Design of a New Digital Cognitive Screening Tool on Tablet: AlzVR Project

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Keywords: Digital Tablet, Screening, Alzheimer's Disease, Usability.

Abstract: Alzheimer's disease is the first cause of dementia worldwide without any current curative treatment. It represents a public health challenge with an increasing prevalence and associated costs. Usual diagnostic methods rely on extended interviews and paper tests provided by an exterior examiner. We aim to create a novel, quick cognitive-screening tool on a digital tablet. This program, built and edited with Unity®, runs on Android® for the Samsung Galaxy Tab S7 FE®. Composed of seven tasks inspired by the Mini-Mental Status Examination and the Montréal Cognitive Assessment, it browses several cognitive functions. The architectural design of this tablet application is distinguished by its multifaceted capabilities, encompassing not only seamless offline functionality but also a mechanism to ensure the singularity of data amalgamated from diverse sites. Additionally, a paramount emphasis is placed on safeguarding the confidentiality of patient information in the healthcare domain. Furthermore, the application empowers individual site managers to access and peruse specific datasets, enhancing their operational efficacy and decision-making processes. We performed a preliminary usability assessment among 24 healthy patients with a final F-SUS score of "excellent". Participants perceived the tool as simple to use and completed the test in a mean time of 142 seconds.

1 INTRODUCTION

Alzheimer's disease (AD) is the first cause of neurodegenerative decline, affecting millions of people worldwide with a considerable cost for countries (International et al., 2020). In AD, patients progressively lose their cognitive abilities, and behavioral troubles can occur. Without any current and efficient treatment, loss of memory and autonomy become an essential burden for caregivers and families. AD management is a global and public challenge for health systems that face a constantly increasing prevalence in aging populations.

Precocious screening of cognitive decline leads to better and early support for patients and their families. Unfortunately, general practitioners (GPs) do not always have enough time to perform initial cognitive explorations. They address their patients at specialized centers whose appointments can be long, delaying diagnostic but also symptomatic and social measures. These labeled memory consultations are primarily available in hospitals, and the diagnostic process still relies on paper tests involving an exterior examiner.

We have developed the AlzVR project, which aims to propose a multimodal digital program for cognitive screening. The first published program was an autonomous immersive assessment composed of thirteen tasks inspired by MMSE and MoCA and displayed on Oculus Quest® (Maronnat et al., 2020, 2022). This assessment has not yet been tested among an older population, but Clay et al. showed that immersive environments could be efficient in cognitive screening (Clay et al., 2020). However,

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Maronnat, F., Loup, G., Degand, J., Davesne, F. and Otmane, S.
Design of a New Digital Cognitive Screening Tool on Tablet: AlzVR Project.
DOI: 10.5220/0012837800003753

In *Proceedings of the 19th International Conference on Software Technologies (ICSOFT 2024)*, pages 283-292
ISBN: 978-989-758-706-1; ISSN: 2184-2833

using virtual reality in primary care can be challenging to implement. Thus, we developed a new modality of AlzVR, which could be easier to use as a non-immersive environment. This auto-questionnaire would run on a digital tablet with questions inspired by MMSE and MoCA as in the immersive version. The assessment should browse several cognitive functions in a short time.

2 RELATED WORK

Numerous tests exist to assess cognition (global or precise evaluation), but the Mini-Mental Status Examination (MMSE) (Folstein et al., 1975) and the Montréal Cognitive Assessment (MoCA) (Nasreddine et al., 2005) are widely used in primary screening, and most professionals know them. Both tests share several questions and explore approximately the same cognitive functions, even though MoCA evaluates frontal deficits more precisely. They both browse several cognitive functions quickly and can be repeated through the medical following of patients. More recently, the MoCA seems to have a higher sensitivity (Se) than the MMSE in differentiating healthy subjects from demented patients, whereas MMSE still performs a higher specificity (Sp) (Ciesielska et al., 2016). Nevertheless, there are good correlations between the two tests (Bergeron et al., 2017; Chua et al., 2019).

