

## The Effects of Neurofeedback Training on Concentration in Children with Attention Deficit / Hyperactivity Disorder

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### Abstract

*This study investigated the effects of neurofeedback training on concentration in children with attention deficit/ hyperactivity disorder (ADHD). A single-subject ABA' experimental design was used to determine the effects of neurofeedback training. The participants of the study were three boys with ADHD. In the intervention phase after the baseline assessment, participant 1 and 3 trained neurofeedback for twelve sessions, and participant 2 trained ten times.*

*The EEG was recorded during each session and was analyzed for relative power spectrum by beta/theta ratio. The concentration behaviors were measured on a 10-second interval scale during 15 minutes. The concentration was assessed using Auditory Continuous Performance Test (ACPT), and the ADHD symptoms were assessed by the Conners Teacher Rating Scale-Revised (CTRS-R) in pre and posttest. The data were visually analyzed using graphs and descriptive statistical analysis.*

*The results of the study suggest that, after the neurofeedback training sessions, the participants showed a significant increase in their concentration behaviors. The scores of ACPT and CTRS-R were improved as well. However, no significant EEG change was observed, and no correlation of EEG with concentration behaviors was established.*

**Keywords:** Attention deficit/ hyperactivity disorder (ADHD), Concentration behavior, EEG, Neurofeedback

### 1. Introduction

Neurofeedback training using EEG is an effective treatment to complement medication and behavioral therapy in children with Attention Deficit/ Hyperactivity Disorder (ADHD) [1]. As is known, limitations of medication and behavior therapy include non-responsiveness to drugs, side effects such as lethargy or sleep disorders, return of symptoms when the child discontinues medical treatment, and, with regard to behavioral therapy, its short-term effectiveness [2].

Neurofeedback is based on the cerebral activity as a kind of biofeedback for the brain's neurophysiologic activity, providing immediate feedback on the mental state of self-regulation, and the principles of learning (operational conditioning) are used. Said differently, the therapeutic effect of neurofeedback consists in the normalization of the abnormal EEG activity and the increase of the awareness of the normal EEG pattern in ADHD [3]. Neurofeedback is based on neural plasticity of the brain (neuro-plasticity)

[4] and has the advantage of being a high-safety non-invasive method with no medication side effects or dependency issues [5].

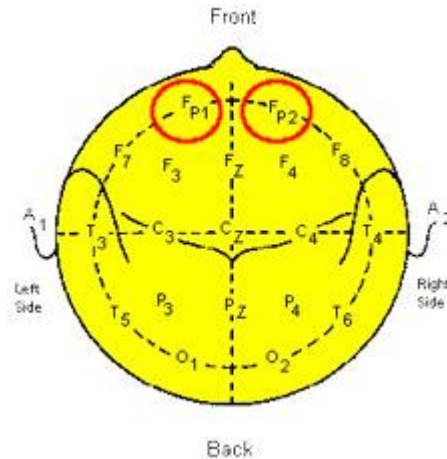
Recently, neurofeedback has been applied to many clinical patients; however, its effectiveness is argumentative on actual changes in brain activation and behavior [2]. The purpose of this study thus is to investigate the effects of neurofeedback training on EEG and concentration in ADHD children.

## 2. Procedure

The participants were three ADHD boys aged 7~9. Participant 1 was a 7.4-year-old boy, a first-grade student of the elementary school. His social index was 117.73, and his social age corresponded to 8.83 years on the community Social Maturity Test. The Full Scale Intelligent Quotient (FSIQ) of participant 1 was 92 on the Korean version of the Wechsler Intelligence Scale for children. The test was used to determine inattention and hyperactivity, and the short form of ADHD Conners Teacher Rating Scale score was 19. Participant 2 was a 9.4-year-old boy, a fourth-grade student. His social index was 107.36, and the social age was 10.20 years on community social maturity test. The FSIQ of participant 2 was 102. The test was used to determine inattention and hyperactivity, and the short form of ADHD Conners Teacher Rating Scale score was 21. Participant 3 was a 9.2-year-old boy, a first grade student of the elementary school. His social index was 115.75, and the social age was 10.80 years in community social maturity test. The FSIQ of participant 3 was 132. The test was used to determine inattention and hyperactivity, and his short form of ADHD Conners Teacher Rating Scale score was 23.

