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Offering Neurofeedback as an Intervention for Children with Attention Deficit/Hyperactivity Disorder in Indonesia: A Feasibility Study

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BACKGROUND: EEG Neurofeedback training is an accepted non-pharmacological therapy for attention deficit/hyperactivity disorder (ADHD). Although stimulant medication is known to decrease ADHD symptoms, possible adverse effects, concerns about prolonged drug use on neural development, and problems related to the compliance with the medications are often reported. In Indonesia, research on the feasibility of EEG Neurofeedback to treat ADHD is still lacking. The current study aimed to investigate whether setting up an EEG neurofeedback training program for children with ADHD would be feasible in Indonesia. METHODS: Nine children (aged 6-12 years) participated in the study. ADHD was diagnosed using the Vanderbilt ADHD Diagnostic Rating Scale (VADRS). Children received twenty-five sessions of sensorimotor rhythm (SMR) neurofeedback training twice a week. Each session consisted of a 3-minute baseline, followed by 5*3 minutes of training. IQ scores and VADRS scores were collected at baseline, after completion of the intervention, and at 3 months follow-up, while school reports were provided by the schools. The EEG spectral content was determined for all 25 training sessions. In addition, a Go/No-Go Task, was administered at the first 5 training sessions, and at session 10, 15, 20 and 25. RESULTS AND CONCLUSION: An overview of all the collected data is provided descriptively, given the small group size. One child dropped-out during the training because of parental request, but the remaining eight children completed the full intervention program. Descriptive data suggested improvement with respect to both the ADHD symptomatology and performance IQ. These findings are in line with previous studies. Although a control arm was not included, we propose that the abovementioned SMR neurofeedback protocol may still be offered as a suitable non-pharmacological intervention for children with ADHD in Indonesia and deserves further research.

INTRODUCTION

Attention deficit/hyperactivity disorder (ADHD) is defined as a pattern of inattentiveness and/or hyperactivity-impulsivity that interferes with functioning or development [1]. ADHD has been divided into three different types: predominantly inattentive; predominantly hyperactive/impulsive; and a combined presentation; based on the specific pattern of symptoms that appear. Although there is no single causal risk factor of ADHD, several studies have proposed that genetics and/or prenatal environmental factors affect neural development that can cause ADHD [2]. ADHD has also been associated with decreased activity and volume of mainly the prefrontal cortices that are crucial for attention, working memory and decision making [3,4]. Worldwide average prevalence of ADHD appears to be around 5% [5]. There is no clear data available on the prevalence of ADHD children in Indonesia, however, the prevalence of ADHD in children from the city of Yogyakarta has been reported to be at 4% [6].

Next to the inattentiveness and/or hyperactivity-impulsivity, ADHD has also been associated with lowered academic achievement [7]. For example, a cohort study found that children with ADHD symptoms were more likely to show difficulties with reading, spelling, and/or mathematics [8]. In line with this finding, another study reported that children with ADHD have difficulties in basic number processing, especially number comparison [9]. In addition, grade retention is more common for children with ADHD compared to their peers [10], and children with ADHD are more likely to use ancillary services (e.g. tutoring assistant, after-school programs, and other such services) than children without ADHD [11]. Finally, without treatment, a child with ADHD is more likely to develop risk behavior, to become harmful to their self and to society, and in more extreme cases to violate

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the law. These behaviors may continue into adulthood that subsequently lead to severe problems during the adult years [2].

For over 50 years, methylphenidate hydrochloride (MPH) has been one of the most commonly prescribed stimulant treatment for children with ADHD worldwide, including Indonesia [12,13]. MPH is thought to amplify dopamine signals by blocking the dopamine transporters in the striatum leading to improved attention and decreased distractibility [13]. Although stimulant medication is known to decrease ADHD symptoms [14] adverse effects are often reported [15]. The most common short-term adverse effects are loss of appetite, abdominal pain, headaches, and sleep disturbances [14]. In addition, significant decreases in height growth rates in children with ADHD treated with stimulant medication have also been found [16].

EEG neurofeedback (NF) training has been reported to be an effective intervention for ADHD [17]. NF training has been proposed to improve self-regulation via operant conditioning of cortical oscillations [18]. Different NF protocols have been described for the treatment of ADHD, for example providing feedback on the EEG slow cortical potentials (SCP), the theta/beta ratio (TBR), and the sensorimotor rhythm (SMR) [19].