Besides these classical evaluations, numerous authors have developed new screening tools on digital tablets that show good correlations with usual tests. Although several recent systematic reviews have been published (Amanzadeh et al., 2022; Chan et al., 2021; Tsoy et al., 2021), only one meta-analysis with good results focused on digital drawing tasks (Chan et al., 2022). In all these studies, numerical tests could run either on digital tablets or simple computer touch screens and were self or hetero-administered. Unfortunately, few of these programs were available in French (Liu et al., 2021; Rai et al., 2020; Wu et al., 2017), limiting their use in francophone patients.

Finally, they have not exceeded the experimentation stage and are not used in daily practice by health practitioners, whereas many of these applications are already available on commercial platforms such as Apple iTunes or Google Play Store (Thabtah et al., 2020).

However, the usability of digital tablets has been globally demonstrated among large populations (Kortum & Sorber, 2015), and there is better accessibility to new technologies, with most patients owning a tablet or a smartphone. Physicians would benefit from using these innovative tools to perform early cognitive assessments in primary care before addressing their patients for specialized consultations. Digital tablet assessment should be short, reliable, and understandable for patients with cognitive tasks reproducing classical questions from usual paper tests.

Facing this lack of available digital assessments, we aim to create a new auto-questionnaire on a touchscreen-based application inspired by MMSE and MoCA tests.

3 MATERIALS AND METHODS

3.1 Experiences Architecture

We constructed our program using Unity® (v.2021.3.11) for Android® (tablet).

The game consists of 3 main scenes:
1. The "Menu" scene includes the main menu, medical questionnaires, and results consultation;
2. The "InGame" scene contains the tutorial and all the user's tasks;
3. The "Survey" scene collects user feedback, which the administrator can only consult.

The main module of the "InGame" scene, the GameManager, references the list of nine tasks to be performed. Although each task has a different objective, each has textual and audio instruction and then proposes none, one or several answers in the form of images or text. So, the "JExperience" parent class groups all the attributes and methods common to all the tasks. However, the specific features of each task have necessitated the creation of new classes ("JExpMonoChoice", "JExpChoiceTown", "JExp Images") inherited from "JExperience" (Figure 1).

3.2 Welcome Menu

Three scenes compose AlzVR: the welcome menu, playing scene, and F-SUS questionnaire.

When launching the application, there are three possibilities (Figure 2):
1. Supervised experience: medical questionnaire and cognitive assessment;
2. Quick experience: cognitive assessment only;
3. Results: Results visualization.

3.3 Medical Questionnaire

The supervised experience includes a primary medical questionnaire to collect socio-demographic items (name, age, type of residence) and medical background (diagnostic, previous cognitive tests, treatments, and sensory loss).

3.4 Anonymization

After the last validation of the medical questionnaire, the program generates an automatic anonymized number composed of date and hour until seconds without integrating the name's initials. A typical anonymous number looks like YYYYMMDDHHMMSS. This process safeguards the confidentiality of patient information (personal information) and allows a further blinded analysis. In "quick experience", an "A" precedes all anonymized numbers, such as A-YYYYMMDDHHMMSS. In "supervised experience", the letter of an eventual medical center can be automatically added before the number.

