in Indian population, *Ann Indian Acad Neurol*, **26(3)** (2023) 247–255, https://doi.org/10.4103/aian.aian_903_22.

18 Roy R R, Manjhi A & Mahto J, A comparative study on receptive speech among patients suffering from schizophrenia with AIIMS comprehensive neuropsychological battery, *Indian J Health Wellbeing*, **7(1)** (2016) 113–116.

19 Halder S & Mahato A, Identifying multiple domain memory impairment in high–risk group for Alzheimer's disorder, *J Geriatr Ment Health*, **6(1)** (2019) 14–18, https://doi.org/10.4103/jgmh.jgmh_4_19.

20 Serrano C M, Sorbara M, Minond A, Finlay J B, Arizaga R L, Iturry M, Martinez P, Heinemann G, Gagliardi C, Serra A & Magliano F C, Validation of the Argentine version of the Montreal Cognitive Assessment Test (MOCA): A screening tool for mild cognitive impairment and mild dementia in elderly. *Dement Neuropsychol*, **14(2)** (2020) 145–152, https://doi.org/10.1590/1980-57642020dn14-020007.

21 Caili W, Paul D & Carmen M, A pilot study to measure cognitive impairment in patients with severe schizophrenia with the Montreal Cognitive Assessment (MoCA), *Schizophr Res*, **158(1)** (2014) 151–155, https://doi.org/10.1016/j.schres.2014.07.006.

22 https://developer.android.com/studio/intro (11 August 2021).

23 Pyae A, A usability evaluation of the Google Home with non–native English speakers using the system usability scale, *Int J Netw Virtual Organ*, **26(3)** (2022) 172–194, https://doi.org/10.1504/IJNVO.2022.122849.

24 Bakkour N, Samp J, Akhras, K, El Hammi E, Soussi I, Zahra F, Duru G, Kooli A & Toumi M, Systematic review of appropriate cognitive assessment instruments used in clinical trials of schizophrenia, major depressive disorder and bipolar disorder, *Psychiatry Res*, **216(3)** (2014) 291–302, https://doi.org/10.1016/j.psychres.2014.02.014.

25 Kang K W, Choi S M, Shin M H, Kweon S S, Park H C, Dong–Chan O, Choi M J, Lee M H, Kim D E, Choi K H & Baek S J, Cognitive function and activities of daily living in people affected by leprosy: A cross–sectional, population–based, case–control study, *Neurol India*, **64(4)** (2016) 656–660, https://doi.org/10.4103/0028-3886.185410.

26 Das D, Biswas A, Roy A, Sauerbier A & Bhattacharyya K B, Cognitive impairment in idiopathic Parkinson's disease, *Neurol India*, **64(3)** (2016) 419–427, https://doi.org/10.4103/0028-3886.181533.

27 Krishnan S, Justus S, Meluveettil R, Menon R N, Sharma S P & Kishore A, Validity of Montreal Cognitive Assessment in non–English speaking patients with Parkinson's disease, *Neurol India*, **63(1)** (2015), 63–67, https://doi.org/10.4103/0028-3886.152637.

28 Jacinto A F, Brucki S M D, Porto C S, Martins M A, Citero V A & Nitrini R, Suggested instruments for general practitioners in countries with low schooling to screen for cognitive impairment in the elderly, *Int Psychogeriatr*, **26(7)** (2014) 1121–1125, https://doi.org/10.1017/S1041610214000325.