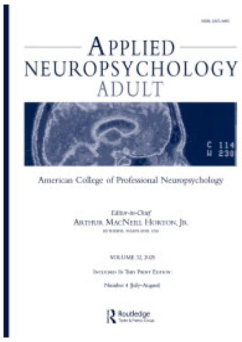

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Adaptation of the Cognitive Screening Test (Triagem Cognitiva – TRIACOG) for computer-mediated assessments: TRIACOG-Online

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ABSTRACT

This study aims to present the adaptation, evidence of content validity and results of a pilot study of the Cognitive Screening Test - Online (TRIACOG-Online) in a clinical sample of patients after stroke. The process comprised four stages: 1) Adaptation of the instructions, stimulus and responses; 2) Seven experts analyzed the equivalence between the previous printed version and the online version; 3) A pilot study was carried out with seven adults who had experienced a stroke in order to check the comprehension and feasibility of the items; and 4) The development of the final version of TRIACOG-Online. Expert validity testing of the questionnaire yielded a content validity index (CVI) of 100% for correspondence and construct in 13 items, and a CVI of 87.71% in four items. In the pilot study, problems related to the internet led to the decision to use a single section form. No difficulties were observed in carrying out the tasks and understanding the instructions. Participants reported being able to adequately visualize the stimuli and remain motivated to complete the tasks presented. It was shown that TRIACOG-Online evaluated the same constructs as the pencil-and-paper version, can be used in remote neuropsychological assessments and face-to-face settings.

KEYWORDS

Cognitive screening; psychological testing; psychometrics; stroke

Introduction

The use of computerized tests represents a significant advance when it comes to the practice of neuropsychological assessment, incorporating technology and psychometrics to improve the efficiency and accuracy of assessment processes. Instruments for evaluating personality traits and cognitive abilities have demonstrated efficiency and precision when combined with Information and Communication Technologies (ICTs; Hartig & Buchholz, 2020; Millsap, 2011).

The use of computerized psychological tests brings benefits such as greater control over timing, the order of stimulus presentation, accuracy in recording responses and latencies, and the development of alternate forms of the test (Charchat-Fichman et al., 2014; Poletti et al., 2017; Schmand, 2019). Automation can minimize possible application and correction biases and increase the reliability of results (Cohen et al., 2018). It could also be useful for large-scale and low-cost population screening (Bertini et al., 2023). Furthermore, this form of assessment can be useful when in-person sessions are not possible, as experienced during the pandemic period or due to geographic barriers (Chapman et al., 2020), in addition to providing the possibility of continuous diagnoses and treatments (Brearly et al., 2017).

It is worth noting that the literature highlights various ways of using tests mediated by ICTs. The first model involves computerized administration, with or without a therapist mediating the application in the same environment as the patient. The second model involves online application, carried out through remote or distance access. It is important to highlight that the two forms of application are not directly equivalent (Conselho Federal de Psicologia – CFP, 2020a).

These benefits also apply in respect of instruments for carrying out cognitive screening, a study reported that computerized methods can present more accurate and sensitive results than traditional methods (Zhang et al., 2023). Computerized cognitive screening involves the use of advanced technologies, such as computerized tests and specialized software, to efficiently and objectively assess cognitive functions.

Although it presents several advantages, there are still lack of evidence regarding the use of online cognitive screening to evaluate patients after stroke. Brearly et al. (2017) carried out a systematic review and meta-analysis to evaluate the effect of using video conferencing to undertake neurocognitive tests for adults, and whether there was a difference when compared to the results of in-person assessments. The authors analyzed 12 studies comprising 497 healthy participants or those undergoing medical treatment, and found that the application via videoconferencing did not produce significant changes in the test scores. Tests carried out through a high-speed connection were affected by the use of video conferencing. Connection failures or equipment

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malfunctions were not found to be responsible for affecting the results. Verbal tasks, such as digit span, auditory list learning and verbal fluency tests, showed no differences when applied via videoconferencing. However, tests that involve interaction with physical objects, such as the Mini Mental State Examination (MMSE), which requires the naming of common objects such as a pen or watch, showed greater variability in results, making the interpretation of effects difficult (Brearly et al., 2017).

