Development of User Suitability Evaluation Method of Cognitive Training System Through Application ^x

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Abstract

Background: To check in advance whether there are any problems in use and to address these in the process of designing a medical device, it is necessary to evaluate user suitability. Yet currently, there are a few user suitability evaluation constructs established for unique technologies. Therefore, the development of user suitability evaluation constructs for the user suitability evaluation of self-developed computerized cognitive rehabilitation applications should be prioritized.

Method: To evaluate the user suitability of the computerized cognitive rehabilitation application developed in this paper, we derived the user suitability evaluation constructs of user satisfaction, time satisfaction, difficulty, comprehension, effectiveness, efficiency, and error, and after clinical trials for user suitability evaluation, we analyzed the results and tried to identify and address the problems of the developed evaluation constructs. Twenty-four senior citizens over 55 years of age participated in the clinical trial, and performed cognitive rehabilitation training once a week for 3 weeks using our self-developed cognitive rehabilitation application.

Result: As the weeks progressed, satisfaction increased in orientation training and concentration training. User suitability evaluation constructs for effectiveness, efficiency, and error were appropriate, but there were insufficient aspects in the evaluation scales for user satisfaction, time satisfaction, difficulty, and understanding; **Conclusion:** we were able to derive an improvement plan by extracting the established user suitability evaluation scale.

Trial registration: Ethics approval and consent to participate. The evaluation was conducted after obtaining Institutional Review Board approval from Dongguk University Ilsan Hospital (DUIH2020-07-001-001).

1. Introduction

1.1 The Background of User Suitability

The concept of usability has been discussed since 1990. Usability, as defined by Jakob Nielsen, is a term that indicates how easy it is to use a product to achieve a user's desired purpose [1]. In the process of designing a product or service, it also indicates how to improve the product to make it easier for users to use. The sub-attributes of usability defined by Jakob Nielsen are 1. Learnability, 2. Efficiency, 3. Satisfaction, 4. Memorability, and 5. Errors. 1. Learnability refers to the ease with which users can perform basic tasks with a design they first encounter. 2. Efficiency refers to the speed of task execution when users are familiar with the design. 3. Satisfaction refers to how pleasantly satisfied the user is when using the design. 4. Memorability refers to the ease with which the user can perform a task when user encounters the design again after a period of not using the design. 5. Errors refer to how often and how many errors users make when working with the design, and how easily they can overcome them.

User suitability has recently emerged as a metric in the process of developing medical devices, and research on developing evaluation methods suitable to the characteristics of products for user suitability evaluation in various fields is ongoing. In the usability test, a suitable evaluation method for the product should be developed so that all factors that hinder the training effect can be found and prevented according to the convenience, usage errors, cognitive errors, and perceptual errors that may occur in the user's direct use. Therefore, testing usability by establishing usability evaluation constructs that can clearly test the usability of the product in the development process before the actual product is made is one of the effective ways to check whether there is any problem with the product

1.2 The Need for User Suitability

A user suitability test provides many advantages while developing a product or service. Through a user suitability evaluation, problems can be found and addressed before a product's release, saving time and cost. Therefore, it is possible to reduce unnecessary processes in the product development process by establishing usability evaluation constructs that can clearly test the usability of the product and conducting the user suitability test. In addition, for medical devices, it is necessary to continuously check whether there are any problems after market release through follow-up management. At this time, through the usability test, it is possible to discover supplements and improvements to the product, and to confirm the needs and preferences of users.

1.3 The Background of User Suitability

Since no user evaluation method has been established for cognitive rehabilitation application, we analyzed previous studies to develop an evaluation method that is suitable for cognitive rehabilitation application. Looking at previous studies that evaluated user suitability of web services or applications in fields other than cognitive rehabilitation, Park Min-su et al. established effectiveness, efficiency, and error evaluation as user suitability evaluation scales for web usability evaluation, measured training performance, required time, and error rate, and confirmed whether users can process information as desired. For the success/failure of the task, the training performance was quantified through satisfaction by grade and the number of errors. Total execution time of the task was measured for the efficiency and the number of errors were measured for the error, and the satisfaction score was quantified using a 5-point Likert scale [2]. In addition, in the study of human-computer interaction Gee, Park Ji-hyeong et al. studied the effects of the repetitive context of the game and the potential effect of interactivity on job training, and is pursuing ongoing research on web usability evaluation, such as how the design, interactivity and response speed of an application give satisfaction to users and increase their loyalty to applications [3][4]. Based on these previous studies, we tried to develop a user suitability evaluation method for cognitive rehabilitation training. In addition, we conducted clinical trials using the user suitability evaluation method developed to evaluate cognitive rehabilitation applications, and attempted to derive and address the problems of user suitability evaluation constructs through clinical trials. The clinical trial was conducted on subjects over the age of 55 with normal cognitive abilities, and the safety of the subjects was considered through IRB approval for safety in use.

