Original Research Article

DIGITAL HEALTH

DIGITAL HEALTH
Volume 11: 1–12

DOI: 10.1177/20552076251324015
journals.sagepub.com/home/dhj

Sage

Feasibility and acceptability of a remote computerized cognitive training employing telehealth in older adults with subjective cognitive complaints

Marion Ferrandez y Montesinos[1,2,3], Rachid Guerchouche[1,2], Justine Lemaire[1,4], Esther Brill[5], Stefan Klöppel[5], François Bremond[1,6], Fabio Solari[7], Philippe Robert[1,2], Guillaume Sacco[1,4,8] and Valeria Manera[1,2]

Abstract

Introduction: Computerized cognitive training (CCT) represents promising solutions for remote training of cognitive abilities in older people with cognitive decline. In the present article, we tested the feasibility and acceptability of a CCT performed at home via a telehealth platform, with participants connected remotely to a clinician, in comparison to an in-person CCT.

Methods: Thirty participants took part in the study. Twelve participants opted for classical in-person training and met a neuropsychologist twice a week for 12 weeks, for a total of 24 30-minute sessions. Eighteen participants opted for the remote home-based training and met with the clinician virtually via a telehealth system at the same frequency and duration. The intervention consisted of a serious-game platform training memory, spatial abilities, and executive functions. All participants underwent a neuropsychological and clinical assessment before and after the training.

Results: Results showed a high adherence to training and a strong acceptability in both the remote and the in-person groups. A significant improvement in mental flexibility and planning abilities was observed in both groups (as measured by the Zoo planning test), but no other neuropsychological tests showed improvement.

Discussion: This non-randomized study suggests the feasibility and acceptability of the telehealth CCT intervention. When participants are able to select their preferred intervention modality, training adherence and efficacy are comparable between remote and in-person delivery. Future studies should be performed to verify which are the most effective intervention parameters, such as training frequency and duration.

Keywords

Computerized cognitive training, serious games, telehealth, remote training, subjective cognitive decline

Submission date: 11 November 2024; Acceptance date: 11 February 2025

[1]CoBTeK, Université Côte d'Azur, Nice, PACA, France
[2]Association Innovation Alzheimer, Nice, France
[3]LAPCOS, Université Côte d'Azur, Nice, France
[4]Centre Hospitalier Universitaire de Nice, Service Clinique Gériatrique du Cerveau et du Mouvement, Centre Mémoire Ressources et Recherche, Université Côte d'Azur, Nice, PACA, France
[5]University Hospital of Old Age Psychiatry, University of Bern, Bern, Switzerland
[6]INRIA Sophia Antipolis, STARS team, Sophia Antipolis, PACA, France
[7]DIBRIS, University of Genoa, Genoa, Liguria, Italy
[8]CNRS, INSERM, IPMC, Université Côte d'Azur, Nice, PACA, France

Corresponding author:
Valeria Manera, CoBTeK Lab, Université Cote d'Azur, Institut Claude Pompidou, 10 rue Molière, 06100 Nice, PACA, France.
Email: valeria.manera@univ-cotedazur.fr

Introduction

Neurocognitive disorders (NCDs) such as Alzheimer's disease are a leading cause of disability worldwide. The DSM-5 describes a mild NCD stage, characterized by the presence of cognitive impairment in functions such as memory, attention, language, and/or executive functions, that do not affect the patient's autonomy in activity of daily living.[1] When reaching the major NCD stage, cognitive impairment starts affecting daily functioning and progressively leads to dependency, which represents a major health and societal issue. Biomarker evidence suggests that the pathophysiological changes leading to major NCD can start decades before the onset of clinical symptoms.[2] Subjective cognitive decline (SCD), defined as a self-perceived decrease in cognitive performance despite normal scores in cognitive testing, is now considered as a possible early at-risk state for progression to NCD.[3] This preclinical stage, together with the early stages of mild NCD, is considered an optimal window to put in place preventive non-pharmacological strategies aiming to slow down cognitive decline.[4]

One promising intervention to improve cognitive function in SCD and mild NCD is represented by cognitive training (CT), encompassing a range of interventions aiming to improve cognitive domains—such as memory, attention, and executive functions—through repeated practice based on exercises targeting specific skills and strategies.[5] Computerized CT (CCT), also known as digital cognitive training/interventions[6] employ digital devices such as computers, tablets, smartphones, or VR headsets to deliver the CT. CCT can be employed by patients alone at home (remote CCT), replacing at least part of the classical face-to-face training sessions,[7] or together with a clinician in face-to-face sessions (in-person CCT). In this case, CCT represents an additional tool that the clinician can employ to make training more engaging.[8] Evidence on the acceptability and effectiveness of CCT in the elderly with and without cognitive impairment is growing,[9,10] and suggests that CCT targeting multiple domains may be more effective than single domain training on both global cognition, and specific cognitive functions, such as attention, working memory, processing speed, and delayed recall.[11] Advantages of CCT compared to classical CT include the possibility to collect more accurate performance measures (e.g. response-times), allowing to adapt training difficulty in real-time thanks to performance-adaptive algorithms,[12] and the possibility of building training based on a game-like format (known as serious games), increasing motivation and training adherence, also in older adults with NCD.[13]

Boosted by the COVID-19 pandemic, the interest in remote assessment and training solutions increased significantly in the last years.[14] Most of the studies testing the acceptability and efficacy of remote CCT focused on autonomous training, in which the patient does the exercises alone employing a training platform (online or installed on a device), supervised by a clinician through weekly follow-ups.[7,15–18] This autonomous training is sometimes associated with individual or group sessions delivered in person, to improve training adherence.[19] Home-based autonomous CCT has several advantages, including cost- and time-effectiveness, increased accessibility for people living in remote regions and rural areas, and the possibility to repeat the training more frequently, for instance on a daily basis, with more beneficial effects.[11] While several studies reported good acceptability and preliminary evidence of efficacy in older adults with SCD and mild NCD,[11] there are also disadvantages to home-based autonomous CCT. These include limited social interaction, lack of individualized attention and support,[6] and low adherence in a non-negligible percentage of participants (e.g. 38% by Diaz Baquero et al.[20] and 59% by Robert et al.[7]), possibly due to a lack of extrinsic motivation and reinforcement.