The sensory motor rhythm, SMR, is an EEG frequency band (12-15 Hz), measured at the sensorimotor area of the scalp, just behind the motor cortex. This rhythm is generated as part of a thalamocortical circuit and signals the inhibition of conduction of sensorimotor information to the cortex [20]. SMR is of particular interest with respect to ADHD treatment because high amplitudes of this frequency have been associated with relaxed attentiveness and decreased impulsivity [18,21,22]. Apart from that, it plays a role in sleep onset latency [23,24]. Thus, SMR training has been shown to shorten sleep onset and improve sleep quality, a factor that has received increasing attention in ADHD research lately [25,26,27]. Furthermore, meta-analyses on controlled SMR studies, as well as pre- and post-design studies, found large effect sizes of NF training on impulsivity and inattention; and medium effect sizes on hyperactivity in ADHD [17,28].

With regard to intelligence-related effects, previous studies suggested that NF training may increase both verbal IQ (VIQ) and performance IQ (PIQ) due to its abilities in improving cognitive functions such as visual-spatial attention, behavioral inhibition, motor planning, and timing [29]. As IQ scores are a strong predictor for academic achievement, IQ-related gains seem important to improve the academic achievement [30,31].

During NF training, children with ADHD learn to restrain their motor activity and maintain sensory activity that improves mental alertness and physical relaxation [21,32]. Mental alertness learned during NF training may contribute to enhanced cognitive functions such as attention, verbal working memory, and response inhibition involved in effective learning, thereby may improve academic achievement [32,33,34,35,36]. Despite the growing interests and attempts in using NF training worldwide, research and practice on NF for ADHD in Indonesia is still lacking [37].

Currently, the primary mode of ADHD treatment in Indonesia is medication [12] and cognitive behavior therapy [38,39]. Although child clinics do provide treatment, it is often out of reach for many children due to travel distances and financial reasons. Furthermore, only few studies have explored the role of the educational system as a channel for treatment delivery of neurofeedback for ADHD [40,41,42,43]. Training at school may facilitate attendance and provides a translational approach of laboratory-based effects. Hence, the aim of this study was to investigate whether a standardized SMR NF training program for children with ADHD in Indonesia could be offered as a feasible non-pharmacological intervention in various treatment settings, including in-school setting, that can be performed not only by highly trained specialists but also by teachers and/or parents in collaboration with professionals.

MATERIALS AND METHODS

1) Participants

Eight males and one female with ADHD aged between 6 and 12 years old were recruited from several schools in Central Java, Indonesia. These schools are regular public and private schools that provide inclusive education, including for students with ADHD. The ADHD classification was based on the Vanderbilt ADHD diagnostic rating scale (VADRS), filled out by parents and a school teacher, and finally reviewed by a child psychologist. Intellectual functioning was assessed using the Wechsler Intelligence Scale for Children Revised (WISC-R). Only children with ADHD and IQ scores ranging between 80 and 120 were included. Children with a comorbidity of a neuropsychiatric or neurologic disorder were excluded, as were children who were currently receiving ADHD medication, e.g. MPH. Parents' approval were obtained by means of a written informed consent. The study was approved by the ethical committee of Soegijapranata Catholic University Semarang (001A/B.7.5/FP.KEP/II/2018) and was conducted in compliance with the Declaration of Helsinki.

2) Measures

ADHD

The Vanderbilt ADHD diagnostic rating scale (VADRS) is a psychological assessment tool based on DSM-IV used to examine the presence of ADHD symptoms and comorbidities. It consists of two forms: a teacher-report (VADTRS) and a parent-report (VADPRS) [44]. The validity and reliability of the Indonesian version is yet available. However, the original versions of both scales have good internal reliability with a Cronbach's alpha coefficient of > .90 for the parent scale and >.89 for the teacher scale [45]. Test-retest reliabilities were assessed as adequate (r >.80) whereas the interrater reliability between the two scales is low (r=.27 – .34) [45,46]. VADTRS includes items that assess school functioning, and the VADPRS includes a comparable subscale to assess parents' perceptions of school and social functioning. Both teachers and parents have to rate the child's behavioral frequency as follows: 0 "never", 1 "occasionally", 2 "often" and 3 "very often". To meet the criteria for the diagnosis, the child must have at least 6 positive responses (score 2 or 3) to the inattentive subtype (item number 1-9) or hyperactive subtype (item number 10-18) questions. If the child meets both criteria (inattentive subtype and hyperactive subtype) then the diagnosis will be the combined subtype [47].

IQ

The Wechsler Intelligence Scale for Children-Revised (WISC-R) is one of the most widely used tests of cognitive ability for children ages 6 through 16 years. In the current study, we used the Indonesian version of the WISC-R. WISC-R measures intelligence through 12 subscales: information; similarities, arithmetic, vocabulary, comprehension, digit span, determining the verbal IQ or VIQ, and picture completion, picture arrangement, block design, object assembly, symbol coding, mazes, determining the performance IQ or PIQ. It was used to evaluate the intellectual functioning and to rule out intellectual disability in this study.

