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Improvement of the Cognitive Perceptual Assessment for Driving (CPAD) based on Usability Test

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Objective: The aim of this study was to perform a usability test for CPAD (Cognitive Perceptual Assessment for Driving) and improve it based on the test results.

Background: The cognitive perceptual assessment for driving is a computer-based assessment tool to assess the driving capacity of people with brain-damages. It may be a good tool for evaluating the brain-damaged drivers' safe driving capabilities and screening cognitive and perceptual deficits related to driving. We performed a usability test to improve the CPAD based on the result.

Method: Both the software consisting of 8 sub-tests (depth perception, sustained attention, divided attention, stroop test, field dependency, digit span, trail making A, trail making B) and the hardware including the input and output devices (joystick, mouse, keyboard, touch screen) were evaluated through user interviews. Also we identified the problems and issues in using them by observing the participants performing the CPAD tasks.

Results: Based on the results, the task instructions were visually and auditorily improved and more practice examples were added to help the users understand the instructions better and increase the input accuracy, a response time window was added and the joystick and touch screen were simplified, which made it easier for the user to perform the CAPD tasks.

Conclusion: User discomforts were minimized by improving the task environment, unless it had affected the evaluation criteria.

Application: We plan to distribute the improved version of the CPAD to the regional rehabilitation hospitals, and the driving support centers for people with disabilities throughout the country, so it could be used as an evaluation tool for disabled drivers' cognitive and perceptual functions.

Keywords: CPAD, Driving, Usability test, Stroke

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1. Introduction

According to a 2000 fact-finding survey for people with disabilities, the most frequently used transportation means by them was public buses accounting for about 34.5%, and the second most was private cars accounting for about 24.3% (Byeon et al., 2000). However, private cars became the most frequently used transportation means (30.2%) exceeding public buses by about 2% in 2005 (Byeon et al., 2005) and even reached at 32.3% in 2011. With all these, it is clear that the use of private cars

has become the main transportation means for people with disabilities, and the ratio has been still rising gradually (Kim et al., 2011). It was reported that people with disabilities used private cars slightly more, while walking less overall, compared to the general public (Byeon et al., 2000, 2005; Kim et al., 2011). The more they desire to return to society, the more frequently they drive their own cars.

However, driving is not a simple task, but a task that requires complex cognitive functions and motor-cognitive coordination. The driving capabilities of people with brain impairments, affected by either cerebrovascular diseases or impairments in various areas of the brain, generally decline (Akinwuntan et al., 2002; Sundet et al., 1995; Fisk et al., 2002; Hajek et al., 1989). Because, this can cause traffic accidents that may result in physical and economic damages to both the disabled drivers themselves or others, it is essential for safe driving to evaluate the cognitive driving abilities of people with brain impairments (Engum et al., 1988). Therefore, previous studies have asserted that evaluation tools to assess such cognitive functions of disabled drivers as judgment, attention, memory for safe driving need to be developed so that their driving capabilities on the real roads may be predicted and accordingly, a suitable system should be established (Choi et al., 2008; Katz et al., 1990; Shore et al., 1980; Van et al., 1987; Mazer et al., 1998). Looking at overseas cases, following evaluation tools for cognitive driving abilities have already been developed: CBDI (cognitive behavioral driver's inventory) (Engum et al., 1988), DCAT (drivable cognitive assessment tool) (Dobbs, 2005; Korner-Bitensky and Sofer, 2009), UFOV (useful field of view) (Mazer et al., 2001; Sarti et al., 2000) and SDSA (cognitive behavioral driver's inventory) (Lundberg et al., 2003). Also, their usefulness in predicting brain-damaged patients' safe driving was reported, and their effectiveness in terms of returning to society and safe driving was demonstrated. In Korea, however, the CAPD (cognitive perceptual assessment for driving), a tool for the evaluation for cognitive driving abilities developed by the National Rehabilitation Center has been exclusively used. The CAPD to evaluate the cognitive driving abilities of stroke patients was developed on the basis of CBDI (Lee et al., 2004), and its validity and effectiveness were proved by analyzing the relationship between in-field driving course-functional assessment and road test in previous studies (Jang et al., 2006; Choi et al., 2008). Currently, CAPD is being used as a tool to evaluate cognitive driving abilities of stroke patients in the designated local rehabilitation hospitals and driving support centers including the National Rehabilitation Center. The KoROAD conducts evaluation for cognitive driving abilities as part of traffic safety education targeting elderly people.

