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ORIGINAL ARTICLE

VRainSUD: content validation of a cognitive training program using the Delphi method

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Abstract

Substance abuse has undeniable effects on several cognitive domains, with these associated deficits contributing to poorer treatment outcomes in substance use disorders (SUD). Cognitive training programs (CTPs) address these cognitive deficits, contributing to improved treatment outcomes. The main goal of this study was to validate the content of VRainSUD, a CTP virtual reality-based platform and a mobile follow-up application that proposes to reduce cognitive deficits in SUD. The Delphi method was used to reach a consensus on each of the program's characteristics (e.g., structure, cognitive training tasks). A panel of experts was invited to participate in the content validation by answering two rounds of questions (scale and free-text boxes) regarding the program. Changes were made between the rounds according to the results of the first round. The consensus was defined as at least 70% of the experts agreeing on the validity of a characteristic. From 39 invited experts, 11 completed the first round, and 6 completed both rounds. The structure of the program reached a consensus on the first round, along with most tasks (with the exception of two mobile application tasks). Significant changes were made following the feedback received, namely turning the program personalizable, and adding positive feedback to the tasks in order to improve adherence and engagement. The Delphi method was a valuable tool to improve VRainSUD. The experts' opinions validated main features and informed important additional changes, highlighting the importance of expert feedback in the development of cognitive interventions.

Keywords Substance use disorders · Cognitive training · Virtual reality · VRainSUD · Delphi method · Content validation

1 Introduction

1.1 Substance use disorders, brain changes and cognitive deficits

The global prevalence of substance use disorders (SUD) has increased significantly over the last decades (Degenhardt et al. 2018). According to Our World in Data, it is estimated that around 1.3% (Ritchie and Roser 2022a) and 0.7% (Ritchie and Roser 2022b) of the world population have an alcohol or drug use disorder, respectively. The disease burden of these disorders is high. The latest data reveal that each year more than 300.000 direct deaths can be attributed to SUD (Ritchie and Roser 2022a, b). With indirect deaths, the number more than doubles. In 2019, SUD had a disease burden of 35.13 million disability-adjusted life years, higher than natural disasters, conflict and terrorism, and interpersonal violence (e.g., murder) (Roser et al. 2021).

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Given its growing prevalence and significant disease burden, it is not surprising that treatment for SUD has been the object of considerable interest from the scientific community. However, relapse rates remain high with more than two thirds of individuals returning to substance use within one year of finishing treatment (Brandon et al. 2007). The consistent relapse rates have been attributed to the chronicity of SUD, which itself is at least in part explained by neural changes that are shown to persist after substance use stops (Parvaz et al. 2022).

According to Koob and Volkow (2016), the preoccupation and anticipation stage of addiction, explained by the changes in prefrontal cortex as well as in the insula and allocortex, could be a main element of relapse in humans. Imaging studies have found deficits in executive function associated with a decrease in frontal cortex activity that impacts working memory, decision-making, inhibitory control, and self-regulation (Volkow et al. 2011). Considering the influence that deficits in these cognitive domains seem to have on the relapsing nature of SUD, an effective intervention to mitigate them could be an important addition to treatment. A promising possibility is cognitive training.

1.2 Cognitive training programs for substance use disorders

The effectiveness of cognitive training is still a controversial subject. Some studies (e.g., Sala and Gobet 2019) have reported that effects resulting from cognitive training may be short-term or training specific, not translating into an improvement of general cognitive functioning in a given domain. However, some authors suggest that the lack of "far-transfer" effects may be due to a failure to broaden its concept as well as an almost exclusive reliance on primary outcomes (e.g., Brooks et al. 2020). Nonetheless, even amid the absence of consensus regarding its effectiveness, the state of the art indicates that cognitive training programs (CTPs) can lead to significant improvements in a number of populations, particularly in mild cognitive impairment (Brum et al. 2009; Mendoza Laiz et al. 2018; Zhang et al. 2019), Parkinson's disease (Leung et al. 2015; Gavelin et al. 2022), traumatic brain injury (Hallock et al. 2016; Vander Linden et al. 2019), as well as in patients living with HIV (Wei et al. 2022).

We have recently conducted a systematic review looking into the effective of cognitive training on memory, executive functioning and processing speed in individuals with SUD (Caetano et al. 2021). From the 26 studies included in the review, 18 found some type of cognitive improvement, even though two of these saw only marginally significant effects. The majority of the included studies focused on computerized CTPs and only five used a paper-and-pencil modality. Even though it is clear that these types of programs are increasingly using new technologies (e.g., smartphone applications), none of the studies included in the review utilized one of the most recent—virtual reality (VR).

1.3 Virtual reality interventions and cognitive training

VR can be described as a simulated environment with scenes and objects that appear to be real and with which the user can interact as if they were present (Biocca 1992). By providing an immersive and, at times, naturalistic environment, VR seems to enhance motivation and engagement (Makransky et al. 2019, 2021). The research into the use of VR technology in healthcare interventions is still recent, but shows promising results.

In a recent systematic review, Rowland et al. (2022) found that VR was an efficacious treatment modality for emotional disorders, namely anxiety disorders and post-traumatic stress disorders. Another review looking specifically into the use of VR in the treatment of addictive disorders, also reported positive results (Segawa et al. 2020). These findings are supported by a systematic review of reviews conducted by Cieślik et al. (2020), which provided evidence for the positive impact of VR interventions in psychiatric disorders. While these and other studies focused on psychological interventions, such as cognitive and behavioral therapy and exposure therapy (Bordnick et al. 2011; Hone-Blanchet et al. 2014; Segawa et al. 2020; Rowland et al. 2022), there have been also studies interested in the use of VR for cognitive training in these populations.