Academic Achievement

Academic achievement was based on the children's consecutive school reports of the semester before the intervention started, of the first semester after treatment, and of the semester matching the long-term follow up. For further analysis, school performances were clustered into: Moral Education (Religion and Civic education); Science (Science and Mathematics); Language and Culture (Social Science, Bahasa Indonesia, English, and Javanese); Fine and Gross Motor Skill (Physical Education and Arts).

3) Procedure

Intervention Design

The included children were offered 25 sessions of SMR NF training. Only eight children completed all NF sessions (N=8), one boy dropped out after the first 5 sessions due to parental request. Of the remaining eight children, four children received in-school training and the other four children received in-laboratory training. Sessions were provided twice a week. Whenever a session was missed, the program continued at the regular scheduled sessions until all 25 sessions were completed. Each training session consisted of a 3-minute baseline, followed by 5*3 minutes of SMR NF training. In total, including the preparations, each session lasted on average around 30 minutes.

Training Session Protocols

Participating children performed a Go/No-Go task on session number 1 to 5, 10, 15, 20, and 25, just before the SMR NF training. After EEG preparations, the child was asked to relax and watch the computer screen. If the childs's' EEG exceeded the SMR threshold, along with a sufficiently low theta amplitude (individually determined at baseline), a picture and a sound appeared for around 500 ms. At the end of each training block, the child was asked to close their eyes for 10 seconds before continuing the subsequent block.

EEG SMR neurofeedback

The training was administered using the portable EEG Personal Efficiency Trainer PET (Brainquiry) and BioExplorer software (CyberEvolution, Inc.). Prior to all training sessions, the electrode sites were cleaned with Aximed Alcohol Prep Pad. With respect to the EEG NF setup, a Brainquiry Personal Efficiency Trainer (PET) was used with the active electrode located at the C3 position, the reference electrode was over the left mastoid, and the ground electrode over the right mastoid according to the international 10-20 system.

EEG was recorded at 200 samples per second, band filtered with IIR filters, and epochs were 0.45 sec. All children received a visual (nature scenes) and auditory (MIDI sound) reward each time the SMR surpassed a session-fixed SMR threshold. Thresholds for feedback were initially set at 40% SMR reward over baseline average, only if the activity over the threshold continued for longer than 500 msec, and if theta activity was below 90% of the baseline average leading to a total reward frequency of about 25% of the time. According to these rules, the number of SMR bursts and average SMR burst duration (time over 60th percentile score) were recorded for data analysis. The adaptation procedure in each block was as follows: after 30 seconds a percentile score of 60 was calculated for SMR, providing an amplitude value. It was compared to the ongoing threshold amplitude. If the percentile amplitude was larger than the ongoing threshold amplitude, a new threshold was computed, being the mean of the two amplitudes. If it was smaller, the ongoing threshold remained in place.

For theta comparable rules were followed based on the 90th percentile amplitude. Due to the inhibitory character of theta feedback, the change rules mirrored those in the SMR feedback. With these rules we stayed close to the early suggestions by Sterman & MacDonald [48], who considered 10 to 20 rewards per minute to be attainable if the rewarded amplitudes are sufficiently distinct from background activity.

EEG data were recorded during each training session. Offline spectral analyses of the recorded EEG data are available from session 1, 5, 10, 15, 20 and 25. In addition, during session 1, 2, 3, 4, 5, 10, 15, 20 and 25, Go/No-Go task was administered before the NF training.

Go/No-Go Task

The Go/No-Go Task is a computerized test to measure selective response speed and response inhibition [49]. The children were instructed to press the spacebar of the computer keyboard as quickly as possible every time the target stimulus was presented in green (the Go-trials), but refrain from responding if the target word was presented in red (the No-Go trials). The target stimulus was a brief visual presentation of the word PRESS (or TEKAN in Bahasa Indonesia). There were 40 trials in total. The Inverse Efficiency Score (IES) was defined as by RT (Reaction Time) divided by the PC (Proportion of Correct Responses). The IES from consecutive sessions was analyzed by means of linear regression analyses using the program sGraphPad Prism version 6 for Windows, GraphPad Software, San Diego California USA, www.graphpad.com.