Another systematic literature review on the psychometric properties and usability of remote neuropsychological assessment instruments analyzed 14 studies carried out in Italian samples, with most of the studies involving older adults or neurological patients (Zanin et al., 2021). Two tools for online cognitive screening were analyzed, the telephone and videoconferencing based MMSE, and the Telephone Interview for Cognitive Status. The authors found that the studies demonstrated evidence of validity, reliability, sensitivity and specificity for the tests, demonstrating the clinical applicability of cognitive screenings carried out remotely.

González-Osornio et al. (2022) carried out a study to assess the equivalence of the original and the videoconference versions of the Brief Neuropsychological Battery in Spanish (NEUROPSI Brief). Thirty-two Mexicans aged 16 to 70 divided into four random groups participated in the study, responding to both the original and adapted versions of the instruments - in person and via videoconference. When applied to the general sample, the Wilcoxon test showed statistically significant differences between the in-person application and the application via videoconference. However, this difference did not occur for all groups. Those who started with the videoconference application had greater differences than participants who responded to the in-person test first. The authors concluded that the application of NEUROPSI Brief remotely is viable and meets the needs of respondents and psychological assessment.

Iiboshi et al. (2020) carried out a study with 73 healthy Japanese older adults with mild cognitive impairment or dementia to evaluate the reliability of the Montreal Cognitive Assessment (MoCA), comparing in-person application to application via videoconference. The applications alternated between in-person/videoconference or videoconference/in-person. The authors calculated the intraclass correlation coefficient (ICC), and found a high correlation for the general sample (0.85). For the subgroups, these indices ranged from moderate to high, being 0.82 for participants with mild cognitive impairment, 0.82 for participants with dementia, and 0.53 for healthy participants. The authors found that participants had good satisfaction with the application via videoconference, and highlighted the viability of the application of the MoCA in this modality.

Munro Cullum et al. (2014) analyzed the reliability of a battery of neuropsychological tests administered via videoconference for 83 people with cognitive disabilities and 119 healthy controls. The tests used were: the MMSE, the Hopkins Verbal Learning Test (Revised), the Digit Span forward and backward test, the short form Boston Naming Test, the Letter and Category Fluency test, and the Clock Drawing test. The tests were administered in person and via videoconference, randomly alternating between the means of application. ICCs were calculated and the results demonstrated reliability of the remote tests, with an average ICC of 0.74, varying between 0.55 and 0.91 for the groups. The authors observed consistency between the results for individuals with or without cognitive impairment, demonstrating that the application via videoconference is valid and reliable for the tests applied.

Chapman et al. (2019) compared the results of the MoCA administered to stroke patients in-person and via videoconferencing. The study included 48 adults, 26 of whom were men, with a mean age of 64.6 years ($SD = 10.1$), and with strokes that had occurred between three months and 16 years previously ($M = 5.2$; $SD = 4.0$ years). The assessments took place in person and via videoconference on Zoom over a 15-day interval, randomly alternating. There were no differences in the participants' performances between the in-person and remote applications; however, the ICC found it was low, and there were wide limits of agreement, indicating variability between sessions. It was also observed that no participant variable predicted a difference in MoCA performance. Despite this, the authors concluded that there was evidence to support the use of the MoCA via videoconferencing.

Finally, Chapman et al. (2020), aiming to evaluate the possibility of carrying out neuropsychological assessments via videoconference in stroke patients, applied a battery of instruments with the same sample and randomization as their previous study in 2019. The authors reported that in most of the tests used, performance was not affected by the method of application, demonstrating an agreement between the results in the different methods used, with an ICC ranging from 0.40 to 0.96 in all measurements. This result was not satisfactory only in the Hopkins Verbal Learning Test (revised), as there was lower performance by participants when the test was out via videoconference. The results demonstrated the reliability of the neuropsychological instruments applied via videoconference.

