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(Degree)

博士（保健学）

(Date of Degree)

2015-09-25

(Date of Publication)

2016-09-25

(Resource Type)

doctoral thesis

(Report Number)

甲第6487号

(URL)

<https://hdl.handle.net/20.500.14094/D1006487>

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Development of Computer-Aided Cognitive Training Program for Elderly and Its Effectiveness through a 6 Months

Group Intervention Study

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Abstract

Since the increasing population of aging, cognitive training is focused as one of the non-pharmacological preventive approach of cognitive decline. Although the accumulation of the knowledge, they hardly reflect to the programs for clinical use. We developed a task set named “Atama-no-dojo,” designed to activate multiple cognitive functions and enhance motivational incentives. The objective of our study is to confirm the effect of our program through a 6 months group intervention program.

The intervention program conducted in a day service center for 6 months in the duration of 45 minutes per day, 4 days per month for a total of 25 sessions. Participants worked to the tasks on the screen all together with filling in the answering sheet. Neuropsychological tests, SF36 and GDS were assessed at pre-/post-intervention periods. Participants filled in a questionnaire about impression to the program at the last training session. Fourteen women (82.2 ± 2.9 years old) were analyzed and significant changes were found in the improvement of memory, attention, inhibition, GDS and some items of SF36. All participants recognized the program as fun and wanted to continue. Some of the participants' positive impressions to the program correlated to cognitive improvement.

The improved cognitive functions by 6 months intervention of “Atama-no-dojo” were mainly related to prefrontal cortex and the motivational incentives seemed supported the effect of task contents. We recognized the importance of task difficulty setting and motivational incentives to reduce frustration from working on difficult tasks and enhance the effects of improvement from activating brain function.

Keywords: aging, cognitive decline, group approach, motivation, novelty, pleasantness

Introduction

In 2015, 25.1% of the Japanese population will be 65 years old or older; this figure would continue to increase to 39.9% within 50 years [1]. Similar situations are occurring in many developed countries as well as some developing countries [2]. In light of this situation, a study focus on the age-related decline in cognitive functions and the decrease of the risk of dementia from the perspective of health promotion becomes increasingly important. An effective solution to

help prevent cognitive decline would not only lead to a better quality of life (QOL) for the elderly and their families, but also reduce the costs of social security for elderly care. As a result, many studies have been conducted on this topic in recent years.

Deterioration of cognitive functioning from aging affects multiple domains, including memory, executive function, reasoning, attention, inhibition, and cognitive control [3-7]. This functional decline is the result of some shrinkage of the prefrontal cortex (PFC), hippocampus, and basal ganglia [8], the changes between their connections [9], and a decrease in the synthesis and the binding of dopamine, serotonin, and acetylcholine [11-15]. Many researchers have often focused on the PFC because it involves the functions that play a central role in controlling human behavior; these tend to decline with increasing age and cause trouble for the elderly in their daily lives.

Certain researchers have proposed a hypothesis that involves the maintenance of good cognitive performance by the brain mechanisms of cognitive reserve and compensation [16-17] against the age-dependent anatomical and physiological changes of the brain. Forming their scaffolding theory of aging and cognition, Park and Reuter-Lorenz (2009) hypothesized that compensatory changes in PFC activation can create supportive neural structures (scaffolding) or boost the existing one. They also declared cognitive engagement exercise as one of the factors that strengthen the ability to use this mechanism.

A number of studies have reported the improvements of cognitive functions in the elderly due to the cognitive training intervention programs conducted in the past 15 years [18-25]. These studies revealed improvements in the trained domain functions due to a strategy-based training and the betterment was maintained for five years [18-20], improvements in untrained task scores after the implementation of a computer-based program [21], and increased

cerebral resting blood flow in the participants after intervention [22]. Plassman *et al.* (2010) carried out a systematic review of the factors and possible prevention of cognitive decline in later life. They found a high quality of evidence supporting a decreasing risk of cognitive decline through cognitive training, as opposed to other interventions (e.g., vegetable intake, Mediterranean diet, ω -3 fatty acids, physical activity, and noncognitive or nonphysical leisure activities) [26]. Gates *et al.* (2010) recommended computer-based training because of its potential to facilitate multi-modal and multi-domain training, enable unobtrusive real time monitoring of cognitive performance, and allow a reduction in personnel and implementation costs [27]. Despite the accumulated research knowledge in this area, the programs for clinical use have not yet reflected the use of this knowledge.