To overcome part of these limitations, some research started to test the interest in performing CT remotely, with the clinician delivering the intervention through telehealth systems.[21] Compared to remote autonomous CCT, in which the patient performs the training alone on a digital device, in home-based telehealth CCT, the clinician is connected with the patient through a telehealth platform and leads the session similarly to in-person sessions. This allows the maintenance of one-to-one social interaction, creation, and maintain a therapeutic alliance, helps to fix rapidly problems in the application use, and increases adherence to training thanks to individualized follow-up (e.g. the clinician can propose alternative exercises if the patient does not like one, or propose to move to another exercise if he/she gets stuck). Studies performed on children and adults with autism, ADHD, language and learning disabilities,[22] and stroke[23,24] showed that delivering CCT remotely using telehealth systems is feasible, and results in retention rates, adherence, and cognitive and functional outcome improvements are comparable to those observed when CCT is delivered in in-person settings. Studies on older adults with subjective cognitive decline are still missing.[25] A recent study tested the feasibility of home-based telehealth delivery of CT training in patients with mild NCD, showing promising results on acceptability and feasibility.[21] However, the training was not computerized. Delivering CCT remotely using a telehealth platform poses additional challenges compared to remote CT, especially for older adults and people not familiar with new technologies. Indeed, the patients need not only to employ a telehealth system (i.e. connecting to a software/platform, activating audio, and webcam), but also to share their screen with the clinician, while keeping their audio and video active. To the best of our knowledge, no study

so far focused on the acceptability of remote CCT in older adults with SCD or mild NCD.

The aim of this study was to evaluate how feasible and acceptable it is for older adults with cognitive decline to use CCT at home through a telehealth platform, with remote clinician support, compared to undergoing CCT sessions in person.

Material and methods

Participants

Thirty participants took part in the study (25 females and five males, mean age = 72.3 ± 6.7 years). Participants could be included if they were older than 55 years, living at home, autonomous in the activities of daily living, fluent in French, and presented cognitive complaints. The diagnosis of major Neurocognitive Disorder (based on the DSM-V definition), the presence of psychiatric conditions in an acute phase, the presence of major sensory and motor impairments, and the inability to understand and sign an informed consent represented non-inclusion criteria. The study was conducted in accordance with the Declaration of Helsinki and approved by the national French ethical committee (CPP Ile de France IV, ref 2022/04, RCB: 2021-A03126-35). All participants signed an informed written consent before starting the study.

Procedure

The data were collected as part of the E-santé Silver Economy feasibility study, aiming at testing the feasibility of interventions targeting cognitive, physical, and social stimulation delivered remotely (at home) vs. in-person. Participants in the E-santé Silver Economy study were recruited through local hospitals, Community Social Support Centers (CCAS), and Home Support Centers (AMDR) in Nice, Cagnes sur Mer, and Digne-Les-Bains (France) by means of fliers. Participants interested in cognitive stimulation contacted the study coordinator and received the information note. After the verification of the inclusion and non-inclusion criteria by a clinician (who also excluded the presence of major NCD based on a clinical interview), they signed the informed consent, and they underwent the screening visit (V0), in which they filled out self-report questionnaires on health-related complaints, and underwent a brief cognitive, psychiatric, and physical performance assessment (as detailed below). At the end of V0, they decided together with the clinician the intervention format that they preferred, either in-person or remote. None of the participants had previous experience in remote CCT.

In the assessment visit (V1) participants underwent a detailed neuropsychological assessment (detailed below) with a trained neuropsychologist. The assessment was exactly the same for all the participants, but it was administered in-person for the in-person group, and online for the remote group, using the "*DeepSpa PsyTime*" Tele-Neuropsychology System,[26] specifically designed to allow online neuropsychological assessment. The same three neuropsychologists performed both online and in-person assessments, to increase comparability of the results between groups. The online assessments were performed in a non-clinical facility (e.g. home support centers), in which patients were provided with a PC with a webcam and a stable internet connection and met the neuropsychologist online through the Psy-time platform. An IT manager was present in the local facility (outside the patient room) in case any technical problem occurred, and provided printed material for neuropsychological tests that were not validated for online use.

After V1, all participants underwent a 12-week CCT, with two 30-minute training sessions per week (for a total of 24 training sessions) with a neuropsychologist. The training consisted of a serious game composed of eight games played on a tablet (as described below). To match more closely than possible real CT delivered in the clinical practice, we did not establish a fixed exercise/game program. Rather, the neuropsychologist selected, for each participant and each session, which games to propose, and how long to play each of them, considering factors such as the participant's profile, preferences, actual performance, fatigability, etc.

Participants in the in-person group met with the neuropsychologist in a clinical facility and performed the training on a Samsung tablet Galaxy Tab A8. Participants in the remote group received at home the same tablet model with the game installed and configured with each participant's pseudo-anonymous code. Each tablet was equipped with Skype, configured again with a pseudo-anonymous account. The neuropsychologist used an identical tablet model, also set up with Skype, to enable a video conference connection between the participant and the neuropsychologist. Participants received training on tablet use, including instructions on using Skype, sharing the screen, and launching games. At the beginning of each remote session, participants were asked to share their screens, with webcams activated for both the clinician and the participant. During the last four weeks, participants in both groups performed one of the two weekly sessions autonomously, playing a list of games decided by the neuropsychologist. For each training session, the neuropsychologist recorded if the session was performed as scheduled, the reasons for canceled/skipped sessions, and the presence of any technical (e.g. bad internet connection) or other types of issues (e.g. session starting late).

At the end of the training (V2), participants repeated the assessment performed in V1 and filled in the same self-reports completed in V0. In addition, they completed a questionnaire concerning the intervention acceptability.

Pre and post-training assessment

In the screening visit (V0), participants completed French-validated self-report scales to assess wellbeing (Warwick-Edinburgh Mental Well-Being Scale—WEMWBS[27]), perceived fatigue (multidimensional fatigue inventory—MFI, assessing general fatigue, physical fatigue, reduced motivation, reduced activity, and mental fatigue),[28] apathy (the French Apathy Motivation Index—AMI-f, assessing behavioral activation, emotional sensitivity, and social motivation[29]), and cognitive and non-cognitive subjective complaints (domains assessed were memory, attention, language, physical health, mood, motivation, sensory organs, general health, stress, and social interaction) measured using a visual analog scale, employed in the Memento cohort study.[30] The presence and severity of neuropsychiatric symptoms (apathy, depression, and anxiety) were assessed using the neuropsychiatric inventory, clinician version (NPI-C),[31] and the diagnostic criteria for apathy (CDA).[32] The level of cognitive impairment was assessed with the Montreal Cognitive Assessment (MoCA) scale.[33] Physical performance was assessed using the five times sit-to-stand test (FTSTS)[34] to evaluate the functional strength of the lower limbs, the timed up and go test (TUG)[35] to assess functional mobility (transfer movement, walking, and dynamic balance), and the four-meter walk test[36] to assess walking speed.