To our knowledge, only two studies have looked into the effectiveness of a VR cognitive training intervention in individuals with SUD. Man (2018) investigated the impact of a VR-based vocational training system in the cognitive performance, vocational outcomes, and work-related self-efficacy of young ketamine users. The results indicated that the VR group showed significant improvements in attention and memory, both maintained after 3 months. Participants from that group also presented a higher employment rate, even though the difference was not significant. Gamito et al. (2021) studied the effect of the Systemic Lisbon Battery, a VR-based serious games platform previously developed by Gamito et al. (2016), in individuals with alcohol use disorder undergoing inpatient treatment. The results indicated that this platform positively impacted attention and cognitive flexibility.

Even though these studies categorize their interventions as cognitive training, both appear to be more focused on improving functioning on an everyday context, something more akin to cognitive rehabilitation. The presented example tasks mirror real-world activities, such as choosing clothes to wear, going to the supermarket or, in the VR-based vocational training system studied by Man (2018), doing the work of a salesman on a clothing shop. They do not target specific cognitive domains as much as complex daily chores.

1.4 VRainSUD

VRainSUD is a CTP developed as an add-on intervention to be used with patients already receiving treatment for SUD, with the goal of mitigating cognitive deficits caused by long-term substance use and, hopefully, contribute to overall treatment success and a reduction of the relapse rates. It includes two modalities for two different stages of treatment: (1) a fully immersive VR platform with training exercises targeting specific cognitive domains, to be administered by psychologists or neuropsychologists (with training in the area of cognitive training) to patients undergoing treatment; (2) a mobile follow-up application also with cognitive training exercises, for Android and iOS, to be used by the patients (who previously used the VR platform) at their discretion after the end of treatment.

The VR platform aims to improve memory, executive functioning, and processing speed, while the follow-up application intends to maintain potential cognitive gains achieved through the VR platform during treatment.

This CTP was created taking into account an exhaustive search of cognitive training (programs and tasks) for psychiatric disorders in general and SUD in particular. Their input was invaluable for the creation of a program to which the patients will adhere to and feel motivated to complete. For example, while both of the studies presented before (Man 2018; Gamito et al. 2021) used ecologically sound tasks focused on daily activities (e.g., going to the supermarket), the professionals with years of experience with individuals with SUD who were questioned, before the creation of the CTP, do not consider that this type of task would be an added value and did not believe that this type of task would attract the population with SUD. As such, we opted for more attractive and gamified domain-specific tasks, which distinguishes our platform from existing ones.

Despite the extensive research that was conducted, we believe that content validation is essential to arrive at the best possible program. To that end, our goal was to utilize the Delphi method to gather expert opinion on and validate the following dimensions of the CTP: (1) structure of the program (e.g., organization, number, and duration of sessions; type and number of tasks per session); (2) cognitive training tasks of the VR platform; (3) cognitive training tasks of the mobile follow-up application.

2 Methods

2.1 Study design

The Delphi technique is an established research method that involves rounds of survey questions sent out to a panel of experts on a given subject and that, according to Häder (2014, as cited in Niederberger and Spranger 2020), can be used to achieve one or more of the following goals: (1) find consensus among experts; (2) aggregate ideas; (3) make future predictions; (4) determine experts' opinions. It is founded on the believe that the opinions of many outweigh those of a single individual, even if the individual is the foremost expert in their field.

In the present study, an online platform was used to anonymously collect the survey responses from an international group of experts. Similarly to the original Delphi method (Hasson et al. 2000), this study used a mixed-methods approach, with both rounds including Likert scales for quantitative analysis of consensus and free-text boxes to gather the experts' opinions and allow for the sharing of new ideas about how to improve the program.

All respondents gave their informed consent before participating in the study.

2.2 Participants

The participants were professionals with academic and/or practical experience in SUD and cognitive training.

2.2.1 Inclusion criteria

The identification of the experts was based on literature review, existing academic contacts, and a web search for CTP (for SUD or other conditions) and the respective scientific teams. The search was conducted from 30 November 2021 to 02 February 2022, with PubMed and combining search terms and MeSH terms being used to capture *cognitive training* AND *substance use* (e.g., addiction, specific substances such as alcohol, cocaine, etc.) AND *virtual reality*.

Considering the diverse methods to consider someone an expert in a given field (Shanteau et al. 2002), a simple point-based evaluation system was implemented to facilitate the selection process. We included all professionals with a final evaluation of at least 2 points. Regarding academic experience, we considered the following factors: At least one publication on the field of cognitive training (1 point) & at least one publication on the field of SUD (1 point) OR at least one publication on the field of cognitive training in SUD (2 points). Concerning practical experience, we considered experience in the development of a cognitive training program (1 point).

2.2.2 Recruitment

A sample size of 8 to 15 respondents has been recommended for Delphi studies, given that smaller samples reduce reliability and bigger ones do not appear to add much value (Keeney et al. 2010). For this study, we aimed to recruit 10–12 participants.

After being evaluated in accordance to the point system previously described, professionals who met the inclusion criteria (2 points or more) were invited to participate by email. In the initial questionnaire, they were asked to recommend other professionals who they considered to be experts in the field. Recommended professionals who met the inclusion criteria were contacted and invited to join the expert panel. In cases where no response was received, a follow-up reminder was sent after a two-week interval.

A total of 39 professionals were invited to participate in the expert panel.

2.3 Survey design

Even though classic Delphi studies use a qualitative approach in the first round, with the goal of allowing a broader understanding of the expert's opinion on a given topic, this would not have been adequate for the current study.