Questionnaire for User Interface Satisfaction (QUIS) [5] and Satisfaction and Ease of use Questionnaire (USE) [6] have been heavily used among the cases of other questionnaires used in the existing user suitability evaluation, but their evaluation constructs are inappropriate to evaluate the user suitability of a computerized cognitive rehabilitation training system. Accordingly, Ahmed Mohammed Elaklounk developed evaluation constructs based on the constructs of the verified questionnaire for user suitability evaluation of the rehabilitation game system for cognitive deficits [7]. Therefore, in this paper, we developed evaluation constructs suitable for the computerized cognitive training system based on the frequently used questionnaire. In addition, we set up evaluation factors to measure the evaluation scale by referring to existing studies [8].

2. Method

2.1 Cognitive Rehabilitation and Cognitive Training

Cognitive training is a program that trains learners in skills and strategies to improve specific cognitive functions, and consists of training tasks that reflect that cognitive function in a prescribed way. For Cognitive rehabilitation, disability and health are judged at the body organ level, individual level, and social level with International Classification of Functioning, Disability and Health(ICF) introduced in 2001 [9]. The concept of cognitive rehabilitation is one of a treatment process that aims to restore, complement, and replace the deteriorated cognitive function from the point of

view of the functional level of the body. From an individual and social level perspective, the focus will be on the limitations of daily life and social life due to a decline in cognitive function.

2.2 Subjects for Cognitive Training Evaluation

According to the Act on the Prohibition of Age Discrimination in Employment and the Promotion of Employment of the Elderly in Korea, a person aged 55 or older is referred to as an elderly person [10]. Zhengxiang Pan et al. studied the effect of familiar design on elderly users in wellness games for elderly users over 65 years of age. As a result, it was found that familiarity with design improved satisfaction and adoption potential among elderly users [11]. Based on this, in this study, we consider that the age group that perceives the most difficulty in skillfully operating the application is the senior layer, and the improvement of the senior layer's familiarity in design will be an important factor to improve the satisfaction. Therefore, we recruited 25 adults over the age of 55 to use the self-developed application, and then conducted a user suitability evaluation. The Korean version of Mini-Mental State Examination (MMSE-K) was performed to screen the cognitive abilities of the seniors, who are the subjects of clinical trials. Cognitive rehabilitation was designed with reference to the typical cognitive training tasks of each cognitive domain to proceed with each subdomain of orientation, concentration, and memory using the application. We also developed a questionnaire necessary for user suitability evaluation with user suitability questions for each construct on a 5-point scale, as shown in Table 4. A high score in each item of the user suitability questionnaire evaluation means that the user suitability is high. It is designed to give 1 point if it is very difficult or very inconvenient, 2 points if it is difficult or inconvenient, 3 points if it is moderate, 4 points if it is easy or convenient, and 5 points if it is very easy or very convenient.

2.3 Cognitive Rehabilitation Training Process

The usability evaluation period of the cognitive rehabilitation training application considering the user's safety through the IRB was performed once a week for 3 weeks. The trainings constituting the cognitive rehabilitation application are orientation, memory, and concentration, which are functions that recognize time, place, and humans. Table 1 shows the detailed composition of memory and concentration.

Table 1 Cognitive rehabilitation application detailed training items (in the case of orientation training, detailed training items do not exist)

Training	Detailed training items
Memory	Word memory, general number memory, mental arithmetic number memory, color memory, matching memory
Concentration	Continuous concentration, memory concentration, colour matching concentration, search concentration

Table 2 User suitability evaluation contents

Training	Detailed training	Factors Affecting User Suitability
Concentration	Search concentration	Text; find provided letters in similarly shaped letters, incorrect answer rate
	Continuous concentration	Number; find consecutive correct answers in numerical, ascending and descending order, incorrect answer rate
	Color concentration	Letters and colors; match colors and letters to find the same correct answer, incorrect answer rate
	Memory concentration	Picture and memory; find consecutive correct answers according to the number of pictures, incorrect answer rate
Memory	Word memory	Text, text and picture related, time
	General number memory	Number, number order, time
	Mental arithmetic number memory	Number, mental arithmetic, time
	Color matching memory	Color, color order, time
	Matching memory	Location, location shape, time

In the first week, before proceeding with full-scale training, the subjects filled out a consent form and a personal information questionnaire asking for personal information such as age, gender, academic background, and medical history. Cognitive rehabilitation training was conducted through a program the subject accessed through a tablet computer that proceeded through orientation, concentration, and memory, and after training the subjects filled out a questionnaire to evaluate satisfaction in terms of time satisfaction, use satisfaction, comprehension, and difficulty. Required time, number of errors, and training performance were recorded automatically at the end of each detailed training. Each detailed training required the subject to enter the correct answer before proceeding to the next stage. The user suitability evaluation process conducted for 3 weeks is shown in Fig. 1, and MMSE-K was performed before the first week of cognitive rehabilitation training and after the third week of cognitive rehabilitation training. The training was required to be performed by the subjects themselves, but the investigator waited in the same room so that the subjects could freely ask for help during the training. Table 2 shows factors that can be the subjects of user suitability evaluation in each detailed training of the cognitive rehabilitation training using applications.

2.4 Cognitive Rehabilitation Training Applications

This application allows the level of training to be classified according to the difficulty of the task. In the area of orientation, there are a total of 5 questions, and as shown in Fig. 2, the current year, month, and day are asked, and then selecting a different material, selecting a specific fruit, selecting a different purpose, and selecting a seagull and a sweet potato are included among the examples given.

