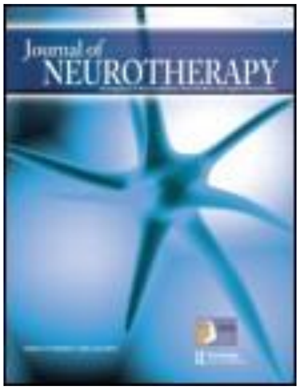

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Neurofeedback in Residential Children and Adolescents with Mild Mental Retardation and ADHD Behavior

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SCIENTIFIC FEATURES

NEUROFEEDBACK IN RESIDENTIAL CHILDREN AND ADOLESCENTS WITH MILD MENTAL RETARDATION AND ADHD BEHAVIOR

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Neurofeedback (NFB) research has reported improved concentration and attention in children with attention deficit/hyperactivity disorder (ADHD) and progress maintained over time. Would that also apply to children with an IQ between 50 and 70 (mild mental retardation [MMR]) and an IQ between 70 and 85 (borderline retardation [BR]) with characteristics of ADHD? To our knowledge this is the first NFB treatment study with long-term follow-up in this particular group. Ten adolescents with MMR and BR and ADHD received 30 sessions of quantitative electroencephalogram (QEEG)-based NFB. QEEG differences with a gender- and age-matched group without mental handicap and ADHD (data provided by BRAINnet) were investigated, at pre- and posttreatment and at 6-month follow-up. Neuropsychological functioning was tested administering the Bourdon-Vos, and the Amsterdam Neuropsychological Testing Program subscales SA DOTS and SSV. Pretreatment eyes-closed EEGs were not statistically different in the children with MMR compared to the controls. With eyes open higher amplitudes were found in the lower frequencies in the children with MMR, normalizing over time. The neuropsychological tests improved for reaction times and errors. On the complex tasks in the SSV a number of errors remained. The subjects perceived an improvement in ADHD and increasingly enjoyed the study. After NFB treatment, attention and concentration in children with MMR and BR have improved. Task span and effort also increased, although impulse control remained weak. This may be explained by a limited working memory capacity. The subjective reports may have been affected by situational factors and should be interpreted with caution. This study is limited by its nonrandomized design.

INTRODUCTION

Neurofeedback (NFB) is a form of treatment that attempts to influence brain activity by operant conditioning. The brain activity of the client is measured with an electrode on the head, then the level of activity is fed back to

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the client. The goal of treatment is to have selected brain activity to occur more or less, depending on the symptoms of the client and the pattern of his or her brain activity. It is expected that changing the brain activity and cognitive functioning of the client changes the behavior. In people with a mental or neurological disorder, different patterns are often seen in the electroencephalogram (EEG) than in healthy people. Thus, children with attention deficit/hyperactivity disorder (ADHD) sometimes show high-amplitude theta waves in a particular brain region and small-amplitude beta waves elsewhere (Barry, Clarke, & Johnstone, 2003). NFB at the motor cortex at 12–15 Hz or 15–18 Hz has proven effective in treating ADHD (Arns, de Ridder, Strehl, Breteler, & Coenen, 2009; Levesque, Beauregard, & Mensour, 2006; Monastra et al., 2005). In this disorder inattention, hyperactivity, and impulsiveness are reported to be reduced to the same extent by NFB as by medication (Fuchs, Birbaumer, Lutzenberger, Gruzelier, & Kaiser, 2003). The effects are retained over time, unlike the effects of medication that are gone within a week after discontinuation (Fuchs et al., 2003; Gevensleben, Holl, & Albrecht, 2010; Monastra et al., 2005; Monastra, Monastra, & George, 2002). Note, however, that NFB and medication have not been compared in randomized designs and that Arns et al. (2009) reported lower effect sizes in randomized controlled studies (also see, e.g., Gevensleben et al., 2010). Comorbid mood disorders and IQ scores improve, the latter probably due to an increased attention span (e.g., Fuchs et al., 2003). One of the main supposed benefits of this method is that it uses the resilience and the learning ability of the brain itself. The self-regulating ability of the brain is addressed. NFB therapy is not invasive, that is, nothing is added to or taken away from the body. The therapy allows the brain itself to improve the physiological basis of the problem, the activity and internal communication of the different brain areas. The actual training takes place via a specifically designed computer program and takes about 30 sessions. The computer is programmed to respond with rewards when the desired activity of selected brain areas is achieved. This not only causes a learning effect but also will develop new patterns of activity in the brain, and the undesirable behavior improves or disappears over time. After much practice, a client with attention problems tends to concentrate better.

NFB appears to work for both children and adults (Masterpasqua & Healey, 2003), although controlled studies investigating NFB in adults is lacking. The flexibility of the developing child makes it particularly suitable for children. Hyperactivity, attention deficit disorder (ADD)/ADHD, and behavior problems can often be treated well (Arns et al., 2009).