At the time of content validation, VRainSUD was already on a beta phase, during which structural features already existed (e.g., the possibility of hitting a ball with a racket), although the specifics and objectives of the task were not yet fully determined. The program was designed to be delivered in an inpatient treatment setting for substance abuse to patients over the age of 18, following an initial neuropsychological assessment. Exclusion criteria included the presence of a neurological disorder and a diagnosis of gambling disorder. The main purpose was to get feedback on very specific characteristics such as the cognitive training tasks and the structure of the program. This could only be achieved through directed questions. As such, we used a modified study design that included both Liker-scale questions (from 1-strongly disagree to 5-strongly agree) and free-text boxes for qualitative feedback.

The draft of the first-round survey was reviewed by three academics/clinicians—two from psychology and one from neuropsychology. Taking into account their feedback, the following changes were made: (1) more background information on VRainSUD was added; (2) information on the cognitive training tasks was simplified and demonstrative GIFs were included; (3) the structure of the survey was redesigned in order to reduce its length and avoid repetition.

2.4 Procedure

The Research Ethics and Deontology Committee of the Faculty of Psychology and Educational Sciences of the University of Coimbra approved the research project in which this content validation study is integrated (CEDI/FPCEUC:54/7-14/09/2021).

The link for the first-round survey was sent to the participants by email, along with a brief explanation on how to access it and the planned deadline (1 month). The questionnaire was delivered using google forms, allowing the participants to complete it electronically while ensuring anonymity.

In the first part of the questionnaire, participants were asked to give their electronic consent and provide some basic sociodemographic and professional information. We collected the participants' sex, age, educational background, and profession as well as country and city of work. Moreover, we also inquired about the participants' practical experience in cognitive training.

The Likert-scale responses from the first round were analyzed to understand which questions had reached consensus and which needed to be addressed before being included in the second round. The responses from the free-text boxes were first transcribed verbatim and then subject to qualitative content analysis. They informed additional changes that could be made to improve the structure of the VRainSUD program.

The link to the second-round survey was sent approximately two weeks after the first round closed. In the first part of this second questionnaire, a summary of the results from the first round was presented, along with additional information requested from some of the participants (e.g., regarding the target population). Participants were given two weeks to complete the second survey.

2.5 Analysis

Quantitative analyses were conducted using IBM SPSS version 28.

A database was created with every sociodemographic and Likert-scale questions/items (e.g. "The program using the VR platform consists of 12 individual sessions, held 3 times a week, for 4 weeks, with a duration of 30 min per session."). Categorical variables were encoded (e.g., 0-female and 1-male) and ordinal scale variables (Likert-scale questions/items) used the following correspondence: 1-strongly disagree; 2-disagree; 3-neither disagree nor agree; 4-agree; 5-strongly agree. Consensus in a given question/item was defined as at least 70% of responses being of agreement (i.e., ratings of 4-agree or 5-strongly agree; Sumsion 1998). Descriptive statistics were used to characterize the sample and assess consensus on both rounds of the survey. When the assumption of normality was not met, the non-parametric Mann–Whitney U test was used to evaluate the significance of the differences between the two rounds.

Qualitative content analysis was conducted to assess the free-text box responses. The feedback from the experts was organized by categories (e.g., program structure, session zero, performance sequence, and others), facilitating its interpretation and the recognition of recurring themes or patterns. This organization also resulted in the structure of the second-round questionnaire.

3 Results

Email invitations to participate in the expert panel were sent to a total of 39 professionals. This included 35 who were identified by the research team and 4 who were recommended by one of the experts. Of these, 11 (28.2%) completed the first round. Six (15.4%) of those who responded to the first round also completed the second round. The 28 professionals who did not participate in round 1 and the five who did not complete round 2 either did not respond to our initial invitations or subsequent reminders.

An overview of the sociodemographic data is presented in Table 1. Sociodemographic data were not collected in the second-round questionnaire.

A description of the follow-up mobile application cognitive training tasks is available in Table 2. Sociodemographic data were not collected in the second-round questionnaire.

Table 1 Sociodemographic and professional characteristics

Sample characteristic	Median	n	%
Age (years)	44.50	10	
Length of time of practical clinical experience	11.00	9	
Gender			
Male		7	63.6
Female		4	36.4
Educational background			
Clinical neuropsychology		3	27.3
Psychology		2	18.2
Cognitive neuroscience and psychology		1	9.10
Experimental psychology		1	9.10
Clinical psychology		1	9.10
Cognitive psychology		1	9.10
Cognitive psychology and cognitive neuroscience		1	9.10
Smart healthcare		1	9.10
Occupation			
Professor		9	81.8
Researcher		2	18.2
Country of employment			
United States of America		2	18.2
United Kingdom		1	9.1
South Africa		1	9.1
Australia		1	9.1
Austria		1	9.1
Iran		1	9.1
Canada		1	9.1
India		1	9.1
Portugal		1	9.1
Korea		1	9.1

3.1 Round 1

An overview of the results from round 1 is presented in Table 3.

3.1.1 VR platform

In the round 1 questionnaire, the experts were presented with various general aspects of the VR platform, namely program structure, session zero and performance sequence, as well as the VR cognitive training tasks and a set of structured sessions (which from session 7 onwards would be administered sequentially to all patients). Several suggestions were taken into account following the 1st round questionnaire.