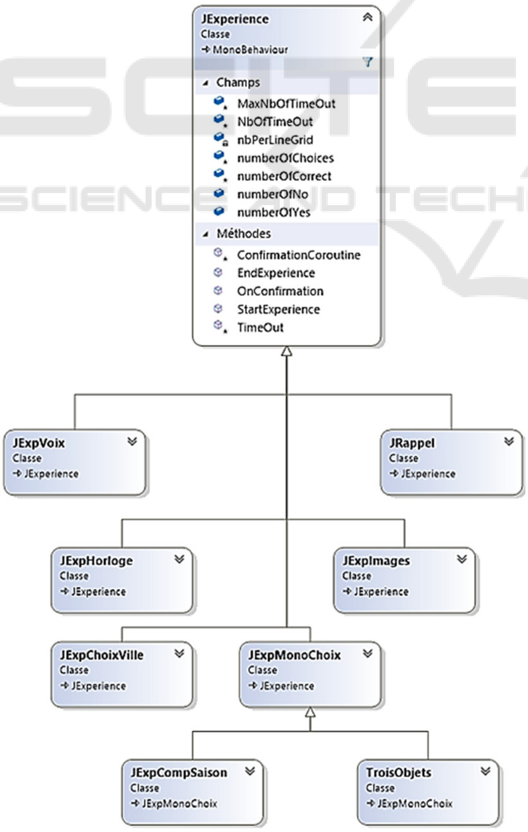

Figure 1: Main classes' diagram.

3.5 Playing Scene

3.5.1 General Aspect

The visual aspect should be simple without any cognitive surcharge. All scenes appear on a uniform-coloured background.
In all experiences, the user must select answers by touching one or several buttons. These buttons are big, allowing for an easy touch. A maximum of 8 buttons are on the screen, ensuring good visibility. All the pictures implemented into the scenes (cognitive tasks) are royalty-free.

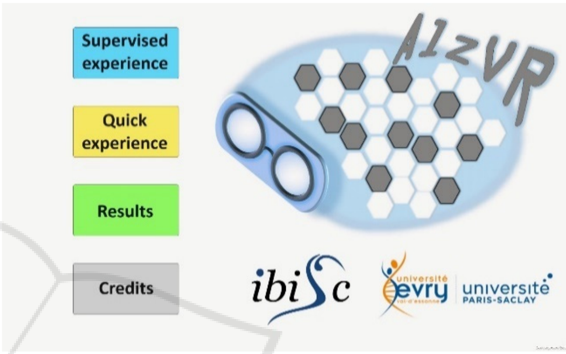

Figure 2: Welcome menu view.

3.5.2 Answer Modality

Since the user selects all the answers, a confirmation screen appears with a button "Yes" and "No". This step avoids inattentive answers and validates the choice (Figure 3). A "Yes" leads to the next question, and "No" allows a new chance to answer. Each exercise lasts 30 seconds maximum. The next question automatically occurs if the user does not answer within the time (counted as "Timeout"). The choice of a "No" in the confirmation step reinitializes the time, but only three attempts are allowed. In every

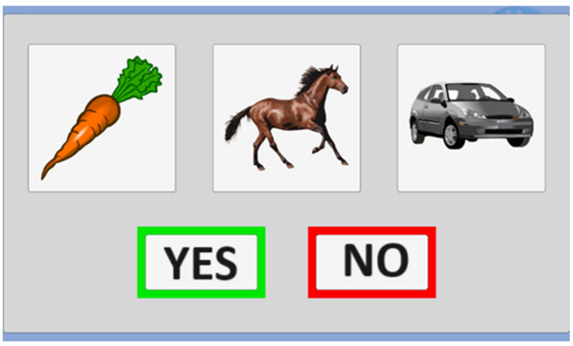

Figure 3: Answer modalities.

case (success or failure), a message "Well done!" congratulates the user. This message provides a cheerful ambiance and can reduce further false results of stress or fear.

3.5.3 Preliminary Training Task

A training session occurs before the cognitive questionnaire to ensure a good understanding of the tablet's functioning. The user needs to touch shapes on the screen following an oral order delivered by the program "Please touch the shape – a heart" (Figure 4). A failure in the training tasks leads to the assessment's stopping, and the test cannot continue.

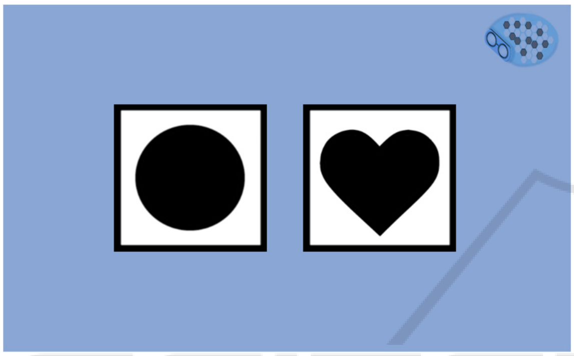

Figure 4: Training task.