Among children with mild mental retardation (MMR), ADHD occurs three to four times as often as in normally gifted children (Biederman, Newcorn, & Sprich, 1991). For children living in residential care (Ponsioen, 2010), these behaviors even occur more often. About 70% of mentally disabled children are unfortunate sufferers of psychiatric disorders, including ADHD problems. In the Netherlands there are specialized institutions for MMR care, namely, orthopedagogical treatment centers (OBCs). The classification of these groups is based on the description of the target criteria of the mental handicap care (NVGz-nota, 1995). In these settings, children with severe family and/or behavioral problems are supervised and treated.

The purpose of this pilot study is to find clues to the usefulness of NFB in children and adolescents (hereafter referred to as children) with MMR, aged from 9 to 18 years with features of ADHD behaviors. Like the 21 other OBCs in the Netherlands, the OBC Jan Pieter Heije looks consistently for new developments, especially for children with disorders that often need intensive treatment and support and who remain dependent on medical support for a long time. They are vulnerable members of our society, and their complaints are a big burden to themselves and others. The pilot study focuses on these children. By treating targeted brain areas with NFB and without invasive treatments, we expect a continued improvement in the symptoms.

RESEARCH QUESTIONS

Based on the previous discussion, this pilot study aims to answer the following questions:

RQ1: Does attending an NFB treatment in residential children with MMR lead to improvement in performance on some neuropsychological tests (Sustained Attention Dots [SAD] and Shifting Attentional Set–Visual [SSV] Amsterdam Neuropsychological Testing Program [ANT]; Bourdon-Vos)?

RQ2: What does the QEEG of residential children with MMR and ADHD problems look like?

RQ3: Does the QEEG of these children normalize after NFB treatment?

RQ4: To which changes in subjective experience of their situation does an NFB treatment of children with MMR and ADHD lead?

METHODS

Subjects

Participants were recruited from children living on or near the OBC Jan Pieter Heije (about 150 children). Exclusion criteria were (a) use of psychotropic drugs or their use in the past half year, (b) motor or visual defects, and (c) relocation or possible relocation of children in the OBC Jan Pieter Heije. After applying these exclusion criteria, 58 children were still eligible for the study.

Inclusion criteria were (a) children aged 9 to 18 years and $50 \leq IQ \leq 85$ as measured by the Wechsler Intelligence Scale for Children (3rd ed.), (b) children residing in the downtown facility of the OBC Jan Pieter Heije, and (c) clinical assessment of the severity of ADHD by the remedial therapist/practitioner (hereafter referred to as practitioner) at or greater than 5 on a scale of 1 to 10.

An initial screening for ADHD was based on three observational lists—Strengths and Difficulties Questionnaire (Widenfelt, Goedhart, Treffers, & Goodman, 2003), the ADHD Questionnaire (Scholte & van der Ploeg, 2005), and the Social and Emotional Questionnaire—all completed by group leaders. There was also an overall severity assessment given by the practitioner. The results of the observation lists gave no clear picture of the seriousness of the problem. Observations by the group leaders were also significantly different from the valuation of the practitioner. Previously Embregts (2000) noted that the assessment of behavioral problems in children with mental disabilities using the Child Behavior Checklist in the institution was unreliable.

After this, it was decided to rely solely on the clinical assessment of the practitioner, being the best informed through reports, discussions, and personal observations. Of the 58 children between 9 and 18 years there were 26 children with the highest severity above median valuation of the practitioner who qualified for the next step in determining the sample, the neuropsychological screening.

The neuropsychological screening occurred if there was a failure on three or more of the five neuropsychological tasks (z score < -1). In this screening five attention and concentration tasks (see Measuring Instruments section) were administered. Ten children were selected for final participation in the pilot study. The group consisted of five boys and five girls from 10 to 16 years of age, on average. They had been treated on average for 2.6 years in OBC Jan Pieter Heije.

Phases and Research Instruments

The research project consisted of four successive phases: the pretest, treatment, posttreatment test, and follow-up measurement at 6 months after the end of treatment. Within each phase, various instruments were administered (see Table 1). The design is a tenfold $N = 1$ study, and each individual study looks at the background of the person, neurophysiology, neuropsychology, and satisfaction measures. A full report of these $N = 1$ studies can be found at http://www.pluryn.nl/Website/Professionals/Research%20to%20Development/Onderzoeken.aspx.

Neuropsychological Measurements

ANT. ANT is a computerized test battery developed to evaluate the basic processes

TABLE 1. Research Design

Measurements	Stages			
	Pretraining	Training 10 weeks, 30 sessions	Posttraining	Follow-up at 6 months after end of training
Neuropsychological measures ANT/Bourdon-Vos	X		X	X
QEEG	X	XXXXXX	X	X
Satisfaction measures	X	every 10 sessions	X	

Note. ANT = Amsterdam Neuropsychological Testing Program; QEEG = quantitative electroencephalogram.

underlying the execution of complex processes such as attention, memory and executive function in a standardized way (http://www.sonares.nl).