In the area of search concentration, as shown in Fig. 3A, letters composed of numbers and English letters are displayed in a row, and it is a training to identify how many characters suggested in the lower left box appear in the presented strings. It consists of a total of 5 stages. In stage 1, a single-character string is presented, and the number of strings presented increases as the difficulty increases. In the case of continuous concentration, as shown in Fig. 3B, the numbers are selected sequentially from small to large, but starting from the blue box containing the numbers between the blue box and yellow one to the other coloured boxes alternately. In stage 1, the numbers presented are

sequential, and in stage 2, the numbers presented are out of sequence. In stage 3, as shown in Fig. 3C, the objective is to click from the small number to the large number alternately in the boxes of different colours. Colour matching concentration is a training find a match between the colour of a word and the colour that the word means. There are 4 levels in total, and the number of colours presented increases as the difficulty increases. In the case of memory concentration, as shown in Fig. 3D, it is a training to memorize pictures or words and select matching words by memorizing actual pictures, and consists of a total of 5 stages.

For word memory, the component is a training to remember consecutive words, as shown in Fig. 4A. It consists of a total of 5 stages, and the number of words presented increases as the difficulty increases. General number memory is a training to remember consecutive numbers and their sequence as shown in Fig. 4B. It consists of a total of 5 stages, and the number of numbers that must be remembered increases as the difficulty increases. For mental arithmetic number memory, it is a training in mental arithmetic, and there are a total of 5 questions. For colour memory, it is a training to remember colours as shown in Fig. 4C. It consists of a total of 5 stages, and the number of colours to remember increases as the difficulty increases. Matching memory is a training to memorize words to find images, and memorize images to find words, as shown in Fig. 4D, and there are a total of 8 stages. As the difficulty increases, the number of words and images presented increases.

3. Result

3.1 User suitability evaluation method developed for cognitive rehabilitation applications

Evaluation constructs for user suitability evaluation of computerized cognitive rehabilitation training applications are user satisfaction, time satisfaction, difficulty, understanding, effectiveness, efficiency, and error. In addition, the evaluation factors for measuring each construct were whether the execution of the task is possible/impossible for 'effectiveness,' task execution time for 'efficiency,' and the number of errors for 'error.' User satisfaction, time satisfaction, difficulty, and understanding were measured on a 5-point scale using a questionnaire, and the evaluation points of the questionnaire are shown in Table 3. If incorrect answers are given more than 5 times, the investigator measured the effectiveness by making the task impossible to perform, and quantified the effectiveness, efficiency, and errors of each training for the record. In the meantime, the subjects filled out the user suitability questionnaire, completing the user suitability evaluation.

Table 3 User suitability questionnaire evaluation points

The evaluation scales for use satisfaction, time satisfaction, difficulty, and understanding constructs are shown in Table 4, and each evaluation scale for the effectiveness, efficiency, and error constructs is shown in Table 5.

The constructs set for the user suitability evaluation suitable for computerized cognitive rehabilitation application were use satisfaction, time satisfaction, difficulty, and understanding, with which we tried to check whether the use method of training through each application was easy, whether the time limit set for each training was appropriate, whether it was difficult to understand the training method because the subject was 55 years of age or older, and whether the difficulty level was appropriate; also, we tried to check how well users can learn and use the system without errors with the constructs of effectiveness, efficiency, and errors. [12].

Table 4 Evaluation items for user satisfaction, time satisfaction, difficulty, and understanding

User suitability questionnaire evaluation points		Constructs
Cognitive/ perceptual errors	<ul style="list-style-type: none"> - Understanding how to use and function - Considering the general information processing method - Clear and accurate visual/auditory presentation - Overall design, structure and contents 	Understanding
Use convenience	<ul style="list-style-type: none"> - How the user touches the screen - Interfering with the user's view of the screen - Convenience of transportation and storage 	Use satisfaction
Reflecting the domestic environment	<ul style="list-style-type: none"> - Using traditional domestic language, images and expressions - Minimizing visual/auditory confusion that may occur due to age difference 	Reflecting overall constructs
Application difficulty	<ul style="list-style-type: none"> - Adjusting the difficulty of the application - Training contents of the application 	Difficulty