We conducted a community-based cognitive training program for the elderly in 2008 by using some pre-existing paper texts. At the same time, we started developing a computer (PC) aided multi-tasked intervention program for clinical use. A PC-based program is superior to a paper-based program in activating the PFC-related functions, such as attention, working memory, and inhibition, at the point of presentation of the stimulus that includes time-dependent changes.

The main purpose of our study was to make an effective cognitive training program and confirm its effects on cognitive function. The important components were the effective task contents and the motivational incentives. We hypothesized that motivational incentives affect the amount of improvement in cognitive performance. We proposed that the task contents should include a stimulus that activated the multi-modal cognitive functions and have an adequately high difficulty level. The adequately high difficulty level would mean that the subjects could try hard but not too hard as to lose their motivation from frustration. To activate the target brain functions, it is necessary for subjects to struggle with

problems that have some amount of difficulty [28-32], but it is also true that subjects tend to become fatigued and frustrated when the task becomes more difficult. We carefully decided on the level of difficulty for the tasks by testing elderly subjects while referring to the average scores of standardized neuropsychological tests, especially in the tasks that included attentional loads. Many of our tasks included a 5-step difficulty level that varied from very easy to very difficult; this allowed the elderly subjects with different levels of cognitive performance the chance to both gain a sense of accomplishment from getting a correct answer and struggle hard with the difficult problems.

In the area of motivation, which is another important component, a number of studies have demonstrated the achievement of better performance and brain processes with motivation [33-36]. To maintain the subjects' high motivation, it is necessary to supply not only an adequate level of difficulty in tasks, but also some contrivance to prevent their boredom. Buitenweg *et al.* (2012) suggested that novelty seems to be an important factor for achieving longer-lasting effects from brain training, especially in the elderly, and that the inclusion of novel stimuli or tasks could motivate the elderly to invest more effort and energy into learning [37]. In light of these suggestions, we included different and unfamiliar items in each session that had not yet become automatizations for the subjects. In addition, to allow the program to evoke familiarity and pleasant feelings in the subjects, we adopted task materials that were related to seasonal events and everyday life, alongside amiable illustrations.

In this paper, we report the contents of the program that we developed and the results of a 6-month intervention study with a group of home-dwelling elderly.

Materials and Methods

Task set “*Atama-no-dojo*”

We developed a Java script software called “*Atama-no-dojo*,” which means “training gym for the brain” in Japanese. The task set contained 14 cognitive training tasks (see Table 1 and Figure 1) developed to activate the different domains of cognitive functions that tend to decline in later life, such as attention, memory, inhibition, reasoning, visual-space search, and calculation. Each task had a different version in each session (same rules but different materials, words, and images). The task set had two play modes: “Play Alone” and “Play in a Group.” “Play Alone” was for playing by oneself and answering the task questions by using the mouse and the keyboards or the touch screen panel. In “Play in a Group,” participants worked on the tasks by watching the screen with other participants and answering the questions by using paper and pencils. We designed this task set for an annual run of 48 sessions (4 sessions a month). A session included 8 tasks for “Play Alone” and 7 tasks for “Play in a Group” out of all 14 tasks. Four types of task combinations were ordered by turns. Each task performance was scored from 0 to 5 according to the level of difficulty or the number of successful responses accomplished. In “Play Alone,” the player operated the program by oneself along with the instructions shown on the screen. The task program fed back the result of the performance by presenting signs of correct/wrong on the spot, which were recorded as log data, so that not only we, but also the players themselves could check the changes in performance between sessions. In “Play in a Group,” a facilitator was required to conduct the session by checking the answers on the spot and providing feedback and hints if necessary, while the answering sheets recorded the performance data.

Table 1. “Atama-no-dojo” task contents.