General aspects of the VR platform In the first round, regarding general aspects of the VR platform, the consensus was reached on all topics included, namely on the structure of the program (72.2% of consensus; the number of weeks, sessions per week, duration of the sessions), session zero (90.9% of consensus) and performance sequence (72.7% of consensus). Even though there was consensus on all these aspects of the platform, some experts suggested that more sessions should be done per week or that the duration of the intervention should be extended in order to increase the total hours of cognitive training (*"Consider higher dosage, i.e., daily cognitive training for 4 weeks or longer duration 8 weeks."; "It suggested a longer intervention in time, even if only with two weekly sessions."*). Still regarding the general aspects of the VR Platform, another expert suggested: *"I suggest to reduce the features that may induce stress on participants, particularly for the first sessions. For example time pressure, lack of positive feedbacks, graphical designs. Having sounds that induce a feel of achievement and enjoy is highly suggested (you might already have these feature)."*

VR platform's cognitive training tasks Consensus (more than 70% of the answers were Agree or Strongly Agree) was also reached on all the VR cognitive training tasks (described in Table 2). One of the experts mentioned: "*I like the task design. Particularly the inhibitory control task and working memory tasks (I have more familiarity with lab-based versions of these tasks, so it's easier to see how they would be implemented in VR*". Another expert suggested: *"…to have brief dynamic feedback for the Labyrinth navigation task,*

Table 2 Description of CTP tasks

Task	Task name	Cognitive domains	Objective	Description
1. Virtual Reality (VR) platform tasks				
Task 1	Labyrinth navigation	Logical/deductive reasoning, planning, processing speed	Reach the labyrinth's exit	During the time designated for the task in question, several labyrinths appear to the subject. He must use the provided auxiliary map to successfully navigate each labyrinth and reach the exit. The auxiliary map also allows the subject to visualize his current position
Task 1.1. (before Task 2)	Remembering space	Long term memory	Select "YES" for the objects memorized in the task "Labyrinth Navigation" and "No" for the objects that have not appeared before	During the "Labyrinth Navigation" task, various objects will appear in the labyrinths, which the subject will have to memorize. In this task, the subject is presented with these and other objects that have not appeared before and should select "YES" only when he identifies objects that were present in the "Labyrinth Navigation" task
Task 2 (before Task 3)	Number sequence	Cognitive flexibility, logical/deductive reasoning, processing speed	Complete number sequences	The subject must understand the logic of the presented sequence and complete it with the numbers he has at his disposal
Task 3 (before Task 4)	Passing balls	Cognitive flexibility, inhibitory control, processing speed, working memory	Only hit the allowed balls	In this task, the subject has at his disposal a racket, which will allow him to hit the balls that appear in the task scenario. Instructions regarding which balls should not be hit will alternate throughout the task. The instructions for the balls to avoid appear for a few seconds and then disappear, so that the subject must pay attention to the change and memorize it. The longer the subject manages to only hit the allowed balls, the more points he adds to the total score (the higher the total score)
Task 4 (before Task 5)	Cube memory	Working memory	Remember the location of numbers in sequential order	In the scenario, some numbered cubes will appear, which rotate after a few seconds, hiding the number in question. The subject must select the cubes that had numbers, following the order by which they appear
Task 5 (before Task 6)	Working maze	Working memory	Reach the labyrinth's portal (which can only be found if the subject follows all directions correctly)	At first, the subject visualizes a sequence of directional arrows (e.g.,→↑→←) on the floor of the maze. He will have to memorize the sequence and use it to navigate the maze. The subject has no longer visual access to the directions when advancing through the maze
2. Mobile follow-up application tasks				
Task 1	Remember the object	Working memory	Only select objects that have not been selected previously	The subject will be selecting objects and will have to memorize them. As more objects appear, he will have to continue selecting only objects that have not been previously selected
Task 1.1 (before Task 2)	Remembering space	Long term memory	The subject will have to indicate with "Yes" or "No" if he had seen the object before	In this subtask, the patient must identify objects presented in the previous task (task 1)
Task 2 (before Task 3)	Name changed to squares of memory (before treasure hunt)	Working memory	Remember the location of numbers in sequential order	Some numbered squares will appear in the scenario, and after a few seconds, the numbers in question will be hidden. The participant must select the squares that had numbers, following the order by which they appeared initially
Task 3 (before Task 4)	Number sequence	Cognitive flexibility, logical/deductive reasoning, processing speed	Complete number sequences	The subject must understand the logic of the presented sequence and complete it with the numbers he has at his disposal
Task 4 (before Task 5)	Colors and shapes	Cognitive flexibility, inhibitory control and processing speed	Select objects according to the instructions provided	The subject should select only objects that meet the instructions provided. Objects with a confusing characteristic will appear, for example, red square, red circle. If the patient makes a mistake, the participant will be informed of the mistake but will be allowed to continue trying to find the correct rule until the time set for the task comes to an end