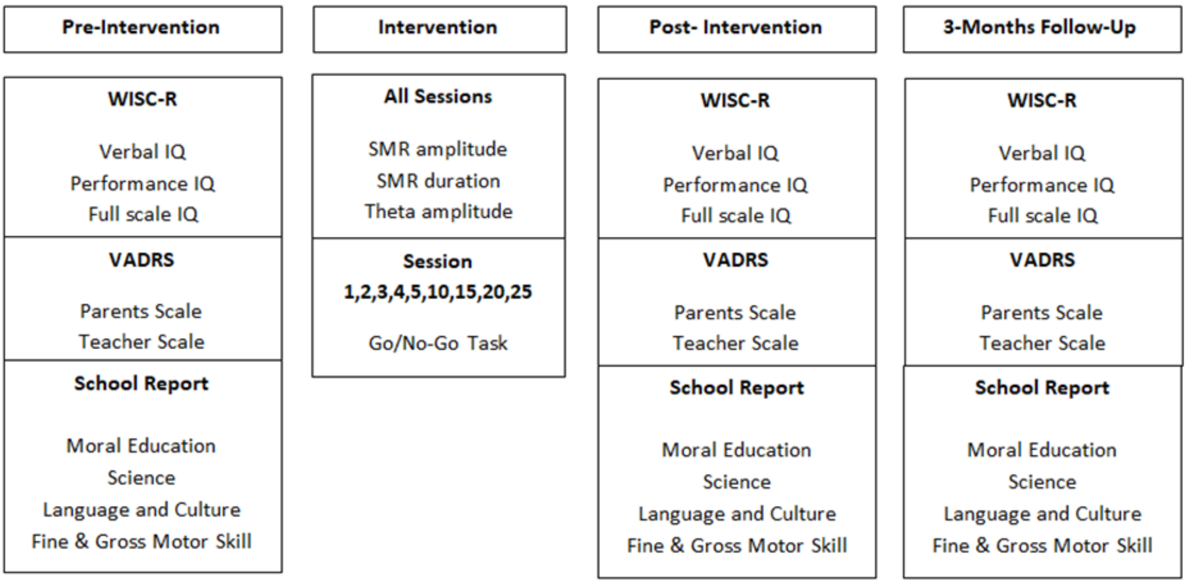

Figure 1. Measurements of the study.
(Note: Pre-Treatment School Report is based on two semesters)

RESULTS

1) Demography

Eight males and one female diagnosed with a combined ADHD subtype were enrolled in this study (aged 8.8 years ± 2.0). Eight children completed all NF sessions. After 3 months follow-up, all but 1 child showed a decrease in symptoms, mostly with respect to inattentiveness. This assessment result was based on the Vanderbilt ADHD diagnostic rating scale (VADRS for parents and teachers) and confirmed by a child psychologist (See Table I).

Table I. Demographics and Clinical Information

Participant Number	Sex	Age	Grade	ADHD Subtype Pre-Intervention	ADHD Subtype Post- Intervention	ADHD Subtype Follow-Up
1	F	10	5^{th}	Combined	Hyperactive	(Not Present)
2	M	8	3^{rd}	Combined	Hyperactive	Hyperactive
4	M	7	2^{nd}	Combined	(Not Present)	Hyperactive
5	M	9	4^{th}	Combined	Inattentive	(Not Present)
6	M	12	6^{th}	Combined	(Not Present)	Inattentive
7	M	8	3^{rd}	Combined	(Not Present)	(Not Present)
8	M	6	1^{st}	Combined	(Not Present)	(Not Present)
9	M	11	5^{th}	Combined	Combined	Combined

Note: “Not Present” indicating that the ADHD symptom (inattentiveness and/or hyperactive) is no longer present based on VADRS

2) Data collected at baseline, post intervention and at 3-months follow up.
Vanderbilt ADHD Diagnostic Rating Scale

We performed a 3-way within-subjects ANOVA with time (3 levels: pre-intervention; post intervention; 3 months follow-up), role (2 levels: parents; teacher), and scale (2 levels: hyperactive; inattentive) being the within-subject variables. The test of within-subjects effects (Sphericity assumed) showed a marginally significant main effect of time, and for scale but not for role. No interaction effects were observed (See Table II). Higher scores were observed during baseline than post treatment and follow up (see Figure 2).

Table II. 3-way within-subjects ANOVA for VADRS

	df	F	p	η2
Time	2	3.585	.055	.339
Scale	1	4.193	.08	.375
Role	1	.142	.718	.020
Time*Scale	2	.037	.963	.005
Time*Role	2	2.464	.121	.260

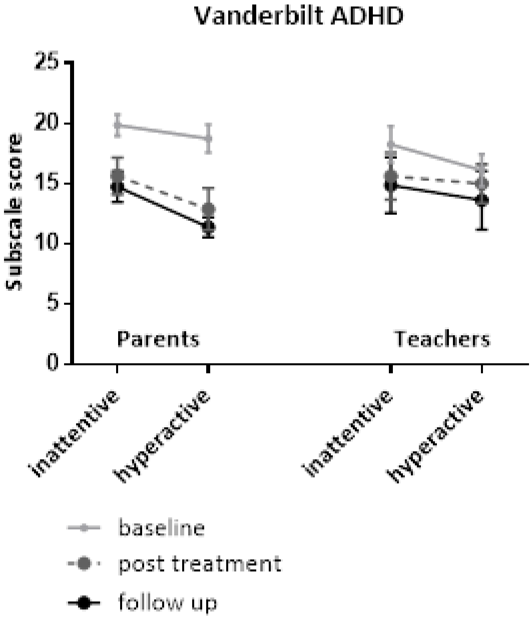

Figure 2.
Pre-intervention, post-intervention and follow-up scores on the VADRS according to parents (on the left) and teachers (on the right).