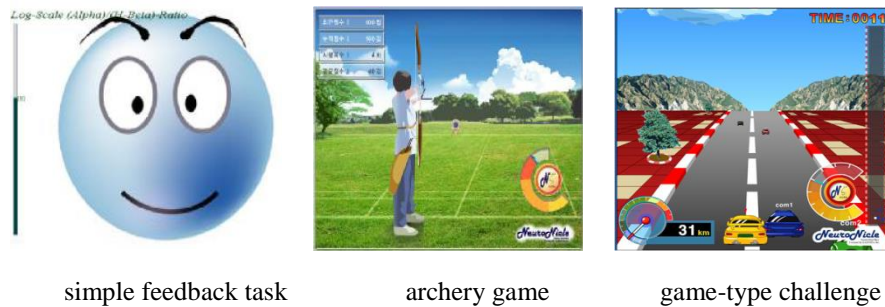
This study was the single-subject experimental research in the ABA' design. Baseline 1 phase (A) consisted of four sessions, intervention phase (B) consisted twelve sessions, and baseline 2 (A') consisted of four sessions. Every session of neurofeedback training in the intervention period lasted 30 minutes.

The EEG was measured after neurofeedback training, and QEEG-8 system (LXE3208: Laxtha Inc, Daejeon, Korea) was used. EEG electrodes were attached to the areas of concentration, such as the prefrontal cortex that is responsible for cognitive function [6]. The EEG electrodes used in the study were circular-shaped sponge stickers. In total four electrodes attached to the head included two disposable electrodes on both sides of the forehead (Fp1, Fp2) that were measuring electrodes; a ground electrode, and a reference electrode. The placement of the electrodes was based on the 10/20 international electrode batch method (see Figure 1) where bilateral frontal Fp1 (front-polar 1: left forehead) and Fp2 (front-polar 2: right forehead) were attached to the measuring electrodes; the reference electrode was attached on the protruding bone part of the auricle behind; and the ground electrode was attached to the back of the neck. The EEG bands were set to delta band (0.1 ~ 4Hz), theta band (4 ~ 8Hz), alpha band (8 ~ 13Hz), SMR (13 ~ 15Hz), low beta band (16 ~ 20Hz), beta band (21 ~ 30Hz), and gamma band (30 ~ 50Hz). The EEG measure environments were set the sampling EEG (256Hz), passes through a filter (0.5-50Hz), 12bit AD conversion.



**Figure 1. The 10/20 Electrode System of the International Federation**

Neurofeedback training program has three categories of tasks (simple feedback task, archery game, and game-type challenge) that change the visual image, the height of the bar graph, and the auditory stimulus of computer tasks. These tasks were controlled using the EEG concentration index in real time (Figure 2).



**Figure 2. Neurofeedback Training Program (Laxtha Inc, Korea)**

During the 12-week intervention period, neurofeedback training was conducted 2 to 3 sessions a week, and each session lasted 30 minutes in all three categories of tasks. While the simple feedback task and archery game were performed for 5 minutes on each task, game-type challenge task lasted 20 minutes. In order to faithfully perform training in neurofeedback, when the child was not involved, the researcher stopped training or gave the instruction to promote sustained performance by verbal and physical cues.

The effects of neurofeedback on concentration behavior and brain concentration index were examined. The concentration behavior of each participant, what was operational defined was measured by video recording for 15 minutes; when a homework task was performed, behavior was measured on a 10-second interval scale. The concentration behavior (%) was the behavior percentage of the total task performance time (15 minutes).

The concentration was assessed using Auditory Continuous Performance Test (ACPT) [7], and the ADHD symptoms were assessed by Conners Teacher Rating Scale-revised (CTRS-R) [8] in pre and posttest. The ACPT used to measure the concentration and attention, as this test measures selective attention and continued attention on the

auditory stimuli in several studies of children with ADHD [7]. The ACPT used in this study is a subtest consisting of the total of eleven different individual subtests included in the Computerized Neurocognitive Function Test (CNT), a standardized test in Korea. The ACPT method is whenever selecting target stimulus among random stimuli during a 9-minute period. The CTRS-R consists of the total of 28 questionnaire items that are questions about conduct problems (8 items), hyperactivity(7 items), inattention items (8 items), and the others(5 items). The higher scores one obtains on the test, the more severe ADHD behavioral problem he or she has.