Evaluation constructs		Evaluation items	Evaluation scales
Use satisfaction	No. 1	Did you find it uncomfortable to view the words, pictures, blinking, and effects that appear during training?	Ease of words, pictures, and effects
	No. 2	Did you find it inconvenient to click and touch?	Ease of hand operation
	No. 3	Did you feel uncomfortable with the overall color of the training program?	Ease of color
	No. 4	Did you find it inconvenient to use the overall training program?	Overall ease of use
Time satisfaction	No. 1	Did you have enough time to think and click on answers to questions during training?	Q&A Click Time Satisfaction
	No. 2	Did you have enough time when using the program?	Total time satisfaction
	No. 3	Did you have enough time to prepare before starting training?	Preparation time satisfaction
	No. 4	Would you be willing to do this program if you had to train more than 3 times a week for less than 30 minutes?	Intent to reuse
Difficulty	No. 1	Was the training difficulty level 1 and 2 difficult?	Difficulty level 1 & 2
	No. 2	Was the training difficulty level 3, 4 and 5 difficult?	Difficulty level 3, 4, and 5
	No. 3	Do you think that the overall difficulty classification (modulation) of training is equally controlled?	Difficulty control satisfaction
	No. 4	Do you think the number of questions for each difficulty level is adjusted equally?	Satisfaction with the number of questions
Understanding	No. 1	Did you find it difficult to understand the words and pictures that appear during training?	Understanding words and pictures
	No. 2	Did you find it difficult to understand the meaning of the questions?	Understanding question
	No. 3	Was it difficult to understand how to use the device?	Understanding how to use
	No. 4	Did you understand the explanations to help you solve the questions before training and the final results after the training?	Understanding problem solving

Table 5 User suitability measuring constructs evaluation points

User suitability evaluation point		Measuring method	Evaluation scale
Effectiveness	- Whether the task execution is possible / impossible	5 or more errors: impossible to execute	Training performance
		Less than 5 errors: possible to execute	
Efficiency	- Task execution time	Execution time per task	Required time
Error	- Number of errors	Measuring number of errors per task	Error rate

3.2 Korean version of Mini-Mental State Examination (MMSE-K) Results

Table 4 shows the results of executing MMSE-K, which can measure a patient's cognitive function, on select seniors with normal cognitive ability among the recruited personnel. In the MMSE-K, a score of 24 or more out of 30 is judged to be normal. According to the MMSE-K results, none of the subjects had any cognitive problems.

Table 6 Mental State Examination-K (MMSE-K) Results

Subject (n=24)				p-value
MMSE-K	Pre	Post	Difference Mean	0.142
	27.88 ±1.70	28.63 ±1.69	0.75 ±2.42	

3.3 User Suitability Evaluation Results

3.3.1 Effectiveness results

For training performance, inability to perform did not occur in orientation, and 14 subjects were treated as unable to perform training because they failed to correct a problem more than 5 times in the concentration and memory training.

As a result of the training performance of the concentration training, as shown in Table 7, the number of incorrect answers decreased as the weeks progressed in the search concentration and continuous concentration, where inability to perform occurred in week 1, and the number of subjects who were unable to perform also decreased. Colour concentration, where the largest number of subjects showed inability to perform in the 1st week, showed a decreased number of subjects who were unable to perform in the 3rd week.

Table 7 Result of training performance of concentration training (number of subjects unable to perform, unit: persons)

Training performance	1 st week	2 nd week	3 rd week
Search concentration	6	0	0
Continuous concentration	9	4	4
Colour concentration	21	2	4
Memory concentration	0	0	0

As a result of the performance of memory training, in Table 8, the number of subjects who were unable to perform in general number memory and mental arithmetic number concentration, which occurred in the 1st week, was smaller in the 3rd week than in the 1st week.

Table 8

Results of training performance of memory training (number of subjects unable to perform, unit: persons)

Training performance	1 st week	2 nd week	3 rd week
Word memory	0	0	0
General number memory	3	0	1
Mental arithmetic number memory	12	1	6
Colour memory	0	0	0
Matching memory	0	0	0

3.3.2 Effectiveness results

In terms of the total satisfaction score, the evaluation of use satisfaction, time satisfaction, understanding, and difficulty for orientation training was high, and evaluation of use satisfaction, time satisfaction, understanding, and difficulty for concentration training was the lowest.

In the result of the orientation training questionnaire, upon adding up scores for each week for each item in Table 9, the score for question 3 for time satisfaction in Table 4 was the lowest at 8.08, and the score increased as the weeks progressed. Adding up each week of the 2nd question of use satisfaction and the 2nd question of time satisfaction in Table 4 showed the highest score result of 14.17.

Table 9 Result of questionnaire survey on orientation (red: the item with the highest score, blue: the item with the lowest score)

Orientation	Question	1 st week	2 nd week	3 rd week	3 rd week - 1 st week
Use satisfaction	No.1	4.58	4.71	4.79	0.21
	No.2	4.67	4.67	4.83	0.17
	No.3	4.63	4.5	4.75	0.13
	No.4	4.67	4.67	4.75	0.08
	Sum	18.54	18.54	19.13	0.58
Time satisfaction	No.1	4.42	4.75	4.83	0.42
	No.2	4.5	4.79	4.88	0.38
	No.3	2.79	2.38	2.92	0.13
	No.4	4.04	4.63	4.58	0.54
	Sum	16.17	17.79	17.38	1.21
Understanding	No.1	4.21	4.67	4.42	0.21
	No.2	4.08	4.88	4.46	0.38
	No.3	4.21	4.33	4.42	0.21
	No.4	4.42	4.5	4.5	0.08
	Sum	16.92	18.38	17.79	0.88
Difficulty	No.1	4.25	4.5	4.5	0.25
	No.2	4.25	4.42	4.46	0.21
	No.3	4.29	4.33	4.5	0.21
	No.4	4.21	4.38	4.54	0.33
	Sum	17	17.63	18	1

In the result of the questionnaire survey of concentration training, it was found that when each week was added up for each item in Table 10, as with the survey results of orientation, the score of item 3 of time satisfaction in Table 4 was

the lowest at 8, and the score increased as the weeks progressed. In Table 5, the sum of use satisfaction, time satisfaction, understanding, and difficulty of concentration training were the lower than that of other training, but the satisfaction with use satisfaction, time satisfaction, understanding, and difficulty increased as the weeks progressed. However, as the score for the user satisfaction question 2 of Table 4 decreased in the 3rd week compared to the 1st week, this shows that the ease of touch and click under the user satisfaction is lower, as shown in use satisfaction question 2 of Table 5.