3.5.4 Cognitive Questionnaire

If the training tasks are successful, the cognitive assessment begins and comprises seven tasks from the MMSE and the MoCA. We wanted a varied assessment, so we selected questions from multiple cognitive fields presented in Table 1.

Table 1: Numerical cognitive tasks.

Paper test	Cognitive function explored	Numerical cognitive task
MoCA, MMSE	Auditory memory and attention	Three words task (immediate recall)
MoCA	Memory and attention	Clock recognition
MoCA, MMSE	Auditory memory and attention	Three words tasks (delayed recall)
MoCA, MMSE	Spatial orientation	Flags
		Town
MoCA, MMSE	Temporal orientation	Season
		Year
MoCA	Abstraction	Abstraction

The first task is the « three words » test. In the MMSE or MoCA, the examiner orally delivers the three words, and the patient must repeat them (immediately and with a delayed recall). To get a self-questionnaire, we kept the oral deliverance by the program (sound only) but replaced the oral repetition with a choice of 3 images among eight. There is still an immediate and delayed recall. The three words belong to different semantic fields (animal, vehicle, and vegetable).

The clock recognition task is inspired by the clock drawing test (Sunderland et al., 1989), where the patients draw a circle, number, and needles indicating a precise hour (11h10, for example). We created a novel task proposing three different clocks: the good one (10h30), the symmetric clock (05h50), and a false clock. The oral instruction delivers the hour to choose ("select the clock indicating …"), and the patient selects on the screen. There are two series of clocks followed by the three words delayed recall.

To explore spatial and temporal orientation, we selected a simple format with an oral question (what is the current season? Select the country's flag where we are) and several pictures as answers. The country is represented as a flag, limiting written instructions for spatial orientation. Names of town are presented as classical French signs. The answer for the town can be changed depending on the site assessment.

Temporal orientation tasks are relatively similar, as the user needs to select the current season and present the name of the season and a typical image (Figure 5). Considering varying dates for season changes, we left a 48-hour margin for the answer.

In the year test, we introduced several confusing dates (minus one year, minus one century). All dates finish by the same number as the current year.

In the MoCA test, abstraction's ability is tested on the similarity between two words (for example, an orange and a banana are fruits). In the abstraction task, the user must fill a fruit series with a third picture (Figure 6). A confusing element is among the four choices (one picture from the three-word test).

Figure 5: Season test.

3.6 Results Menu

The results' menu allows a simple visualization of the patient's score after the cognitive questionnaire (Figure 7). A password protects this section and only uses an anonymized number (ID patient). Three possibilities exist: "X" (failure), "V" (success), and "?" (Timeout).

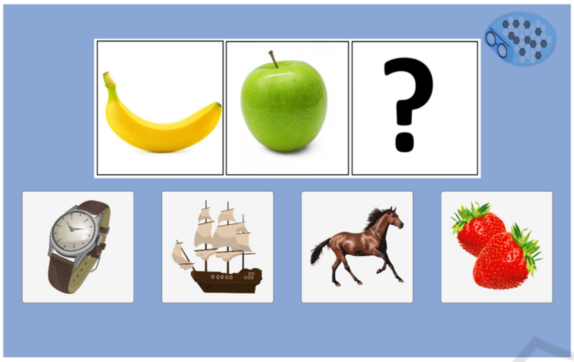

Figure 6: Abstraction test.

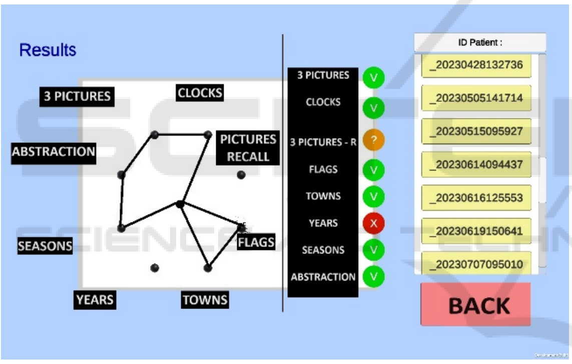

Figure 7: Results menu view.