IQ Scores

Within subject ANOVA was performed on the IQ test's scale (2 levels: VIQ; PIQ), subscales (6 levels), and by time (3 levels: baseline; post treatment; 3-months follow up).

Whenever Mauchly's test of sphericity indicated that the assumption of sphericity had been violated, a Greenhouse-Geisser correction was used (marked in Tables IIIa, IIIb and IIIc).

Table IIIa. Within subject ANOVA on IQ tests.

	df	*F*	*p*	η^2
Time#	1.158	.117	.777	.016
Scale	1	2.312	.172	.248
Subscale	2.240	.856	.455	.109
Time*Scale	1.422	5.830	.028*	.454
Time*Subscale	3.348	3.482	.028*	.332
Scale*Subscale	5	11.612	.000**	.624
Time*Scale*Subscale	3.741	1.949	.136	.218

#: Greenhouse-Geisser corrected.
*: $p \leq 0.05$, **: $p \leq 0.001$

Table IIIb. Time effects per subtest (VIQ)

Time effect	*df*	*F*	*p*	η^2
Information	2	1.144	.347	.140
Comprehension	2	1.784	.204	.203
Arithmetic	2	5.347	.019*	.433
Similarities	2	.935	.416	.118
Vocabulary	2	.707	.510	.092
Digit Span	2	.431	.658	.058

*$p \leq 0.05$

Table IIIc. Time effects per subtest (PIQ)

Time effect	*df*	*F*	*p*	η^2
Picture Completion	2	2.240	.143	.242
Picture Arrangement	2	.174	.842	.024
Block Design	2	.232	.796	.032
Object Assembly	2	4.058	.041*	.367
Symbol Coding	2	5.995	.013*	.461
Mazes	1.205	7.929	.018*	.531

*$p \leq 0.05$

The post-hoc repeated measures ANOVA (bivariate comparisons) from all the twelve subscales showed a decrease in Arithmetic (VIQ) and an increase in object assembly, symbol coding, and mazes (PIQ) (See Figure 3).

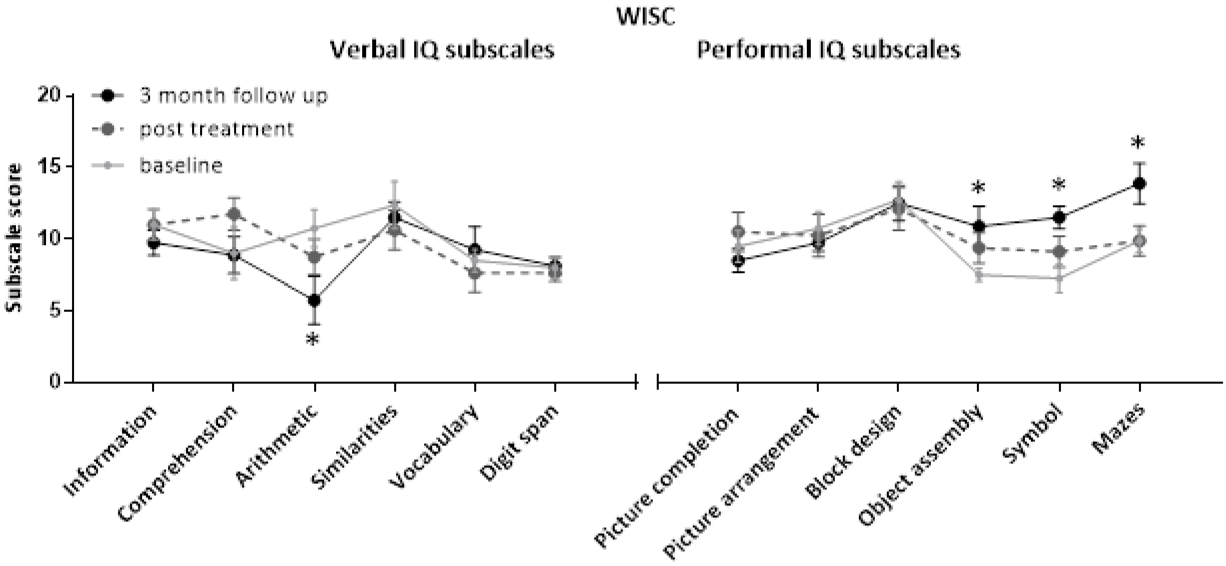

Figure 3. Pre-intervention, post-intervention and follow-up scores on WISC 12 subscales of VIQ and PIQ; vertical lines signify SEMs; asterisk marks a significance of p<.05 in the posthoc repeated measures ANOVA per subscale. See also table IIIa-c.