Usability is all the measurable characteristics of user interface (Mayhew, 1999), and is a core factor comprising HCI (Human-Computer Interaction). A usability test to assess such characteristics is diversely adopted and utilized in the fields of software engineering, information and communications service, home appliances and transportation (ISO, 2001). The CPAD is also a computer-based software assessment tool. Because the main evaluatees of CPAD are people with mobility problems due to motor and cognitive, more issues on usability can be found, compared with existing tools. Especially, CPAD is a tool for assessing cognitive abilities, and any trivial problem in usability may affect assessment results. As a result of the survey on CPAD problems facing CPAD evaluators, it was reported that there was a need to adjust the level of difficulty in some test items. To solve such a problem, the depth perception test among CPAD sub-tests was revised, and a touch screen input device was added, and the CPAD use environment was improved in this study (Choi et al., 2013). However, the revisions were made only in the expert's position, and usability test has never been conducted targeting the actual CPAD users. Therefore, a practical study was required to improve the CPAD use environment.

In this regard, the present study was to carry out the CPAD usability test targeting the evaluators administering the CPAD at KoROAD and rehabilitation hospitals to stroke patients who had received the test, and to look into use environment problems and their improvements.

2. Composition of CPAD

2.1 Test items of CPAD

CPAD was developed through a co-research project of the Dept. of Biomedical Engineering at Hanyang University, based on the driving aptitude test tool developed by the Institute of Psychological Science (IPS) at the Seoul National University SNU.

CPAD was the only cognitive perceptual assessment for driving for disabled people suffering from stroke in Korea. This study selected following CPAD sub-test eight items composed of depth perception, sustained attention, divided attention, stroop test, digit span test, field dependence and trail making test A and trail making test B and two items composed of correct responses on the tests and response time as variables targeting 15 disabled people with brain impairment through a correlation analysis and a factor analysis of CBDI (Lee et al., 2004). This study calculated the mean and standard deviation of ten items performed by 101 people with brain impairment, and standardized each variable's mean to be 50, and standard deviation to be 10 adjusted for unit unification. Through a principal component analysis, this study calculated the weights, the representative coefficients of the ten sub-test measurements. As for the assessment criteria, 42 and lower of the weighted scores were determined as "fail", 53 and higher of the weighted scores were as "pass", and the weighted scores in-between were as "borderline", based on an in-field driving course function assessment (Jang et al., 2006). According to these criteria, both of the positive and negative prediction rates in the relationship with actual road tests were revealed to be 100% (Choi et al., 2008).

2.1.1 Depth perception

As a test to evaluate scanning and depth perception required for driving, an evaluatee needs to press the button on the joystick, when he/she recognizes a horizontal bar with arrow tips at both ends moving up and down along the two vertical lines (closer at the top, more distant at the bottom, like a ladder showing virtual depth) become aligned with several small lines protruded inside the two vertical lines. After practicing three times, correct responses and response time are measured by carrying out 20 times at low speed, and 20 times at fast speed.

2.1.2 Sustained attention

As a test to evaluate sustained attention and information processing abilities, eight ㅂ-shaped letters are arranged irregularly on the screen. An evaluatee needs to constantly scan the screen, and press the button on the joystick as soon as the person recognizes that the letter's direction changed. Correct responses are measured by conducting this experiment 40 times, after three times or practices.

2.1.3 Divided attention

As a test to evaluate divided attention on various stimuli upon driving, the figures composed of 12 quadrangles are arranged in a circular shape on the screen. When the left or right sides of the quadrangles disappear, an evaluatee needs to move the joystick to the directions of disappeared sides. Also, the evaluatee must press the button on the joystick by simultaneously responding to auditory stimulus of "clang" randomly presented while responding to the visual stimulus. After three times of practice, a total of 57 times of accuracy are measured with 40 times of visual stimuli and 17 times of auditory stimuli.