Table 10 Result of questionnaire survey on concentration (red: the item with the highest score, blue: the item with the lowest score)

Concentration	Question	1 st week	2 nd week	3 rd week	3 rd week – 1 st week
Use satisfaction	No.1	3.58	3.63	4.25	0.67
	No.2	4.63	4.25	4.46	-0.17
	No.3	3.92	3.71	4	0.08
	No.4	4.04	3.88	4.38	0.33
Sum		16.17	15.46	17.08	0.92
Time satisfaction	No.1	3.83	3.83	4.5	0.67
	No.2	3.88	3.88	4.46	0.58
	No.3	2.71	2.46	2.83	0.13
	No.4	4.29	4.38	4.33	0.04
Sum		15.29	15.63	16.46	1.17
Understanding	No.1	3.83	3.92	4.33	0.5
	No.2	3.67	3.83	4.5	0.83
	No.3	4	3.92	4.38	0.38
	No.4	4.13	4.375	4.458	0.333
Sum		15.63	16.042	17.667	2.042
Difficulty	No.1	3.75	3.958	4.292	0.542
	No.2	3.625	3.833	4.25	0.625
	No.3	3.833	4.125	4.25	0.417
	No.4	3.958	4.083	4.375	0.417
Sum		15.17	16	17.167	2

From the memory training questionnaire survey, through adding up each week for each item in Table 11, it was found that the item that received the lowest score of 8 points was item 3 of time satisfaction in Table 4, but the score increased as the weeks passed. With a total score of 13.5 for each week, the item with the highest score was item 2 of use satisfaction of Table 4. In Table 11, the sum of use satisfaction, time satisfaction, understanding and difficulty of

memory training decreased as the weeks passed, while the satisfaction with the preparation time before starting increased.

Table 11 Results of questionnaire survey on memory (red: the item with the highest score, blue: the item with the lowest score)

Memory	Question	1 st week	2 nd week	3 rd week	3 rd week – 1 st week
Use satisfaction	No.1	4.46	4.25	4.17	-0.29
	No.2	4.67	4.38	4.46	-0.21
	No.3	4.58	3.92	4.04	-0.54
	No.4	4.63	4.33	4.33	-0.29
Sum		18.33	16.88	17	-1.33
Time satisfaction	No.1	4.29	4.13	4.21	-0.08
	No.2	4.42	4.25	4.25	-0.17
	No.3	2.42	2.67	2.92	0.5
	No.4	4.58	4.42	4.13	-0.46
Sum		16.88	16.13	15.67	-1.21
Understanding	No.1	4.21	4.17	4.21	0
	No.2	4.25	4.17	4.08	-0.17
	No.3	4.33	3.88	4.21	-0.13
	No.4	4.38	4.17	4.29	-0.08
Sum		17.17	16.38	16.79	-0.38
Difficulty	No.1	4.29	4.33	4.04	-0.25
	No.2	4.33	4.17	3.96	-0.38
	No.3	4.29	4.13	3.96	-0.33
	No.4	4.25	4.21	4	-0.25
Sum		17.17	16.83	15.96	-1.21

3.3.3 Error and Efficiency Results

The evaluation scales for the error and efficiency evaluation constructs are error rate and time required, respectively. In orientation training, the results of the training for each stage are shown in Table 12, with the number of errors and time required decreasing as weeks passed.

Looking at Table 13 in the 4th stage of the search concentration training, the number of errors and the time required increased in the 3rd week compared to the 1st week. Table 14 shows the results of the reduction in the number of errors and the time required as the weeks passed in continuous concentration training. Referring to Table 15, as the difficulty of color concentration increased, the number of errors decreased and the time required also decreased. As for the memory concentration in Table 16, the number of errors and the time required decreased as the weeks passed

Looking at Table 17, in terms of word memory, the number of errors in the 4th stage, the highest difficulty word memory training, increased as the weeks passed. In Table 18, the number of errors and time required increased in general number

memory in stage 3 as the weeks passed. Table 19 shows the results of the increase in the number of errors and the time required in stages 4 and 5 as the weeks passed in mental arithmetic number memory training. In Table 20, the number of errors and the time required increased as the weeks progressed in the 5th stage of colour memory training. Table 21 shows that both the number of errors and the time required increased in the 3rd stage of matching memory.

