Available online at www.sciencedirect.com

SCIENCE DIRECT®

Cognitive Brain Research 23 (2005) 287–292

COGNITIVE BRAIN RESEARCH

www.elsevier.com/locate/cogbrainres

Research report

The effects of alpha/theta neurofeedback on personality and mood

Joshua Raymond[a], Carolyn Varney[a], Lesley A. Parkinson[b], John H. Gruzelier[a,*]

[a]*Division of Neuroscience and Psychological Medicine, Imperial College London, St Dunstan's Road, London, W6 8RF, England*
[b]*Brainhealth, c/o The Diagnostic Clinic, 50 New Cavendish Street, London W1G 8TL, England*

Accepted 30 October 2004
Available online 4 February 2005

Abstract

Alpha/theta neurofeedback has been shown to be successful both in treating addictions and in enhancing artistry in music students. How its effects are mediated are not yet clear. The present study aimed to test the hypothesis that alpha/theta neurofeedback works inter alia by normalising extreme personality and raising feelings of well being. 12 participants with high scores for Withdrawal (as measured by the PSQ) were given either alpha/theta neurofeedback or mock feedback and their personality and mood were assessed. Withdrawal scores on the PSQ-80 were not found to change in either group but significant effects were found for the Profile Of Mood States (POMS), with real feedback producing higher overall scores than mock feedback (P = 0.056). Real feedback caused participants to feel significantly more energetic ($P < 0.01$) than did mock feedback. Sessions of real feedback made participants feel more composed ($P < 0.01$), agreeable ($P < 0.01$), elevated ($P < 0.01$) and confident ($P < 0.05$), whilst sessions of mock feedback made participants feel more tired ($P < 0.05$), yet composed ($P < 0.01$). These findings suggest that, whilst 9 sessions of alpha/theta neurofeedback was insufficient to change personality, improvements in mood may provide a partial explanation for the efficacy of alpha/theta neurofeedback.

Theme: Brainwave biofeedback
Topic: Mood enhancement

Keywords: Mood; Personality; Alpha/theta neurofeedback

1. Introduction

Neurofeedback is a means by which participants can learn voluntary control of the EEG and has been applied to a range of clinical conditions such as epilepsy, attention deficit hyperactivity disorder and the locked-in syndrome [1,17,19], and to optimise performance in healthy subjects [6]. Participants have electrodes attached to the head and EEG activity is converted to sounds or pictures on a screen and fed back to them. By reproducing internal sensations associated with different feedback configurations, participants learn to modulate their EEG activity. This is one of a series of investigations seeking to validate neurofeedback [11].

Alpha/theta neurofeedback allows one to gain control over low-frequency EEG activity and remain in a state of deep relaxation without falling asleep. It has been shown to have clinical benefits in the treatment of alcoholism [15] and crack cocaine abuse [2]. In healthy individuals, it has been shown to improve artistry in music students [7], as well as dance performance in a recent study of Ballroom and Latin university dance champions [16].

How alpha/theta training exerts its effects remains unclear. Peniston and Kulkosky's participants who had neurofeedback were tested with the Millon Clinical Multiaxial Inventory [14] and showed personality changes towards being more warm-hearted, intelligent, emotionally stable, socially bold, relaxed and satisfied. Bodenhamer-Davis and Callaway's participants showed comparable improvements on the Minnesota Multiphasic Personality Inventory [4]. Although Egner and Gruzelier did not employ measures of personality in their study, participants who had alpha/theta neurofeedback reported feeling better in themselves after training [6].

* Corresponding author. Fax: +44 20 8846 1670.
E-mail address: j.gruzelier@imperial.ac.uk (J.H. Gruzelier).

0926-6410/$ - see front matter © 2004 Elsevier B.V. All rights reserved.
doi:10.1016/j.cogbrainres.2004.10.023

It is possible that personality change is one mediating factor in the effectiveness of alpha/theta training. Research into personality change with alpha/theta neurofeedback has always involved clinical populations with highly deviant personality traits.