Table 3 Appraisal of the Cognitive Training Program (CTP) in round 1

Item	Statements	Round 1 (n = 11)		
		Consensus, n (%)	Median	IQR
1. Virtual Reality (VR) platform				
1.1 General aspects of VR platform				
1.1.1. Program structure	The program using the VR platform consists of 12 individual sessions (held 3 times a week, for 4 weeks, with a duration of 30 min per session)	72.7	4.00	0.50
1.1.2 Session zero	A session will be held before the 1st Session (Session zero), during which instructions will be provided for the use of VR glasses and the patients will be allowed to explore the platform and clarify any questions that may arise. The objective of this session is to ensure that all patients have an adequate mastery of the virtual environment before the start of the training sessions	90.9	5.00	0.00
1.1.3 Performance sequence	All participants will perform the same execution/performance sequence. The tasks must take place sequentially according to the pre-defined logic. In total, the VR platform comprises 6 distinct tasks	72.7	4.00	1.00
1.2 Description of VR platform tasks				
1.2.1 Task 1	Labyrinth navigation	72.7	4.00	2.00
1.2.2 Task 2 (changed to task 1.1. An round 2)	Number sequence	72.7	4.00	1.25
1.2.3 Task 3 (changed to task 2 an round 2)	Remembering space	72.7	4.00	0.50
1.2.4 Task 4 (changed to task 3 an round 2)	Passing balls	90.9	4.00	1.00
1.2.5 Task 5 (changed to task 4 an round 2)	Cube memory	90.9	4.50	1.25
1.2.6 Task 6 (changed to task 5 an round 2)	Working maze	81.8	4.00	1.50
1.3 Sessions of VR platform tasks				
1.3.1 Session 1	Session 1 is composed of tasks 1 (Labyrinth Navigation, 10 min.), 2 (Number Sequence, 15 min.) and 3 (Remembering Space, 5 min.)	45.5	3.00	1.00
1.3.2 Session 2	Session 2 is composed of tasks 4 (Passing Balls, 15 min.), and 5 (Cube Memory, 15 min.)	45.5	3.00	1.00
1.3.3 Session 3	Session 3 is composed of tasks 1 (Labyrinth Navigation, 10 min.), 4 (Passing Balls, 15 min.), and 3 (Remembering Space, 5 min.)	45.5	3.00	1.00
1.3.4 Session 4	Session 4 is composed of tasks 6 (Working Maze, 15 min.) and 5 (Cube Memory, 15 min.)	54.5	3.50	1.00
1.3.5 Session 5	Session 5 is composed of tasks 1 (Labyrinth Navigation, 10 min.), 6 (Working Maze, 15 min.), and 3 (Remembering Space, 5 min.)	45.5	3.50	1.00
1.3.6 Session 6	Session 6 is composed of tasks 1 (Labyrinth Navigation, 10 min.), 4 (Passing Balls, 15 min.), and 3 (Remembering Space, 5 min.)	54.5	3.50	1.00
1.3.7 Sequentially repeated sessions	From the Session 7 on (regarding the VR platform) the sessions will repeat sequentially	54.5	3.50	1.00
2. Mobile follow-up application				
2.1 General aspects of mobile follow-up application				
2.1.1 Program structure	It is recommended that the subject uses the mobile follow-up application for approximately 30 min a day, three times a week, which makes 24 sessions over a period of 8 weeks	81.8	4.50	1.00
2.1.2 Task completion	The mobile follow-up application consists of 5 tasks. In each 30-min session, the subject is expected to alternate between the various tasks in order to provide training in the various cognitive domains	72.7	4.00	1.25
2.2 Description of the mobile follow-up application tasks				
2.2.1 Task 1	Remember the object	81.8	4.00	1.25
2.2.2 Task 2 (changed to Task 1.1. an round 2)	Remembering space	63.6	4.00	1.50
2.2.3 Task 3 (changed to Task 2 an round 2)	Treasure hunt	72.7	4.00	1.25

Table 3 (continued)

Item	Statements	Round 1 (n = 11)		
		Consensus, n (%)	Median	IQR
2.2.4 Task 4 (changed to Task 3 an round 2)	Number sequence	81.8	4.00	0.50
2.2.5 Task 5 (changed to Task 4 an round 2)	Colors and shapes	54.5	4.00	2.00

IQR = interquartile range

since the participant may proceed and then realize he/she might went wrong and the time is up… Overall, the tasks seem amazing.".

Cognitive training sessions with VR platform In the 1st round, the VR Platform sessions were presented in a structured way with a specific task sequence selected for each session. However, the consensus was not reached on the structure of the sessions and on the fact that the sessions would be repeated after the seventh. One of the experts suggested *"to put working memory related tasks as the first training task for each session, since it demands more cognitive energy and keep those tasks which are more gamified… for the last part of the session"*. Likewise, most experts suggested that sessions be personalized for each patient. One suggested *"consider performance-based training vs. everything sequentially, i.e., train in tasks that patient exhibits the worst performance at baseline"*, while another considered it would *"be more appropriate an evolution considering the previous neuropsychological assessment and contingent on the performance of the tasks would"*.

3.1.2 Mobile follow-up application

In the round 1 questionnaire, all information about the program structure, how to complete the tasks, as well as a description of all the tasks included in the mobile application was made available to the experts. Several suggestions from experts to improve the mobile application in question were also considered.

General aspects of the mobile follow-up application Although all general aspects of the follow-up mobile application obtained a consensus of more than 70%, some experts suggested some improvements and made some considerations. One of the experts mentioned: *"30 min a day can be quite intensive for participants; it would be nice if you could reduce time commitment while maintaining the same active ingredients. It would also be important to consider the context in which participants will train, e.g. supervised or unsupervised,…"*. Another commented that *"It would be interesting to have assessment after 3 month/6 months of interval to measure the true transfer effect of CTP on cognitive functioning"*. Other suggestions for improvement from another expert were also taken into account: *"I think repeating the training tasks during follow-up could be less intense in terms of the frequency of sessions (i.e., two times per week)."*

Mobile follow-up application's cognitive training tasks Consensus (more than 70% of the answers were Agree or Agree Completely) was reached on the cognitive training tasks 1, 3 (which became task 2), and 4 (which became task 3). We did not reach a consensus on tasks 2 (which became task 1.1.) and 5 (which became task 4). For task 4 (before task 5) we considered the following suggestions for improvement: *"I suggest that instead of the instruction appear objects with the confounding characteristic, for example, red square, red circle. Instead of finishing the task if you make a mistake, I suggest displaying the information that you made a mistake and allowing you to keep trying until you get the rule right, a bit like in WIT or Wisconsin."* and *"Task 5 has many cognitive functions involved; (motor) inhibition may not very well targeted"*.

3.2 Round 2

An overview of the results from round 2 is presented in Table 4.