Academic Achievement

Only seven children were included in this measurement, since we did not have the complete school reports of participant #08. Participant #08 was still in kindergarten when the pre-treatment data were collected, and the school report was more descriptive than numerical.

For academic achievement, we performed a 2-way within-subjects ANOVA with several academic domains (4 levels: Moral education; Science; Language and culture; Fine and gross motor skills) by time (3 levels: baseline; post treatment; 3-month follow up). Whenever Mauchly's test of sphericity indicated that the assumption of sphericity had been violated, a Greenhouse-Geisser correction was used. No main effect of time was observed. However, a main effect of academic domain was found (See Table IV and Figure 4).

Table IV. Two-way within-subjects ANOVA for academic achievement.

	df	*F*	*p*	η^2
Time	2	1.717	.221	.222
Academic Domain	2.005	5.397	.021*	.474
Academic Domain*Time	6	1.195	.331	.166

*$p \leq 0.05$

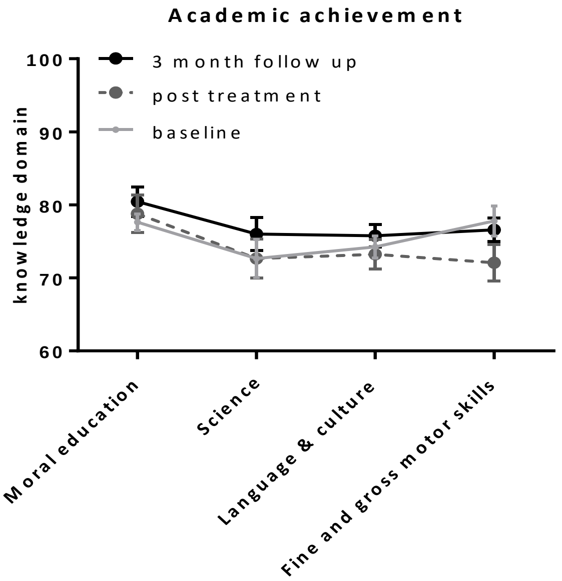

Figure 4.
Pre-intervention, post-intervention and follow-up scores on Academic Achievement.

3) Data collected during NF training.

Apart from one participant who dropped-out, we demonstrated that the SMR NF training was implemented successfully with regard to compliance of the full study protocol. The remaining eight children were able to understand and follow all the instructions of the SMR NF training.

EEG spectral content

The SMR amplitude for the baseline showed no training effects. In contrast, the SMR amplitude during the training blocks decreased over sessions ($F_{(1,23)}$ = 4.34; p = .049; r^2 = .159). This may be explained by decreased muscle artefacts. The SMR duration did not show an effect, neither during baseline, nor during blocks (see Figures 6a-6d). No training effects with respect to the theta activity were observed.