In summary, studies suggest that computerized and remote neuropsychological assessment is feasible and can be performed in different clinical samples. However, to date, there have been no Brazilian studies using computer-mediated neuropsychological instruments with stroke patients. Thus, aim of this study was to present the process of adapting the pencil-and-paper version of the Cognitive Screening instrument - TRIACOG (*Triagem Cognitiva – TRIACOG,* Rodrigues, Bandeira et al., 2021) to be used in a computerized form in in-person or remote assessments (TRIACOG-Online). Specifically, this study investigated the evidence of content validity and carried out a pilot study of the TRIACOG-Online instrument in a clinical sample of stroke patients.

The TRIACOG had previously been shown to present adequate evidence of psychometric properties in a Brazilian context (Rodrigues et al., 2020; Rodrigues, Bandeira et al., 2021; Rodrigues, Salles et al., 2021; Schmidt et al., 2022). The most recent study presents clinical standards of the instrument (Schmidt et al., 2022). This study provides validity evidence for the TRIACOG specifically in post-stroke patients, highlighting its effectiveness in identifying cognitive impairments in this population. This study is warranted, as a stroke is a serious pathology which affects a large number of people annually and has consequences in different areas of life. Assessment with an instrument that can be quickly applied (online or in-person) can contribute to investigating the deficits caused by stroke, and expand access to neuropsychological screening assessments in those Brazilian patients.

Method

The study was divided into four steps. Step 1 – adaptation of the original TRIACOG (pencil-and-paper version) to the TRIACOG-Online (computerized version); Step 2 – analysis by expert judges; Step 3 - pilot study; and Step 4 – development of the final TRIACOG-Online. The specific procedures for each stage are described below:

Step 1: adaptation of the original TRIACOG (pencil-and-paper version) to the TRIACOG-Online (a computerized version)

TRIACOG-Online was developed based on the content of the existing printed version of the Cognitive Screening instrument (TRIACOG; Rodrigues, Salles et al., 2021). The test was developed in Brazil for the assessment of adults (18 to 89 years old) who have suffered a stroke, and are in the acute or chronic phases of the disease. The TRIACOG is assessed individually and takes approximately 20 minutes to complete. It is comprised of 22 subtests, which evaluate eight main neuropsychological domains: orientation (time); episodic-semantic verbal memory (immediate and delayed recall); praxis (constructive and ideomotor); visual episodic memory; auditory attention/working memory; executive functions (verbal fluency, processing speed, inhibition and shifting); language (oral and written comprehension, oral and written expression); and numerical processing (transcoding and calculations). The TRIACOG materials include an instruction manual, a stimulus book, a quantitative scoring protocol and a qualitative analysis protocol (Rodrigues, Salles et al., 2021). Studies of the psychometric properties of the TRIACOG demonstrated that the instrument presented evidence of validity based on content, validity based on the relationship with other variables, validity based on the response process, and validity based on conceptually related constructs (predictive). The instrument also presented inter-rater reliability and temporal stability (Rodrigues et al., 2020; Rodrigues, Bandeira et al., 2021; Rodrigues, Salles et al., 2021; Schmidt et al., 2022).

The adaptations to TRIACOG-Online mostly involved the digitization of the stimuli and the register protocol. The visual stimuli to be presented to patients were inserted in a Power Point presentation, and the form to be completed by the examiner was included in Google Forms. In tasks in which there were no visual stimuli, the task information was presented on the screen, followed by its respective identification number. In tasks involving visual stimuli, they were displayed on the screen. For tasks involving written responses (constructive praxis, calculations, dictated writing and visual memory) the patient was asked to write with a pen (blue or black) and paper in their environment, as we did not have software that would allow the patient to write or draw on the computer screen precisely yet. Accordingly, we chose to maintain the paper-based method because drawing with a mouse or digital pen may not provide the precision and natural feel required for our target population (adults/elderly post-stroke). The tactile sensation, precision, and freedom of movement associated with pencil and paper are essential for capturing organic nuances and expressions crucial for accurate assessment. The aim of TRIACOG-Online is to make the neuropsychological assessment as natural as possible, as if it were carried out in person with materials familiar to the patients.