3.7 F-SUS Questionnaire

After the cognitive tasks, we implemented the French translation of the System Usability Scale (Brooke, 1996), the F-SUS questionnaire (Gronier & Baudet, 2021). It evaluates global satisfaction through ten questions and five degrees of response from 1 (strongly disagree) to 5 (strongly agree). F-SUS results do not appear in the results menu and are directly stored.

3.8 Data Storage

All data are stored inside the tablet's internal memory in CSV format. This type of file can be easily exported and exploited. We planned separate storage for personal information (first name, last name, date of birth) from other results (experiences and F-SUS) in different files. All results are presented using only the anonymized identification number. Thus, a blinded analysis is possible using only anonymized data (Figure 8). Correspondence with identified data is restricted to investigators.

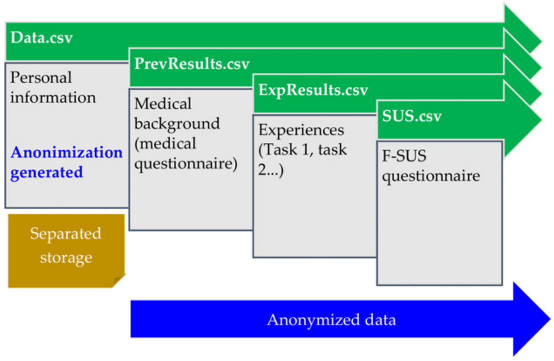

Figure 8: Process of data storage and anonymization.

3.9 Preliminary Usability Assessment

3.9.1 Study Population

We carried out an experimental, qualitative study in IBISC Laboratory (University of Évry-Paris Saclay, Department of Sciences and Technologies) among volunteers (staff and students) to assess preliminary usability using ISO 9241-11 norm (International Organization for Standardization, 2018) and the Nielsen method (Valentin & Lemarchand, 2010). The tablet was a Samsung Galaxy Tab S7 FE® (screen of 315.0 mm, 2560x1600) running on Android 11 (user interface One UI 3.1).

The exclusion criteria were age < 18 years old, no understanding of the French language, and visual or hearing loss with no equipment.

Participants were recruited through mailing lists of university and advertisements in locals.

3.9.2 Ethical Statement

This work has been carried out in accordance with the Declaration of Helsinki of the World Medical Association, revised in 2013 for experiments involving humans. Data exploitation was anonymous using an automatic number of participation generated from the date and hour of completion. The local University Paris-Saclay ethics committee approved all documents and protocols on 2022/07/07 (file 433). Informed consent was obtained from all subjects involved in the study. Participation was free with no remuneration.

3.9.3 Stages

Participants successively and anonymously achieved several stages:

1. Pre-questionnaire: fill in an online questionnaire to collect socio-demographic data (age, profession, sex) and numerical habits (smartphone and tablets);
2. Quick experience;
3. F-SUS questionnaire;
4. Post-questionnaire: online questionnaire to collect free comments about the program.

3.9.4 Data Collection and Analysis

During the tests, we collected the following parameters: answer (success, fail), number of trials, and response time (ms).

We chose the total F-SUS score calculated on the author's recommendation (Brooke, 1996; Gronier & Baudet, 2021) as the primary endpoint to assess usability with a goal of 85.5 %, considered "excellent".

All data were blinded, collected, and analyzed using the anonymized numbers of participants.

4 RESULTS

4.1 Population

We included 24 participants between 2022/09/27 and 2022/10/12. Their socio-demographics are presented in Table 2, and their numerical habits are in Table 3.

Table 2: Socio-demographic characteristics of the population.