Bourdon-Vos. The Bourdon-Vos test (Vos, 1992) is a selective visual attention task for children. The test is a sheet with 33 lines, each consisting of 24 random three-, four-, and five-dot characters. One has to tick only the four-dot characters. The main task variables are the speed and accuracy. Accuracy is considered as an indicator of impulsiveness.

Neurophysiological Measurements

The EEG was obtained using a Quickcap and a 40-channel NuAmps amplifier with electrodes placed at the following 26 locations: FP1, FP2, F7, F3, Fz, F4. F8, FC3, FCz, FC4, T3, C3, Cz, C4, T4, CP3, CPZ, CP4, T5, P3, Pz, P4, T6, O1, Oz, and O2. Horizontal eye movements were measured with electrodes attached at 1.5 cm side of the outer corners of the eye. Vertical movements were measured with electrodes 3 mm above the center of each eye, and 1.5 cm below the center of the lower left eyelid. Further physiological data were obtained from the orbicularis oculus and the masseter. All data were recorded in relation to a virtual ground and referenced to the mastoids (so-called ''linked ears'' montage). Average power spectra were calculated for eyes-open and eyes-closed condition. The data were transformed to the log-linear approach required for statistical analysis. For more details on the procedure, see Breteler, Arns, Peters, Giepamns, and Verhoeven (2010).

Satisfaction Measurements

The satisfaction measurement (see Table 2 and http://www.pluryn.nl/Website/Professionals/Research%20to%20Development/Onderzoeken.aspx) was conducted for all children who participated in the study and included five measurement points. The measurement is performed by administering a questionnaire consisting of four to six questions with a scale ranging from 0 to 10 (Likert scales). The questionnaire was administered verbally, always by the same interviewer.

Several questions concerned (a) the experience of NFB, (b) satisfaction with the care provider during the study, and (c) the experience of participating in the study.

The response to similar questions from the parents/legal representatives was so low that these results are not included in the study.

Preparing Treatment Protocols

Based on the measurement of QEEG, differences with the Brain Resource International Database were established (see, e.g., Breteler et al., 2010). Thus the three most significant

TABLE 2. Subjective Experience of the Participating Children with Regard to Their Attention Deficit/Hyperactivity Disorder (ADHD) Problems, the Counselors, and Participation in the Research

Experience	Pretreatment	Posttreatment	Difference
Concentration	7.5	7.5	0
Change in DL	5.4	6.6	1.2
Burden by ADHD	4.9	6.9	2
Total: experience	5.9	7	1.1
Information	8.3	7.5	–0.8
Explanation	8.7	6.5	–2.2
Listening	8.7	7.8	–0.9
Total: satisfaction with counselor	8.6	7.3	–1.3
Feeling at ease	6.6	7.8	1.2
Nice to participate	5.3	6.4	1.1
Total: participation in the research	6	7.1	1.1

Note. The experience was measured on an 11-point scale from 0 (*very bad*) to 10 (*excellent*). DL = daily living.

discrepancies that are related to attention and impulsivity were determined. For these differences protocols were established. This mostly concerned central or frontal sites, downtraining slow frequencies. However, also increases of alpha ampltude at parietal sites were trained if applicable. If protocols required eyes closed, they were trained first.

Neurofeedback Training

For 10 weeks all children got a half-hour NFB training at a fixed time, three times a week. All children trained three protocols. Protocols 1 and 2 were provided all 30 sessions. The first 15 sessions of Protocol 1 consisted of 3×5 min listening to midi sounds with eyes closed (in a process of building up from 3 and 4 min). During the first 15 sessions Protocol 2 consisted of 10 min of Pacman, or playing with a puzzle. From Session 16 the third protocol was added. The session then consisted of 2×5 min music (with eyes closed), 2×5 min puzzling or video, and 2×5 minutes video. The children were free to choose music or movies of their own liking. The structure of the training and the purpose of the training were explained to the children in advance. The interaction and clear explanation was considered important for the motivation to participate. At the end of each session the children were given a stamp, and after 10 stamps a small present like a bouncing ball or a sticker.

RESULTS

Table 3 presents an overview of the characteristics of the children and the protocols.

Data Analysis

The questions regarding the QEEG were examined with a multivariate repeated measures analysis of variance with EC (eyes closed) values as dependent variables. The values of the control group on the three waves were kept the same. In the neuropsychological data the reliable change index (see Veerman, Janssens, & Delicat, 2004) was used, to give an impression of significant changes in attention and concentration, taking into account the psychometric characteristics of the questionnaires.

Next the results of the group as a whole are described. The first research question is, Does following an NFB treatment in children with MMR lead to improvement in the functioning on the SAD and SSV of ANT and the Bourdon-Vos?

ANT, SAD

Compared to the pretest, the reaction times and errors significantly improved. This is in line with expectations. During the follow-up the strongest advances are found. The response during follow-up has improved to an extent that they are of average value ($-1.28 < z < 1.28$) and for the errors an improvement close to the average is found. The children generally work faster and more accurately (see Table 4).