The EEG raw data were analyzed by the relative power spectrum method; furthermore, the concentration index (sensory motor rhythm + beta/ theta wave ratio) was calculated [9]. Afterwards, concentration behaviors were analyzed using the visual graphs and the statistically significant changes were tested within the two standard deviations band( $\pm 2SD$ ) analysis method. When concentration behavior yielded values that were over than the two standard deviations of baseline data at two or more sessions, that increase was statistically significant [10].

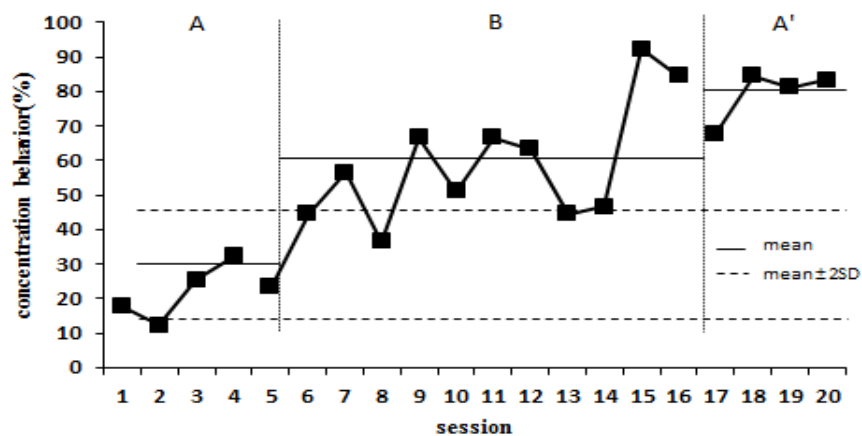
### 3. Results

The concentration behaviors of all participants were significantly improved in the intervention phase (Table 1and Figures 3a~3c).

**Table 1. Mean of Concentration Behaviours in Baseline and Intervention Phases (ABA')**

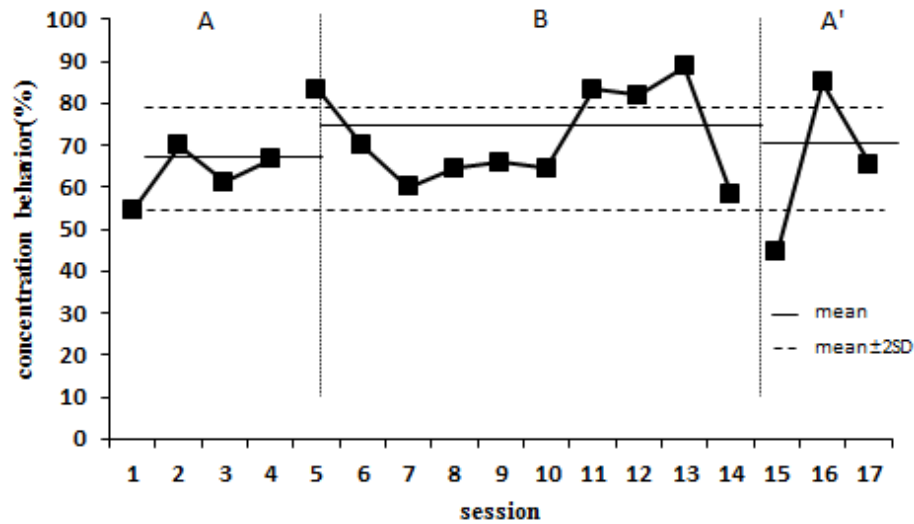
Participant	baseline 1 (M $\pm$ SD)	intervention (M $\pm$ SD)	baseline 2 (M $\pm$ SD)
1	21.90 $\pm$ 8.77	53.36 $\pm$ 19.62	79.15 $\pm$ 7.69
2	63.02 $\pm$ 6.82	72.00 $\pm$ 11.19	64.96 $\pm$ 20.31
3	38.20 $\pm$ 18.45	82.10 $\pm$ 7.08	83.00 $\pm$ 3.67

The average value of the concentration behavior of participant 1 has increased from 21.90% in baseline 1, through 53.36% in the intervention phase, to 79.15% in baseline 2 (Figure 3a).