The equipment required was defined (a computer with a webcam and a screen of at least 14 inches, with the current versions of Chrome, Safari, Firefox or Edge installed, and headphones if necessary), the internet settings, the screen position, and the need for a pen or pencil. Adjustments in the initial instructions were related to: being in an environment (room) that supported the use of the equipment (computer/keyboard/internet networking); being in a room that had lighting suitable for the use of a computer screen; and ensuring there were no interruptions by other persons. The examiner and the patients were co-located, with the patient using a notebook and the examiner using a tablet, both connected via the Internet. The examiner's protocol utilized Google Forms, chosen for its simplicity and accessibility. However, we prioritized data security by ensuring that no personal health information was stored on the web. All data collected were de-identified before storage, protecting the patients' privacy and adhering to data protection standards.

Step 2: analysis by expert judges

To assess content validity, we invited seven expert judges to evaluate the correspondence between the original TRIACOG and the TRIACOG-Online version (Question A), determine if different constructs were being evaluated (Question B), and provide suggestions for improvements (Question C). The experts included PhD candidates (n = 2), PhD holders (n = 4), and a postdoctoral researcher (n = 1), with five of the seven experts being male. Each expert had at least five years of training in psychology (M = 11.8; SD = 4.18), with a minimum of one year of clinical experience (M = 5.8; SD = 4.03) and five years in academia (M = 10.2; SD = 5.06). The qualifications and backgrounds of our evaluators adhere to the standards outlined by the American Educational Research Association et al. (2014). We developed a 20-question survey, corresponding to the number of items in the test, to facilitate this evaluation.

To analyze the agreement index between the experts, Fleiss' kappa analysis and Intraclass Correlation Coefficient (ICC) were conducted in relation to the total responses in Questions A and B. In addition, the Content Validity Index (CVI) related to the experts' responses in each of the tasks analyzed for Question A and B was calculated.

Step 3: pilot study

The pilot study was conducted after the development of a second version of the TRIACOG-Online, based on feedback from expert judges. Their insights and recommendations guided the improvements and refinements made to the second version of the test. Seven stroke patients, three in an acute state admitted to a stroke unit in a general hospital, and four in a chronic state from a physiotherapy school clinic from the university, all seven from the North of Brazil. The patients were aged between 43 and 83 years, three were female and four were male. The inclusion criteria for the study sample were: being over 18 years old, literate, Brazilian, a native speaker of Portuguese, and having had at least one episode of stroke. The exclusion criteria were having any other neurological diagnoses, having a reduced level of consciousness or drowsiness at the time of application.

This study aimed to include individuals from relevant subgroups, as recommended by the guidelines of AERA, APA, and NCME (2014). These subgroups consisted of participants with strokes (both in hospital and clinical settings), encompassing those with and without physical, cognitive, and language sequelae. The diversity of these participants significantly contributed to our understanding of test item functioning and allowed us to make necessary adaptations for the practical use of the instrument. It's worth noting that, for the purposes of this study, the educational level was not considered a relevant variable, as the focus was on practical difficulties related to test administration rather than individual results.

Participants contributed with the aim of assessing the feasibility of the protocol, identifying potential issues, ensuring that participants understood the test language, as well as its design, content, and format. Adjustments were made before conducting a larger study and subsequently making TRIACOG-Online operational. The focus was on evaluating the applicability of the online instrument and the suitability of its items, which could be assessed through small samples. To achieve this, we employed a qualitative evaluation approach without inferential purposes to understand test equity, following the Standards for Educational and Psychological Testing (AERA; APA; NCME, 2014).

The assessments were conducted at the hospital or in the clinic, with the patient using a notebook, and the examiner a tablet. As both were in the same environment, it was not necessary to use headphones. The examiner protocol in Google Forms was divided into different sections for each task. So that after completing each task, the examiner could move to the new section of the protocol (page in the Google Forms). This strategy was adopted to make the process flow more smoothly while the examiner completed the form.