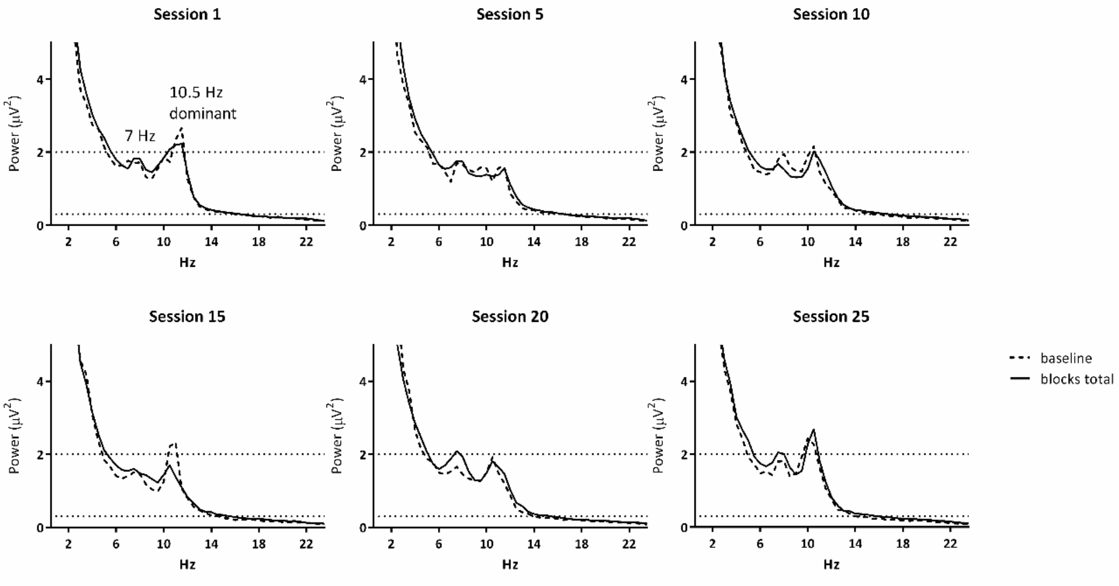

Figure 5. Full spectra of the EEG during NF training

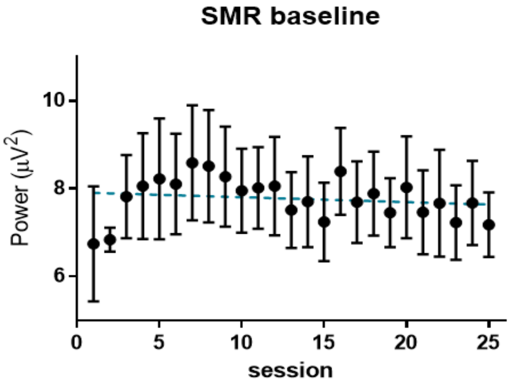

Figure 6a. SMR amplitude baseline

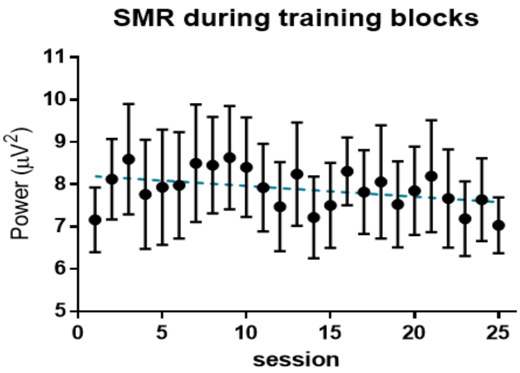

Figure 6b. SMR amplitude during training blocks

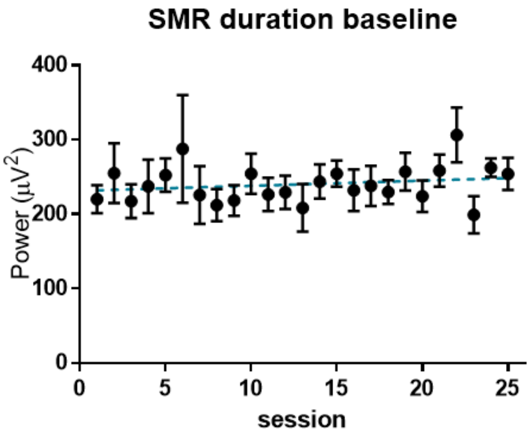

Figure 6c. SMR duration baseline

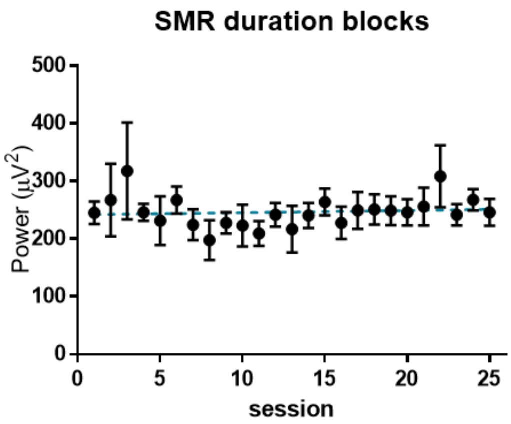

Figure 6d. SMR duration blocks

Go/No-Go Task

A linear regression of the Inverse efficiency scores (IES) showed a significant decrease with time ($F_{(1,8)}$=7.8; p=.027) This means that the children's showed an improvement with respect to selective response speed and response inhibition.

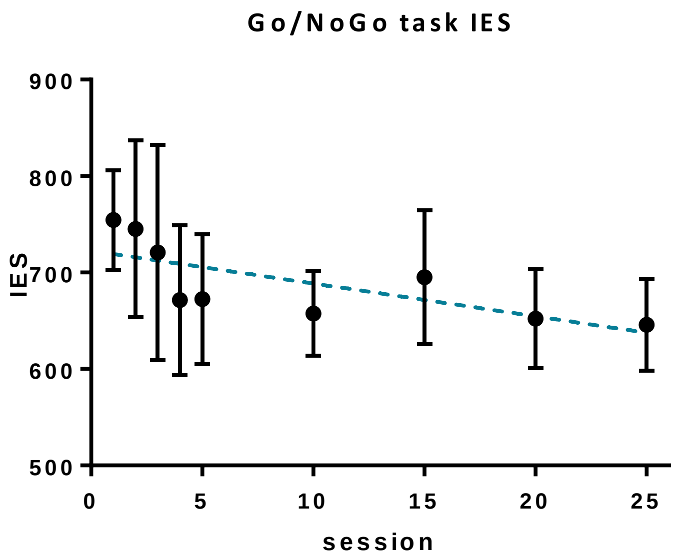

Figure 7. Go/No-Go IES values (in ms) of the inhibition task for session 1-5, 10, 15, 20, and 25