ANT, SSV

For all time measurements the response times of almost all parts are of average value. The course of the errors is, however, unpredictable. There is no clear progress. For Part 1 only some change is visible in the average area. For Part 2, we find a strong improvement in the posttest, but 3 months after training during the follow-up there is a decline to almost the level of pretraining measurement. For Part 3, we find a slight change outside the average area (see Table 4).

Bourdon-Vos

In general, the work rate increases during the research, and this is in line with expectations. At the posttest there is a positive trend, which is continued during follow-up in the direction of average values (see Table 4). Using a univariate analysis we examined whether there is significant improvement from the baseline. It appears that both at posttest and follow-up there is a significant effect ($F = 5.5$, respectively [1.9], $p = .043$ and $F = 21.3$ [1.9], $p = .001$).

Table 4 shows that generally there is an average precise work style. The univariate analysis does not show any significant effects for both Investigation 1 and 2 ($p = .45$ and $p = .38$). Table 5 shows the similarity of the scores on the neuropsychological test for different factors such as gender, age, and IQ scores.

TABLE 3. Subject Characteristics and Protocols

Case ID	Age	Duration of stay: years; months	IQ (range) pre	IQ (range) post	VIQ/PIQ pre	VIQ/PIQ post	NFB protocol 1[a]	NFB protocol 2[a]	NFB protocol 3[a]
1	14	4; 6	72 (67–81)	75 (69–84)	74/75	80/75	EC F3 3–7 Hz ↓	EO F3 3–7 Hz ↓	EO Pz 10–12 Hz↓
2	13	3; 3	67 (62–76)	66 (61–75)	59/82	66/71	EC C4 2–9 Hz ↓	EO CPz 2–9 Hz ↓ 13–17 Hz↓	EO CP4 2–9 Hz ↓ 13–17 Hz↓
3	10	0; 4	69 (64–78)	87 (81–95)	67/77	78/101	EC Fz 7–8 Hz ↓	EO Pz 7–8 Hz↓ 10–12 Hz↑ 18–20 Hz↑	EO CP3 + CP4 32–34 Hz↓
4	10	0; 11	68 (63–77)	64 (59–74)	76/64	66/66	EC Fz 2–4 Hz ↓	EO Fz 10–12 Hz↓	EO T3 8–11 Hz ↓
5	15	6; 7	72 (67–81)	NA	74/75	NA	EC Fz 4–8 Hz ↓ 8–11 Hz ↑	EO Fz 4–8 Hz ↓	EO P4 8–11 Hz↑
6	11	3; 7	59 (54–69)	57 (53–67)	70/<55	67/55	EC Cz 0.5–4 Hz ↓	EO Cz 0.5–4 Hz ↓ 4–12 Hz ↓	EO Fz 4–12 Hz ↓
7	10	2; 1	61 (56–71)	57 (53–67)	67/60	63/56	EC Pz 6–10 Hz ↑	EO Cz 12–16 Hz ↑	EO O2 8–12 Hz ↑ 13–17 Hz↑
8	10	0; 5	74 (68–83)	63 (58–73)	73/81	63/68	EC C3 + C4 4–6 Hz ↓	EO Pz 4–5 Hz ↓ 8–11 Hz ↑	EO C3 12–15 Hz↑
9	9	2; 0	71 (66–80)	66 (61–75)	74/73	60/78	EC Pz 17–19 Hz↓	EO Pz 9–12 Hz ↑	EO CP4 17–20 Hz↓
10	11	1; 6	78 (72–87)	70 (65–79)	73/88	69/77	EC C3 4–8 Hz ↓	EO C3 4–8 Hz ↓ 11–13 Hz↑	EC C3 + C4 4–6 Hz ↓

[a]The protocols have been described as EO = eyes open, EC = eyes closed, followed by the skull location according to the 10–20 system, the frequency bands in cycles per second (Hz = Hertz), ↑ = reward large amplitudes, ↓ = reward small amplitudes.

TABLE 4. Performance on Neuropsychological Tests: *Z* Scores and Reliable Change Indices