Step 4: development of the final version of TRIACOG-Online

The final step consisted of the development of the final version of TRIACOG-Online, and included the adjustments as a result of the findings of the pilot study. These adjustments were discussed among the authors of the original version of TRIACOG to ensure that the changes needed did not modify the original constructs of the TRIACOG. The researchers also improved the layout and design of the TRIACOG-Online protocol of responses. More details about the concerns and adjustments made will be discussed in the results and discussion.

Results and discussion

Step 1: adaptation of the original TRIACOG (pencil-and-paper version) to the TRIACOG-Online (a computerized version)

First, the authors designed the digital version of the stimuli for the visual tasks, which were contained in the TRIACOG Stimulus Book, using Power Point. The stimuli for the verbal tasks were initially intended to be presented through a recording. The instructions, however, had to be verbalized by the examiner, who read them from the online Google Form. The scores for the tasks were also designed to be registered on the same form. Unlike in the studies by Chapman et al. (2019) and Chapman et al. (2020), who sent the books/stimulus for applying the instruments to the participant, the TRIACOG-Online stimuli were readily accessible to the examiner and the participant. One of the advantages of not sending the printed stimulus books in advance is that it avoids the possibility of the participant looking at the tasks and "rehearsing" the answers (especially for tasks that involve visual memory and rapid serial naming of shapes). With regard to the written answers, the authors decided to keep the original method of answering using a pen (blue or black) and paper that were provided at the location where the assessment was conducted. This was necessary, due to the lack of equipment able to capture words and drawings using the computer. When the tests were applied remotely, the patients were asked to take a photograph of their written response and send it to the examiner.

The examiner interface contained all the instructions, the stimuli and fields for the scores and the typed answers. Google Forms was used for this as it is free and easy to edit, allowing the creation of a research form that can be customized, with the data later being downloaded onto spreadsheets. The other advantages of using this form are its diversity in respect of the types of responses possible in TRIACOG-online (multiple choice, text, check boxes, etc.), in addition to the possibility of including file uploads, and the fact that it works in different internet browsers. This interface provided all the instructions and stimuli for each task, their possible corrections and scores, fields for typing answers when necessary, and a field for uploading files relating to the tasks performed on pencil and paper (written responses). For future studies, we intend to use a more modern platform to minimize the risk of data leakage, automate scoring by the examiner, and provide an automatic performance report of the participant.

Step 2: analysis by expert judges

Table 1 shows the results of the Fleiss Kappa (Matos, 2014; Miot, 2016) and the Intraclass Correlation Coefficient (ICC)

Table 1. Fleiss Kappa and ICC results.

	Agreement percentage	Fleiss' Kappa			ICC				
		Kappa	Z	P	ICC	Lower limit	Upper limit	F Test	P
Question A	92.86%	0.162	3.157	0.002	0.176	0.042	0.406	2,482	0.003
Question B	95.24%	0.125	2.430	0.015	0.144	0.024	0.363	2,259	0.006

Table 2. Evidence of content validity through the answers of the expert judges and calculation of the CVI per task/question.

Task	Question	J1	J2	J3	J4	J5	J6	J7	CVI
1) guidance	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00
2) (2.1) immediate recall (list of words)	A	1	1	0	1	1	1	1	0.86
	B	1	0	1	1	1	1	1	0.86
3) (3.1.1) constructive praxis	A	1	1	0	1	1	1	1	0.86
	B	1	1	1	1	1	1	1	1.00
4) (4.1 and 4.2) auditory attention and working memory (forward and backward digit span)	A	1	1	0	1	1	1	1	0.86
	B	1	0	1	1	1	1	1	0.86
5) (5.1) executive functions (verbal fluency)	A	0	1	1	1	1	1	1	0.86
	B	1	1	1	1	1	1	1	1.00
6) (6.1) language (listening)	A	1	1	1	1	1	0	1	0.86
	B	1	1	1	1	1	0	1	0.86
6) (6.2) language (naming)	A	1	0	1	0	0	0	1	0.43
	B	1	0	1	0	1	0	1	0.57
6) (6.3) language (vocabulary/semantic memory)	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00
3) (3.2) praxis (ideomotor praxis)	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00
6) (6.4) language (reading)	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00
6) (6.5) language (interference processing)	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00
6) (6.6) language (written comprehension)	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00
6) (6.7 and 6.8) language (repetition and writing under dictation)	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00
7) (7.1, 7.2 and 7.3) numerical processing (transcoding and calculation)	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00
3) (3.1) praxis (constructive praxis)	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00
5) (5.2) executive functions and processing speed (rapid serial naming of shapes)	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00
2) (2.2) episodic-semantic verbal memory (late recall)	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00
8) visual memory	A	1	1	1	1	1	1	1	1.00
	B	1	1	1	1	1	1	1	1.00