DISCUSSION

The present feasibility study aimed to investigate whether setting up an NF training program for children with ADHD would be feasible in Indonesia. With regard to compliance of all the intervention protocols, this study showed that children with ADHD were able to understand and follow the intervention protocol in this study. In the current study, we observed that the children's ADHD symptoms showed a modest improvement after NF training (post-intervention and at 3 months follow-up compared to pre-intervention). This result is in line with previous findings that NF training improves ADHD symptoms [26,50,51].

With respect to the IQ scores, we found no effects on the VIQ, while there were some increments on the PIQ which is also in line with previous studies [52,53]. It should be noted however that these studies use a different NF training protocol, which provided SCP feedback. However, it has been reported that SCP and SMR training lead to comparable results, presumably due to the interrelationship between the two networks involved [54].

Administering SMR NF might help children with ADHD improve in certain areas such as attention, planning, and behavioral inhibition [18,21,22,29], yet there are still insufficient numbers of studies addressing improvements in working memory. In this study, a decreased performance on the arithmetic subtest was observed after NF training. Observation during testing suggested that some children refused to finish this subtest at the post treatment session and follow up measurement. Thus, the observed decrease could be explained by a decrease in motivation to complete the task over time, since this subtest also relies on motivation [55].

With reference to the improvement of the PIQ scores, this study conducted SMR NF that is associated with relaxed attentiveness and decreased impulsivity [18,21,22]. This may explain why some subscales in PIQ, namely object assembly, mazes, and symbol, showed marked improvements after training, even at 3-months follow up. This corresponds with a prior fMRI study that showed activation in several brain areas associated with cognitive functions such as visual-spatial attention, behavioral inhibition, motor planning, and timing after NF training sessions for children with ADHD [29].

In the current study we used school reports as the indicator of children's academic achievements, which were the results of the children's achievement in each semester. There were no changes observed on children's academic achievement. In line, previous studies also failed to find a clear effect of NF training on the academic achievement. This might be partly due to the use of different measures and criteria [43]. Previous studies suggested that observed improvements after NF training were mostly related to decreased ADHD symptoms such as inattention and hyperactivity, whereas school achievements require more complex abilities and might be also determined by other external factors, such as forms of teaching [56] and school climate [57].

No effects of the NF training with respect to SMR duration were observed. However, we found a reduction of SMR amplitude during training, possibly due to a more general decrease in muscle activity.

Lastly, we found an effect of the NF training on a task measuring inhibitory control. This finding is supported by previous studies [20]. SMR training may have led to an improved regulatory control, thus to a more efficient attentional processing [58]. Nonetheless, these findings might also be (partly) caused by repeated testing [59].

In summary, this study found that NF can be provided as a school-based non-pharmacological treatment for ADHD in children in Indonesia, and children that participated in the study showed a decrease in their ADHD symptoms. However, some methodological limitations should be addressed as it raises a certain degree of bias in this study. Notably, only a small group of children participated in the study, and no data was collected from a control group. Thus, observed effects might be due to maturation, repeated testing, and/or expectations about the NF treatment.

In addition, based on our observations, there are other factors that might have affected the training, such as the training environment. For NF training, a quiet and comfortable environment is advisable to minimize distraction during training. A noisy room with many distractions may cause the child unable to do the training properly, which may have been the case for children who received training sessions at the school. Among the children in the current study who received the NF training at school, school activities often prevented the delivery training based on the initially set schedule. This resulted in administration of sessions at an irregular timetable, that may have influenced the effectiveness of the NF training. Thus, the differences of contextual factors (i.e. school and laboratory settings) and its effect toward NF should be examined further as well.

For future studies in Indonesia, larger samples and the inclusion of a control group is recommended to extend generalizability from rigorous study designs. In addition, taking into account other variables such as clinically efficacious medications and more standardized training conditions is recommended.

CONCLUSIONS

To the extent of our knowledge, this is the first study that investigates whether setting up a NF training program for children with ADHD would be feasible in Indonesia. Despite various limitations, our study showed that the protocol of NF for children with ADHD was feasible based on our samples of Indonesian children with ADHD. Therefore, this treatment modality warrants further research in Indonesia.

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