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Flow experience enhances the effectiveness of attentional training: A pilot randomized controlled trial of patients after traumatic brain injury

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Abstract

BACKGROUND: Flow is an optimal psychological state when people engage in a training task, and it is a theory explaining the absorbed state.

OBJECTIVE: To investigate the additional effect of flow on attention deficits for chronic patients after traumatic brain injury.

METHODS: Twenty patients were randomly assigned to the flow group (n=10) or the control group. Patients performed a video game task, one inducing flow (flow group) and the other not (control group) for 4 weeks, and they were assessed with the flow state scale for occupational tasks (FSSOT) regularly and neuropsychological tests at baseline, after intervention, and at 4 weeks after intervention (follow-up).

RESULTS: Although both groups significantly improved their attentional function after intervention, patients in the flow group tended to show more improvement of attention. The effect size of the neuropsychological test of attention was positive, and its value was small to medium. There was a significant positive correlation between improvement of attention and the FSSOT score.

CONCLUSIONS: Attention training with induction of the flow was associated with greater improvement of attention. The results of this study may provide provisional evidence of the effectiveness of rehabilitation considering the patient's psychological state.

Key words: flow state, attention, brain injury, randomized controlled trial, rehabilitation, psychological effects

Introduction

In rehabilitation, how deeply patients are absorbed in a task should be assessed, because absorption may influence the training effects. However, no quantitative studies of the relationship between a patient's absorption in a task and rehabilitation effectiveness have been conducted.

Several studies have reported that high motivation enhances effectiveness of rehabilitation for patients with a psychiatric disease (Choi and Medalia, 2010; Nakagami et al., 2010), traumatic brain injury (TBI) (Tasky et al., 2008; Tatla et al., 2014), and stroke (Sugavanam et al., 2013). Although strong motivation may improve behavior and performance, it does not necessarily reflect subjective experience when patients are performing tasks. It is of clinical significance to elucidate the effects of a patient's absorption during a training task.

The best theory for explaining the absorbed state is most likely flow theory, which is defined as "the state in which people are so intensely involved in an activity that nothing else seems to matter; the experience itself is so enjoyable that people will do it even at great cost." (Csikszentmihalyi, 1975, 1990; Nakamura and Csikszentmihalyi, 2002). Through a series of studies, the following nine universal factors of flow were identified: (1) challenge-skill balance; (2) action-awareness merging; (3) clear goals; (4)

unambiguous feedback; (5) concentration on the task at hand; (6) a sense of control; (7) loss of self-consciousness; (8) transformation of time; and (9) autotelic experience. Among these, challenge-skill balance is the most important factor for inducing flow. If the challenge level exceeds the skill level, it may be a source of anxiety, while the converse may lead to boredom. When the challenge-skill balance is appropriate at a high degree of difficulty, it induces concentration on a task and disengages the resources spent on receiving and interpreting information unrelated to the task. Thus, a distorted sense of timing is experienced. When in flow, a person displays the maximum capacity at a controllable level of performance and feels an intrinsic reward. This intrinsic reward encourages spending much time and energy in improving their skills, and thus flow is also assumed to be a growth and development model (Nakamura and Csikszentmihalyi, 2002; Csikszentmihalyi and Csikszentmihalyi, 1988; Csikszentmihalyi and Nakamura 2010). Flow experience may facilitate the rehabilitation effects, because it is considered an optimal experience to perform any activities.

The neural correlates of flow experiences have been investigated by several functional brain imaging studies (Klasen et al., 2012; de Manzano et al., 2013; Ulrich et al., 2014; Yoshida et al., 2014). Although these studies used variable imaging methods, the reward-related region, including the striatum and accumbens nucleus, the

emotion-related region, including the amygdala, and the attention-related region, including the middle frontal gyrus (MFG), inferior frontal gyrus (IFG), and medial prefrontal cortex, have been reported to be associated with flow experiences. In addition, recent findings indicate a possibility that the reward system optimizes neurocognitive functions such as visual search and visual selective attention (Chelazzi et al., 2013). Thus, flow experiences seem to be related to the reward system and the attentional system in the brain, so a therapeutic approach that applies flow experience may facilitate the effect on attentional function specifically.

One of the neurological diseases that causes serious attention deficits is traumatic brain injury (TBI). Patients with TBI show diverse cognitive deficits, such as attention deficit, memory disorder, and executive dysfunction, which persist for years (Millis et al., 2001). They are easily fatigued because of deterioration of information processing, anxiety symptoms, and depression; they may have difficulty concentrating on tasks and sufficiently exerting their ability (Ponsford et al., 2012). Attention training that applies flow experience would promote engaging in tasks and exerting their potentials, and it may, therefore, facilitate the training effect.