Legend: CVI: content validity index; 1: Yes; 0: No.

(Koo & Li, 2016; Matos, 2014; Miot, 2016) for TRIACOG-Online. Despite a percentage of agreement that exceeded 90%, the Fleiss Kappa and ICC indices were classified as poor (below 0.5) (Koo & Li, 2016; Matos, 2014; Miot, 2016). However, there were very few items with disagreement between judges, this will be discussed in more detail below.

In Table 1, we observed a low Intraclass Correlation Coefficient (ICC). This reduced consistency can be attributed to two main factors: limited data variation and a restricted range of responses. When data shows little variability and responses are concentrated within a narrow range, ICC values tend to be low. It is crucial to consider these factors when interpreting ICC results.

Table 2 provides evidence of the content validity of the instrument based on the experts' responses and the subsequent calculation of the content validity index (CVI). The experts' detailed answers to each task and question are presented. The agreement between the judges regarding the equivalence of the contents of the original version compared to the TRIACOG-Online version was 100% for 12 of the evaluated tasks and 86% for the remaining five tasks (Question A). When asked whether the online version of the test assessed the same constructs as the original version, there was 100% agreement for 14 tasks and 86% for the remaining three tasks (Question B). These tasks demonstrated acceptable content validity indices, as according to Yusoff (2019), the expected CVI value for six to eight judges is 0.83.

Only the Language task (naming) presented a lower than expected CVI in both questions. One hypothesis to explain this low value is that because the patients were asked to click on the correct answer, rather than verbalizing it, the judges were of the opinion that a different construct would be evaluated than the one initially proposed in the pencil-and-paper version. Thus, this instruction was changed so that the task followed the same instructions as the original version, ensuring the assessment of the same constructs.

The analysis by the expert judges was essential to provide evidence of content validity (Rodrigues, Bandeira et al., 2021).

Regarding the general instructions for TRIACOG-Online, the experts suggested the inclusion of a ban on the use of rulers and calculators when completing the tasks, which had not been previously considered. This suggestion was included in the general instructions relating to before starting the application of the instrument. Well-designed and clear instructions are important for both the patient and the examiner of the test in order to ensure that the assessment process takes place with minimal disruption, as is laid out by the Federal Council of Psychology (CFP) (Conselho Federal de Psicologia – CFP, 2020b) in the Good Practices Guide for Psychological Assessment. For the tasks that require recorded responses, the experts stressed the need to request authorization for any audio recording, and this was also included in the general test instructions.

In relation to suggestions for modifications, the experts suggested not using recordings to present verbal stimuli in the test (the immediate recall task with a list of words, and the auditory attention task/working memory with a forward and reverse digit span), since Brazil presents different accents that which could influence listening comprehension. This suggestion was accepted, as many patients have post-stroke linguistic deficits (Rodrigues et al., 2020) and unfamiliar verbalization can influence test performance. Thus, both the words and digits are verbalized by the test examiner.

In the Language Task (oral comprehension), the experts suggested that the participant should point to the requested figure before clicking on the screen. In Language task (naming), the experts recommended making it clear that the test taker should make a verbal response in relation to the images viewed. To meet these requests, the test instructions were changed, and the item was retained. Based on the suggestions of the experts, a second version of TRIACOG-Online was created. This was tested in a pilot study with stroke adults.