It is possible that alpha/theta training may also exert its effects through enhancing well-being, with the consequence that addicts lose their drug habit; mood may be a mediating factor in its success. At the same time, the results of Egner and Gruzelier [7,10] indicate that the improvements in artistry in music performance could not simply be attributed to anxiety reduction, though some long-term EEG changes were in keeping with reduced anxiety [8]. Furthermore, Egner et al. [9] compared real with mock, or noncontingent, alpha/theta neurofeedback (in which one is played the sounds from someone else's session, believing them to be one's own) and found no significant difference in levels of activation between the two groups, with both groups becoming less activated as assessed by the Thayer activation and deactivation scales [18]. Activation/anxiety is, however, only one measure of mood.

The present study aimed firstly to look for personality change in withdrawal in the normal population, in order to see how alpha/theta training might benefit personality in healthy individuals. The personality scale chosen was the Withdrawal scale of the Personality Syndrome Questionnaire (PSQ-80; [12]). This measures three subscales of avoidant behaviour, associated with withdrawn schizotypy: Social Withdrawal, Affective Withdrawal and Social Anxiety. It was hypothesised that alpha/theta neurofeedback would make highly withdrawn participants less withdrawn via relaxation and positive imagery.

The present study aimed secondly to test the effects of real versus mock neurofeedback on a more comprehensive mood measure: the Profile Of Mood States (POMS; [13]). This has subscales of composed–anxious, agreeable–hostile, elevated–depressed, confident–unsure, energetic–tired and clearheaded–confused.

2. Method

2.1. Participants

Participants were 12 second-year medical students who scored in the top 30% on the Withdrawal scale of the PSQ-80. They were invited to take part in a study examining the effects of neurofeedback on personality without being told what aspect of personality was being looked at. Participants were randomly allocated into Real and Mock neurofeedback groups.

2.2. Procedure

Neurofeedback was carried out using the Brainmaster (Ohio, USA) with the active electrode placed at Pz (following [7,8]) and referenced to the ear. Skin was prepared with NuPrep and electrodes attached with Ten20 conductive paste. Impedances were checked by visual inspection of the raw signal. Participants were seated in a comfortable chair and asked to complete the POMS. Before the first session, the underlying principles of neurofeedback were explained to the participants who were instructed to close their eyes and relax as deeply as possible, without falling asleep. All feedback was carried out with eyes closed. A 2-min, eyes-closed, feedback-free run was carried out to assess the individual's dominant alpha frequency (IAF), as recommended by Doppelmayr, Klimesch, Pachinger and Ripper [5]. The mean modal alpha frequency was extracted from this initial run and an alpha band was calculated as 1.5 Hz on either side of this value. Theta was defined as a 3-Hz band whose median frequency lay 4 Hz below the IAF. For example, if a participant had an IAF of 10 Hz, alpha was defined as 8.5–11.5 Hz and theta as 4.5–7.7 Hz.

Feedback began after this initial assessment and took the form of sounds presented to participants via the computer's speakers. When participants' alpha was higher than theta, a "babbling brook" sound was heard, and when theta was higher than alpha, this changed to "crashing waves". Each band also had an amplitude threshold, and supra-threshold bursts of alpha or theta were rewarded by a high- or low-pitched gong sound, respectively. These thresholds were set manually by the experimenter and updated such that alpha and theta amplitudes were over these thresholds approximately 60% of the time. Before each session of neurofeedback, participants were told that the goal state was to have theta higher than alpha and so to hear the "crashing waves" sound and more of the low gong than the high. Participants were told that, when they could hear the waves, they should visualise themselves being the sort of person they most wanted to be and solving problems in the best way possible. This instruction was based on the idea that guided imagery in a state of deep relaxation might help mediate change (e.g., [3]). The participants' goal was to elevate theta over alpha but they were not told to "try" to do anything as effort tends to detract from the experience of alpha/theta neurofeedback. Participants were told that all the sounds were good but that they could expect to hear more of the theta sound over time as they became more relaxed.