We conducted a two-patient exploratory case study with a within-subject AB design to examine whether flow experience facilitates the effects of attention training (Yoshida

et al., 2014). In that exploratory case study, the intervention of a video game task inducing flow experience was more effective than general occupational therapy or a control video game task. However, a case study generally has some limitations, such as the carry-over effect, the practice effect, and a small sample size, so that the effect of flow has not been shown with a sufficient level of evidence.

The objective of the present study is to examine the effect of flow experience on attention deficit in patients after TBI in a pilot randomized controlled trial (RCT). If the effectiveness of attentional training inducing flow experience is observed in terms of statistical significance and effect size, it will provide provisional evidence that flow experience may facilitate the recovery from attention deficit after TBI.

Methods

This study was a prospective, double-blinded, RCT with minimization. This study protocol was approved by the Ethics Committee of the Hokkaido University Hospital (approval number 015-0139), and was registered in the University Hospital Medical Information Network Clinical Trial Registry (UMIN-CTR, Study ID: UMIN000019408). All patients provided written, informed consent.

Participants

Participants were recruited from among patients with chronic attention deficits after TBI who had a history of hospitalization or visited Hokkaido University Hospital from 2007 to 2015. The presence of attention deficits in the patients was determined by any of the following scores being below the cut-off: the Trail Making Test (TMT) (Reitan, 1958), the Symbol Digit Modalities Test (SDMT) (Smith, 1968), and the Paced Auditory Serial Addition Test (PASAT). The patients were required to be adults (>18 y) and to be at least 6 months post-injury. Exclusion criteria were mental diseases, developmental diseases, and neurotic diseases from pre-injury, severe aphasia, and lack of information about consciousness at the time of injury. Figure 1 shows the outline of this study. Twenty participants (four females, mean age = 41.7 ± 9.37 y) fulfilled the eligibility criteria and consented to participate in this study.

The random allocation by minimization method

After confirming that the patients fulfilled the qualification criteria for this study, they were randomly allocated to the flow group or the control group by a researcher in charge of randomization. Sex and severity of injury were controlled by minimization. Severity of injury was determined by the Glasgow Coma Scale (GCS) score: severe

(3-8), moderate (9-12), and mild (13-15) (Jennett and Teasdale, 1977). Several patients did not have GCS scores at the time of injury; their severity was determined by converting their Japan Coma Scale (JCS) score to the GCS score according to the criteria of Namiki et al (2007).

Intervention

Three factors of flow theory (i.e. challenge-skill balance, action-awareness merging, and clear goals) are the essential condition for inducing flow experience and are controllable from the outside (Csikszentmihalyi and Nakamura, 2010). Therefore, a training task including these three factors to induce flow experience easily was created. Two types of video game tasks for attentional training were created: a flow task and a control task. These tasks had identical content, except that the flow task was designed to induce flow by increasing task difficulty according to patients' skill and giving clear goals and quick feedback about the score. The control task maintained a constant level of task difficulty regardless of the patient's skill and did not give any goal and feedback about the score.

Square: Patients are required to control a central blue square using a mouse and avoid red squares coming towards it from the right, left, top, or bottom of the screen. If the squares coming towards the blue square are black, patients get points to hit them. The score is calculated based on the number of black squares hit and the duration of play. During the flow task, the speed of the squares increases, and the number of the distractors is incremented according to the patient's increasing score. This task particularly requires divided attention.

Click number: Patients are required to click and delete disks in numerical order. The score is calculated based on the number of discs deleted within the time limit. The task difficulty is adjusted by increasing the number of discs and distractors according to the patient's increasing score. This task particularly requires selective attention.

Tower: Blocks of three different colors are randomly piled up. The patients are required to click and delete the right side, left side, or center of a block based on its color as quickly as possible. The time to delete all blocks is calculated. During the flow task, the number of blocks increases according to the patient's increasing score; the patient has to delete all blocks within the time limit to move onto the next level. This task particularly requires alternating attention.

Outcome measures

Outcome measures were selected based on previous studies (Wilde et al., 2010; Shukla et al., 2011) to evaluate the complete characteristics of patients after TBI. The primary outcome measure was attention as measured by SDMT, TMT, PASAT, Continuous Performance Test X task (CPT-X) (Rosvold et al., 1956), and Moss Attention Rating Scale (MARS) (Whyte et al., 2008; Sawamura et al., 2012). The secondary outcome measures included the Mini-Mental State Examination (MMSE) (Tombaugh and McIntyre, 1992), Rey's Auditory Verbal Learning Test (RAVLT) (Schmidt, 1996; van der Elst et al., 2005) as a memory function test, and the Wisconsin Card Sorting Test (WCST) (Heaton et al., 1993) as an executive function test. In addition, the Rivermead Post Concussion Questionnaire (King et al., 1995) was used as a questionnaire on symptoms after TBI, and the Cognitive Failure Questionnaire (CFQ) (Broadbent et al., 1982) was used as a questionnaire on cognitive failures in daily living. Patients' flow state was confirmed by the Flow State Scale for Occupational Tasks (FSSOT) (Yoshida et al., 2013). The scale can measure comparative changes in the flow state with good reliability and validity.