3.2.1 VR platform

In the second-round questionnaire, all items that did not reach consensus in the first round were considered, as well as items that, although they had reached consensus, would benefit from and could be adjusted according to the experts' suggestions.

General aspects of the VR platform Regarding the VR platform, even though consensus had been reached in the first round on the structure of the program (72.7%) and on the performance sequence (72.7%), we chose to make changes based on the experts' suggestions. Therefore, these dimensions were once again evaluated in the second-round questionnaire. Based on the experts' suggestions, we extended the inpatient treatment duration from 6 to 8 weeks, which allowed us to increase the cognitive training program by another 2 weeks (6 weeks instead of 4). The first week

Table 4 Appraisal of the Cognitive Training Program (CTP) in round 2

Item	Statements	Round 1 (n = 6)		
		Consensus, n (%)	Median	IQR
1. Virtual reality (VR) platform				
1.1 General aspects of VR platform				
1.1.1 Program structure	Instead of 12 training sessions (3 times per week, for 4 weeks, 30 min each session), we changed to 18 training sessions (3 times per week, for 6 weeks, 30 min each session). The total number of sessions went from 12 to 18. Note: Taking into account the total duration of the inpatient treatment and the treatment as usual (TAU) in the center where the program will be implemented, which has other daily therapeutic activities, it is not feasible to increase the duration of the training sessions or their frequency. However, we managed to extend the inpatient treatment duration from 6 to 8 weeks, what allows us to increase the cognitive training program another 2 weeks (6 weeks instead of 4). The first week of treatment will be used for the pre-test, the cognitive training will happen between the second and the seventh weeks (inclusive) and, the last week will be used for the post-test	100	5.00	1.00
1.1.2 Performance sequence	Previously, the program had 6 distinct sessions that repeated sequentially. Based on the experts' feedback, it was decided that the training will be personalized, and more focus will be given to the cognitive domains in which the participant presents the most difficulties at baseline. Consideration will also be given to prior neuropsychological assessment and task performance as the sessions progress	83.3	5.00	1.50
1.2 Description of VR Platform Tasks				
1.3 Sessions of VR Platform Tasks				
1.3.1 Sessions	Based on the experts' suggestions, the tasks administered will be based on the participant's individual needs, so there will no repetition of structured sessions (previously, from the 7th session, the patients repeated the same structured sessions that they had already performed in the first six training sessions)	100	5.00	1.00
	Although the training will be personalized, other suggestions for improvement will also be considered, namely regarding the order of the tasks within the same sessions. The first task of every session will be a working memory task. On the other hand, the more gamified tasks will be left for the last part of the session	83.3	4.00	0.50
2. Mobile follow-up application				
2.1 General aspects of mobile follow-up application				
2.1.1 Program Structure	Since most experts mentioned that 30 min a day could be quite intense for the participants, it was decided to reduce the training frequency throughout the follow-up mobile application. Also, in accordance with the feedback given, a directive training was chosen (based on follow-up consultations) twice a week. The psychologist will instruct the participant to dedicate 20 min, two times a week (total of 40 min) to complete the tasks. The psychologist will instruct the participant to do two specific tasks in each of these 20 min training sessions	100	4.50	1.00
2.1.2 Task Completion	All tasks in the mobile application do not end immediately if the participant makes a mistake. There will be a set time for each task, so each task only ends when this time comes to an end	100	4.00	0.25
2.2 Description of the Mobile Follow-up Applications Tasks				
2.2.1. Task 1.1. (before Task 2)	Task 2 will no longer exist (so it will become part 2 of task 1. Task 2 will be automatically linked with task 1. That is, after task 1 is finished, task 2 automatically appears (which we will call task 1.1.) In this subtask, the patient must identify objects presented in the previous task (task 1), selecting "Yes" for the objects they remember. (To remind: In task 1, the participant selects objects and will have to memorize them. As more objects appear, he will have to continue to select objects that he has not previously selected.)	83.3	4.00	1.25
2.2.2. Task 2 (before Task 3)	Task 3 consisted of the following: Connect two points (a boat to a treasure) without falling into the existing traps. It has been changed and replaced by the following task (similar to one of the VR platform tasks that achieved a high consensus—greater than 90%): Remember the location of numbers in sequential order. Some numbered squares will appear in the scenario, and after a few seconds, the numbers in question will be hidden. The participant must select the squares that had numbers, following the order by which they appeared initially. The difficulty increases as more numbered squares appear and the subject will have to memorize a longer sequence	100	4.50	1.00
2.2.3. Task 4 (before Task 5)	Based on the experts' suggestions, task 5 was reformulated as follows: Instead of the instruction indicating the objects that the subject will have to avoid, objects with a confusing characteristic will appear, for example, red square, red circle. On the other hand, instead of the task ending if the patient makes a mistake, the participant will be informed of the mistake but will be allowed to continue trying to find the correct rule until the time set for the task comes to an end	100	4.00	0.25

IQR = interquartile range

of treatment will be used for the pre-test and establishment of a baseline, the cognitive training will happen between the second and the seventh weeks (inclusive), and the last week will be used for the post-test. Previously, the program had 6 distinct sessions that were repeated sequentially. Based on the experts' feedback, it was decided that the cognitive training will be personalized, and more focus will be given to the cognitive domains in which the participant presents the most difficulties at baseline. Consideration will also be given to prior neuropsychological assessment and task performance as the sessions progress. Since the tasks administered will be based on the participant's individual needs, there will be no repetition of structured sessions (previously, from the 7th session, the patients repeated the same structured sessions that they had already performed in the first six training sessions). Other suggestions for improvement were also considered, namely regarding the order of the tasks within each session. The first task of every session will be a working memory task while the more gamified tasks will be left for the last part of the session.