Task	Play mode		Contents	Target function
	Alone	Group		
Warm-Up (Don't be deceived)	○	○	Answering quickly to the stimulus emerging on the screen one after another, with inhibiting Stroop effect. The item categories are number, color, form vs. words, and defeat by rock/ paper/ scissors. In a session, 15 trials of one category are presented continuously. The duration of a stimulation changes from 2 seconds to 1 second as the difficulty level changes.	Inhibition Attentional switching
What's This? (Reasoning)	○	○	Reasoning what the item is from the partial photo images. The difficulty level changes according to the size of the parts; smaller parts of a whole image will render the recognition of the item more difficult, and the hint button will change the photo into an easier one.	Reasoning Image construction
What's This? (Puzzle)	○	-	Sorting the ten pieces of a photograph, which are the parts of a thing, to recreate the whole image within a time limit.	Reasoning Image construction
Witty Words	○	○	Reasoning how to read words with letters that are characterized by special features of form, layout, and color. 5-step hints are prepared to give letters of the name one by one from the beginning of the word.	Reasoning Verbal analogy
Spot the Five Differences	○	○	Finding five differences in two almost identical paintings. The differences are arranged as five difficulty levels of noticeability in the changes of shape color, size, and the subject/background.	Visual space search Image verification
Catch It (Word)	○	-	Touching or clicking the words that suit the given rule from the words that appear one after another. The dummy words are similar in visual or phonological features.	Sensory motor speed Word-meaning reaction Inhibition
Catch It (Moving image)	○	-	Touching or clicking on the moving target, but not the dummy target. The speed of motion and the number of targets change as the level of difficulty changes.	Sensory motor speed Motion capture Inhibition
Calculation (Cooking)	○	○	Calculating the quantity or price of ingredients to make a certain dish. The complication of calculation increases as the level of difficulty increases.	Executive function Calculation
Calculation (Hidden number)	○	○	Counting the number of items that are going in and out of the shade and indicating the number of items remaining behind the shade at the end. The player tries the sequence five times. The frequency of in/out increases from three to seven times as the level of difficulty increases.	Counting Calculation Working memory
Remember (Breakdown)	○	-	Finding five pairs of the same pictures from ten closed cards by opening two cards at once during the time limit. This has the same rules as the card game breakdown.	Memory of spatial allocation
Remember (Motion)	○	-	Three graphic images move one after another. The players remember	Sequence memory

sequence)			and reproduce the order of motion afterwards. There are five trials and the frequency of motion increases from three to seven as the level of difficulty increases.	Memory of spatial allocation
Remember (Word sequence)	☐	☐	Remembering the order of the words that appear one after another and indicating the number sequence of the words afterwards. There are five trials and the number of words increases from three to seven as the level of difficulty increases.	Sequence memory Phonological memory
Remember (Today's tasks)	☐	☐	Answering five questions (four questions for Group mode) about the task contents that have been carried out during the same session.	Episodic memory
Read Aloud	☐	☐	Reading a famous poem or sentence aloud, fluently, heartily, and comfortably, and then evaluating the performance with self-rating scales.	General activation Self-monitoring



Figure 1. The task images of “Atama-no-dojo.” The illustrations are related to the season or month of the task setting. For example, the paintings for Spot the Five Differences are about the Feast of Dolls, the traditional Japanese celebration of girls on March 3rd.

Subjects

We held this intervention study in a day-service center that was used by the frail elderly to maintain healthy lifestyles in Hyogo Prefecture, Japan. The subjects of this study were the users of this day-service center and lived independently in the applicable site of the city without suffering from any cognitive impairment. Eligibility criteria for our study included people over 75 years of age with no ongoing cardiovascular, psychiatric, or neurological diseases, who had achieved over 24 points in the Mini Mental State Examination (MMSE) [38] and up to 10 points in the Geriatric Depression Scale (GDS) [39], and had enough visual and auditory ability to work at a desk. We excluded subjects who attended less than 20 sessions (the attendance ratio of 80 %) out of the full 25 sessions to control the variable of the attendance ratio. Unfortunately, we could not include any male subjects because the center had no male users during that period. The ethical review board of Kobe University approved the study protocol and all participants signed the written informed consent forms.

Intervention

We conducted the “Play in a Group” session, which lasted approximately 45 minutes/session, once a week for 4 times a month, for about 6 months, which totaled to 25 sessions. Together, the subjects viewed the tasks projected onto an 80" screen and two 17" monitors and wrote on their own answering sheets. The current author facilitated the program by checking the answers on the spot and providing hints if needed. The facilitator told subjects repeatedly not to be afraid of writing the wrong answer, and encouraged them to work hard for effective brain activation.