Table 12 The number of errors and the time required in each stage of orientation training

Table 13

Evaluation construct <Orientation training>	Training accuracy					Training time				
	Number of errors					Time required (sec)				
	1 st week	2 nd week	3 rd week	Average	3-1	1 st week	2 nd week	3 rd week	Average	3-1
Difficulty stage 1	0.25	0.04	0	0.1	-0.25	15.04	4.96	5.21	8.4	-9.83
Difficulty stage 2	0.04	0.08	0.04	0.06	0	10.79	6.67	6.38	7.94	-4.42
Difficulty stage 3	0.08	0.17	0	0.08	-0.08	6.71	5.75	4.83	5.76	-1.88
Difficulty stage 4	0	0.04	0	0.01	0	6.5	5.92	5.08	5.83	-1.42
Difficulty stage 5	0	0.04	0	0.01	0	9.17	5.67	5.29	6.71	-3.88
Total	0.38	0.38	0.04	0.26	-0.33	48.21	28.96	26.79	34.65	-21.42

The number of errors and the time required in each stage of search concentration training

Evaluation construct <Concentration training> Search concentration	Training accuracy					Training time				
	Number of errors					Time required (sec)				
	1 st week	2 nd week	3 rd week	Average	3-1	1 st week	2 nd week	3 rd week	Average	3-1
Difficulty stage 1	0.08	0	0	0.03	-0.08	27.04	4.96	5.21	8.4	-9.83
Difficulty stage 2	0.46	0.38	0.08	0.31	-0.38	34.33	27.5	19.75	27.19	-14.58
Difficulty stage 3	0.33	0.38	0.25	0.32	-0.08	33.79	31.13	27.5	30.81	-6.29
Difficulty stage 4	0.35	0.21	0.58	0.38	0.24	36	29.13	40.96	35.36	4.96
Difficulty stage 5	0.26	0.29	0.21	0.25	-0.05	54.22	40.46	35.88	43.52	-18.34
Total	1.48	1.25	1.13	1.29	-0.36	185.38	148.04	140.88	158.1	-44.51

Table 14

The number of errors and the time required in each stage of continuous concentration training

Evaluation construct	Training accuracy					Training time				
	Number of errors					Time required (sec)				
	1 st week	2 nd week	3 rd week	Average	3-1	1 st week	2 nd week	3 rd week	Average	3-1
Continuous concentration										
Difficulty stage 1	0.4	0	0.28	0.23	-0.12	17.38	15.96	14.92	16.08	-2.46
Difficulty stage 2	2.71	1.12	1.3	1.71	-1.4	31.04	24.42	25.08	26.85	-5.96
Difficulty stage 3	4.94	4	3.81	4.25	-1.13	75.67	78.13	62.58	72.13	-13.08
Total	8.05	5.12	5.39	6.19	-2.65	124.08	118.5	102.58	115.06	-21.5

Table 15

The number of errors and the time required in each stage of colour concentration training

Evaluation construct	Training accuracy					Training time				
	Number of errors					Time required (sec)				
	1 st week	2 nd week	3 rd week	Average	3-1	1 st week	2 nd week	3 rd week	Average	3-1
Colour concentration										
Difficulty stage 1	3.5	0.63	0.13	1.42	-3.38	148.13	64.88	38.79	83.93	-109.33
Difficulty stage 2	1.13	1.08	0.46	0.89	-0.67	79.96	71.04	51.79	67.6	-28.17
Difficulty stage 3	0.48	0.71	0.17	0.45	-0.31	38.74	54.29	31.63	41.55	-7.11
Difficulty stage 4	0.48	0.42	0.17	0.35	-0.31	36.78	47.83	29.5	38.04	-7.28
Total	5.59	2.83	0.92	3.11	-4.67	303.6	238.04	151.71	231.12	-151.89

Table 16

The number of errors and the time required in each stage of memory concentration training

Evaluation construct	Training accuracy					Training time				
	Number of errors					Time required (sec)				
	1 st week	2 nd week	3 rd week	Average	3-1	1 st week	2 nd week	3 rd week	Average	3-1
<Concentration training> Memory concentration										
Difficulty stage 1	0.29	0.29	0.25	0.28	-0.04	20.04	20.04	16.83	18.97	-3.21
Difficulty stage 2	0.29	0.29	0.21	0.26	-0.08	23.29	19.88	15.88	19.68	-7.42
Difficulty stage 3	0.13	0.13	0.08	0.11	-0.04	17.08	15.92	14.04	15.68	-3.04
Difficulty stage 4	0.63	0.5	0.17	0.43	-0.46	25.71	20.71	14.21	20.21	-11.5
Difficulty stage 5	0.04	0.04	0.04	0.04	0	18.5	13.92	13.46	15.29	-5.04
Total	1.38	1.25	0.75	1.13	-0.63	104.63	90.46	74.42	89.83	-30.21

Table 17

The number of errors and the time required in each stage of word memory training

Evaluation construct	Training accuracy					Training time				
	Number of errors					Time required (sec)				
	1 st week	2 nd week	3 rd week	Average	3-1	1 st week	2 nd week	3 rd week	Average	3-1
<Memory training> Word memory										
Difficulty stage 1	0	0	0	0.00	0	28.13	26.04	26.33	26.5	-2.79
Difficulty stage 2	0	0	0	0.00	0	28.75	26.13	27.08	27.32	-1.67
Difficulty stage 3	0.13	0	0.04	0.06	-0.08	32.63	27.63	28.54	29.6	-4.08
Difficulty stage 4	0.13	0.17	0.21	0.17	0.08	42.46	40.54	40.42	41.14	-2.04
Total	0.25	0.17	0.25	0.22	0	131.96	120.33	121.38	124.56	-10.58