2.1.4 Stroop test

Stroop test is the one assessing the abilities to cope with, adjust and control disturbing stimuli that may occur in driving: when

the red-, yellow- and green-colored words "red", "yellow", "green" are randomly presented on the screen irrelevantly of their actual colors (e.g., a green-colored word written as "red"), an evaluatee needs to move joystick to left, right or upward, respectively responding to the red-colored, yellow-colored and green colored letters ignoring the presented word's meaning (e.g., respond to "green" which is the actual color of the letters rather than responding to "red" which is the meaning of the word). The accuracy and response time are measured for 40 stimuli after practicing three times.

2.1.5 Digit span

This is a test evaluating short-term and working memory required for driving. Using the numbers from 1 to 9, the numbers between three to nine digits are presented auditorily, and an evaluatee should remember the presented set of numbers and press them in the same order on the keyboard's keypad. After practicing two times, the highest number of digits the evaluatee correctly remembered is recorded as the output measure.

2.1.6 Field dependency

This is a test to assess an ability to detect some necessary pieces of information amid a complex driving environment. An evaluatee must move the joystick to left, if the same-shaped and sized quadrangle, just shown on the previous slide, exists on the screen, or move it to right, if it does not exist, after remembering the size and shape of the quadrangle presented on the screen before.

2.1.7 Trail making test A

This test is to evaluate visual scanning, visuomotor coordination, planning and executive function required in driving. An evaluatee should connect the numbers in sequence from 1 to 16 with mouse click or screen touch, when the numbers are scattered irregularly on the screen. If the next number in sequence to the previous number is clicked on the mouse or touched on the touch screen, a line appears automatically and connects the two consecutive numbers. The time spent for completing the task by connecting all of the 16 numbers is measured.

2.1.8 Trail making test B

Like the trail making test A, this test is for evaluating the abilities to find complex orders and to perform visuomotor coordination, planning and executive function. An evaluatee needs to click the mouse or touch the screen in the order of number→letter →number→letter (i.e., "1→ga→2→na"). The numbers from 1 to 8 and the letters from ga to ah are placed on the screen in the same manner as the trail making test A. The time spent to complete the task is measured.

2.2 Input device of CPAD

The CPAD was developed as a computer-based evaluation tool and the input device consisted of a joystick, mouse and keyboard. A commercialized joystick with a button was used, and it was used for the input in such sub-tests as depth perception, sustained attention, divided attention, stroop test and field dependency. The keyboard was used for inputting the numbers in the digit span test. The mouse was used in the trail making test A and trail making test B. The reason that we used both the mouse and the touch screen as the input device was because those who could not use the mouse might be able to alternatively use the touch screen. However, various input devices need to be developed for disabled and elderly people, because they are not proficient in computer operation.

3. Usability Test of CPAD

The users of CPAD are both the evaluators who administer the evaluation of cognitive driving abilities, and the evaluatees who receive the evaluation. Therefore, the usability test of CPAD needs to be carried out in both of the groups. Accordingly, this study conducted the usability tests on the separate groups of evaluators and evaluatees.