Outcomes

The assessment batteries included are shown in Table 2. Certain trained occupational therapists, except for the current author, executed the assessments in a face-to-face testing situation. The subjects filled out an MOS 36-Item Short-Form Health Survey (SF-36) and a GDS by themselves under the supervision of the experimenters. The pre- and post-assessments took approximately an hour for each subject and were conducted a week before/after the intervention period. To exclude the learning effect, we used the different versions of episodic memory test items (story recall and “three words memory” in the MMSE) between the two assessment sessions. The questionnaire about the impressions of the intervention program (Impression Questionnaire) was provided at the final intervention session. Participants answered seven questions by choosing an answer from the following five options: “strongly agree,” “agree,” “undecided,” “disagree,” and “strongly disagree” (see Appendix).

Table 2. Assessment batteries.

Measure	Target function	Reference
MMSE	General intelligence.	[38]
FAB	General cognitive function of prefrontal cortex.	[40]
TMT A, B, B/A	Executive attention, attentional shifting.	[41]
Stroop I, II, II/I, II errors	Executive attention, inhibition of stereotype.	[42,43]
Story recall immediate, delayed	Episodic memory, extracted from the Rivermead Behavioral Memory test (RBMT).	[44]
SF-36	Health-related quality of life (QOL).	[45]
GDS	Mood status, depression.	[39]

MMSE: Mini Mental State Exam, FAB: Frontal Assessment Battery, TMT: Trail-Making Test, Stroop: Modified Stroop Test (Japanese version), Story recall: a test item extracted from the Rivermead Behavioral Memory test, SF-36: MOS 36-Item Short-Form Health Survey, GDS: Geriatric Depression Scale.

Analysis

We analyzed the changes of scores between pre- and post-intervention by using the paired t-test and Cohen's-d [46, 47] for neuropsychological tests and the Wilcoxon signed-rank test for the SF-36 and the GDS (Excel statistics 2008, SSRI Co.). We confirmed the results of frequency distribution from the Impression Questionnaire and also inspected the correlation with the changes in cognitive function (the post-score minus the pre-score) by converting the answers into an ordered score from "5 = strongly agree" to "1 = strongly disagree" (Spearman Rank Correlation, Excel statistics 2008, SSRI Co.). For this correlation analysis, we applied the $p < .01$ qualification for significance discrimination to avoid a false correlation from the obscurity of subjective data.

Results

We analyzed 14 subjects out of the 19 users of the center who met our criteria (Table 3). One of the 5 excluded women had an optical problem from macular degeneration, another was hospitalized with lung cancer during the intervention period, and excluded three others who attended less than 80% of our program session for personal reasons, including traveling, going to the hospital and attending the other hobby classroom. The average age of the 14 eligible women was 82.2 ± 2.9 years old, with 10.5 ± 1.7 years of education. They attended an average of 22.6 ± 1.7 sessions. Thirteen of them lived alone and one lived with her husband. Eight people had independent gaits and six needed the help of walking sticks.

Table 3. The baseline data of the included and excluded subjects. The demographic, cognitive and mood status including the outcome measures in pre-intervention assessment.

	n	age Ave. (SD)	family living together	gaits	year of education Ave. (SD)	frequency of attendance Ave. (SD)	MMSE Ave. (SD)	GDS Median (interquartile range)
Included subjects	14	82.21 (2.89)	no family: 13 with family: 1	independent: 8 with stick: 6	11.07 (2.53)	22.64 (1.69)	27.5 (2.14)	4.5 (2.25)
Excluded by attendance ratio	3	84.33 (3.51)	no family: 1 with family: 2	independent: 2 with stick: 1	12 (4)	15 (2.65)	26.67 (2.89)	4 (4)
Excluded by health problem	2	85 (5.66)	no family: 1 with family: 1	independent: 1 with stick: 1	12.5 (3.54)	13 (14.14)	27.5 (2.12)	3 (2)

Results from the pre- and post-intervention assessments are shown in Tables 4 and 5. We found a significant improvement in Story recall delayed ($p=.022$, $d=.8$), MMSE (under 28, $p=.018$, $d=.97$), Stroop II/I ($p=.033$, $d=.46$), and Stroop II errors ($P=.010$, $d=.94$). In the MMSE, we examined the participants who scored under 28 during the pre-intervention assessment because of the ceiling effect. There were no significant changes in Story recall immediate, Frontal Assessment Battery (FAB), Trail-Making Test (TMT) A, TMT B, TMT B/A, Modified Stroop Test (Stroop) I, and Stroop II. Significant changes were also found in the GDS and the SF-36. We found point reductions in the GDS ($p=.019$). In the SF-36, there was an increase in “Physical role” ($P=.009$) and “Social functioning” ($p=.012$), a decrease in “Bodily pain” ($p=.0005$), and no significant changes in “Physical functioning,” “General health,” “Vitality,” “Emotional role,” and “Mental health.”