In the assessment visits (V1 and V2), participants underwent a detailed neuropsychological assessment to assess different cognitive domains, including verbal episodic memory (Free and Cued Selective Reminding Test—FCSRT[37]), verbal fluency (animals and letter P[38]), auditory attention and working memory (digit span forward and backward[39]), motor and mental speed, and visual working memory (WAIS-III digit symbol coding[40]), inhibitory control (Victoria Stroop test[41]), sustained attention (D2-R),[42] and executive functions (action planning and mental flexibility; Zoo Test Map[43]). For the assessments performed remotely, participants had printed copies of the tests that were not validated for online use (D2-R; digit symbol coding).

In V2, participants also completed the self-reports completed in V0 (WEMWBS, MFI, and AMI), the MoCA (same version employed in V0), and an acceptability questionnaire adapted from a VR study conducted by our group,[8] consisting of 11 rating questions assessing on a scale from one to 10 participants' satisfaction in terms of overall interest, satisfaction, motivation, perceived utility, ease of use, pertinence, level of experienced discomfort, level of external help needed, experience of positive and negative emotions, and fatigue.

Computerized CT

The CT was delivered through a CT app developed by researchers at the University of Bern (Bern, Switzerland), and described in detail by Brill et al.[19] The serious-game application contains 12 tablet-based training games targeting episodic memory, spatial abilities, attention, working memory and executive functions, and semantic memory. Individual games are connected by an overarching storyline (a sailboat traveling from one island to the next where each island represents a game). The game difficulty adapts in real-time to players' performance, to ensure that the game is sufficiently stimulating without becoming too challenging. For the present study, the games were translated from German to French by the members of the research team in Nice (France) and implemented using the Unity game engine by the research team that developed the application in Bern (Switzerland). We focused on a set of eight games that relied minimally on verbal abilities. Specifically, we translated "Billboards," and "What's my Name?" targeting episodic memory; "Mental Map," "Magic Camera," and "Mansion game" targeting spatial abilities; and "Memor bear," "Safari," and "Animal Park" targeting attention, working memory, and executive functions. See Brill et al.[19,44] for a more detailed description of these games.

The same three neuropsychologists performed sessions in both online and in-person groups. A neuropsychologist was not assigned to individual participants. Rather, all neuropsychologists performed sessions with all participants, to increase comparability of the results between participants and groups, avoiding that training compliance and acceptability were influenced by the clinicians' attitudes (engagement, empathy, etc.) and familiarity with new technologies (skills in using the game application).

Data analysis

Data are presented as mean and standard deviations for quantitative variables and as frequency and percentage for qualitative variables (sex and the presence of diagnostic criteria for apathy). For the acceptability questionnaire, the items concerning the level of experienced discomfort, the need for help, negative emotions, and fatigue were reversed, to compute a meaningful average acceptability score.

At baseline (V0 + V1), comparisons between the groups (remote vs. in-person group) were performed using the Mann-Whitney *U*-test for quantitative variables (due to the small sample size, and as several variables did not follow a normal distribution, as shown by Shapiro-Wilks tests) and χ^2 for qualitative variables. To analyze the progression of self-reported well-being, apathy, fatigue, and of scores at neuropsychological tests between before and after the training in the two groups, we performed repeated-measures ANOVAs, with Time (baseline vs. V2) as within-subject factor, and group (remote vs. in-person) as between-subject factor. Despite the small sample size and the violation of the normality assumption, we decided to present the results of parametric analyses as they allowed us to test

simultaneously the effects of group, time, and their interactions. To check if the violation of the normality assumptions impacted the results, we also performed nonparametric tests to check the effect of group (remote vs. in-person) on scores at V2 and on the delta between V2 and baseline (Mann-Whitney *U*-test), and to check the effect of time (baseline vs. V2; Wilcoxon signed-ranks test). As the results were comparable, we decided to present a more concise parametric analysis.

Results

Demographic and clinical features

A CONSORT diagram showing the flow of participants through each stage of the study is presented in Figure 1.

Out of the 30 participants included in the study, 18 selected the remote intervention, and 12 the in-person intervention. As presented in Table 1, no significant differences in demographic features, clinical characteristics, and physical performance were found between the remote group and the in-person group.

The MoCA score ranged from 17 to 30 ($M = 26.8$, $SD = 3.0$), with only one participant scoring lower than 23, the cutoff score suggested to differentiate normal aging from mild neurocognitive disorder.[45] The baseline neuropsychological assessment (see Table 1) confirmed that most of the participants presented results in the normative range.

Thirteen participants (43%) presented neuropsychiatric symptoms of anxiety, depression, or apathy (as indexed by the NPI-C), with a mean severity score overall in the sample of 2.5/36 ($SD = 3.1$; range: 1–9). Five participants (16.7%) met the diagnostic criteria for apathy. As these five participants did not differ from non-apathetic participants in terms of treatment adherence nor cognitive performance ($p > 0.05$), we did not perform separate analyses based on apathy presence.

In terms of self-reported complaints, the overall mean score was 33.1/100 ($SD = 15.7$). The complaints reported more often included difficulties in memory ($M = 4.1/10$, $SD = 2.6$) and attention ($M = 4.1/10$, $SD = 2.7$), followed by complaints concerning the general health status ($M = 3.8/10$, $SD = 1.8$). The complaints reported less often were those linked to difficulties in engagement in leisure activities ($M = 2.0/10$, $SD = 2.3$) and social interactions ($M = 2.3/10$, $SD = 2.5$).

Feasibility and acceptability

Only two participants (6.7%) dropped the study, both in the in-person group. One of the participants dropped the study for personal reasons after the third stimulation session, and the other for unknown reasons after the seventh stimulation session.

For the remaining 28 participants, the average number of sessions performed was 21.6/24 (90%; $SD = 2.4$) for the remote group, and 20.1/24 (84%; $SD = 3.0$; $U_{(26)} = 61.5$, $p = 0.166$) for the in-person group. The percentage of performed sessions in which a problem occurred (e.g. technical issues with internet connection, bug in the game platform, and delayed session) was 6.4% and was significantly higher in the remote group (12.8%) compared to the in-person group (3.2%, $U_{(26)} = 49.5$, $p = 0.035$).

Over the 72 missed sessions for the overall group, only six (8.3%) were due to technical problems (e.g. issues with internet connection and bugs in the game platform), and all occurred in the remote group. The remaining 66 missed sessions (91.6%) were due to other problems, such as illness or personal constraints of the participant or the clinician; transportation problems; closure of the clinical facility; or forgotten session. The percentage of these missed sessions did not significantly differ between the remote group ($N = 29$, 43.9%) and the in-person group ($N = 37$, 56.1%; $U_{(16)} = 61.5$, $p = 0.100$).