Procedure

The outline of this study is shown in Figure 1. First, all medical records of patients diagnosed with TBI from 2007 to 2015 were checked, and 114 patients fulfilled the eligibility criteria. Ninety-four of the patients were excluded because of no transportation, scheduling conflict, no motivation for this study, and no means of contact. Finally, 20 patients agreed to participate in this study. After the presence of attention deficits in the patients was confirmed by the attentional neuropsychological tests, they were randomly assigned to the flow group and the control group. Then, a baseline evaluation was conducted. The patients received 2×20 -min sessions in a day. They were instructed to play the video game for 40 sessions in 4 weeks and not to intensively finish them in a short time. The FSSOT was completed every 10 sessions. In addition, each patient's training schedule was recorded by the PC, making it possible to confirm their implementation status after training. Evaluations after the training and at follow-up (4-weeks after training) were conducted a week after each period. All evaluations were conducted by three well-trained occupational therapists who could not know which group the patients assigned to. All patients had not taken any other rehabilitation training during the study period.

Statistical analysis

Demographic data at baseline such as age, sex, education, duration of post injury, and severity were analyzed by the unpaired *t*-test and the chi-squared test, as appropriate.

Outcome measures were analyzed by two-way repeated measures analysis of variance (two-way repeated measures ANOVA) with Time (baseline, after intervention, and at follow-up) and Group (flow group and control group) as factors. The Bonferroni correction was applied as a post hoc test.

The MARS score was converted into a logit score, and the SDMT, TMT, and PASAT scores were converted into *Z*-scores. Then, a composite score as an index of attention was calculated as the *Z*-score average of SDMT, TMT, and PASAT. A correlation analysis was performed between the scores of the FSSOT and the effect of attentional training, which were calculated by subtracting composite and logit scores at baseline from those after intervention. Furthermore, Cohen's *d* effect size, which is little affected by sample size, was calculated. Statistical analysis was performed using SPSS 23.0.

An intention-to-treat (ITT) analytic approach, in which all participants were included in the analyses, regardless of whether they completed the intervention or not,

was adopted.

The significance level was set at .05 for all analyses.

Results

A patient in the flow group completed only 8 of 40 sessions and did not answer the FSSOT. However, he completed the evaluation after intervention and after follow-up. All data obtained from this patient were included in the statistical analysis in accordance with the principle of ITT analysis.

There were no significant group differences in age, sex, severity of injury, education, duration since injury, or neuropsychological test results at baseline. In addition, there was also no major variation between the groups in the area of brain damage (Table 1).

Table 2 shows the results of two-way repeated measures ANOVA. A significant main effect of Time was found on MARS ($F(2,36)=8.08$, $p<0.01$), PASAT 2s ($F(2,36)=19.18$, $p<0.01$), PASAT 1s ($F(2, 36)=25.5$, $p<0.01$), TMT-A ($F(2,36)=6.21$, $p<0.01$), TMT-B ($F(2,36)=7.82$, $p<0.01$), SDMT ($F(2,36)=5.08$, $p<0.01$), and the composite score ($F(2,36)=53.26$, $p<0.01$). In addition, there was a trend towards a main effect of Group on the PASAT 2s ($F(1,18)=4.00$, $p=0.06$), PASAT 1s ($F(1,18)=2.89$,

$p=0.10$), and WCST category achieved ($F(1,18)=3.59$, $p=0.07$), though these effects were not significant ($p \leq 0.1$). There was no significant interaction between Group and Time.

The FSSOT score was significantly higher in the flow group than in the control group. In the combined data of both groups, there was a significant positive correlation between the increase in the composite score of attention and the FSSOT score (i.e. Z-score after intervention – Z-score at baseline; $r = 0.545$, $p < 0.05$) (Fig. 2). However, when calculated for each group, both groups showed a positive correlation coefficient that was not significant (Flow: $r=.456$, $p=.21$; Control: $r=.554$, $p=.09$). The flow group showed a high training effect on the composite score of attention compared with the control group, but it was not significant ($t=1.338$, $p=.19$).