Each session lasted for 20 min, with EEG data being gathered in twenty 1-min "runs". The feedback sounds would then be faded out and the participant brought gently to full wakefulness. Participants were constantly monitored by the experimenter for excessive delta activity or sleep-like behaviour, whereupon they would be tapped gently on the knee until they acknowledged that they were awake. The only difference between the feedback groups was that the Real group heard sounds relating to their own brain activity, but the Mock group heard a variable "demonstration" session, contained within the feedback software, that involved the same basic sounds but bore no relation to brain activity. Participants were given the PSQ-80 before and after training and the POMS before and after each session. Participants were given two sessions of neurofeedback per week for 5 weeks.

After all the sessions were complete, participants were asked to rate how well they felt they had been able to control their EEG on a scale of 1–5, with 1 representing "not at all" and 5 "extremely well". This was to make sure that participants in the Mock group could not tell that they were receiving mock feedback.

3. Results

3.1. Between-group comparisons

There was no significant difference between the groups at pre-testing for age [Real mean = 24.3 (7.94) years, Mock mean = 19.83 (1.16) years], PSQ Withdrawal score [Real mean = 9.17 (2.32), Mock mean = 10.34 (2.07)] or total POMS score [Real mean = 40.86 (24.92), Mock mean = 38.32 (32.46)].

3.2. Perceived control of EEG

The mean perceived control score was 3.00 (0.89) for the Real group and 2.83 (0.98) for the Mock group. A Mann–Whitney U test showed no significant difference between these scores (z = 0.341, P = 0.73). Participants in both groups felt equally able to control their EEG, suggesting that the Mock feedback was not recognised as such.

3.3. Personality

Mean pre-training scores on the PSQ-80 were 9.17 (2.32) for the Real group and 10.34 (2.07) for the Mock group. Mean post-training scores were 9.67 (3.67) for the Real group and 8.00 (4.54) for the Mock group. A 2 × 2 (time × group) ANOVA found no main effect of time (F = 0.926, P = 0.358) and no interaction (F = 2.213, P = 0.168).

3.4. Mood

Mean pre-session POMS scores were 40.86 (24.92) for the Real group and 38.32 (32.45) for the Mock group. Mean post-session POMS scores were 50.87 (20.26) for the Real group and 40.40 (25.06) for the Mock group. There was an approximately 10-point increase for the Real group and a 2-point increase for the Mock group.

A 2 × 2 (time × group) ANOVA found a significant main effect of time (F = 7.352, P < 0.01), indicating that sessions both of real and mock feedback improved participants' moods, and a borderline significant interaction effect between Group and Time (F = 3.748, P = 0.056). A paired-samples t test on the Real group's scores yielded a significant difference (t = 3.841, P < 0.01), indicating that sessions of real feedback improved mood significantly. There was no change in the Mock group (t = 0.478).

In the light of this difference between the groups, the subscales of the POMS were examined (see Fig. 1). 2 × 2 (time × group) ANOVAs were carried out on the subscales. Interaction terms and significances are shown in Table 1. These indicate that the Real group felt significantly more energetic and showed a trend towards feeling more confident than the Mock group. The Mock group in turn showed a tendency to become more composed than the Real group, but it should be noted that both groups' composure significantly improved (see Figs. 1 and 2). Paired-sample t tests showed the Real group to have improved significantly on subscales composed_anxious, agreeable_hostile, elevated_depressed, confident_unsure and energised_tired. The Mock group by contrast improved only on the composed_anxious subscale and showed a significant move towards tiredness on the energised_tired scale.

It is unlikely that the lack of mood change in the Mock group was due to frustration caused by lack of perceived control over the feedback sounds. Upon debriefing, none of the participants in the Mock group had any idea that their feedback had not been genuine.