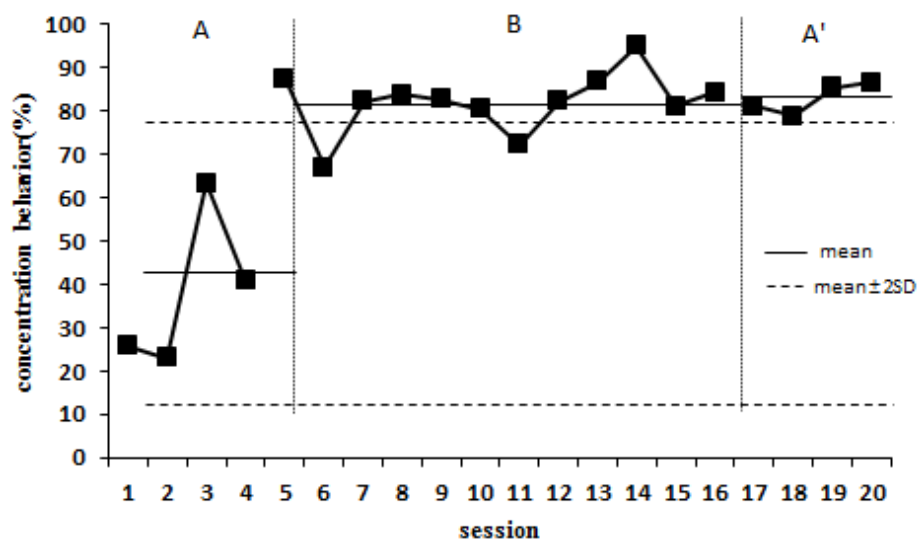
**Figure 3a. Concentration Behavior of Participant 1**

The concentration behavior of participant 2 has increased from baseline 1 (63.02%) to the intervention phase (72.00%), and has decreased in baseline 2 (64.96%).



**Figure 3b. Concentration Behavior of Participant 2**

The average value of concentration behavior of participant 3 has increased from 38.20% in baseline 1, through 82.10% in the intervention phase, to 83.00% in baseline 2.



**Figure 3c. Concentration Behavior of Participant 3**

The EEG data did not yield significant changes after neurofeedback (Table 2).

**Table 2. Mean of EEG in Baseline and Intervention Phase(ABA')**

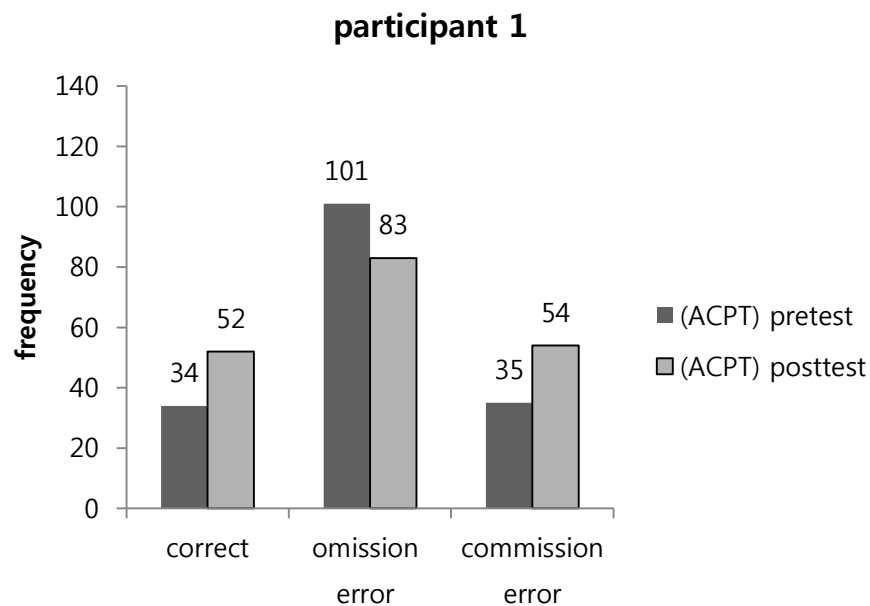
Participant	Region	Baseline 1 (M $\pm$ SD)	Intervention (M $\pm$ SD)	Baseline 2 (M $\pm$ SD)
1	Fp1	15.42 $\pm$ 1.49	16.98 $\pm$ 3.19	19.28 $\pm$ 2.21
	Fp2	15.62 $\pm$ 2.58	17.29 $\pm$ 3.26	18.52 $\pm$ 1.99
2	Fp1	21.82 $\pm$ 10.30	14.35 $\pm$ 3.31	16.03 $\pm$ 2.39
	Fp2	25.16 $\pm$ 12.92	16.65 $\pm$ 4.79	19.38 $\pm$ 5.47
3	Fp1	17.47 $\pm$ 3.96	17.25 $\pm$ 9.49	16.13 $\pm$ 6.27
	Fp2	16.99 $\pm$ 5.55	16.26 $\pm$ 4.97	14.53 $\pm$ 5.16