Table 18

The number of errors and the time required in each stage of general number memory training

Evaluation construct	Training accuracy					Training time				
	Number of errors					Time required (sec)				
	1 st week	2 nd week	3 rd week	Average	3-1	1 st week	2 nd week	3 rd week	Average	3-1
General number memory										
Difficulty stage 1	0.21	0.17	0.04	0.14	-0.17	19.33	18	13.33	16.89	-6
Difficulty stage 2	0.13	0.04	0.04	0.07	-0.08	15.75	12.5	13.21	13.82	-2.54
Difficulty stage 3	0.08	0	0.17	0.08	0.08	14	12.63	15.83	14.15	1.83
Difficulty stage 4	0.13	0.54	0.08	0.25	-0.04	14.75	21.5	13.83	16.69	-0.92
Difficulty stage 5	0.54	0.17	0.33	0.35	-0.21	24.71	17.67	19.08	20.49	-5.63
Total	1.08	0.92	0.67	0.89	-0.42	88.54	82.29	75.29	82.04	-13.25

Table 19

The number of errors and the time required in each stage of mental arithmetic number memory training

Evaluation construct	Training accuracy					Training time				
	Number of errors					Time required (sec)				
	1 st week	2 nd week	3 rd week	Average	3-1	1 st week	2 nd week	3 rd week	Average	3-1
Mental arithmetic number memory										
Difficulty stage 1	0.13	0.29	0.08	0.17	-0.04	13.17	21.83	11.42	15.47	-1.75
Difficulty stage 2	0.04	0	0	0.01	-0.04	10.79	10.38	9.92	10.36	-0.88
Difficulty stage 3	0.04	0	0	0.01	-0.04	10.29	10.5	9.92	10.24	-0.38
Difficulty stage 4	0.04	0.21	0.04	0.1	0	10.21	16.54	10.92	12.56	0.71
Difficulty stage 5	0.04	0.08	0.29	0.14	0.25	10.29	11.92	14.21	12.14	3.92
Total	0.29	0.58	0.42	0.43	0.13	54.75	71.17	56.38	60.76	1.63

Table 20

The number of errors and the time required in each stage of colour memory training

Evaluation construct	Training accuracy					Training time				
	Number of errors					Time required (sec)				
	1 st week	2 nd week	3 rd week	Average	3-1	1 st week	2 nd week	3 rd week	Average	3-1
Colour memory										
Difficulty stage 1	0.25	0.33	0.25	0.28	0	16.21	16.04	14.25	15.5	-1.96
Difficulty stage 2	0.71	0.29	0.54	0.51	-0.17	21.38	16.38	17.71	18.49	-3.67
Difficulty stage 3	0.67	0.54	0.42	0.54	-0.25	22.67	19.25	17.79	19.9	-4.88
Difficulty stage 4	0.96	1.75	0.33	1.01	-0.63	28.17	36.13	19.29	27.86	-8.88
Difficulty stage 5	1.54	3.29	2.21	2.35	0.67	38.83	63.38	45.5	49.24	6.67
Total	4.13	6.21	3.75	4.69	-0.38	127.25	151.17	114.54	130.99	-12.71

Table 21

The number of errors and the time required in each stage of matching memory training

Evaluation construct	Training accuracy					Training time				
	Number of errors					Time required (sec)				
	1 st week	2 nd week	3 rd week	Average	3-1	1 st week	2 nd week	3 rd week	Average	3-1
Matching memory										
Difficulty stage 1	0	0	0	0.00	0	13.42	13.17	12.75	13.11	-0.67
Difficulty stage 2	0	0.08	0	0.03	0	22.92	23.13	19.21	21.75	-3.71
Difficulty stage 3	0.04	0	0.13	0.06	0.08	27.38	23.71	29.29	26.79	1.92
Difficulty stage 4	0.17	0.13	0.04	0.11	-0.13	39.46	37.67	33.46	36.86	-6
Difficulty stage 5	0	0	0	0.00	0	16	14.58	14.67	15.08	-1.33
Total	0.21	0.21	0.17	0.19	-0.04	119.17	112.25	109.38	113.6	-9.79

4. Discussion

In this paper, we developed an appropriate method for a user suitability evaluation that can save time and money by pre-evaluating the usability of a developed cognitive rehabilitation training program. The developed user suitability constructs were judged to be suitable for evaluating cognitive rehabilitation applications, and as the training is

repeated in the course of conducting a clinical trial using the developed user suitability evaluation method, it was considered that the number of errors and the time required would be reduced as the time satisfaction, use satisfaction, understanding and difficulty, which affect user satisfaction and loyalty, are improved.