There was no significant correlation between the FSSOT score and the MARS logit score ($r=-.28$, $p=.24$). When analyzed for each factor of MARS, a significant negative correlation was obtained only between the sustained/consistent factor of MARS and the FSSOT score ($r=-.51$, $p<.05$). Table 3 shows the effect size of the attentional neuropsychological tests and MARS. The effect size other than for SDMT and MARS was small to medium, and the effect size of the composite score was medium.

Discussion

The objective of this study was to examine, in an RCT, which is a clinically more robust, whether the flow state during training has an additional effect on the improvement of attentional function in patients with attention deficits after TBI. In order to examine the effect of flow experience during training, a two-way repeated measures ANOVA with Time and Group as factors was performed, and the correlation between the FSSOT and the training effect of attention was examined. In addition, not only was the statistical significance of Time and Group examined, but also the effect size and the effect of flow on the training effect.

The FSSOT scores were significantly higher in the flow group than in the control group. It was suggested that the training task based on flow theory was effective in inducing flow. In addition, the training task using a PC in the present study was considered to be a specific training task for attention, because in both groups there was a significant improvement in attention, while there was no improvement in other functions such as memory or executive function.

Two-way repeated measures ANOVA for the data at baseline, after intervention, and after follow-up showed significant main effects of Time on MARS, PASAT, TMT, composite score, and CFQ. Because the main effect of Time was also observed on

MARS, which is a scale of behavioral assessment for attention, it followed that the training task in this study had an effect not only on the paper tests for attentional function, but also on the behavior related to attention. The trend towards a main effect of Group on PASAT showed a possibility that the effects of attention training may differ depending on the presence of flow. On the other hand, there was no significant improvement in other test results such as memory. These results are also consistent with previous studies, in which a direct training of attention was effective in improving its function, but it is difficult to generalize to other functions such as memory and executive function (Rohling et al., 2009; Cicerone et al., 2011).

The CFQ score of both groups decreased significantly after the intervention. It is known that decreased sustained attention is related to decreased self-awareness and error awareness, and patients after TBI generally have poor awareness of self and error (McAvinue et al., 2005; O' Keeffe et al., 2007). The decreasing CFQ score after intervention may reflect improved awareness of the self-situation with improved attentional function.

In a comparison of the increase of the composite score between the groups, the flow group showed a larger increase in the composite score, though it was not significant. Therefore, the training effect was examined using Cohen's *d*, which is an index of effect

size, because it is little affected by sample size. As a result, the effect size of PASAT, TMT, and the composite score in the flow group was estimated to be small to medium, showing that the effect of training group tended to be higher in the flow than in the control group. According to a recent meta-analysis and systematic review, the effect size of attentional training for patients after TBI was estimated to be small to medium (Virk et al., 2015; Hallock et al., 2016; Weicker et al., 2016). Considering that the additional effects of flow experience are small to medium, it can be an adequate effect size to apply it to training. Despite the fact that the control group showed a significant improvement in attention, the flow group showed a higher training effect on attention. This result supports our idea that flow experience during training facilitates the training effect.

In all patients, there was a significant positive correlation between the increase in the composite score of attention and the flow state scale score. Then, the correlation of each group was examined separately, and a positive correlation coefficient was obtained with each group, though it was not significant. These results suggest a possibility that patients who experienced deeper flow experience achieved a higher training effect on attention.

In the theoretical background of flow, persons who are experiencing flow are

considered to exert a high level of attention with a low sense of effort, and, at the same time, they seek a more challenging task because they get an intrinsic reward from the task (Csikszentmihalyi and Nakamura, 2010). Recent brain functional imaging studies showed that the IFG and MFG, which are related to attention and concentration, and the striatum and accumbens nucleus, known as the reward system, were activated during flow experiences (Ulrich et al., 2014; Yoshida et al., 2014). In addition, it is suggested that the reward system also modifies attentional function, including visual search and visual selective attention (Chelazzi et al., 2013) and may contribute to the effect of rehabilitation (Sawada et al., 2015). It is therefore presumed that flow experience can contribute to the improvement of attentional function from both the theoretical background and the brain functional imaging studies. The positive correlation between the FSSOT score and the composite score of attention suggests that flow experience during training may have an additional effect on the improvement of attention. However, the cause-effect relationship should be carefully discussed, because the result of the present study merely shows a correlation between them.

There was no significant correlation between FSSOT and MARS scores. On the other hand, there was a significant negative correlation between the flow scale score and the sustained/consistent factor of MARS. This result therefore shows that patients who

experienced flow at a lower level improved the sustained/consistent factor. The low score of the FSSOT means that the patients had difficulty in exerting their attention and engaging in the task. In this condition, repeating the set number of the tasks requires patience, so it may be the reason why they showed improvement of their behavior related to the sustained/consistent factor of MARS. In addition, because flow experience is mainly related to proficiency in specific skills, it is also thought that the improved attentional function is difficult to generalize to other cognitive or behavioral areas such as memory, executive function, and behavioral tests of attention. Further study is necessary in this regard.