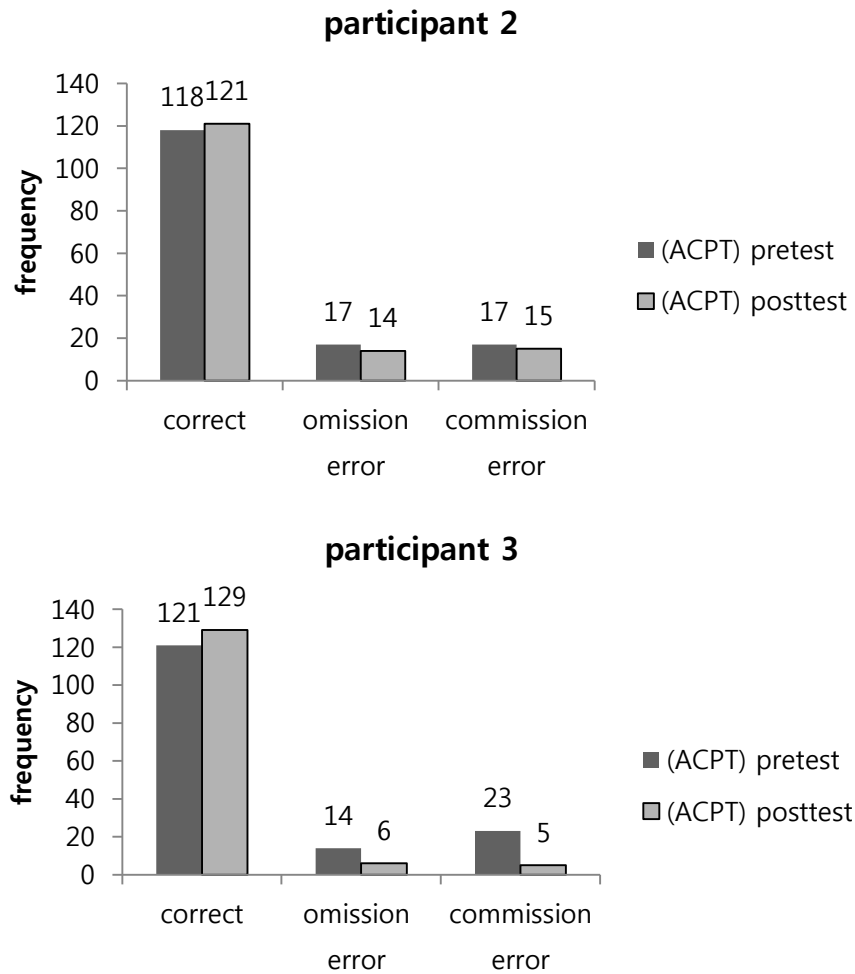
There was no correlation between the EEG concentration index and concentration behavior during task performance Table 3.

**Table 3. The Correlation of EEG Concentration Index and Concentration Behavior**

Participant	EEG (Fp1)		EEG (Fp2)	
	r	p	r	p
1	.255	.279	.229	.332
2	.108	.679	-.041	.876
3	.065	.789	-.127	.594
Total	.088	.514	-.010	.941