Concerning the acceptability questionnaire, participants reported very high acceptability ratings in both the remote ($M = 8.6/10$, $SD = 0.65$) and the in-person group ($M = 8.6/10$, $SD = 1.28$; see Figure 2). Specifically, participants reported average ratings higher than 8.5/10 concerning the overall satisfaction, interest, usefulness, ease of use, and pertinence of the intervention modality, and ratings higher than 7.5/10 for the experience of positive emotions. They also reported scores lower than 1.5/10 in the experience of negative emotions and the need for help to undergo the intervention and a score lower than 3/10 for experienced fatigue. No significant differences between the remote and the in-person groups were found for the average acceptability, nor for any of the specific questions (Mann-Whitney *U*-tests, all $ps > 0.05$).

Evolution between before and after the training

Results are presented in Table 1. The repeated measures ANOVA with time (baseline vs. V2) as within-subject factor and group (remote vs. in-person) and between-subject factor revealed no significant effect of group for any of the assessment scales, nor the neuropsychological tests, suggesting the remote and the in-person groups were not significantly different in any of the assessments. Similarly, no significant interaction between time and group was found for the self-reports nor for the neuropsychological tests, suggesting that there was no significant difference in the evolution over time between the remote and the in-person group. The overall cognitive level, as indexed by the MoCA score, increased over time by 0.8 points in the overall sample (V0, $M = 26.7$, $SD = 3.0$; V2, $M = 27.5$, $SD = 2.5$), but the result was not statistically significant ($p = 0.068$). Self-reported fatigue, as indexed by the MFI scales, increased significantly from baseline to V2 of 4.8 points ($p = 0.014$). In terms of neuropsychological tests, a significant effect of time was found only for the

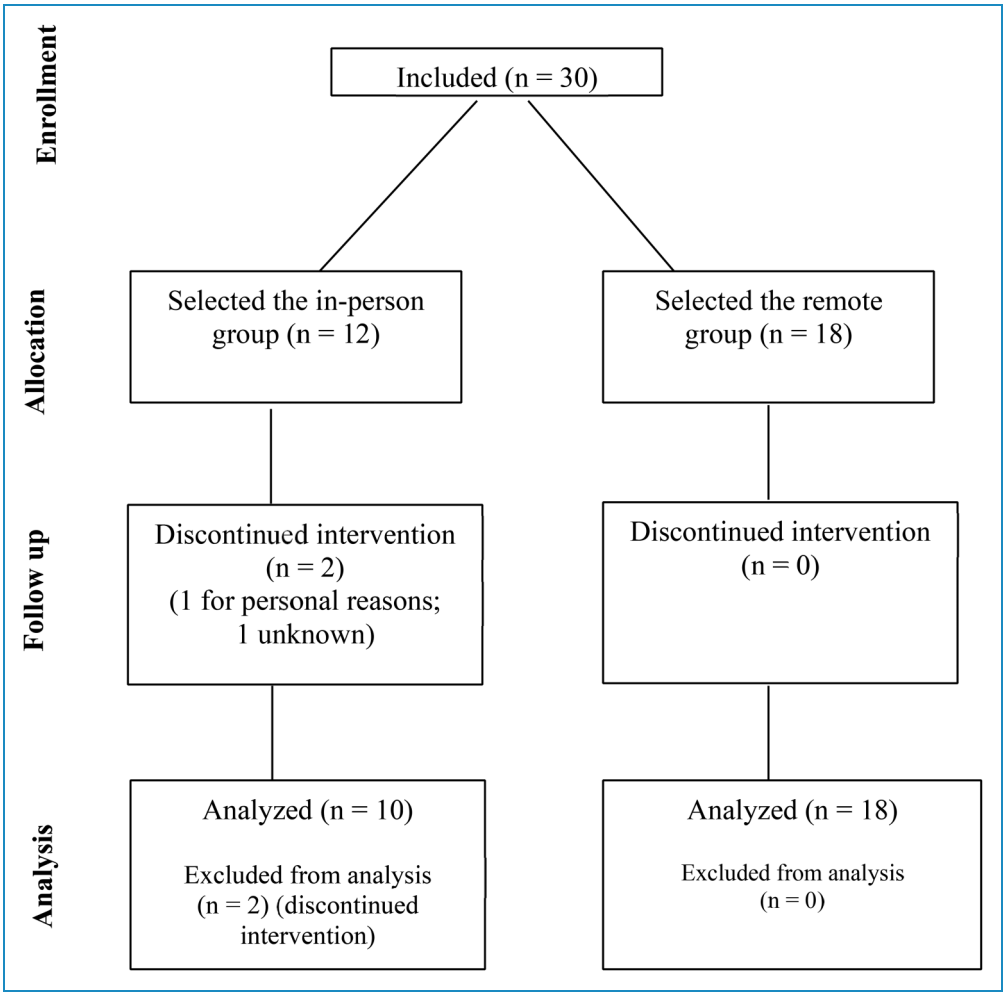

Figure 1. Consolidated Standards of Reporting Trials (CONSORT) diagram showing the flow of participants through each stage of the study.

Zoo planning test, with an average improvement of 0.5 points ($p = 0.029$). No other significant effect of time was observed for any of the other assessments.

Discussion

Worldwide in rural and isolated areas, also called "medical deserts," access to diagnosis and care is often limited, creating inequalities in access to healthcare compared to cities.[46] In France, medical deserts are increasing, with nearly 3.8 million French people living in an area underprovided with general practitioners (5.7% of the population) in 2018, compared to 2.5 million (3.8% of the population) in 2014.[47] This problem is particularly important for older adults with cognitive decline: access to tailored non-pharmacological interventions is indeed crucial to improve or maintain their cognitive level and maintain autonomy in daily living.[48] Accelerated by the COVID-19 pandemic, the use of telemedicine and CCT is now considered as a promising solution to bring CT to home, allowing anyone with access to an internet connection and a digital device to perform regular cost and time-effective training.[18] Despite the interest in using CCT autonomously at home, allowing patients to train flexibly when they want, with gains in cognitive functions comparable to those obtained with in-person CCT,[6] autonomous training may reduce adherence and engagement, and increase social isolation and lack of social interaction in people living remotely. Telehealth solutions allowing patients to connect remotely with a clinician may be useful to make remote CCT closer to classical in-person stimulation.[23] However, several challenges do exist: if telehealth sessions represent themselves as a technological barrier, performing digital training during a telehealth session may increase the task complexity (e.g. screen sharing and managing several applications simultaneously). In the present study, we tested the feasibility and acceptability of a remote, home-based 12-week CCT delivered individually employing a telehealth system, compared to the same CCT delivered in person, in a classical clinical

Table 1. Description and progression of participants in the remote and in-person groups throughout the study.