3.2.2 Mobile follow-up application

For the follow-up mobile application, the second-round questionnaire considered aspects that had not reached consensus among the experts, as well as other suggestions for improvement.

General aspects of the mobile follow-up application Even though the consensus was reached on task 2 (before task 3; 72.7%), on the program structure (81.8%), and on the task completion (72.7%), with the goal of improving the mobile application, some of the experts' suggestions were introduced. Since most experts mentioned that 30 min a day could be quite intense for the participants, the advised training frequency will be reduced. A directive training approach will be adopted with each participant being asked to complete 20 min of training, twice a week (based on the follow-up individual sessions). The psychologist will instruct the participant to do two specific tasks in each of these 20 min training sessions.

Mobile follow-up application's cognitive training tasks Task 2 will no longer exist, becoming a subtask of task 1. After task 1 is finished, task 1.1. (previously task 2) will automatically appear. In this subtask, the patient must identify objects presented in the previous task (task 1), selecting "Yes" for the objects they remember. Even though consensus had been reached on task 2 (before task 3), considering some comments from the experts, this task was replaced with a modified (non-VR) version of the VR task targeting the same cognitive domain (which reached a consensus greater than 90%). Thus, task 2 became remembering and reproducing a number sequence. Some numbered squares appear in the scenario, and after a few seconds, the numbers in question are hidden. The participant must select the squares where the numbers were, following the order in which they appeared initially. The difficulty increases as more numbered squares appear and the subject will have to memorize a longer sequence. Based on the experts' suggestions, task 5 (now task 4) was reformulated. Thus, instead of the instruction indicating the objects that the subject will have to avoid, objects with a confusing characteristic will appear, for example, a red square, or red circle. Finally, it was decided that all tasks in the mobile application will have a set time instead of coming to an end when a participant makes a mistake. The participant will be informed of the mistake but will be allowed to continue trying to successfully complete the task until the established time comes to an end.

3.3 Differences between rounds

A summary of the changes made between the two rounds is presented in Table 5.

The median difference for each item repeated on both rounds was calculated by subtracting the median of the first round from the median of the second.

In Table 5, median differences between the rounds are presented. No difference was statistically significant ($p > 0.05$).

4 Discussion

The main goal of this study was to validate the content of VRainSUD, a cognitive training program developed to mitigate the cognitive deficits of individuals receiving treatment for SUD. The focus was on two major dimensions of the program: the structure (e.g., number, frequency, and duration of sessions; type and number of tasks per session) and the cognitive training tasks (of the VR platform and the mobile follow-up application).

With the exception of two cognitive training tasks in the mobile follow-up application, both of these two dimensions reached the required level of consensus in the first round. Despite this, significant changes were made taking into account the feedback from the panel of experts.

Initially, VRainSUD was designed to follow a specific sequence of sessions with a pre-determined combination of cognitive training tasks, with the goal of giving similar training time to the various cognitive domains being targeted (i.e., memory, executive functions, processing speed). However, several experts indicated that a personalizable program would not only be more versatile but potentially also more effective. This is consistent with previous research on

Table 5 Summary of Consensus in the two rounds

Item	Round 1 (n=11)			Round 2 (n=6)				
	Consensus, n (%)	Median	IQR	Consensus, n (%)	Median	IQR	U	*p*
Program Structure	72.7	4.00	0.50	100%	5.00	1.00	14.00	0.062
Session zero	90.9	5.00	0.00	–[2]	–[2]	–[2]	–	–
Performance Sequence	72.7	4.00	1.00	83.3%	5.00	1.50	22.50	0.301
1.1 Description of VR platform tasks								
Task 1	72.7	4.00	2.00	–[2]	–[2]	–[2]	–	–
Task 1.1. (before Task 2)	72.7	4.00	1.25	–[2]	–[2]	–[2]	–	–
Task 2 (before Task 3)	72.7	4.00	0.50	–[2]	–[2]	–[2]	–	–
Task 3 (before Task 4)	90.9	4.00	1.00	–[2]	–[2]	–[2]	–	–
Task 4 (before Task 5)	90.9	4.50	1.25	–[2]	–[2]	–[2]	–	–
Task 5 (before Task 6)	81.8	4.00	1.50	–[2]	–[2]	–[2]	–	–
1.2 Sessions of VR platform tasks								
Session 1	45.5	3.00	1.00	–[2]	–[2]	–[2]	–	–
Session 2	45.5	3.00	1.00	–[2]	–[2]	–[2]	–	–
Session 3	45.5	3.00	1.00	–[2]	–[2]	–[2]	–	–
Session 4	54.5	3.50	1.00	–[2]	–[2]	–[2]	–	–
Session 5	45.5	3.50	1.00	–[2]	–[2]	–[2]	–	–
Session 6	54.5	3.50	1.00	–[2]	–[2]	–[2]	–	–
Sequentially repeated sessions	54.5	3.50	1.00	–[2]	–[2]	–[2]	–	–
Sessions based on individual needs	–[1]	–[1]	–[1]	100%	5.00	1.00	–	–
Order of the tasks	–[1]	–[1]	–[1]	83.3%	4.00	0.50	–	–
2. Mobile follow-up application								
2.1 General aspects of mobile follow-up application								
Program Structure	81.8	4.50	1.00	100%	4.50	1.00	28.50	0.660
Task Completion	72.7	4.00	1.25	100%	4.00	0.25	−0.44	0.149
2.2 Description of the mobile follow-up applications tasks								
Task 1	81.8	4.00	1.25	–[2]	–[2]	–[2]	–	–
Task 1.1. (before Task 2)	63.6	4.00	1.50	83.3%	4.00	1.25	18.00	0.350
Task 2 (before Task 3)	72.7	4.00	1.25	100%	4.50	1.00	23.50	0.149
Task 3 (before Task 4)	81.8	4.00	0.50	–[2]	–[2]	–[2]	–	–
Task 4 (before Task 5)	54.5	4.00	2.00	100%	4.00	0.25	18.00	0.149

[1]These items were not available in round 1

[2]These items were not available in round 2

IQR = interquartile range; U = Mann–Whitney Test; *p* = *p*-value

personalized computerized CTPs, which has demonstrated significant improvements across various cognitive domains compared to non-personalized cognitive training (Peretz et al. 2011). As such, the structure was altered, while allowing for the personalization of each session according to the baseline deficits as well as the progress of a given patient.