This study had several limitations. The first was a small sample size. It was difficult for many patients to visit the hospital three times because they lived far from the hospital. Some patients did not have information, such as coma scale scores, from the time of injury available, so they were excluded from this study. Therefore, we carried out the analysis using the effect size, which is little affected by sample size. The second was the difficulty of setting the degree of task difficulty. Because the difficulty of the training task influences the effect, it should be controlled in both groups. However, it was also necessary to raise the degree of difficulty gradually in accordance with increasing performance of patients in order to induce flow. Therefore, the task difficulty

in the flow group was different in each patient, and it was technically difficult to provide the same difficulty task for the control group and the flow group, though we set the task difficulty of the control task a little higher than the initial flow task. For this reason, the control group might have shown improvement in the training of attention.

In this study, the focus was on attentional function because it was considered strongly associated with flow experience from reports of the theoretical background and brain imaging studies. Future studies are needed to examine the effect of flow experience on other areas (e.g. memory, learning, and physical performance) and other diseases (e.g. stroke, dementia, and physical disability) with larger sample sizes.

Conclusions

This study is the first using an RCT design to show the effects of flow experience during training on attentional function in patients with attention deficits after TBI. This study found that the neuropsychological tests for attention of both groups improved significantly after intervention, and the effect of attention training tended to be higher in the flow group than in the control group. In addition, there was a significant positive correlation between the composite score of attention and the FSSOT score, and the

effect size of the flow group was small to medium. In conclusion, flow experience during training may have an additional effect on improving attention deficits for patients after TBI, and new evidence that patient's absorption in a task may facilitate the training effect on attention in rehabilitation was provided.

Declaration of Interest

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Table 1. Patients' characteristics at baseline

	Flow group	Control group	p value
n	10	10	
Age*	44.5±11.2	38.9±7.2	0.20
Sex [†]			
Male	8	8	
Female	2	2	1.00
Education*	14.2±2.4	14.6±4.2	0.79
Time after injury (month)*	122.3±105.9	117.1±77.9	0.90
Severity [†]			
Mild	2	1	
Moderate	4	4	
Sever	4	5	0.80
Damaged region			
Diffuse axial injury (DAI)	3	5	
Cerebral contusion			
Right frontal	2	2	
Right temporal	3	2	
Left frontal	1	1	
Left temporal	1	1	
Both sides frontal	4	2	
Traumatic subarachnoid hemorrhage (SAH)	3	2	
Epidural hematoma (EDH)	1	1	
Subdural hematoma (SDH)	2	0	

Note: Values are means ± SD or n.

*Unpaired *t*-test

[†] χ^2 test

SD, standard deviation.

Table 2. Results of two-way repeated measures ANOVA for neuropsychological, behavioral, and subjective measures