Table 4. Scores from the neuropsychological tests - comparison between pre- and post-intervention assessments.

	M(SD)		p-value (t-test)	effect size
	Pre-intervention	Post-intervention	(*<.05, **<.01)	Cohen's-d
Story recall immediate	10.07(002.03)	10.71(002.95)	.23	.25
Story recall delayed	6.71(003.20)	9.07(002.70)	.022 *	.79
FAB	13.79(001.85)	14.14(001.92)	.29	.19
MMSE (under 28; n=7)	25.71(001.25)	27.00(001.41)	.018 *	.97
TMT A (sec)	152.64(064.61)	173.21(075.73)	.13	.29
TMT B (sec)	289.00(143.30)	274.50(121.75)	.31	.11
TMT B/A (sec)	136.43(124.65)	101.21(099.05)	.13	.31
Stroop I (sec)	18.79(005.00)	18.79(003.81)	-	.0
Stroop II (sec)	37.36(011.32)	34.43(010.78)	.14	.27
Stroop II/I (sec)	18.57(007.77)	15.00(007.91)	.033 *	.45
Stroop errors	1.29(000.83)	0.50(000.85)	.01 *	.94

MMSE: Mini Mental State Exam, FAB: Frontal Assessment Battery, TMT: Trail-Making Test, Stroop: Modified Stroop Test (Japanese version), Story recall: a test item extracted from the Rivermead Behavioral Memory test.

Table 5. Scores from the SF-36 and the GDS - comparison between pre- and post-intervention assessments.

	Median (interquartile range)		p-value (Wilcoxon)
	Pre-intervention	Post-intervention	(*<.05, **<.01)
SF-36			
Physical functioning (PF)	35.21(12.34)	33.87(11.56)	.31
Physical role (PR)	36.73(08.39)	41.95(09.20)	.009 **
Bodily pain (BP)	43.44(07.89)	29.81(08.19)	.0005 **
General health (GH)	45.02(06.64)	44.22(05.43)	.31
Vitality (VT)	49.07(04.70)	50.98(06.14)	.094
Social functioning (SF)	47.35(10.34)	53.80(06.06)	.012 *
Emotional role (ER)	39.42(07.12)	43.28(11.72)	.10
Mental health (MH)	50.15(08.53)	53.12(06.42)	.10
GDS	5.07(02.61)	3.57(01.70)	.019 *

SF-36: MOS 36-Item Short-Form Health Survey, **GDS:** Geriatric Depression Scale.

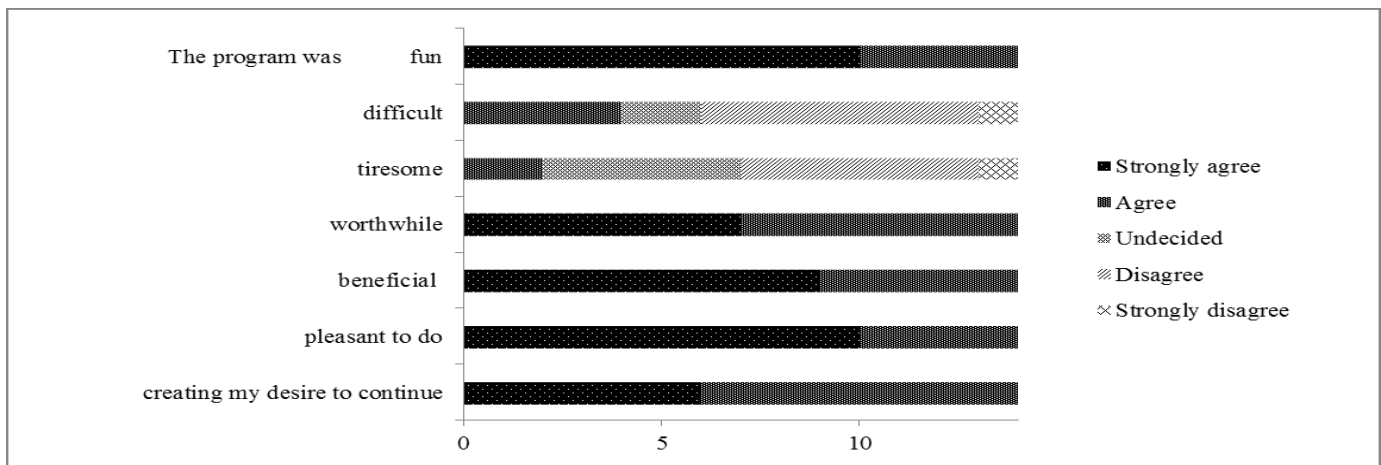


Figure 2. Subjects' impressions of the program and their 5-step rating scale.