	Group							*p*-value		
	Remote ($N=18$)				In-person ($N=12$)					
Female sex (*n* [%])	3 [16.7]				2 [16.7]			1.000[a]		
Age (years) ($M \pm SD$)	73.1 ± 7.5				71.2 ± 5.6			0.432[b]		
Apathy diagnostic criteria (apathy) (*n* [%])	2 [11.8]				3 [27.3]			0.353[a]		
NPI-C (apathy, depression, anxiety/36) ($M \pm SD$)	2.3 ± 3.4				2.8 ± 2.9			0.550[b]		
FTSTS (lower limbs strength in kg) ($M \pm SD$)	13.9 ± 3.3				14.0 ± 4.3			0.925[b]		
TUG (mobility in seconds) ($M \pm SD$)	9.4 ± 3.7				8.4 ± 2.4			0.551[b]		
Four-meter walk test (walking speed in m/s) ($M \pm SD$)	4.3 ± 1.5				3.4 ± 0.9			0.087[b]		
	Remote ($N=18$)				In-person ($N=10$)					
	Baseline		Final		Baseline		Final		Group[c]	Time[c]	Group * Time[c]
MoCA (global cognition/30) ($M \pm SD$)	26.6	± 3.4	27.3	± 2.7	27.1	± 2.2	27.7	± 2.3	0.757	0.068	0.923
WEMWBS (well-being/70) ($M \pm SD$)	49.3	± 6.9	47.3	± 13.2	49.5	± 8.0	50.5	± 6.9	0.562	0.689	0.382
Subjective complaints (/100) ($M \pm SD$)	31.7	±13.4	31.7	±20.3	35.3	±19.3	40.4	±18.9	0.399	0.331	0.453
MFI (fatigue/100) ($M \pm SD$)	41.7	±5.1	48.6	±10.2	52.0	±18.3	55.8	±15.3	0.143	0.014*	0.300
AMI-f (apathy/4) (mean ± SD)	1.2	±0.3	1.2	±0.5	1.3	±0.3	1.3	±0.3	0.508	0.770	0.953
FCSRT-total (verbal memory/48) ($M \pm SD$)	45.8	± 4.1	45.7	± 3.7	46.6	± 1.5	44.1	± 6.8	0.795	0.141	0.198
FCSRT-Immediate recall (visual memory/16) (mean ± SD)	15.8	± 0.8	15.7	± 0.8	15.6	± 0.7	15.1	± 2.2	0.361	0.233	0.457
Phonemic fluency (letter P) ($M \pm SD$)	24.8	±6.0	24.4	±8.1	24.4	±7.6	23.5	±7.0	0.804	0.557	0.787
Semantic fluency (animals) ($M \pm SD$)	31.1	± 13.4	32.5	±11.9	31.0	±8.3	32.6	±5.4	0.373	0.999	0.949

(continued)

Table 1. Continued.

	Group								*p*-value		
	Remote ($N = 18$)				In-person ($N = 12$)						
Forward digit span (auditory attention) ($M \pm SD$)	5.7	±1.0	5.8	±1.1	5.3	±1.5	5.7	±1.3	0.596	0.224	0.488
Backward digit span (auditory attention, working memory) ($M \pm SD$)	4.5	±1.3	4.8	±1.2	4.4	±1.6	4.7	±1.3	0.809	0.218	0.948
Digit symbol coding (visual attention, working memory) ($M \pm SD$)	12.9	±2.1	12.7	±2.2	12.1	±2.9	12.7	±2.7	0.673	0.606	0.139
Victoria Stroop (mental flexibility) ($M \pm SD$)	0.1	±1.4	0.2	±1.0	0.0	±0.9	−0.2	±0.8	0.512	0.757	0.465
D2-R (sustained attention) ($M \pm SD$)	51.7	±31.4	59.3	±30.5	54.5	±37.9	59.3	±35.5	0.930	0.133	0.724
Zoo test maps (action planning) ($M \pm SD$)	2.9	±0.7	3.4	±1.0	2.4	±1.3	3.0	±1.0	0.338	0.029*	0.787

NPI-C: neuropsychiatric inventory, clinician version; FTSTS: five times sit-to-stand test; TUG: timed up and go test; MoCA: Montreal Cognitive Assessment scale; WEMWBS: Warwick-Edinburgh Mental Well-Being Scale; MFI: multidimensional fatigue inventory; AMI-f: French Apathy Motivation Index; FCSRT: Free and Cued Selective Reminding Test; D2-R: Digit symbol coding revised.
aChi2; [b] Mann-Whitney *U*-test; [c] Repeated-measures ANOVA, with group (remote vs. in-person) and between-subject factor and time (baseline vs. final) as within-subject factor.

setting in people with SCD. The intervention consisted of a serious game composed of a set of exercises, built to train specific cognitive functions, such as episodic and working memory, executive functions, and spatial abilities.[19]

Results showed a very good adherence to treatment, and high acceptability for both the remote and the in-person group. The drop-out rate was very low (6.7%), and the two participants who abandoned the study were both in the in-person group. Training adherence was over 90% for the remote group and 84% for the in-person group. Most missed sessions in both groups were due to personal issues/constraints (of the participants or the clinicians), such as illness, holidays, or calendar mismatches. Only 8% of missed sessions in the remote group were due to technical problems, such as the impossibility of connecting to the internet, or bugs in the game platform. Concerning the sessions performed, small technical issues, such as slow internet connection, occurred in only 13% of sessions. The results on training adherence converged with the results of the acceptability questionnaire. Participants reported very high satisfaction, interest, perceived usefulness, ease of use, and pertinence of the intervention modality for both the remote and the in-person group, together with a low need for help to undergo the intervention, and relatively low fatigue. Taken together, these results suggest that the home-based telehealth CCT is feasible and acceptable for older adults with SCD, at least when participants can select their preferred intervention delivery, with results on both training adherence and self-reported acceptability comparable to in-person CCT intervention.

Self-reported fatigue[28] significantly increased after the training for both groups, suggesting that the intervention was perceived as quite intensive. No significant evolution of self-reported apathy[29] was observed between before and after the training, in neither the remote nor the in-person group. This may be explained by the fact that self-reported apathy was quite low in both groups before the training, Similarly, no significant changes in self-reported well-being[27] were observed in neither group. Converging with some studies, this may suggest that CCT do not improve perceived wellbeing.[49] However, these results may possibly be explained by the presence of relatively high well-being scores reported at baseline,[50] or by the fact that the WEMWBS scale may not be very sensitive to detect changes in well-being in pathological populations.[27] The impact of CCT on perceived well-being is under-investigated in the literature. Future studies with bigger samples should investigate this topic, possibly employing several well-being scales.