Outcome variable	Flow group			Control group			Time		Group		Interaction	
	Baseline	After training	Follow up	Baseline	After training	Follow up	F	p	F	p	F	p
MMSE	28.6(1.8)	28.5(1.9)	29.2(1.6)	29.4(0.7)	28.5(1.1)	28.4(1.6)	1.18	0.31	0.00	1	3.00	0.06
CPT												
CD rate (%)	98.2(3.1)	97.8(4.4)	96.6(4.3)	90.4(28.6)	93.6(20.1)	96.6(9.3)	0.55	0.58	0.41	0.53	1.56	0.22
RT	509.1(54.2)	547.1(121.1)	543.1(79.7)	530.9(73.5)	516.4(89.8)	516.2(91.8)	0.37	0.69	0.11	0.74	2.04	0.15
variance	13.8(4.8)	13.4(4.5)	15.9(5.7)	14.8(5.2)	13.5(4.6)	13.1(4.1)	1.04	0.36	0.08	0.78	3.31	*
MARS	52.84(3.41)	54.91(4.26)	54.84(3.10)	52.48(2.07)	56.62(3.23)	56.13(4.14)	7.44	**	0.48	0.49	0.76	0.47
composite score	-1.53(1.07)	-0.74(0.79)	-0.53(0.94)	-2.24(1.58)	-1.75(1.92)	-1.32(1.63)	53.26	**	1.873	0.18	1.32	0.28
PASAT 2s	-1.98(1.22)	-0.79(0.89)	-0.29(1.19)	-2.67(1.39)	-1.89(1.40)	-1.38(1.29)	19.18	**	4	0.06	0.45	0.64
PASAT 1s	-1.71(0.56)	-0.46(0.99)	-0.25(0.82)	-1.83(0.54)	-1.26(0.88)	-0.80(0.88)	25.5	**	2.89	0.1	1.86	0.17
TMT-A	-1.37(2.21)	-0.65(1.55)	-0.45(1.80)	-2.68(3.87)	-2.41(4.19)	-1.45(3.07)	6.21	**	1.14	0.3	0.8	0.46
TMT-B	-0.74(1.67)	-0.26(1.39)	-0.19(1.72)	-0.83(2.08)	-0.42(1.70)	-0.29(1.96)	7.82	**	0.022	0.88	0.05	0.95
SDMT	1.86(0.98)	-1.57(1.11)	-1.45(1.09)	-3.20(2.09)	-2.77(2.28)	-2.67(2.15)	5.08	*	2.82	0.11	0.12	0.89
RAVLT	6.2(3.9)	8.1(3.4)	6.6(3.6)	6.3(3.26)	6.3(3.0)	8.0(3.2)	1.45	0.24	0.006	0.94	2.79	0.08
WCST												
CA	5.1(1.3)	4.3(1.5)	5.0(1.5)	5.5(0.7)	5.8(0.4)	5.4(1.0)	0.45	0.64	3.59	0.07	2.86	0.07
PEM	1.1(1.4)	1.0(1.9)	0.1(0.3)	0.7(1.0)	0.3(0.5)	0.3(1.0)	2.41	0.1	0.75	0.4	1	0.38
PEN	1.4(2.0)	1.3(2.1)	0.6(0.7)	1.6(1.8)	0.7(0.8)	1.5(3.4)	0.45	0.64	0.08	0.79	0.83	0.44
CFQ	27.4(17.8)	31.0(20.2)	29.5(23.9)	32.2(19.7)	38.3(17.2)	38.5(19.5)	3.49	*	0.67	0.42	0.56	0.57
RPCQ	16.6(14.9)	17.4(13.9)	21.1(16.3)	20.3(13.6)	17.5(12.1)	20.5(14.1)	2.64	0.09	0.03	0.86	1.19	0.32

Note: Values are means (SD).

MMSE, Mini-mental state examination; CPT-X, Continuous performance test X task; MARS, Moss attention rating scale; PASAT, Paced auditory serial addition test; TMT-A,B, Trail making test-A and B; SDMT, Symbol digit modalities test; RAVLT, Rey's auditory verbal learning

test; WCST, Wisconsin card sorting test; CFQ, Cognitive failure questionnaire; RPCQ, Rivermead post-concussion questionnaire; RT, reaction time; CA, categories achieved; PEM, perseverative errors in Milner; PEN, perseverative errors in Nelson

* $p < .05$, ** $p < .01$

The PASAT, TMT, and SDMT scores were converted into *Z*-scores.

Table 3. Effect size of attentional neuropsychological tests

	Gain of the Z-score/ logit score		Effect size	
	Flow group	Control group	Cohen's d	
Composite score	0.785±0.386	0.487±0.544	0.63	medium
PASAT 2s	1.176±0.796	0.776±1.488	0.34	small
PASAT 1s	1.255±0.924	0.566±0.817	0.79	medium
SDMT	0.289±0.535	0.426±0.748	-0.21	
TMT-A	0.719±1.397	0.266±1.138	0.36	small
TMT-B	0.486±0.821	0.402±0.594	0.12	none
MARS [†]	2.06±3.16	4.14±2.99	-0.45	

PASAT, Paced auditory serial addition test; SDMT, Symbol digit modalities test; TMT-A, B, Trail making test-A and B; MARS, Moss attention rating scale.

[†]Logit score was used.