This study also found some usability related issues by observing the evaluatees performing the CPAD tests. 22 stroke patients suffering from the stroke for more than six months participated in the usability test of CPAD evaluatees (male: 15, female: 7 and age: 59.4±8.0, height: 163.9±7.9cm, weight: 66.4±6.9kg, left side paralysis: 11 people, right side paralysis: 11 people). As for the usability test of CPAD evaluators participants were 26 occupational therapists and driving instructors who were using the CPAD to evaluate cognitive driving abilities at the national rehabilitation center and the KoROAD. The usability test of CPAD was carried out on the eight sub-tests of the CAPD software (depth perception, sustained attention, divided attention, stroop test, field dependency, digit Span, trail making test A, trail making test B) and also on the hardware input devices (joystick, mouse, keyboard, touch screen). The assessment was performed through interviewing the participants on the suitability, level of difficulty, problem and improvement measure. The eight sub-tests were assessed by the five grade point evaluation scale (i.e., five point Richter scale) for their difficulty (grade 5: very difficult, grade 1: very easy), and the suitability of input device choice was assessed also by a five point scale with 5 being very unsuitable and 1 being very suitable. Dichotomizing at the center of the scale, that was at grade 3 (average), this study carried out single sample *t*-tests, and the difficult or easy sub-tests, and also suitable or unsuitable input devices were categorized, and (a=.05). The interviews to find problems and their improvement directions were carried out in a loosely structured question and answer session. Consequently, one respondent gave many opinions for the same question in some cases, and no opinion was given at all in some other cases. The survey and interview results were categorized into several common factors gathered from the acquired details.

3.1 Level of difficulty and suitability of CPAD

The assessment results of the level of difficulty and suitability of CPAD's components are shown in Tables 1 and 2. The sub-tests the evaluatees felt relatively "difficult" were depth perception, digit span and field dependency ($p < .05$), while the sub-tests the evaluators felt difficult were depth perception, stroop test and field dependency. Concerning the sustained attention test, both evaluatees and evaluators assessed as "relatively easy". In the assessment result of CPAD input devices' suitability, the evaluatees and evaluators felt the most discomfort in using the mouse, and both of the groups evaluated the touch screen was a suitable input device, compared to the other input devices.

Table 1. Level of difficulty in CPAD sub tests and suitability of input devices (evaluatee)

	Sub-tests	Mean	Standard deviation	*p*
Level of difficulty in CPAD Sub-tests	Depth perception	3.73	0.83	.000*
	Sustained attention	2.36	0.58	.000*
	Divided attention	3.14	0.71	.378
	Stroop test	3.14	0.83	.451
	Digit span	3.41	0.73	.016*
	Field dependency	3.82	0.80	.000*

Table 1. Level of difficulty in CPAD sub tests and suitability of input devices (evaluatee) (Continued)

	Sub-tests	Mean	Standard deviation	*p*
Level of difficulty in CPAD Sub-tests	Trail making test A	2.82	0.80	.296
	Trail making test B	3.32	0.99	.148
Suitability of input devices	Joystick	2.68	0.84	.090
	Mouse	3.64	1.22	.023*
	Keyboard	2.95	0.65	.747
	Touch screen	2.45	0.74	.002*

Table 2. Level of difficulty in CPAD sub tests and suitability of input devices (evaluator)

	Sub-item	Mean	Standard deviation	*p*
Level of difficulty in CPAD Sub-tests	Depth perception	3.50	0.76	.003*
	Sustained attention	2.50	0.78	.005*
	Divided attention	2.96	0.86	.814
	Stroop test	3.92	0.50	.000*
	Digit span	3.38	0.92	.059
	Field dependency	3.83	0.78	.000*
	Trail making test A, B	2.61	0.72	.016*
Suitability of input devices	Joystick	2.77	0.81	.204
	Mouse	3.67	0.58	.000*
	Keyboard	3.05	0.84	.803
	Touch screen	2.35	0.78	.001*

3.2 Problems of CPAD composition items

The assessment results on the problems of CPAD items and input devices were categorized into the common factors. Tables 3 and 4 show the categorization results of the problems by each CAPD sub-test. Most suggested improvements on the problems of each sub-test were made except when the improvement might have affected the assessment criteria. Consequently, both the evaluators and evaluatees gave the same opinion that the task instructions were very difficult to understand commonly in most of the sub-tests. In the depth perception test, a common opinion was that correct answer classification was not clear enough, while as for the evaluatees, the lines were too thin thus not very easily recognizable. Exclusively for the evaluators, the assessment time was simply too long. In the sustained attention test, the evaluatees also thought the lines were too thin; while the evaluators took an issue with the fact that the presentation time of all the stimuli were always constant (i.e., for 3 seconds). This problem, consequently, may possibly have caused both evaluatees and evaluators to regard the sustained test as "relatively easy". Concerning the divided attention test, except for a problem, whose correction might change the evaluation criteria, only one problem of the input device was that the front button was also pressed accidently together when a direction key was inputted. In the stroop test, a most common opinion was that remembering the correct joystick direction matched to the color was too