Case ID	*Z*-score SA Dots speed/ error pre	*Z*-score SA Dots speed/ error post	*Z*-score SA Dots speed/ error FU	*Z*-score SSV 123 speed/ error pre	*Z*-score SSV 123 speed/error post	*Z*-score SSV 123 speed/ error FU	*Z*-score/ RCI Bourdon speed pre[a]	*Z*-score/RCI Bourdon speed post[a]	*Z*-score/RCI Bourdon speed FU[a]
1	–4.8/0.8	–10.0/–10.0	–4.6/0.7	–3.9/–5.2	–1.4/–2.8	–1.4/–4.2	–1.9/—	–1.2/1.3	–0.4/**2.9**
2	–3.1/–0.7	–0.5/0.2	–2.7/0.1	–0.9/–6.7	–0.4/–1.2	–0.6/–4.6	–1.1/—	0.8/0.7	0.6/1.1
3	–10.0/–10.0	–1.4/–1.5	–1.8/–1.6	–0.6/–0.8	0.1/–0.5	0.0/0.4	–1.8/—	–2.0/*–0.3*	–0.3/**3.0**
4	–10.0/–10.0	–1.7/–1.3	–1.2/–0.9	–0.8/–0.2	–0.8/–1.4	–1.1/–0.7	–3.9/—	–3.3/1.1	–2.7/**2.1**
5	–1.4/1.0	–0.7/0.7	–0.7/0.2	–0.5/–2.6	–0.4/–2.4	0.0/–4.2	–2.1/—	–1.8/0.6	–1.9/0.3
6	–10.0/–10.0	–10.0/–10.0	–2.3/–2.3	0.3/–1.2	–0.4/–1.8	0.4/–1.3	0.0/—	3.6/**4.8**	3.5/**5.0**
7	–10.0/–10.0	–1.6/–0.4	–1.4/0.9	0.3/–2.4	1.2/–1.1	–0.4/–0.6	–4.7/—	–1.4/**5.7**	0.8/**6.6**
8	–10.0/–10.0	–1.8/–4.9	0.4/–4.4	–0.8/–0.3	0.2/–2.4	–0.1/–0.6	–4.4/—	–1.5/**5.7**	–2.6/**3.4**
9	–10.0/–10.0	–10.0/–10.0	–1.5/–1.5	10.0/–2.8	–0.9/–2.1	–0.1/–2.7	–3.3/—	–0.6/**5.0**	–1.1/**4.0**
10	–1.0/0.8	–10.0/–10.0	–2.1/1.1	0.3/–1.2	–0.2/0.2	–0.5/0.6	–3.9/—	–5.4/*–2.5*	–3.3/1.1
N = 10 average	–7.0/–5.8	–4.8/–4.7	–1.8/–0.8	–0.9/–2.4	–0.3/–1.6	–0.4/–1.8	–3.3	–2.1	–1.7 M

Note. SA = Sustained Attention; FU = follow-up; SSV = Shifting Attentional Set–Visual; RCI = Reliable Change Index.

[a]Concerning the Bourdon-Vos, the RCIs were only calculated for the speed factor. Digits in bold represent a significant RCI (−1.96 < RCI < 1.96); italics represent a negative RCI. For the accuracy factor this was not possible due to the lack of psychometrical data. Unfortunately, no RCIs could be calculated for the ANT tasks (SAD, SSV1, SSV2, and SSV3).

TABLE 5. Neurofeedback Training and the Results on All Neuropsychological Tests, for Gender, Age, IQ Score, and Repeated Wechsler Intelligence Scale for Children (WISC-III) Score

		Pre	Post	Follow-up
	M	–3.26	–2.73	–1.21
	SD	2.76	2.50	0.61
	M	–3.14	–1.91	–0.85
	SD	2.19	1.69	0.22
≥11 years	*M*	–1.86	–2.85	–1.27
	SD	1.61	2.17	0.37
<11 years	*M*	–4.54	–1.79	–0.79
	SD	0.40	1.31	0.27
IQ > 70	*M*	–2.60	–3.07	–1.06
	SD	1.93	1.71	0.31
IQ < 70	*M*	–3.80	–1.57	–1.00
	SD	1.61	1.68	0.50
WISC-III	Total IQ	68.8	67.2	*N* = 9
WISC-III	Verbal IQ	70.3	68.3	*N* = 9
WISC-III	Performal IQ	72.6	73.7	*N* = 9

The second and third research questions were, What does the QEEG recorded children with ADHD problems look like? Does the QEEG of residential children with MMR normalize after treatment with NFB?

To answer these questions, the QEEG profiles of the studied children were compared with a group of normally gifted children from a reference group without ADHD and other symptoms, matched for age and gender. With eyes closed, there are hardly any detectable differences between children with MMR and children without symptoms. Only a difference in occipital delta is observed; in the group of children with MMR it is much higher than in the standard group. After NFB delta power changes toward the group norm; Group × Time interaction is significant, $F(2, 16) = 14.135$, $p = .000$, and the effect size is large (partial $\eta^2 = 0.64$). In theta, $F(2, 16) = 3.408$, $p = .058$, and alpha, $F(2, 16) = 1.382$, $p = .280$, no interactions were found. At pretreatment, beta1 in children with MMR is much higher than in the comparison group. In beta1, we see a normalization after training in the anterior regions: Figure 1, $F(2, 16) = 13.340$, $p = 0.000$, partial $\eta^2 = 0.63$.