Results from the Impression Questionnaire are shown in Figure 2. All subjects felt that the program was “fun,” “worthwhile,” “beneficial,” “pleasant to do,” and creating their desire to continue it in the future. On the other hand, 29% of the subjects felt that the program was “difficult” and 14% felt fatigued from the program. The correlation between the changes of the neuropsychological tests and the questionnaire items was found between “the program was pleasant to do” and both Stroop II ($r=-.66$, $p=.0088$) and Stroop II/I ($r=-.68$, $p=.0065$). In addition, for confirmation, we also investigated the subjects' age, years of education, frequency of attendance to the session, and changes in the GDS scores. There were no significant correlation to the cognitive changes, with the exception of a near significant correlation between the GDS and the FAB ($r=-.63$, $p=.015$).

Discussion

The results revealed that our program could improve memory and attention control, including inhibition. The score betterment in Story recall proved that there was an improvement of memory, especially in delayed conditions. The

delayed condition of Story recall conducted at the end of the assessment session required subjects to remember the story that was given at the beginning of the session. This means that subjects had to remember amidst the interference posed by the other tests conducted between the presentation of the story and its reproduction. Meanwhile, Stroop showed a shortening of the time difference between II/I and a decrease in errors. However, this was not as simple as it appeared because we could not find a significant difference in both versions of Stroop (I and II). The combination of a drop in Stroop I and a rise in Stroop II resulted in a shortening of time difference; the general processing speed (I) declined but the inhibitory control (II) improved during the intervention period. A similar situation was found in TMT A and B, though the changes were not significant. The functions of set shifting and inhibition in the tasks that included interference or stereotypic responses were thought to be related to the attentional control in the dorsolateral PFC (DLPFC) and the inferior frontal junction area (IFJ) [48-50]. These attentional controls in complex tasks and the inhibition of irrelevant stimuli tend to decline with increasing age [51] and become the factors of the seemingly careless errors made by the elderly in their daily lives. Mozolic *et al.* reported attentional improvements and some increases of resting blood flow in the PFC of subjects after cognitive training intervention [23, 52]. In our tasks, “Warm-Up,” “Calculation (Hidden number),” and “Remember (Word sequence)” included some attentional control such as inhibition or working memory manipulation. Our program activated the related PFC area and improved these functions.

The results of Story recall and Stroop demonstrated improvements that are similar to those reported by Klusmann *et al.* [22], who also targeted old women (73.6 ± 4.4 years old) in a study with a similar 6-month duration; their study differed from ours in the number of 230 subjects in three groups, the frequency of 75 times, and the cognitive task contents (memory task, coordination task, and ordinal PC manipulation, which was novel for the participants). They

found significant improvements in Story recall immediate ($p < .001$, $d = .73$), Story recall delayed ($p < .001$, $d = .77$), and Stroop II/I ($p = .004$, $d = .27$). Their results from Story recall delayed and Stroop II/I are similar to ours (Story recall delayed; $p = .02$, $d = .79$, Stroop II/I; $p = .03$, $d = .45$). This means that compared to that of Klusmann *et al*, our program could improve the cognitive functions of older subjects with slightly higher effect sizes in lower frequency.

Although we could also find significant improvements in the MMSE scores (under 28), these other tests showed some increase in average points but not an overall meaningful improvement. We suppose that there would be a significant change with a bigger sample size. We conducted an additional analysis to investigate the enough sample size from the effect size [47] (G*Power 3, F. Faul, Kiel University, Germany) for each neuropsychological test to get a meaningful result in t-test ($p < .05$). This analysis showed that the number of 513 subjects ($n = 513$) was assumed to be enough to achieve significant improvement in TMT B which had the smallest effect size, and likewise did $n = 101$ for Story recall immediate, $n = 173$ for FAB, $n = 75$ for TMT A, $n = 66$ for TMT B, and $n = 87$ for Stroop II. These assumptions help us to plan the sample size for future intervention study. Nevertheless, the evident conclusion is that, in this study, the element functions of fluid intelligence were maintained in most of the subjects and even improved in some cases.