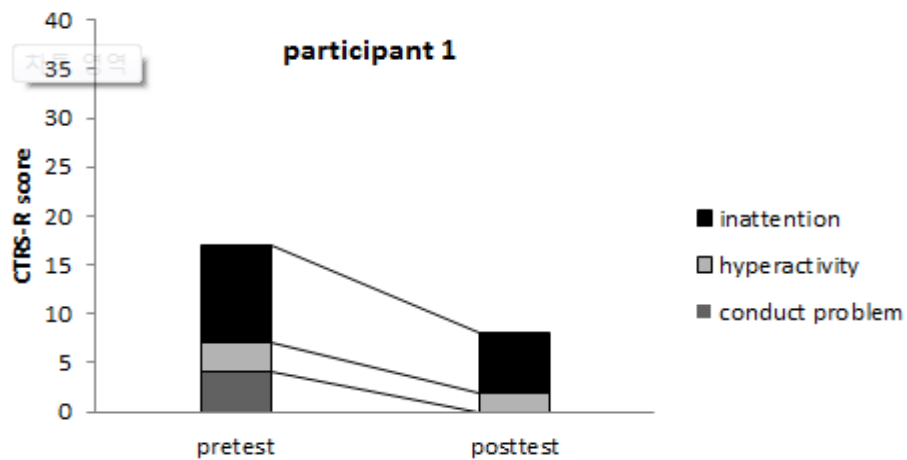
All participants' ACPT and CRTS-R scores improved after neurofeedback training (Figure 4).





**Figure 4. Pre- and Posttest of ACPT**

The scores of CRTS-R in all participants improved Figure 5.



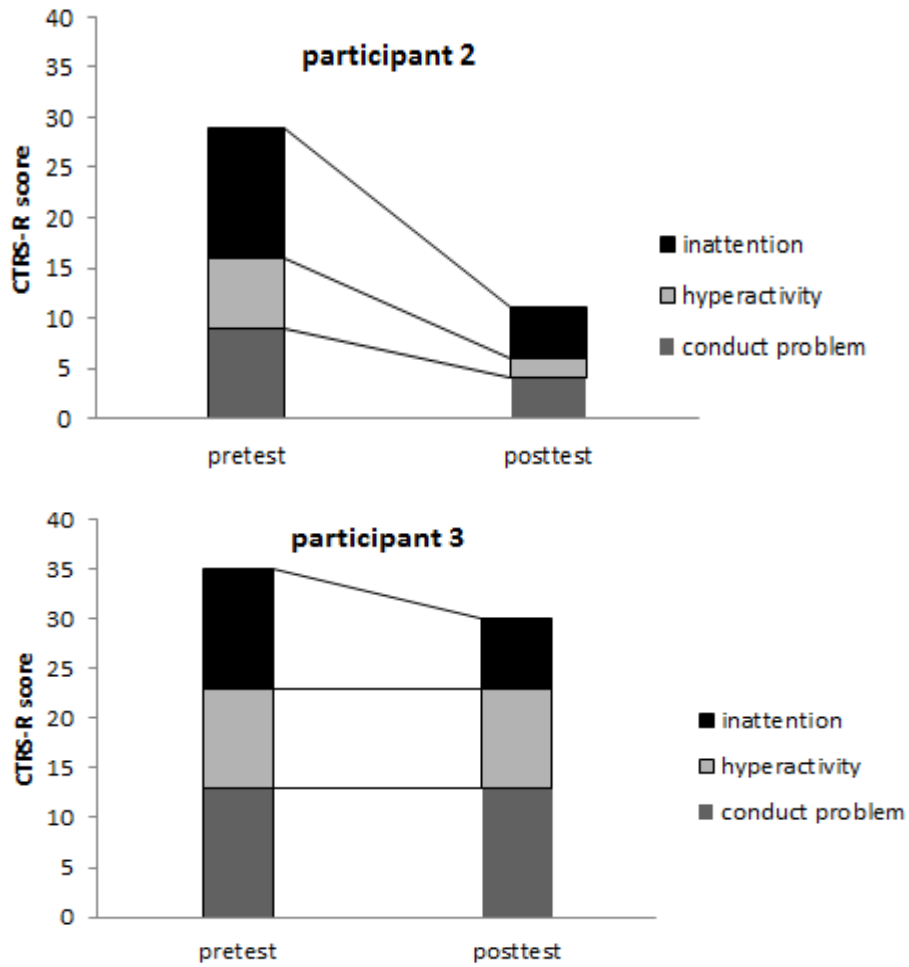
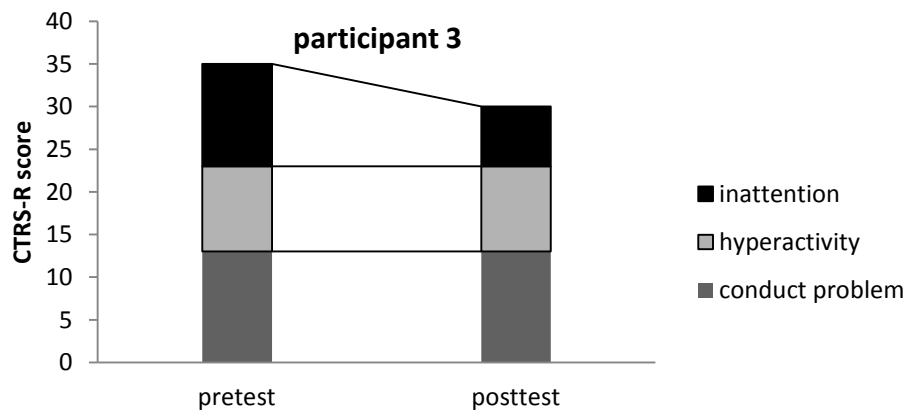