The number of sessions itself was increased by maintaining their frequency (3 sessions per week) but extending the duration of the program. Considering that VRainSUD was developed with a specific setting in mind, this factor was conditioned by the characteristics of the inpatient treatment in question. However, we were able to increase the duration of the treatment from 6 to 8 weeks, allowing for 6 weeks of cognitive training (instead of the initial 4 weeks). Even though this change is significant, some experts considered that an even higher number of cognitive training hours could be beneficial. The optimal number of training hours will likely vary according to the baseline deficits and progression of each individual using the program. Future studies using VRainSUD without our current constraints (i.e., other settings), could investigate the relative effectiveness (and adherence) of different program durations.

In comparison with the VR platform, the mobile follow-up application (e.g., structure and tasks) received more criticism and was subject to more changes. Moreover, it is important to note that despite the increased technical difficulty of the VR platform, the mobile follow-up application may actually be more complex in order regards, given that it will be used without constant supervision. As such, many of the experts' suggestions were focused on not only improving the cognitive training tasks themselves but also increasing the patients' adherence to this part of the program. Both of these factors can have a significant impact on the program's effectiveness.

Regarding the tasks, task 1.1 (before task 2—Remembering Space) was added to the previous one, task 2 (before task 3—Number Sequence) was replaced by a modified version of a VR training task, which had already received a high consensus and yet task 4 (before task 5—Cube Memory) was altered. Equally important, significant changes were made to improve adherence and motivation. The frequency and duration of suggested training sessions was reduced, and the training sessions will be incorporated into the individual sessions the patients will have twice a week with a clinical psychologist (part of an aftercare program offered to those who completed in-patient treatment). Once again, we should note that the structure of this part of the program is constrained by the already existing treatment in which it will be integrated. Future studies could experiment with additional structural changes, but a directive approach (versus self-management of training time) should always be preferred.

The median difference between the levels of consensus of the two rounds was greater for the structure of the VR platform and one of the tasks of the mobile follow-up application. This result is relevant since these are also the two dimensions that suffered the most changes following the feedback received in the first round. Despite this, the differences still weren't statistically significant, which may be explained by the small sample size.

Even though the focus of the content validation was on the structure and tasks of the CTP, the inclusion of free-text boxes on both rounds allowed the experts to comment on/suggest other, more specific, features. It was not possible to accommodate all the suggestions, but we did incorporate a majority of them.

Still looking to improve motivation and adherence, a positive feedback system was added so that a patient is validated (through sounds and visual stimuli) when they successfully complete a task and/or move on to another level of difficulty. A study by Burgers et al. (2015) looking into the impact of feedback on motivation in a brain-training game (a type of cognitive training), reported that positive feedback promotes long-term motivation. In a more recent study with a mental arithmetic task, Peifer et al. (2020) found that the relationship between positive feedback and flow and performance seems to be mediated by self-efficacy.

Certain changes were also made with the goal of preventing/reducing frustration. For the VR tasks, a patient will only move to another level of difficulty if they successfully complete the previous one (starting with a baseline level). Each task has many different exercises for each level. Finally, on the mobile follow-up application, a set duration time was added to all the tasks. When a patient makes a mistake, they receive feedback on this mistake but are allowed to continue training (versus having to start over from the beginning).

The present study has some limitations that should be taken into account when interpreting the results. The sample of experts used was relatively small, especially considering that only around half of the original panel completed the second round. Even though too big samples are not useful when using the Delphi method, we do believe that it would have been beneficial to have a slightly higher number of experts and a better turnout rate at the second round. This limitation could be explained by the fact that the subject under content validation is very specific and therefore, the pool of available experts is itself limited. Another important limitation to consider is the current state of the art on VR and its use for cognitive training in general, and in individuals with SUD in particular. Since VR and its use in health interventions is such a recent innovation, even highly qualified and experienced professionals do not have all the answers regarding the best way to utilize it in order to optimize the intervention's effectiveness. As with every new technology or scientific development, it will take time and many more studies to truly understand and make use of all of VR's potential.

The experts' feedback was essential for taking into account factors such as adherence, motivation, and engagement, which have their own impact on the program's effectiveness. While most current research on VR in the context of SUD focuses on the relationship between environmental stimuli and substance use (Bordnick et al. 2011; Hone-Blanchet et al. 2014; Ghiță et al. 2021), fewer studies have explored VR as a cognitive training tool for SUD (Man 2018; Gamito et al. 2021). Although VR-based interventions are promising for treating SUD (Amista et al. 2017; Taubin et al. 2023), further research is needed to understand the impact of user-related factors on its effectiveness.

While not widely used in the field of clinical or neuropsychology, the Delphi method was a valuable tool in the development of VRainSUD. It allowed not only for the content validation of certain key dimensions of the program, such as its structure and cognitive training tasks, but also for its overall improvement. In view of its contribution, we consider that content validation using the Delphi method should be more often utilized when designing new cognitive or psychosocial interventions.

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Declarations

Conflict of interest The authors declare no competing interests.

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