Concerning the evolution of performance in neuropsychological tests, only the Zoo planning test, assessing planning abilities and mental flexibility,[43] showed significant improvement in performance in both the remote and the in-person group. This may be explained by the fact that the delivered CCT was multi-domain and did not target selectively cognitive functions such as episodic memory and working memory. The significant improvement in planning ability and mental flexibility is interesting as these abilities strongly impact daily functioning, and the ability to deal with real-life events. It would be interesting, in future studies, to assess the impact of the training on everyday functioning, and to investigate the transferability of the gain obtained in neuropsychological tests to real-life situations.

This study has several limitations. The first is the small sample size. The main objective of the present study was to test the feasibility and the acceptability of the proposed intervention. This pilot study was underpowered to detect significant evolution in neuropsychological testing. In addition, inclusion criteria were based on the presence of subjective complaints rather than on actual performance in neuropsychological tests: for instance, no cutoff scores were defined for inclusion based on the MoCA.[33,45] The absence of significant improvement in most of the cognitive tests may thus be explained by the fact that most of the participants had scores in the normal range already before starting the training, leaving little margin for significant improvements, and by the variability of cognitive profiles across participants. Another possibility is that the training was not long and frequent enough to improve cognitive functioning. A meta-analysis focusing on intervention features showed that CCT has greater effect sizes for training including more than three sessions per week, more than eight total training weeks, and more than 24 training sessions.[51] In the present study, participants trained twice a week for 12 weeks, for a total of 24 sessions, thus not being optimized to detect changes in neuropsychological performance. As participants reported to be satisfied with the intervention format, and slightly fatigued by the intervention, a possible solution to intensify the training could be to propose more autonomous sessions. This would allow combining the advantages of the one-to-one clinical sessions and the flexibility of autonomous training.[13]

It would also have been interesting to add a third group performing only autonomous home-based training, to compare the feasibility and acceptability of supervised versus unsupervised training and allow to precisely quantify the added value of clinician's—virtual or physical—presence. As suggested by a recent study using the same game platform that we employed here, training adherence can be high in participants with cognitive decline and also for home-based training combined with weekly group sessions at the clinic.[44]

Another limitation in terms of comparability of the results between the remote and the in-person groups is that the neuropsychologist performing the assessments was not blind concerning group allocation, and that we did not randomize participants. Instead, participants selected the intervention modality that they preferred. While this has the advantage of being closer to the real

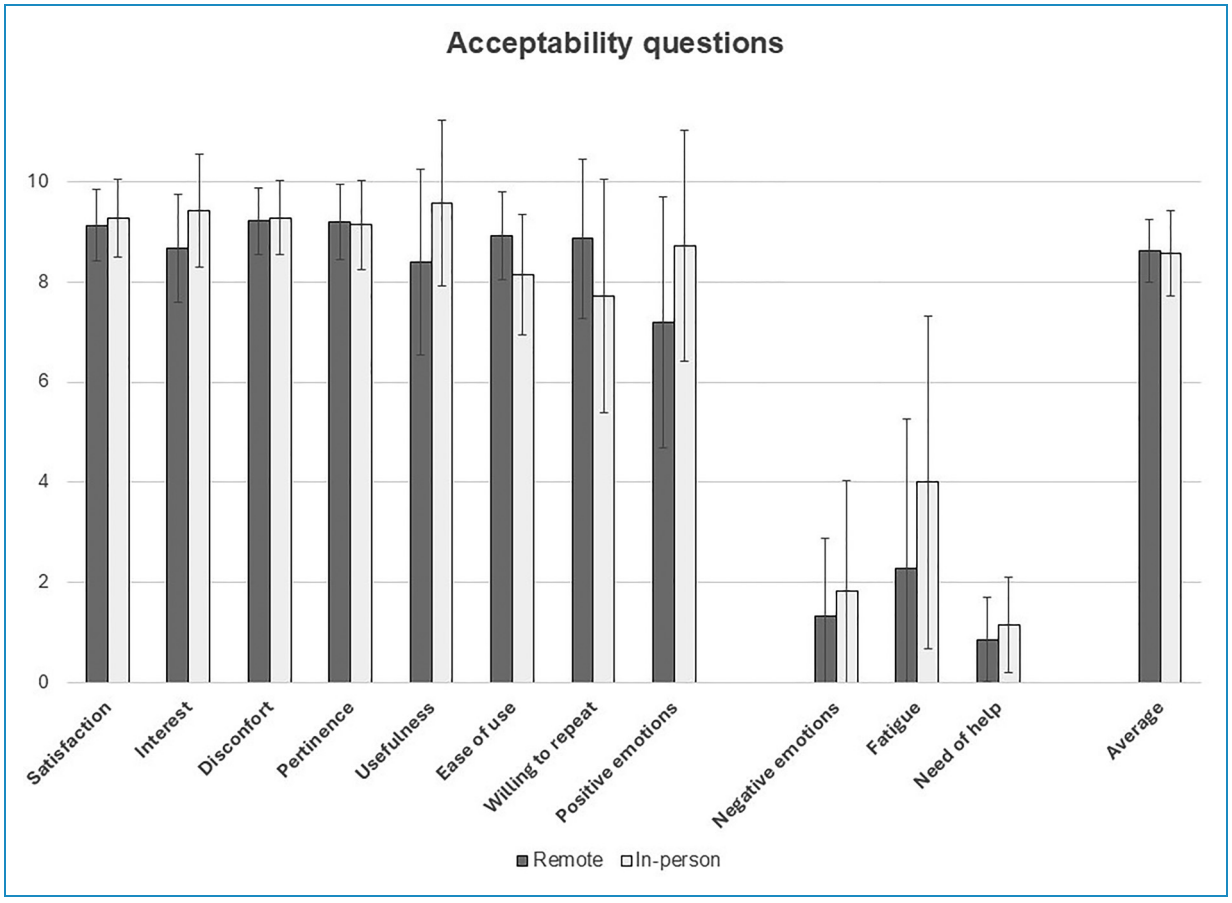

Figure 2. Results of the acceptability questionnaire for the in-person and the remote groups. The items concerning experienced discomfort, the need for help, negative emotions, and fatigue were reversed, to compute a meaningful average acceptability score.

clinical setting, in which patients' interests and preferences orient the choice of non-pharmacological interventions (type of intervention and delivery method), the obtained results are not generalizable to all participants with cognitive decline. Participants in the two groups did not differ in terms of demographic and clinical features. A recent study investigated the preference for remote versus in-person training in people with SCD and mild NCD, and showed that factors related to lifestyle (regular physical activity and Mediterranean diet) and sociodemographic features (higher level of technological skills, and bigger distance from the clinical center) influenced the preference for remote CT delivery.[52] This suggests the importance of considering participants' preferences, and of assessing these factors systematically in memory clinics to select the most appropriate training modality to propose to patients,[53] potentially impacting treatment adherence.