difficult, and a small number of respondents' said that the colors were not clear. In the digit span test, there was a problem that when using the keyboard, the input numbers were not displayed on the screen so the evaluatees could not check whether they put in the numbers correctly also people complained that the size of the numbers written on the keyboard was so small that inputting was difficult. The evaluators thought that the evaluatees should remember the presented numbers first and input the numbers later in assessment, as the digit span item was a working memory test. However, there was no way to prevent them to enter the numbers while the numbers were being presented, therefore, the evaluators complained correct assessment on that test was difficult. Also, they pointed out that incorrect responses could not be checked and corrected during the test, since the inputted numbers were indicated as "*" on the screen. In the field dependency test, a common problem with both of the groups was that assessment was not properly conducted, because the explanation on the presented correct answer pictures was insufficient, and their classification between the same and different shapes and sizes was difficult. The evaluatees posed a problem in that they did not remember the reference pictures and directions presented on the previous screen, and the evaluators pointed out the explanation of practice examples lacked of clarity. Lastly, in the trail making tests A and B, the evaluatees did not present a specific opinion, however, many evaluators said they had difficulties in mouse manipulation, and also they answered it was very difficult to have the evaluatees understand the task instructions, due to the unnecessary English instructions shown together with the Korean instructions on the screen.

Table 3. Problem of CPAD sub-tests (evaluatee)

Sub-tests	Problem	Number of times mentioned
Depth perception	Too fast central bar speed	7
	Poor visibility	4
	Unclear classification of correct answers	3
	Issues of concerning field of vision	2
	Difficulty in understanding task instructions	1
Sustained attention	Blur lines	2
	Too much spaces	1
Divided attention	Accidental button press when entering the arrow key	3
	Difficulty in simultaneous inputs of arrow key and button	1
	Issues of concerning field of vision	1
Stroop test	Difficulty in remembering of correct arrow key	3
	Difficulty in understanding task instructions	2
	Unclear color	1
Digit Span	No input feedback	2
	Too noisy	1
	Too small number buttons	1
Field dependency	Unclear correct answer	12
	Difficulty in remembering in correct pictures and their direction	5
	Difficulty in understanding task instructions	4
Trail making test (A, B)	Difficulty in trail making test B	1

Table 4. Problem of CPAD sub-tests (evaluator)

Sub-tests	Problem	Number of times mentioned
Depth perception	Unclear classification of correct answers	21
	Difficulty in giving instructions	8
	Long evaluation times	7
	Too small number of practices	5
	Too disturbing sound of wrong answers	3
	Low screen position	1
Sustained attention	Difficulty in giving instructions	3
	Constant rotation interval	1
Divided attention	Difficulty in simultaneous sound and response	9
	Poor overall understanding of the task	2
	No information on neglected screen position	1
Stroop test	Difficulty in remembering directions	13
	Difficulty in giving instructions	10
	Difficulty in distinguishing between yellow and green color	1
	Literacy	1
Digit span	Too fast respond the sound without looking	23
	Hearing deficits	3
	No input feedback	3
	Too noisy	2
	Too small number of practices	1
Field dependency	Difficulty in giving instructions	15
	Too small number of practices	7
	Unclear correct answer	3
	Low resolutions	3
	Several problems passed without taking answers	1
Trail making test (A, B)	Difficulty in mouse operation	7
	Difficulty in understanding trail making test B	5
	Confusing english instructions	2