It is clear that our intervention program obtained sufficient compliance from the subjects. All subjects regarded the program as pleasant and beneficial, and wanted it to continue; some positive correlations were also seen in Stroop. This means that the subjects who felt that the program was more pleasant could achieve better scores in the post-intervention test, which would demonstrate the positive effect of motivational incentives on cognitive improvement. In cognitive training, it is necessary for subjects to struggle with problems that have some amount of difficulty to activate the target brain functions [53-57], but it is also true that subjects tend to become fatigued and frustrated when the task becomes

more difficult. In fact, in this study, participants sometimes expressed frustration at encountering difficulty with solving particular problems at the intervention site. The motivational incentives played an important role in helping them to overcome this frustration and work harder even when the tasks were difficult. Since motivation is associated with the activation of the striatum and affects the functions of attention and memory backed by the cortico-striatum circuits including the PFC [35-36, 58], the motivational incentives in our program assisted the subjects' performance by driving this circuit.

Another improvement was seen in the areas of "Physical role" and "Social functioning" in the SF-36 as well as the GDS, despite the worsening of "Bodily pain" in the SF-36. These subjective changes might have been caused by many factors; we cannot confirm that the changes were a direct effect of our intervention. However, we can confirm that subjects felt that our program was fun and beneficial, and wanted it to continue. Having a worthwhile, pleasant task could contribute to these positive feelings. The GDS also showed a nearly significant correlation with Stroop II/I. In some preceding studies, the depressive state is assumed to be associated with cognitive function [59-61]. The enhancement in mood status could be an assistive factor in cognitive improvement; this was indeed the secondary effect of our intervention, as the mood status of the subjects was partially improved by our program.

Our research subjects were restricted to a group of female late elderly living in a specific area and using a specific service center, which may have restricted the use of our results to form valid generalizations for the entire population. Future research should include some control groups, a bigger sample size of more than 513 people (calculated in the additional analysis by effect size) with a wider range of ages and male participants, and use a multi-center research design to incorporate different communities. Although we made some contrivances to maintain the high motivation of

our participants, it is difficult to pinpoint how they may have affected the performance of the participants. Therefore, in order to verify their effects, we are currently planning a new study that would compare the results of groups in programs with some differences in motivational incentives.

Conclusion

We developed a task set, called “*Atama-no-dojo*,” that aimed to prevent age-related cognitive decline.

“*Atama-no-dojo*” included 14 tasks for 2 play modes, and was developed with considerations of the requirements of multi-modal cognitive functions, adequately high difficulty levels, and a novelty of task contents to maintain subjects’ motivation. The 6-month intervention program proved that it could improve memory and attentional control, including inhibition, in the female elderly who were facing cognitive decline. The correlation between cognitive changes and subjective feelings proved the importance of motivational incentives. Further, functional improvements were partially supported by mood enhancement during the intervention period. We concluded that it is important to develop a useful intervention program that includes motivational incentives for effective brain activation and the maintenance of the desire for continuous participation.

Declaration of interest

The authors report no conflict of interest. The authors alone are responsible for the content and the writing of the paper.

Acknowledgements

We would like to thank the staff and members of Kasumigaoka Day Service for their cooperation. We also thank Tatsuo Oshiumi, Shinich Nagai, and Tomoki Murase from the Graduate School of System Informatics, Kobe University, for their technical support during the development of this program.

This study was supported by the Project of Health and Health Promotion for the Elderly, the Ministry of Health, Labor, and Welfare, and was a collaborative study between Kobe University and the city of Kobe.

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Appendix: Questionnaire on impressions of the program

Questionnaire items

Answer the following questions by marking an option that matches your feelings towards the program.

1. Do you think the program was fun?
2. Do you think the program was difficult?
3. Do you think the program was tiresome?
4. Do you think the program was worthwhile?
5. Do you think the program was beneficial?
6. Do you think the program was pleasant to do?
7. Do you think the program was creating your desire to continue?

Rating Scale

Strongly agree – Agree – Undecided – Disagree – Strongly disagree