As a result of the clinical trial, firstly, in terms of the effectiveness, efficiency, and error constructs, due to problems in the app's configuration, as weeks passed or higher levels of training progressed at some stages of training, the time required or number of errors unexpectedly increased; however, overall effectiveness and efficiency were improved and errors decreased. In addition, by measuring the time required and the number of errors, it was possible to determine how well the user was able to learn and use the system with the appropriate difficulty setting. For example, as shown in Table 15, the time required and the number of errors decreased as the difficulty increased, indicating that the difficulty level in the first stage was high for the user. In addition, as shown in Stage 4 of Table 13, Stage 4 of Table 17, and Stage 3 of Table 21, the time required and the number of errors increase as the weeks passed, confirming that there was a problem in learning and using this training. In other words, it was confirmed that the user suitability scales of training performance, time required, and number of errors were suitable to identify constructs of effectiveness, efficiency, and errors.

Second, through the experiment on the evaluation constructs for use satisfaction, time satisfaction, understanding and difficulty, it was found that satisfaction increased as the weeks passed in the training of orientation and concentration; however, the overall satisfaction was decreased in the use satisfaction, time satisfaction, understanding, and difficulty of memory training. In particular, the number of errors and the time required for memory training decreased as the weeks passed, but contrary to expectations, the time satisfaction construct of memory training also decreased as the weeks passed. As the subject repeated the same training as the weeks passed, the time satisfaction was expected to increase as a result of improving the efficiency of the system and reducing the error rate; however, it was considered that the time satisfaction was not improved because the subject had to wait for the answer for a while after suggesting a question due to the program configuration of the application. We judged that the problem of program configuration had an effect on time satisfaction because in the case of concentration training, time satisfaction improved as the weeks passed, despite having the same questionnaire as that of memory training.

Through the above experimental results, it is judged that the user suitability evaluation scale used for user satisfaction evaluation has limitations when it comes to analyzing user satisfaction, and the scale used for user satisfaction evaluation needs to be partially changed according to the detailed training characteristics of the computerized cognitive rehabilitation application. In a training in which a problem is presented and the subject has to wait until subject clicks an answer, it was considered meaningless to evaluate time satisfaction construct. Therefore, it is appropriate to exclude the construct of time satisfaction from the user suitability evaluation of memory training. In addition, in Table 5, the more weeks passed, the lower the ease of touch and click of use satisfaction was obtained. However, since the evaluation constructs of the developed questionnaire were used equally in all training, it was difficult to determine which specific training of the concentration training had difficulties in the area of ease of touch and click. Also, as the weeks passed, the number of errors and the time required increased in the 3rd stage of the general number memory training and in the 5th stage of the color memory training. This is because unlike other training, the mental arithmetic number memory, general number memory training, and color memory training contained random elements, and the subject had to remember mental arithmetic, memory, and random color of random numbers. Accordingly, it was found that the number of errors and the time required increase when a number that is difficult to calculate or remember, or a similar color is presented, even for training that the subjects already know. Therefore, it is necessary to add constructs to check if training suddenly becomes difficult or easier.

Through the user suitability evaluation performed in this way, it was confirmed that it is necessary to develop evaluation constructs suitable for a specific product or service, and appropriate evaluation scales for the developed evaluation constructs are required according to the characteristics of each program.

5. Conclusion

In this paper, we developed an evaluation method for a user suitability evaluation of computerized cognitive rehabilitation applications, and clinical trials were conducted for seniors aged 55 years or older to evaluate whether the developed user suitability evaluation method is appropriate. To evaluate the computerized cognitive rehabilitation application, we derived use satisfaction, time satisfaction, difficulty, understanding, effectiveness, efficiency, and error as evaluation constructs, and through clinical trials, the above constructs were judged to be suitable as evaluation constructs for user suitability evaluation.

However, due to the program characteristics of the computerized cognitive rehabilitation application, we found that the evaluation elements and scales used for evaluation were not appropriate in the constructs of use satisfaction, time satisfaction, difficulty, and understanding.

As such, it is considered that certain evaluation elements and scales used for evaluation need to be added or subtracted according to the product characteristics. Based on this research, we suggest that it is necessary to compose evaluation constructs according to the products or services for user suitability evaluation, and to develop evaluation scales and evaluation elements that reflect the characteristics of products or services.

Declarations

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Authors' contributions

NaHyeon and YoungJun completed the data extraction. JaeHoon and SungMin helped with the creation of the research strategy and analysis. BumSun helped design clinical trials. DaeChang devised the research question. All authors contributed to, read, and approved the final manuscript

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Availability of data and materials

Data and materials can be made available upon reasonable request to the authors

Ethics approval and consent to participate

The respondents were presented with written informed consent on the survey. By starting the survey, the respondents agreed to all terms and conditions.

Consent for publication

Informed consent for publication was obtained from the respondents before starting the survey.

Competing interests

The authors declare that they have no competing interest.

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Figures

Figure 1

User suitability evaluation process conducted in clinical trials.

Figure 2

Orientation training program

Figure 3

Concentration training program (A: search concentration, B: continuous concentration, C: color matching concentration, D: memory concentration)

Figure 4

Memory training program (A: word memory, B: mental arithmetic/general number memory, C: color memory, D: matching memory)