3.3 Problems of CPAD input devices

Tables 5 and 6 show the problems of CPAD input devices. Concerning each input device's problems, both the evaluatees and evaluators were not familiar with the input devices (i.e., keyboard, joystick), except the touch screen. This problem led to the suitability assessment result of the input devices as shown in Tables 1 and 2. As for each input device's problem, both the evaluatees and evaluators pointed out the unstable joystick most frequently, and also they complained about the inconvenience

of joystick's occluding the screen. And other joystick problems the evaluatees posed were the button in front of the joystick pressed uncontrollably upon inputting left or right direction, difficulty in returning the joystick to the original position as revealed in the usability test in the divided attention test, and difficulty in operating devices with non-dominant hand. The evaluators asserted that the same input was made several times in a row, due to the difficulty in bringing the joystick to the original position; therefore, the problem needed to be solved, and pointed out there were many unnecessary buttons. The evaluators said that the evaluatees, mostly stroke patients, could not precisely move the joystick toward the directions (upward, downward, left and right) as they desired, so that measures needed to be taken to solve this problem. They pointed out the joystick currently used was a general joystick for the right-handed, and there was no consideration for left-handed users. Regarding the problems of the mouse, most evaluatees complained difficulty in manipulating the mouse, and most of the evaluators said the response speed and accuracy were low, due to difficulty in mouse manipulation. As for the keyboard problems, an opinion that small-sized numbers were difficult for visual recognition was common for both of the groups. The evaluatees additionally presented an opinion that there were many unnecessary keys other than the input keys, and the order of the numbers was confusing. Regarding the touch screen problems, a common opinion was that touch responses were not good, and the evaluators pointed out that the monitor was unstable and wobbled.

Table 5. Problem of CPAD input devices (evaluatee)

Input devices	Problem	Number of times mentioned
Joystick	Unstable joystick	3
	Accidental frontal button press when entering right and left direction input	3
	Difficulty in returning to original position	2
	Not used	2
	Difficulty in using the non-dominant hand	1
	Screen occluded the joystick	1
Mouse	Not used	4
	Difficulty in using the non-dominant hand	4
	Difficulty in clicking because of hand paralysis	2
	Difficulty in operating mouse	1
Keyboard	Too small keyboard font size	2
	Too many input buttons	1
	Confusing number positions	1
Touch	Not good touch response	2
	Too high touch screen position for people with hand paralysis	1
	Not used	1

Table 6. Problem of CPAD input devices (evaluator)

Input devices	Problem	Number of times mentioned
Joystick	Unstable joystick	8

Table 6. Problem of CPAD input devices (evaluator) (Continued)

Input devices	Problem	Number of times mentioned
Joystick	Screen occluded the joystick	6
	Difficulty in returning to original position	5
	Difficulty in operation	4
	Too many joystick input buttons	3
	Difficulty in using the non-dominant hand	2
	Not used	2
Mouse	Not used	18
	Difficulty in using for people with hand tremor	1
Keyboard	Not used	6
	Issues of concerning field of vision	3
Touch	Not good touch response	9
	Unstable table	4

3.4 User observation

In this study, experimenters observed the evaluatees performing the CPAD tests through the whole process and detected usability-related problems in order to effectively analyze the CPAD usability. The user observation technique is a method used to find usability problems effectively by analyzing user behaviors. Especially, most of the evaluatees of CPAD are stroke patients with cognitive impairments, thus their abilities to recognize problems and communication skills are lower than normal people. Therefore, the user observation technique has a merit that problems not revealed in the questionnaire survey and interview results can be found.

The user observation results show that a total of six problems were revealed in the sub-tests (Table 7), and there were four problems about the input devices (Table 8). The suggested improvements to be made through recognizing such problems included revised task instructions to make them more easily understood, addition of more practice examples, showing correct answer direction and time limit for answering with response time window during the test. Also suggested was that the problem of multiple input counted as correct answers should be solved by proper software programming and that in the case of input devices, the input devices affected by individual skillfulness and cognitive abilities should be improved in consideration of stroke patients' characteristics.