	Population (n = 24)	
Gender (F/M)	10/14	
Age* (years) m(sd) [min-max]	41.88 (13.11) [23-66]	
Profession	Student	2
	Engineer	2
	Doctoral student	3
	Technician	3
	Researcher	5
	Administrative	9

* m = mean; sd = standard deviation; min = minimum; max = maximum

4.2 Success Rate

Cognitive tasks were completed by 100% of participants. We observed a success rate for the questions of 97.4 % (187 correct answers out of 192). The two tests that presented failures were the clock task (2 failures) and the season (3 failures).

Table 3: Numerical habits of the population.

Question*		
Have you ever used a smartphone? (%)	100	
If yes, for how many years? m(sd)	*12.37 (4.8)*	
If yes, during 2022, how often? (%)	*100*	*Everyday*
Have you ever used a digital tablet? (%)	96	Yes
	4	No
If yes, for how many years? m(sd)	*8.25 (3.13)*	
If yes, during 2022, how often? (%)	21.7	Everyday
	13.1	Once/week
	17.4	Once/month
	47.8	Once/year

* m = mean; sd = standard deviation

4.3 Time of Completion

The average test administration time (excluding training tasks) was 141.47 (± 18.77) seconds, and details of task completion times are presented in Table 4.

4.4 F-SUS Questionnaire

Ninety-six percent of participants completed the F-SUS questionnaire (one person left the application before completing it), and the results for each question are presented in Table 5. The overall score on the F-SUS questionnaire was 89.24%, considered "excellent".

4.5 General Remarks

In the post-questionnaire, we collected general opinions about the computer program. Users overwhelmingly found the program to be easy to use. The negative remarks reported were the lack of fluidity of the oral instructions and the tests being judged too simple. User reviews are shown in Figure 9.

5 DISCUSSION

Numerous existing paper tests assessed cognition for a global screening or precisely for a specific function (De Roeck et al., 2019). At the same time, several authors studied the possibility of digital tablet use in evaluating cognitive decline and performing training tasks in healthy and cognitively impaired patients (Koo & Vizer, 2019; Wilson et al., 2022). Despite these numerous and efficient digital tests (Chan et al., 2021), cognitive evaluations still rely on paper tests and need an exterior examiner. Facing an increasing prevalence of patients in the future decades (International et al., 2020) with a more and more precise diagnostic (biological, functional) (Dubois et al., 2021), there is a need to get simple, quick and performing tools to help practitioners in cognitive decline screening. During our conception, we chose to create a new tool in the French language inspired by two primary used and recommended tests (Janssen et al., 2017; Pinto et al., 2019): MMSE, MoCA, and the clock drawing test (CDT) (integrated into the MoCA).

In usual tests, the patient answers most of the questions orally to the examiner. Conceiving our tasks, we chose not to use speech recognition because of its current limitations (Basak et al., 2023). Incorrect speech interpretation would have led to false results. However, excluding oral answers does not allow a global language evaluation as in MMSE or MoCA.

Table 4: Tasks completion times.

Cognitive task	Completion time* m(sd) [min-max]
Three words task (immediate recall)	31.98 (2.62) [25.16-38.60]
Clock recognition (2 series)	36.43 (5.49) [25.86-51.05]
Three words task (delayed recall)	17.41 (2.83) [11.04-22.65]
Flags	12.23 (1.87) [8.66-16.29]
Town	10.91 (2.39) [6.95-16.45]
Year	10.41 (2.12) [6.38-14.68]
Season	11.73 (3.97) [6.75-23.68]
Abstraction	10.39 (2.67) [6.23-15.19]
Total	***141.47 (18.77) [97.64-183.58]***

* m = mean; sd = standard deviation; min = minimum; max = maximum

CDT is hugely used in daily practice and belongs to quick screening tools such as Codex (Belmin et al., 2007) or Minicog (Borson et al., 2003). Müller et al. have proposed a digital clock drawing task using a stylus (Müller et al., 2019), showing good correlations with paper tests. This transposition still requires exterior human validation or automatic image analysis, as proposed by Park et al. (Park & Lee, 2021). We wanted a simple and short task with no exterior analysis, so we switched from a drawing task to a recognition picture task. Drawing a clock and placing needles requires visuospatial abilities and executive functions. Nevertheless, there were technical limitations to producing a self-administered questionnaire with few written instructions, no exterior validation, and simple orders. These limitations may lead to potential bias in cognitive evaluation with an underestimation of executive functions.