Conclusions

The findings of this study suggested that home-based telehealth CCT using a serious game platform is both feasible and acceptable for older adults with SCD who can select their preferred intervention delivery format. Training adherence and self-reported acceptability were high and comparable to those obtained in the in-person group. We believe that this high adherence to training and acceptability is at least partially explained by the fact that participants selected the intervention modality that they preferred, instead of being randomized in the remote vs. in-person group. To generalize these results, and assess the acceptability in a larger population, a randomized controlled trial involving a bigger number of patients would be necessary.

Acknowledgements: Thanks to Annick Martin, Tanguy Baquet, and Lucille Thiebot for their help in patient recruitment. Thanks to Alana Lafarge, Léna Cronenberger, Lyne Daumas, Laura Auclair, and Morgane Benaitreau for their help in delivering the assessments and interventions in the clinical trial.

Contributorship: MFYM, VM, RG, PR, and GS: conceptualization. RG, EB, and JL: data curation. VM: formal analysis. VM, RG, PR, and GS: funding acquisition. MFYM and RG: investigation. MFYM, VM, RG, EB, and SK: methodology. VM, RG, PR, and GS: project administration. EB,

SK, and RG: software. VM, PR, and GS: supervision. JL and RG: validation. MFYM, RG, and VM: visualization. MFYM and VM: writing–original draft. All: writing–review and editing.

Consent to participate: All participants signed an informed written consent before starting the study.

Consent for publication: Not applicable.

Data availability: The datasets generated and analyzed during the current study are available from the corresponding author upon reasonable request.

Declaration of conflicting interests: The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval: The study was conducted in accordance with the Declaration of Helsinki and approved by the National French Ethical Committee (CPP Ile de France IV, ref 2022/04, RCB: 2021-A03126-35).

Funding: The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This work was supported by the Interreg-Alcotra project CLIP "E-SANTÉ / SILVER ECONOMY", by the Interreg Alcotra 2021–2027 "INTEVIDI" (Grant agreement No. 20178), and by the French government, through the UCA^{JEDI} Investments in the Future project managed by the National Research Agency (ANR) with the reference number ANR-15-IDEX-01.

ORCID iD: Valeria Manera https://orcid.org/0000-0003-4490-4485

References

1. American Psychiatric Association D, American Psychiatric Association D. *Diagnostic and statistical manual of mental disorders: DSM-5*. Vol. 5. Washington, DC: American Psychiatric Association, 2013.
2. Petrie EC, Cross DJ, Galasko D, et al. Preclinical evidence of Alzheimer changes: convergent cerebrospinal fluid biomarker and fluorodeoxyglucose positron emission tomography findings. *Arch Neurol* 1 May 2009; 66: 632–637.
3. Pike KE, Cavuoto MG, Li L, et al. Subjective cognitive decline: level of risk for future dementia and mild cognitive impairment, a meta-analysis of longitudinal studies. *Neuropsychol Rev* 2022; 32: 703–735.
4. Roheger M, Hennersdorf XS, Riemann S, et al. A systematic review and network meta-analysis of interventions for subjective cognitive decline. *Alzheimers Dement Transl Res Clin Interv* 1 Jan 2021; 7: e12180.
5. Butler M, McCreedy E, Nelson VA, et al. Does cognitive training prevent cognitive decline? A systematic review. *Ann Intern Med* 2018; 168: 63–68.
6. Zhang H, Huntley J, Bhome R, et al. Effect of computerised cognitive training on cognitive outcomes in mild cognitive impairment: a systematic review and meta-analysis. *BMJ Open* 1 août 2019; 9: e027062.
7. Robert P, Manera V, Derreumaux A, et al. Efficacy of a web app for cognitive training (MeMo) regarding cognitive and behavioral performance in people with neurocognitive disorders: randomized controlled trial. *J Med Internet Res* 2020; 22: e17167.
8. Manera V, Chapoulie E, Bourgeois J, et al. A feasibility study with image-based rendered virtual reality in patients with mild cognitive impairment and dementia. *PloS One* 2016; 11: e0151487.
9. Hill NT, Mowszowski L, Naismith SL, et al. Computerized cognitive training in older adults with mild cognitive impairment or dementia: a systematic review and meta-analysis. *Am J Psychiatry* 2017; 174: 329–340.
10. Ryu SH. Digitalization of cognitive intervention in the elderly: exploring the benefits and challenges. *J Cogn Interv Digit Health* juin 2023; 2: 1–9.
11. Bahar-Fuchs A, Martyr A, Goh AM, et al. Cognitive training for people with mild to moderate dementia. *Cochrane Database Syst Rev* 2019; 3: CD013069.
12. Mishra J and Gazzaley A. *Closed-loop rehabilitation of age-related cognitive disorders*. New York, USA: Thieme Medical Publishers, 2014, pp. 584–590.
13. Manera V, Ben-Sadoun G, Aalbers T, et al. Recommendations for the use of serious games in neurodegenerative disorders: 2016 Delphi panel. *Front Psychol* 2017; 8: 1243.
14. Manera V, Partos C, Beauchet O, et al. Teleconsultations for mental health: recommendations from a Delphi panel. *Internet Interv* 2023; 34: 100660.
15. Book S, Jank M, Pendergrass A, et al. Individualised computerised cognitive training for community-dwelling people with mild cognitive impairment: study protocol of a completely virtual, randomised, controlled trial. *Trials* 2022; 23: 371.
16. Bozoki A, Radovanovic M, Winn B, et al. Effects of a computer-based cognitive exercise program on age-related cognitive decline. *Arch Gerontol Geriatr* 1 juill 2013; 57: –7.
17. Finn M and McDonald S. Computerised cognitive training for older persons with mild cognitive impairment: a pilot study using a randomised controlled trial design. *Brain Impair* 2011; 12: 187–199.
18. Baik JS, Min JH, Ko S-H, et al. Effects of home-based computerized cognitive training in community-dwelling adults with mild cognitive impairment. *IEEE J Transl Eng Health Med* 2024; 12: 97–105.
19. Brill E, Krebs C, Falkner M, et al. Can a serious game-based cognitive training attenuate cognitive decline related to Alzheimer's disease? Protocol for a randomized controlled trial. *BMC Psychiatry* 12 août 2022; 22: 52.
20. Diaz Baquero AA, Perea Bartolomé MV, Toribio-Guzmán JM, et al. Determinants of adherence to a "GRADIOR" computer-based cognitive training program in people with mild cognitive impairment (MCI) and mild dementia. *J Clin Med* 2022; 11: 1714. doi:10.3390/jcm11061714
21. Stypulkowski K, Anquillare E, Twamley EW, et al. Feasibility of a telehealth compensatory cognitive training program for older adults with mild cognitive impairment. *Clin Gerontol* 1 janv 2024; 47: 17–25.