Table 7. Problem of CPAD sub-tests (observer)

Problem	Sub-tests	Improvement
Long evaluation time	Depth perception	Reduced
Keeping pressing button counted as correct answers	Sustained attention, Divided attention	Corrected
Difficulty in remembering correct answers	Stroop test, Field dependency	More practice provided

Table 7. Problem of CPAD sub-tests (observer) (Continued)

Problem	Sub-tests	Improvement
No time limitation for answering	Digit span, Field dependency	Response time window added
No time window for correcting answers	Stroop test, Field dependency	Corrected
Too small number of practices problems	All 8 sub-tests	More practice and instruction added

Table 8. Problem of CPAD input devices (observer)

Problem	Input devices	Improvement
Unstable joystick	Joystick	Fixed tightly
Individual difference in operating input devices	Mouse, Keyboard	Customized input devices
Vision problems	Keyboard	Larger font size
No using the non-dominant hand	Mouse	Alternative input devices

4. Improvement Results

4.1 Test items improvement results

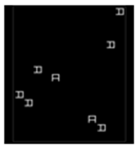
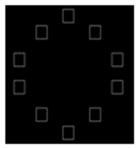
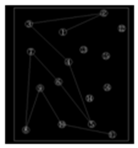
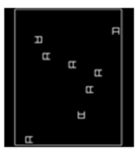
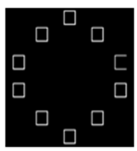
Through the results acquired via the usability test, this study improved CPAD sub-tests (Table 9) (Table 10). The problems that may affect CPAD assessment criteria were excluded from improvements. The difficulty in understanding test instructions, a common problem for both evaluatees and evaluators, was improved by adding more explanation video and voice explanation, and two more practice examples (from three times to five times). These improvements may help minimizing the problem of evaluatees' not being able to remember correct answer directions. Also, based on this study, one of the major problems of the joystick, keeping pressing the buttons counted as correct answers, was solved through a proper program coding, making next input to be counted, only if the input value of joystick went down to 200 or lower (joystick input value: X: -1024~1024, Y: -1024 ~1024) (Tables 6 and 7). The problem with the depth perception, unclear correct answer range, was solved by indicating correct answer range in practice examples. In addition, the lines were made thicker and the number of evaluation stimuli was reduced from 40 to 20. In the sustained attention test, the relatively thin lines were made thicker and clearer, and the length of the stimuli presentation time, which was considered "too long" therefore the test was considered "too easy", was reduced to 2~4 seconds. The problems of divided attention test were solved with the correction of input devices, and additionally the lines were made clear as well. As for the digit span test, this study solved the most serious problem of the testees' just copping the correct answers, during the presentation of to-be-remembered numbers (by not counting the numbers entered during the presentation as correct answers). Also, the existing keyboard input was maintained in line with this study's purpose - input devices minimization - and this study added a touch keypad so that users could respond with an alternative method of screen touch (Figure 1). Also resolved was the problem of not being able to check if the numbers just entered were correct, because they were indicated as "*" on the screen, by showing the number immediately after the input. Also this study added a "Delete" button that could delete the last inputted number, and an "Again" button to delete all the inputted numbers so that wrong input, the evaluatees recognized immediately after, could be corrected. The response time problem and difficulty to remember correct answer directions recognized in the user observation was solved as well (Table 7). In both the trail making tests and the field dependency test, a response time window was added and made visible on the screen and the directions of correct or wrong answers in the field dependency test.

Concerning the trail making tests A and B items, the test instructions were the same, despite the different problem solving modes of the two tests, and it was considered that the B test was relatively more difficult than the A test. Therefore, we added separate instructions for A and B tests respectively. Also, the English instructions, which were irrelevant to evaluation, were deleted.

Table 9. Improvement of CPAD sub-tests

Sub-tests	Improvement
Common issues	Explanation, audio, and video instructions added
	More practice (from 3 to 5 times) provided
	Time window for correcting answers
Depth perception	Thicker line width
	Number of problem (from 40 to 20 times) reduced
	Visual examples of correct answer range provided
Sustained attention	Thicker line width
	Problem presentation intervals randomized (from 3 to 2~4 seconds)
Divided attention	Thicker line width
Digit Span	Touch screen used as an input device
	Input correction enabled
	Response output shown during the input process
	Time left shown within the response time window
Field dependency	Correct direction indicated visually
	Response output shown during the input
Trail making test (A, B)	Separate instructions provided for both TMA and TMB
	English instruction removed