With the eyes open we see a big difference for measurements in the delta range between children with MMR and children in the reference group. The difference gets smaller as time progresses. Posterior differences are smaller than central and frontal, $F(2, 16) = 7{,}849$, $p = .004$; partial $\eta^2 = .495$, see Figure 2. Multivariate analysis of theta shows a Group × Time interaction effect ($F = 9.8$ [2.16], $p = .002$, $\eta^2 = .51$). Pretreatment theta of the children with MMR is increased at F3, which normalized at follow-up. Alpha1 and beta1 power of the children with MMR with eyes open equals those of children from the comparison group. Alpha 1 Group × Time interaction was not significant, $F(2, 16) = 0.826$, $p = .456$ (partial $\eta^2 = .094$). Beta 1 Group × Time interaction

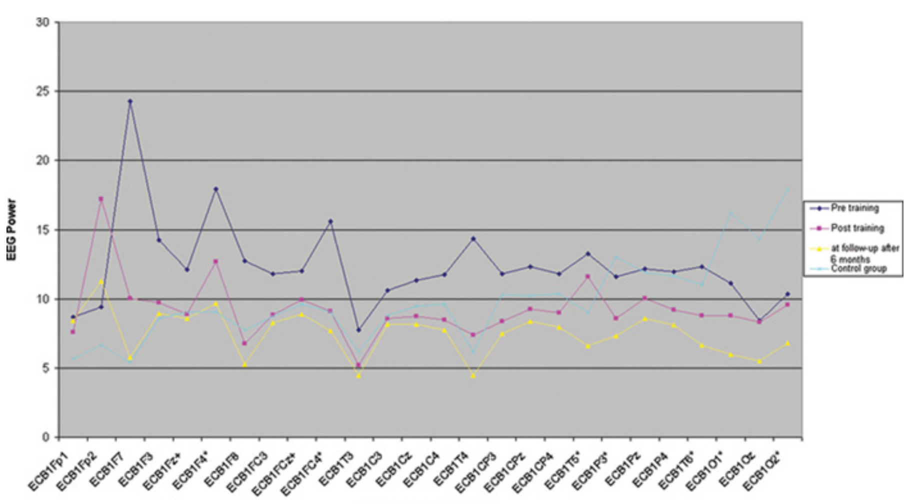

FIGURE 1. Beta1 power with eyes closed of children with MMR and a control group. (Color figure available online.)

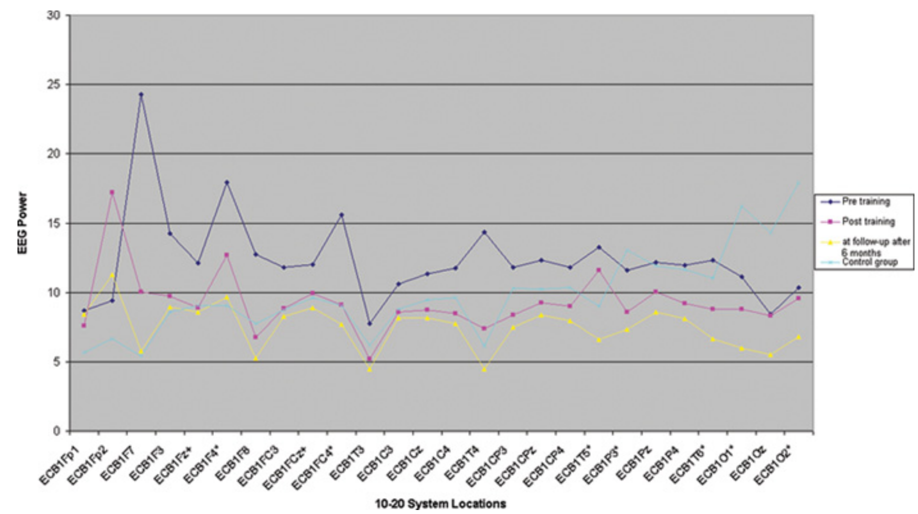

FIGURE 2. Delta power with eyes open of children with MMR and a control group. (Color figure available online.)

was significant, $F(2,\ 16) = 10.010$, $p = .002$. This was a strong effect (partial $\eta^2 = 0.56$).

The fourth and last research question examined in children with MMR and ADHD to which changes an NFB treatment leads in the subjective experience of their situation.

On average the children report a positive change in the perception of their situation from ''neutral'' after 10 NFB sessions to ''well'' after 30 sessions. When asked, ''Were you able today to keep your concentration at the task?'' the average subjective experience remains the same and is positive. When asked, ''Do you perceive anything from the treatment in your everyday life?'' the average subjective experience improves from ''neutral'' to ''good.''

To the question, ''How much does your ADHD bother you now?'' the average subjective experience improves from ''neutral'' to ''good.''

For the overall satisfaction with the care provider the children provide on average a good rating, both at the beginning and end of the study. There is a slight decrease, but the assessment is good. So, the children are happy with the care provider. This applies to all subquestions.

The average experience of participating in the study of the children improved from ''neutral'' at the start of the study to ''well'' at the end of the study. As the research progresses, children enjoy working in the investigation more. When asked, ''Did you feel at ease today?'' the assessment was well. To the question, ''How do you like to work with this investigation?'' the evaluation remains neutral.