Figure 1

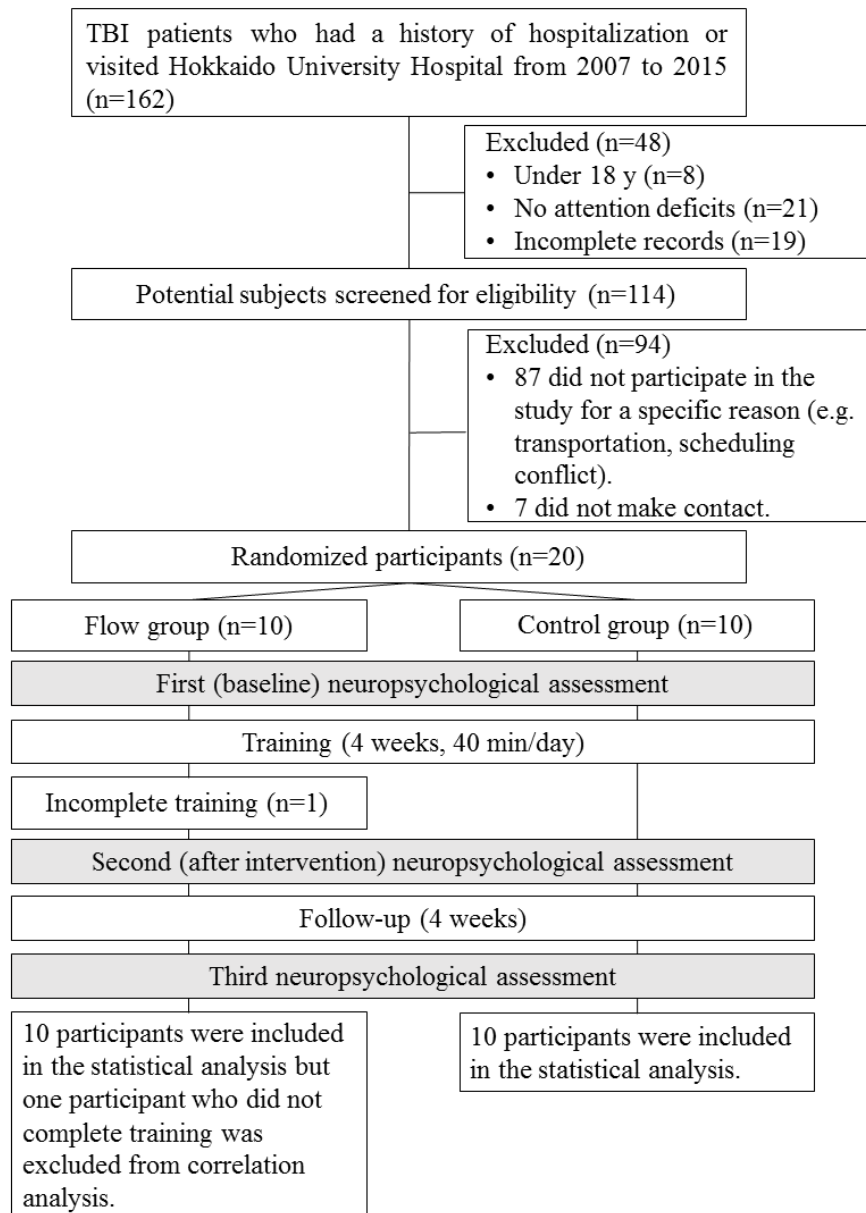


Figure 2

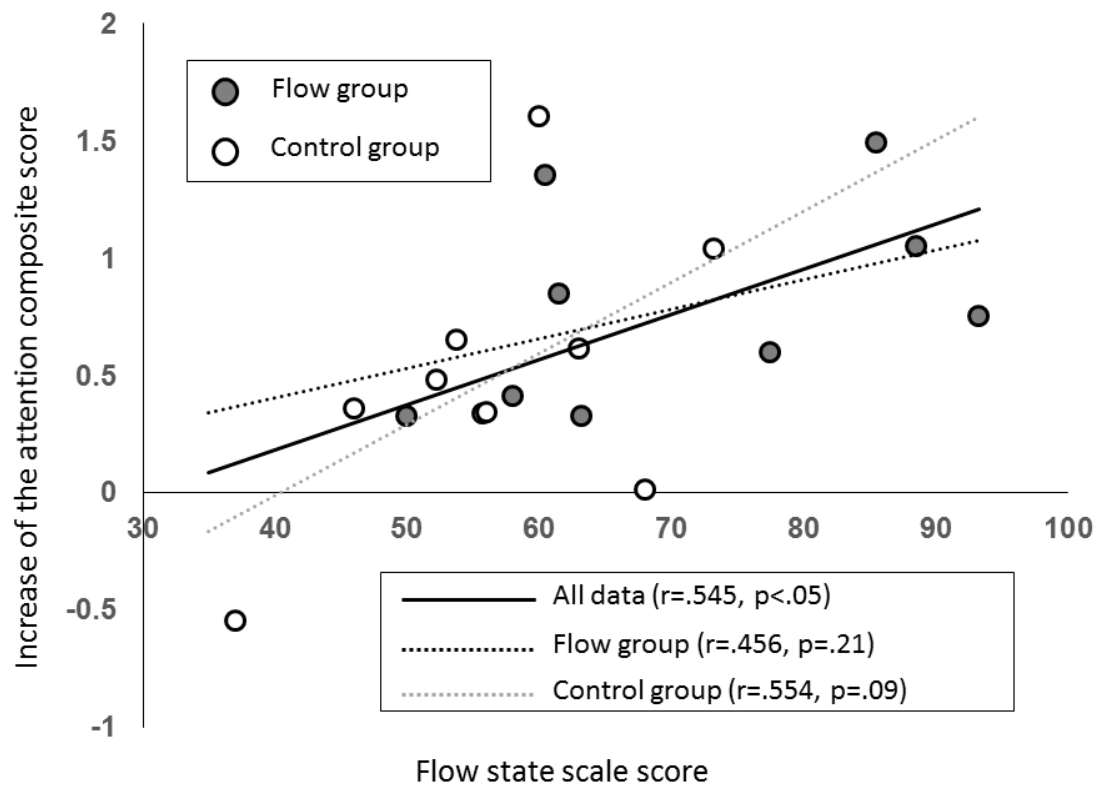


Figure 3

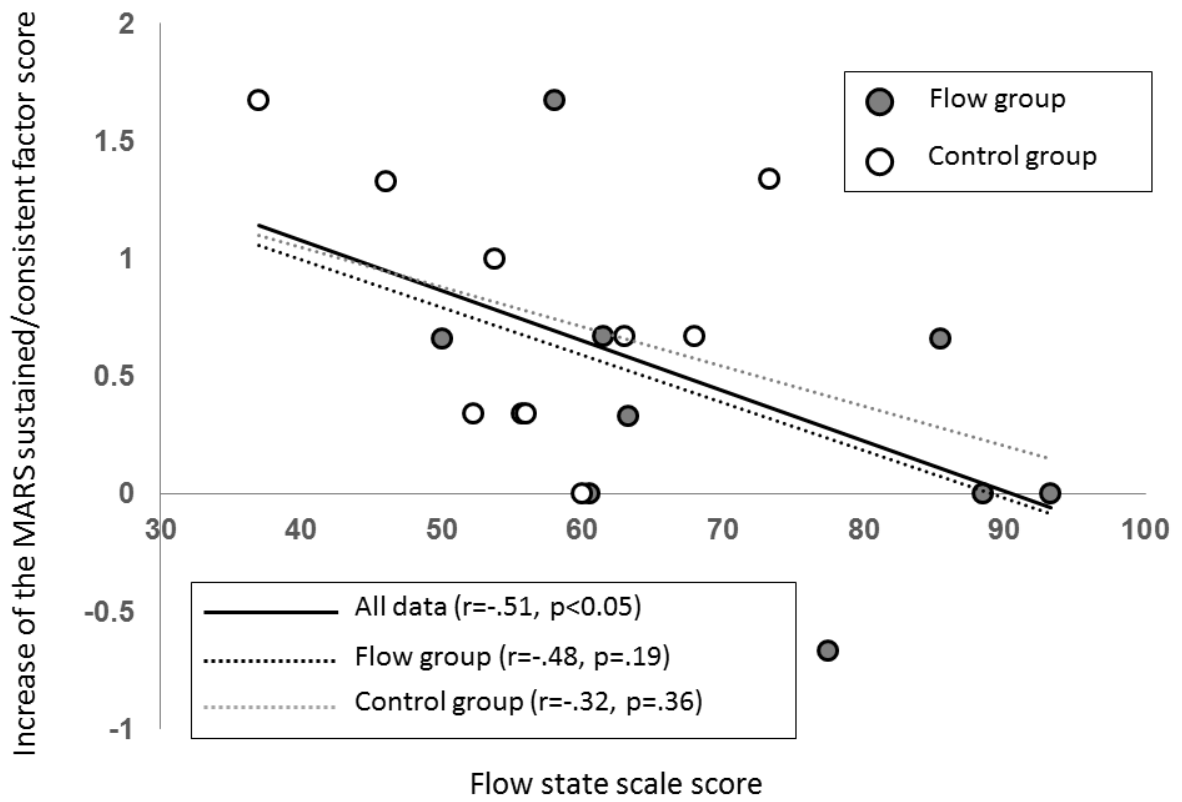


Figure Legends.

Figure 1. CONSORT diagram of this study

Figure 2. Correlation between the FSSOT score and the increase of the attentional composite score

The increase of the composite score (score after intervention - baseline) is on the vertical axis; the FSSOT score is on the horizontal axis. Each plot represents individual data.

FSSOT, Flow State Scale for Occupational Tasks

Figure 3. Correlation between the FSSOT score and the increase of the MARS sustained/consistent

factor score

The increase of the MARS sustained/consistent score (score after intervention - baseline) is on the vertical axis; the FSSOT score is on the horizontal axis. Each plot represents individual data.

MARS, Moss attention rating scale

FSSOT, Flow State Scale for Occupational Tasks