Table 10. Improved CPAD

	Depth perception	Sustained attention	Divided attention	Stroop test	Digit span	Field dependency	Trail making test (A,B)
CPAD ver.2							
Improved CPAD ver.2							

(녹색: Green)

차례대로 눌러주세요: Press in order / 지움: Delete / 다시: Again)

Figure 1. Improved touch system

4.2 Improvement results of input devices

Figures 2 and 3 show the improvement results of input devices, based on the usability test. The mouse, among other input devices, was revealed to be unsuitable in the suitability evaluation; unfamiliarity with the mouse was the main reason. It was also reported, in user observation, the users' skills made differences. Although the keyboard was shown to be relatively suitable as an input device, there were also such problems as users' individual differences of skills or familiarity with the device. In addition, one of the weaknesses of the input devices suggested in the usability test result was that they were not easy to use for people with vision problems. This study excluded the keyboard and the mouse as input devices replacing them with a touch screen considering that the keyboard and the mouse used for only digit span and trail making tests A and B could be a little cumbersome and

(a) Old input devices

(b) Improved input devices

Figure 2. Old and improved input devices

complex (Figure 3). However, as part of improvement, the keyboard and the mouse were added as the input devices, given that the evaluation environment was not always the same. Concerning the joystick, the unstable joystick and occlusion problems were solved by adding a guiding rail to fix and move the joystick. Regarding other problems, this study, we developed a customized joystick for CPAD, since, we believed, the problems could not be solved using the commercialized joysticks sold in the market. This new joystick removed all other buttons except the buttons required for the CPAD evaluation, and got rid of the inconveniences for left-handed people by inserting a left and right-movable support. The joystick was improved to input user's desired directions (upward, downward, left and right) by inserting the use instructions (Figure 2).

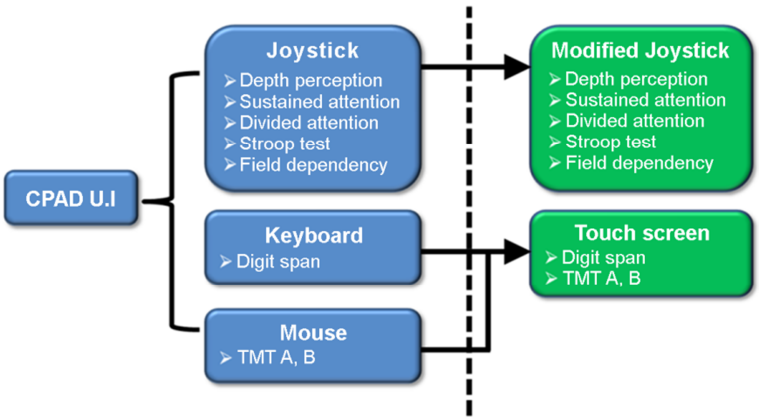


Figure 3. Simplified input devices

5. Conclusion

This study conducted the usability test on the one and only cognitive driving ability evaluation tool for people with disabilities developed in Korea, the CPAD, and improved it based on the results. The usability test of CPAD was carried out in both the evaluatee and evaluator groups, and also, the experimenters observed the evaluatees while they were being tested. The usability test results were categorized by several common issues, and the problems that could affect evaluation criteria were excluded from improvements. The improved CPAD may help the evaluatees understand the test instructions through increased number of practice examples, more explanation with videos and voices on each test. By improving user interface, which was pointed out as a problem, the discomforts of using CPAD use were minimized. The commercialized input devices of CPAD were replaced with the customized joystick and touch screen, minimizing their previous inconveniences (but existing mouse and keyboard could be still used). The input devices were improved to be more convenient for the evaluatees not familiar with computer operation. The CPAD improved based on the findings of this study is expected to be distributed to designated local rehabilitation hospitals and driving support centers nationwide easily accessible to the disabled, to be used as a tool for evaluating cognitive driving abilities for people with disabilities.

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