Step 3: pilot study of the TRIACOG-Online

During the pilot study, it was found that dividing the online form into sections resulted in greater delays in its application. This happened because at the end of each task it took a long time to load the next section, and twice caused the questionnaire to return to the first task. This took place due to difficulties related to internet access, with a slow connection hampering the progress of the task, making it necessary to discontinue it before completion. The Internet connection has been described as an important issue in online assessments by the American Psychological Association (APA), the American Educational Research Association (AERA), and the National Council on Measurement in Education (NCME) (Cardoso et al., 2023; Conselho Federal de Psicologia – CFP, 2020b). Brearly et al. (2017) pointed out that although failures may occur in the connection or equipment, they may not necessarily interfere with the results.

Therefore, it was decided not to divide the online form into sections, but to leave it as a single section. When assessing the test with this single section format, the questionnaire was only updated automatically by Google Forms, reducing the time required to complete all the tasks with the participant.

The participants were asked whether they understood the tasks, and all of them reported being able to adequately visualize the stimuli, understand all the instructions and remain motivated to complete TRIACOG-Online. The ease of completing the TRIACOG was also highlighted in the pilot study of the pencil-and-paper version (Rodrigues et al., 2020; Rodrigues, Salles et al., 2021), and no difficulties were observed in the execution of the tasks and the instructions, as they all followed the model previously proposed in the original version of the test (Rodrigues, Bandeira et al., 2021). Therefore, this instrument can be used in hospitals, clinics, outpatient clinics, or any other environment in which neuropsychological assessment of stroke patients is required.

It should be noted that when assessments are conducted in a hospital environment, the examiner may be using a mask which can make it difficult for the participant to understand what they are saying, so it is important to make sure that they can clearly hear what is being said before starting the assessment. There were few difficulties faced by some of the patients during the test due exclusively to the neuropsychological consequences of the stroke.

The evidence provided by the pilot study demonstrated the feasibility of using the online application of the instrument and corroborates the findings of the authors Brearly et al. (2017), Chapman et al. (2019), Chapman et al. (2020), González-Osornio et al. (2022), Iiboshi et al. (2020), Munro Cullum et al. (2014), and Zanin et al. (2021).

Step 4: development of the final version of TRIACOG-Online

The results of the pilot study indicated that no significant changes were required in relation to the instructions, the format and the timing of application of TRIACOG-Online compared to the paper version. Therefore, the final version of TRIACOG-Online comprised the same items as the original version, with only few changes as described in steps 2 and 3. All questions were made available in a single form on Google Forms for the examiner. The main adjustments to the instructions were the prohibition of the use of rulers and calculators, getting authorization for voice recording, and asking the participant to direct the webcam on their hands when carrying out tasks in remote assessments so that the execution of the task could be properly monitored. The tasks relating to constructive praxis (copying and drawing the clock), language (repetition and writing under dictation) and numerical processing (transcoding and calculation) are carried out with a pen and paper and later sent to the examiner as a photo.

To ensure clarity and avoid document mix-ups, it is recommended to include sequential numbering (1 to 6) on the evaluation sheets. This numbering will facilitate the scanning and sending of the sheets after all activities are completed. Table 3 describes all the adaptations made to the final version of TRIACOG-Online for both the participant and examiner interfaces. Table 3 describes all the adaptations made to the final version of TRIACOG-Online for both the participant and examiner interface.

Table 3. Adaptations made for the participant and the examiner in the final version of TRIACOG-Online.