DISCUSSION

The first research question was, Does attending an NFB treatment in residential children with MMR lead to improvement in performance on some neuropsychological tests (SAD and SSV ANT, Bourdon-Vos)? The attention and concentration are clearly improved. The task span and effort are generally increased. However, impulse control remains weak. Despite an increase in attention or focus, there is still a tendency to respond to distractors (the errors of the SAD and SSV Part 2 and 3 are still outside the average area—even though the margin of error in the SAD improved to nearly average), especially when the complexity increases. A possible explanation lies in the smaller working memory that is attributed to children with MMR (Molen, 2009; Ponsioen, 2010). At the moment when many stimuli need to be processed in working memory, children with MMR are more overloaded than children without mental retardation. This does not apply to the Bourdon Vos, because the errors for all time measurements are of average value. This task is more structured than the SAD, and the feeling of the closeness of the test administrator is also greater. Possibly this has a positive influence on the working style of the children. Another explanation is the better focus on instruction. Earlier studies have observed an increase in IQ attributed to this development (e.g., Lubar, Swartwood, Swartwood, & O'Donnell, 1995). This cannot be confirmed in our study. With caution, it seems that after the NFB treatment (comparing follow-up and posttreatment measures with pretreatment measures) there are no gender differences in success, children younger than 11 years of age benefit more than older children, IQs below 70 benefit more, and the intelligence almost remains the same.

The QEEG of the residential children with MMR showed, compared with a matched control group, mainly increased activity in the slow frequencies, especially in the delta frequency with eyes open. With eyes closed, more frontal EEG activity was seen in the beta1 range. Because the children in the pretreatment measurement were regularly restless, it cannot be excluded that this increased activity is associated with movement unrest. This concerns also the third research question: Does the QEEG of these children normalize after NFB treatment? We see that especially in the delta with eyes open and eyes closed beta with normalization occurs. This leaves open the possibility that the observed normalization is the result of a calmer behavior during the test. However, other research shows that NFB can lead to improved long-term performance (e.g., Gani, Birbaumer, & Strehl, 2008).

Thus the question remains, How it is that the kids are calmer? With this we touch upon a debate in the NFB literature. If the QEEG of children with ADD differs from children without attention, and NFB teaches them to influence it, how is it that we only get to see the limited change in QEEG after treatment? What is the meaning of the EEG in this? Ros, Munneke, Ruge, Gruzelier, and Rothwell (2010) showed in an EEG-TMS study that NFB affects the stimulus sensitivity of the cortex; this could be an explanation. On the other hand, especially at the beginning of the sessions, behavior problems surfaced. Then it was decided to involve clinicians in order to create a proper working attitude.

The last research question related to changes in the children's subjective perception of their situation. At the end of the study, the average score on the three facets of satisfaction measurement qualifies as "good." It should be noted that the results between the participants differ widely. The contact between the interviewer and children, the time of administration, and environmental influences seem to have affected the results of satisfaction questionnaires. The questions were not always clear to the children, often resulting in an oral presentation to be given by the interviewer. This decreased standardization. The interviewer was also actively involved in the research. This may have influenced the answers of the children.

This study has several restrictions that deserve discussion. First, it is a pilot study in a small group, and the selection may not be representative of the children of OBC Jan Pieter Heije. Moreover, there is no randomized control group. The chosen solution of a matched control group for the QEEG can only partially make up for this weakness. For firmer conclusions on the effect, a randomized placebo control design would be preferred, but that brings all sorts of other problems with it (see Lansbergen, van Dongen, Boomsma, Buitelaar, & Slaats, 2011). Furthermore, it proved impossible to collect sufficient data on the satisfaction of the parents and the development of the children outside the setting of the neuropsychological measurements. The changes in the natural context of the children thus remain unknown.

REFERENCES

Arns, M., de Ridder, S., Strehl, U., Breteler, M., & Coenen, A. (2009). Efficacy of neurofeedback in ADHD treatment: The effects on inattention, impulsivity and hyperactivity: A meta-analysis. *EEG and Clinical Neuroscience*, *40*, 180–189.

Barry, R. J, Clarke, A. R., & Johnstone, S. J. (2003). A review of electrophysiology in attention-deficit/hyperactivity disorder: I. Qualitative and quantitative electroencephalography. *Clinical Neurophysiology 114*, 171–183.

Biederman, J., Newcorn, J., & Sprich, S. (1991). Comorbidity of attention deficit hyperactivity disorder with conduct, depressive, anxiety, and other disorders. *American Journal of Psychiatry*, *148*, 564–577.

Breteler, M. H. M., Arns, M., Peters, S., Giepmans, I., & Verhoeven, L. (2010). Improvements in spelling after QEEG-based neurofeedback in dyslexia: A randomized controlled treatment study. *Applied Psychophysiology and Biofeedback*, *35*, 5–11.