Figure 9: Word cloud of user reviews.

Finally, our assessment does not evaluate writing abilities because we did not want to use a stylus or further human validation. Thus, it is known that dysgraphia is a symptom of AD (Onofri et al., 2016). Despite exploring several questions and different cognitive fields, our new assessment has limitations that need following and potential future upgrades in new versions.

Before evaluating our digital tool in an elderly population, we performed a short usability assessment of a healthy population (without cognitive decline) among university users.

Completion time should be short, and the mean time observed in our study (142 seconds) is a good result. Moreover, usability reached the global score of 89.24%, surpassing the initial objective of 85.5% and close to 90.9% (« best imaginable »).

The participants globally perceived the test as easy to use, corresponding to F-SUS scores (questions 3, 5, 7, and 8). It was a positive evaluation because participants did not know about cognitive tests and thus discovered them for the first time. These results are preliminary satisfying data, but there is a considerable limitation about the population. Indeed, our participants were young (41.88 years old), healthy, and used to touch screens. This mean age is widely below the age of AD patients (> 60 years)

(National Institute on Aging, n.d.), which can explain the observed good results. They may not be transposable into an elderly population with cognitive decline and poor use of tablets. Nevertheless, our population uses tablets poorly, with less than 50% of people using them yearly (Table 3). The questions were negatively perceived as « too simple » or « too slow », due to the young age of our participants. AlzVR should be tested in an older patient population for usability assessment and accuracy of discrimination between healthy and demented subjects.

Although the participants were healthy, we noted errors in the clock recognition task, probably due to the needle shapes signaled in complimentary remarks (Figure 9). However, recent findings showed that students had more and more difficulties reading traditional clocks (BBC News, 2018), and our two failed users were 24 years old. These difficulties appear in the mean task time of realization (Table 4); indeed, it is the task with the most significant difference between the minimal and maximal time of realization. Season errors may be explained by the recent season changes (summer/autumn) before the beginning of the study (September 27). We also found an extensive range in task time realization.

When extracting the results from the tablet, we reported no errors in the CSV files. Data were easily exploitable and well anonymized.

Table 5: F-SUS questionnaire results.

Question	Result* m(sd)
I think that I would like to use this system frequently.	2.70 (1.46)
I found the system unnecessarily complex.	1.52 (0.71)
I thought the system was easy to use.	4.91 (0.28)
I think that I would need the support of a technical person to be able to use this system.	1 (0)
I found the various functions in this system were well integrated.	4.65 (0.87)
I thought there was too much inconsistency in this system.	1.43 (0.97)
I would imagine that most people would learn to use this system very quickly.	4.96 (0.20)
I found the system very cumbersome to use.	1.65 (1.34)
I felt very confident using the system.	4.83 (0.38)
I needed to learn a lot of things before I could get going with this system	1.74 (1.42)

* m = mean; sd = standard deviation

6 CONCLUSIONS

We have developed a new digital cognitive screening tool with preliminary good feedback among a young and healthy population. The application could also be transposed onto smartphones to enhance its diffusion and utilization. This preliminary study belongs to the global study COGNUM-AlzVR, which aims to evaluate the efficiency and relevance of two numerical programs on tablets for cognitive assessment in AD patients. The Committee for the Protection of People of Ile de France approved the multicentric project in 2022, and the study began in April 2023 (NCT06032611).

ACKNOWLEDGEMENTS

The authors thank all participants and the Génopole (Evry-Courcouronnes, France) for their partnership with IBISC Laboratory.

CONFLICTS OF INTEREST

The authors declare no conflict of interest and have no known competing financial or personal relationships that could be viewed as influencing the work reported in this paper. This work did not receive any grant from funding agencies in the public, commercial, or not-for-profit sectors.

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