22. Moore AL, Miller TM and Ledbetter C. Remote vs. In-person Delivery of LearningRx One-on-One Cognitive Training During the COVID-19 Pandemic: A Non-inferiority Study. Front Psychol [Internet]. 2021;12. Disponible sur: https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2021.749898.
23. Jaywant A, Mautner L, Waldman R, et al. Feasibility and acceptability of a remotely delivered executive function intervention that combines computerized cognitive training and metacognitive strategy training in chronic stroke. *Int J Environ Res Public Health* 2023; 20: 5714. doi:10.3390/ijerph20095714
24. Lawson DW, Stolwyk RJ, Ponsford JL, et al. Telehealth delivery of memory rehabilitation following stroke. *J Int Neuropsychol Soc* 2020; 26: 58–71.
25. Gould CE, Hicken BL and Freytag JJ. Addressing access to care in diverse older adult populations using information and communication technologies. *Clin Gerontol* 1 janv 2024; 47: –3.
26. Zeghari R, Guerchouche R, Tran-Duc M, et al. Feasibility study of an internet-based platform for tele-neuropsychological assessment of elderly in remote areas. *Diagnostics* 2022; 12: 925. doi:10.3390/diagnostics12040925
27. Trousselard M, Steiler D, Dutheil F, et al. Validation of the Warwick-Edinburgh mental well-being scale (WEMWBS) in French psychiatric and general populations. *Psychiatry Res* 30 Nov 2016; 245: 282–290.
28. Gentile S, Delarozière JC, Favre F, et al. Validation of the French 'multidimensional fatigue inventory' (MFI 20). *Eur J Cancer Care (Engl)* 2003; 12: 58–64.
29. Corveleyn X, Corbel C, Fabre R, et al. Validation study of the apathy motivation index in French adults. *Front Psychol* 2023; 14: 1252965.
30. Dufouil C, Dubois B, Vellas B, et al. Cognitive and imaging markers in non-demented subjects attending a memory clinic: study design and baseline findings of the MEMENTO cohort. *Alzheimers Res Ther* 29 août 2017; 9: 67.
31. de Medeiros K, Robert P, Gauthier S, et al. The neuropsychiatric inventory-clinician rating scale (NPI-C): reliability and validity of a revised assessment of neuropsychiatric symptoms in dementia. *Int Psychogeriatr* 2010; 22: 984–994.
32. Robert P, Lanctôt K, Agüera-Ortiz L, et al. Is it time to revise the diagnostic criteria for apathy in brain disorders? The 2018 International Consensus Group. *Eur Psychiatry* 2018; 54: 71–76.
33. Nasreddine ZS, Phillips NA, Bédirian V, et al. The Montreal cognitive assessment, MoCA: a brief screening tool for mild cognitive impairment. *J Am Geriatr Soc* 2005; 53: 695–699.
34. Teo TW, Mong Y and Ng SS. The repetitive five-times-sit-to-stand test: its reliability in older adults. *Int J Ther Rehabil* 2013; 20: 122–130.
35. Kear BM, Guck TP and McGaha AL. Timed up and go (TUG) test: normative reference values for ages 20 to 59 years and relationships with physical and mental health risk factors. *J Prim Care Community Health* 2017; 8: 9–13.
36. Nguyen AT, Nguyen HTT, Nguyen HTT, et al. Walking speed assessed by 4-meter walk test in the community-dwelling oldest old population in Vietnam. *Int J Environ Res Public Health* 2022; 19: 9788.
37. Grober E, Buschke H, Crystal H, et al. Screening for dementia by memory testing. *Neurology* juin 1988; 38: 900–903.
38. St-Hilaire A, Hudon C, Vallet GT, et al. Normative data for phonemic and semantic verbal fluency test in the adult French–Quebec population and validation study in Alzheimer's disease and depression. *Clin Neuropsychol* 2016; 30: 1126–1150.
39. Wechsler D. Wechsler memory scale. 1945.
40. Wechsler D. *Wechsler adult intelligence scale*. New York: Psychological Corporation, 1997.
41. Bayard S, Erkes J and Moroni C. Victoria Stroop test: normative data in a sample group of older people and the study of their clinical applications in the assessment of inhibition in Alzheimer's disease. *Arch Clin Neuropsychol* 2011; 26: 653–661.
42. Brickenkamp R, Liepman D and Schmidt L. *D2-R: Test d'attention concentrée révisé*. Paris Ed Hogrefe, 2015.
43. Allain P, Nicoleau S, Pinon K, et al. Executive functioning in normal aging: a study of action planning using the zoo map test. *Tennet XV* 1 févr 2005; 57: 4–7.
44. Brill E, Holfelder A, Falkner M, et al. Behavioural and neuronal substrates of serious game-based computerised cognitive training in cognitive decline: randomised controlled trial. *BJPsych Open* 2024/11/06 éd. 2024; 10: e200.
45. Carson N, Leach L and Murphy KJ. A re-examination of Montreal cognitive assessment (MoCA) cutoff scores. *Int J Geriatr Psychiatry* 1 févr 2018; 33: 379–388.
46. Flinterman LE, González-González AI, Seils L, et al. Characteristics of medical deserts and approaches to mitigate their health workforce issues: a scoping review of empirical studies in western countries. *Int J Health Policy Manag* 2023; 12: 7454.
47. Legendre B. En 2018, les territoires sous-dotés en médecins généralistes concernent près de 6% de la population. *Évolution* 2015; 2016:2017.
48. Ngandu T, Lehtisalo J, Korkki S, et al. The effect of adherence on cognition in a multidomain lifestyle intervention (FINGER). *Alzheimers Dement* 2022; 18: 1325–1334.
49. Bureš V, Čech P, Mikulecká J, et al. The effect of cognitive training on the subjective perception of well-being in older adults. *PeerJ* 2016; 4: e2785.
50. Stewart-Brown S and Janmohamed K. Warwick-Edinburgh mental well-being scale. *User Guide Version* 2008; 1.
51. Chiu HL, Chu H, Tsai JC, et al. The effect of cognitive-based training for the healthy older people: a meta-analysis of randomized controlled trials. *PLOS ONE* 1 mai 2017; 12: e0176742.
52. Bernini S, Ballante E, Fassio F, et al. In person versus remote cognitive rehabilitation in patients with subjective cognitive decline or neurocognitive disorders: what factors drive patient's preference? Front Psychol [Internet]. 2023;14. Disponible sur: https://www.frontiersin.org/journals/psychology/articles/10.3389/fpsyg.2023.1266314.
53. Manera V, Vandersteen C, Plonka A, et al. A decision-making algorithm for remote digital assessments of Alzheimer's disease. *Neurodegener Dis* 2024: 41–44. doi:10.1159/000539129