Figure 5. Pre- and Posttest of CRTS-R



#### 4. Discussion



This study investigated the effect of neurofeedback training on concentration in children with ADHD. To this aim, brain waves associated with concentration and concentration behavior were measured, and the correlations between behavior and EEG were analyzed. In all of participants, a significant increase in concentration and a decrease in inattention / hyperactivity were observed. On the other hand, EEG concentration index did not show significant changes in task performance and no correlation between concentration behavior and EEG index was found. These findings suggest that while neurofeedback training improves the concentration in ADHD children, but the effect on brain waves associated with concentration was not conformed. In addition, there was no correlation between EEG and behavior during task performance.

There were significant improvements in concentration behavior of all participants in the intervention phase baseline 2 phases. This means that the increased concentration behavior through neurofeedback was sustained after intervention. In particular, three participants significantly concentrated in intervention phase and higher concentration of participant 1 and 3 were maintained when the neurofeedback training ended. These results can be the carry-over effect of neurofeedback training.

There was higher concentration in the latter two intervention sessions (11th to 13th) of participant 2, but it was not maintained and decreased again in baseline 2. Due to personal circumstances, participant 2 was trained for a shorter period of time (10 sessions) than the other two participants (12 sessions). More than 12 intervention sessions were needed as it was necessary to maintain increased concentration through neurofeedback training.

In previous studies, the effectiveness of neurofeedback in children with ADHD was unclear [11]. Our results suggest that there is a concentration behavior improvement through neurofeedback training; however, no significant changes in EEG are observed. The controversy of the generalizability of carry-over effects of neurofeedback on actual task performances in daily life has previously been noted [12]. The correlation between EEG and behavior observed neither in our results, nor in previous relevant studies [13]. The EEG index did not increase due to several complex reasons in neurofeedback training for concentration in ADHD children.

Loo and Barkley [14] proposed that cognitive-behavior reinforcement of a therapist's supportive attitude in the training settings has contributed to the improvement of concentration behavior. As the child stayed with the therapist during neurofeedback training, the therapist provided more support to the child, and the child wanted to please the therapist and thus had more motivation for improvement. The actual behavior improvement was not generalized from EEG changes in neurofeedback training. It was the behavior that changed based on child's motivation at behavioral therapy rather than the effect of neuro-plasticity.

In order to faithfully perform neurofeedback training in this study, when the child was not truly involved in training, the researcher stopped training or gave instructions to promote sustained performance by verbal and physical cues. This prompting of therapist could have been the cognitive-behavior factor to cause an increase in concentration behavior. The significant change in EEG, an indicator of neurological changes, was not shown, which suggests that there is insufficient evidence for neurological effects of neurofeedback.

The ACPT scores improved that it was computerized screening tool for measuring the concentration after neurofeedback training in this study and many previous studies [15]. The total scores and the scores of inattention items in the Conners Teacher Rating

Scale (CTRS-R) of all participants decreased at posttest, which means the neurofeedback training improved ADHD children's behavior. The decrease in CTRS-R has been shown in both this previous studies [16].

There several limitations of this study. First, the number of the participants was small, so it is difficult to generalize the finding of this study. The clinical application of neurofeedback training in ADHD children for the concentration can be expected to improve/ However, the promotion of brain waves associated with concentration for further research on the effects of neurofeedback will be needed [17-19].

## 5. Conclusion

To summarize, the results of the present study provide evidence on the effects of neurofeedback training on the improvement of concentration behaviors and ADHD symptoms. However, EEG did not change significantly and did not correlate with behavioral change.

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