Task	Adaptation for the person evaluated	Adaptation for the examiner
1) Orientation	View slide with task name	The examiner reads the questions, and during the correction process types the answer given by the participant and clicks on the score for the response
2 (2.1) Verbal memory immediate recall (list of words)	View slide with task name	The examiner reads the list of words and then clicks on the score for each correctly repeated word. The final result will be calculated automatically.
3 (3.1.1) Constructive praxis	View the slide with the figure to be copied and memorized, and point the webcam at your hands while executing the drawing, showing the finished drawing on the webcam	Click on the score for each item drawn appropriately, take a screenshot of the screen to scan the drawing or scan via the app later
4 (4.1 and 4.2) Auditory attention and working memory (forward and backward digit span)	View slide with task name	The examiner reads the list of numbers and then clicks on the score for each correctly repeated number. The final result will be calculated automatically.
5 (5.1) Executive functions (verbal fluency)	View slide with task name	Record the participant's audio, type all the words written within 15 and 30 seconds and enter the final score obtained.
6 (6.1) Language (listening)	View slide with the task stimulus, point to the correct stimulus	Click on the stimulus indicated by the participant and click on the task score
6 (6.2) Language (naming)	View slide with task stimulus	The examiner reads the questions and, during the correction process, clicks on the task score
6 (6.3) Language (vocabulary/semantic memory)	View slide with task stimulus	The examiner reads the question and, during the correction process, clicks on the task score
3 (3.2) Praxis (ideomotor praxis)	View slide with task name	Make sure you are viewing the assessment completely, then click on the task score.
6 (6.4) Language (reading)	View slide with task stimulus	Click on the score of each word read correctly. The final result will be calculated automatically.
6 (6.5) Language (interference processing)	View slide with task stimulus	Click on the task score
6 (6.6) Language (written comprehension)	View slide with the task stimulus and point to the correct stimulus	Click on the stimulus indicated by the participant and click on the task score
6 (6.7 and 6.8) Language (repetition and writing under dictation)	View slide with task stimulus	Click on the score for each word written correctly
7 (7.1, 7.2 and 7.3) Numerical processing (transcoding and calculation)	View slide with task stimulus	Click on the score for each task completed appropriately, take a screenshot of the screen to scan the drawing or scan via the app
3 (3.1) Praxis (constructive praxis)	View slide with the name of the task. Point the webcam at your hands while executing the drawing, show the finished drawing on the webcam.	Click on the score for each item drawn appropriately, take a screenshot of the screen to scan the drawing or scan via app
5 (5.2) Executive functions and processing speed (rapid serial naming of shapes)	View slide with task stimulus	Record the audio of the participant, enter the total score, errors and total time to complete the task.
2 (2.2) Episodic-semantic verbal memory (late recall)	View slide with task name	Click on the score of each correctly remembered word. The final result will be calculated automatically.
8) Visual memory	View the slide with the name of the task, you will receive a warning not to view previous drawings. Point the webcam at your hands while executing the drawing, show the finished drawing on the webcam.	Click on the score for each item drawn appropriately, take a screenshot of the screen to scan the drawing or scan via app

Conclusions

The aim of the present study was to assess the evidence of validity based on the content of TRIACOG-Online and its applicability through the use of information and communication technology in patients with stroke. The analyses by expert judges and the content validity index supported the test's robustness. Notably, the experts' insights were instrumental in refining the instrument, enhancing its accessibility for both the examiner and the examinee. Our pilot study indicated that minimal adjustments were necessary, effectively improving the test's performance through the study process.

However, the study has notable limitations. Primarily, the focus on stroke patients may restrict the generalizability of findings across different neurological conditions or populations. Given that only a pilot study has been conducted, a larger sample is essential to broaden these results' applicability. Additionally, the reliance on an internet-based platform may limit use in areas with poor connectivity. To mitigate this, future versions of the application will not require an internet connection to operate fully. There is also an ongoing need to explore the practical utility of remote assessments more comprehensively, including trials with both clinical and control groups to evaluate the consistency of responses between remote and in-person assessments.

Despite these challenges, the study's strengths are significant. It underscores the importance of adapting traditional cognitive assessments for online implementation, particularly in low- and middle-income countries like Brazil, where technological and socioeconomic disparities are huge. This adaptation process not only facilitates wider accessibility but also showcases the potential for scaling up cognitive assessments using digital tools. The findings affirm that cognitive assessments via TRIACOG-Online are feasible, which is pivotal for advancing stroke assessment and enhancing public healthcare across diverse settings.

By documenting these steps and outcomes, this study serves as a valuable reference for others in the field, promoting further research and development in the digital adaptation of neuropsychological tools. Importantly, the development of a tool with these strengths can make a significant contribution to advancing the field of stroke assessment and improving public health care in Brazil.

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