Embregts, J. C. M. (2000). Reliability of the Child Behavior Checklist for the assessment or behavioral problems of children and youth with mental retardation. *Developmental Disabilities Research*, *21*, 31–41.

Fuchs, T., Birbaumer, N., Lutzenberger, W., Gruzelier, J. H., & Kaiser, J. (2003). Neurofeedback treatments for attention-deficit/hyperactivity disorder in children: A comparison with methylphenidate. *Applied Psychophysiology and Biofeedback*, *28*, 1–12.

Gani, C., Birbaumer, N., & Strehl, U. (2008). Long term effects after feedback or slow cortical potentials and theta and beta amplitudes in children with attention-deficit disorder (ADHD). *International Journal of Bioelectromagnetism*, *10*, 209–232.

Gevensleben, H., Holl, B. Albrecht, B., Schlamp, D., Kratz, O., Studer, P., … Heinrich, H. (2010). Neurofeedback training in children with ADHD: 6-month follow-up of a randomised controlled trial. *European Child and Adolescent Psychiatry*, *19*, 715–724.

Lansbergen, M. M., Van Dongen-Boomsma, M., Buitelaar, J. K., & Slaats, D. (2011). ADHD and EEG-neurofeedback: A double-blind randomized placebo-neurofeedback controlled treatment study. *Journal of Neural Transmission*, *118*, 275–284.

Levesque, J., Beauregard, M., & Mensour, B. (2006). Effect of neurofeedback training on the neural substrates of selective attention in children with attention-deficit/hyperactivity disorder: A functional magnetic resonance imaging study. *Neuroscience Letters*, *394*, 216–221.

Lubar, J. F., Swartwood, O. M., Swartwood, J. N., & O'Donnell, P. H. (1995). Evaluation of the effectiveness of EEG neurofeedback training for ADHD in a clinical setting as measured by changes in TOVA scores, behavioral ratings, and WISC–R performance. *Biofeedback and Self-Regulation*, *20*, 143–160.

Masterpasqua, F., & Healey, K. N. (2003). Neurofeedback in psychological practice. *Professional Psychology: Research and Practice*, *34*, 652–656.

Molen, M. J. van der. (2009). *Working memory in children with mild intellectual disabilities: Abilities and training potential*. Enschede, The Netherlands: PrintPartners Ipskamp.

Monastra, V. J., Lynn, S., Linden, M., Lubar, J. L., Gruzelier, J., & LaVaque, J. (2005). Electroencephalographic biofeedback in the treatment of attention-deficit/hyperactivity disorder. *Applied Psychophysiology and Biofeedback*, *30*, 95–114.

Monastra, V. J., Monastra, D. M., & George, S. (2002). The effects of stimulant therapy, EEG biofeedback, and parenting style on the primary symptoms of attention-deficit/hyperactivitry disorder. *Applied Psychophysiology and Biofeedback*, *27*, 231–249.

NVGz-nota (1995). *Vorm en kleur. Beleidsnota van de orthopedagogische centra voor licht verstandelijk gehandicapte jongeren van de Nederlandse Vereniging voor Gehandicaptenzorg* [Form and color. Policy document of the orthopedagogic centers for mimimallly mentally handicapped adolescents of the Dutch Society for Mental Handicap Care]. Utrecht, The Netherlands: NVGz.

Ponsioen, A. (2010). Een kind met mogelijkheden *[A child with opportunities]*. Houten, the Netherlands: Bohn Stafleu Van Loghum.

Ros, T., Munneke, M. A., Ruge, D., Gruzelier, J. H., & Rothwell, J. C. (2010). Endogenous control of waking brain rhythms induces neuroplasticity in humans. *European Journal of Neuroscience*, *31*, 770–778.

Scholte, E. M., & van der Ploeg, J. D. (2005). ADHD-vragenlijst (AVL) *[ADHD-questionnaire (AVL)]*. Houten, The Netherlands: Bohn Satfleu Van Loghum.

Veerman, J. W., Janssens, J. M. A. M., & Delicat, J. W. (2004). *Opvoeden in onmacht, of . . . ? Een meta-analyse van 17 methodieken voor intensieve pedagogische thuishulp bij normovertrendend gedrag [To educate in impotence, or . . . ? A meta-analysis of 17 methods for intensive pedagogical home help with norm exceeding behavior]*. Nijmegen, The Netherlands: Radboud Universiteit, ACSW/Praktikon.

Vos, P. G. (1992). Bourdon Vos test. Handleiding, tweede herziene uitgave *[Bourdon Vos test. Manual, second revised edition]*. Lisse, The Netherlands: Swets & Zeitlinger BV.

Widenfelt, B. M. van, Goedhart, A. W., Treffers, P. D. A., & Goodman, R. (2003). Dutch version of the Strengths and Difficulties Questionnaire (SDQ). *European Child and Adolescent Psychiatry*, *12*, 281–289.