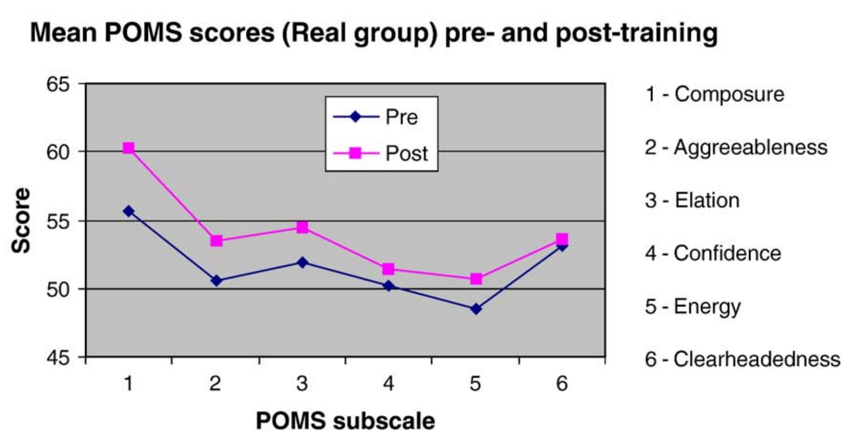

Fig. 1. Mean (±standard error of the mean) scores on POMS subscales pre- and post-training for the Real group. A more positive score indicates feeling more composed, agreeable, elevated, etc.

Table 1
Group × time interaction terms and paired-sample t test scores from POMS subscales

Subscale	F value	Real t score	Mock t score
Composed–anxious	−3.35 (0.063)	5.624 (<0.01)**	7.32 (<0.01)**
Agreeable–hostile	2.01 (0.159)	3.735 (<0.01)**	2.000 (0.051)
Elevated–depressed	2.12 (0.149)	3.266 (<0.01)**	0.910 (0.367)
Confident–unsure	3.39 (0.069)	2.239 (0.029)*	−0.845 (0.402)
Energetic–tired	13.37 (<0.01)**	2.918 (<0.01)**	−2.403 (0.020)*
Clearheaded–confused	2.36 (0.114)	0.872 (0.387)	−1.295 (0.201)
Total POMS score	3.748 (0.056)	3.841 (<0.01)**	0.478 (0.635)

Significance values are shown in parentheses.
* $P < 0.05$.
** $P < 0.01$.

3.5. Neurofeedback learning

The mean theta/alpha (t/a) ratios for all the Real participants were calculated for each of the twenty 1-min time periods in all the sessions. These data were then pooled together across sessions and participants and the mean t/a ratio for each time period was calculated (see Fig. 3). A Spearman's rank correlation showed that theta/alpha ratios rose significantly with time within sessions (Spearman's rho = 0.944, $P < 0.01$).

The mean t/a ratio for each session was calculated for the Real group. A Spearman's rank correlation showed that mean theta/alpha ratios did not change significantly across sessions (Spearman's rho = −0.188, $P = 0.603$).

4. Discussion

4.1. Personality

Neither real nor mock feedback influenced the Withdrawal scale of the PSQ-80. This was not in line with the findings of Peniston and Kulkosky [15] or Bodenhamer-Davis and Callaway [2]. There are two possible reasons for this discrepancy, one methodological and one theoretical. The first, methodological, reason is the small number of sessions used in the present study: an average of nine per participant rather than the twenty used in previous studies. It may be that personality is simply too robust to change over the course of nine sessions within 5 weeks whilst students were engaged in coursework. It may also be the case that personality change was facilitated in the aforementioned studies by the inclusion of other therapeutic interventions such as counselling, which were absent in the present study.

The theoretical reason for the discrepancy is that both Peniston and Kulkosky's [15] and Bodenhamer-Davis and Callaway's results were obtained with drug-addicted populations, who had both highly deviant personalities and great motivation to reform, having volunteered themselves for rehabilitation. By contrast, the present study used healthy students who, whilst in the top 30% of their year group for Withdrawal as measured by the PSQ-80, could not be said to be highly deviant.

4.2. Mood

Sessions of real feedback produced, on average, greater improvements in mood than did sessions of mock feedback. These changes were most notable in the subscale "energised–tired" with participants having real feedback feeling much more energised after feedback than those having mock feedback. They also rated their mood as more

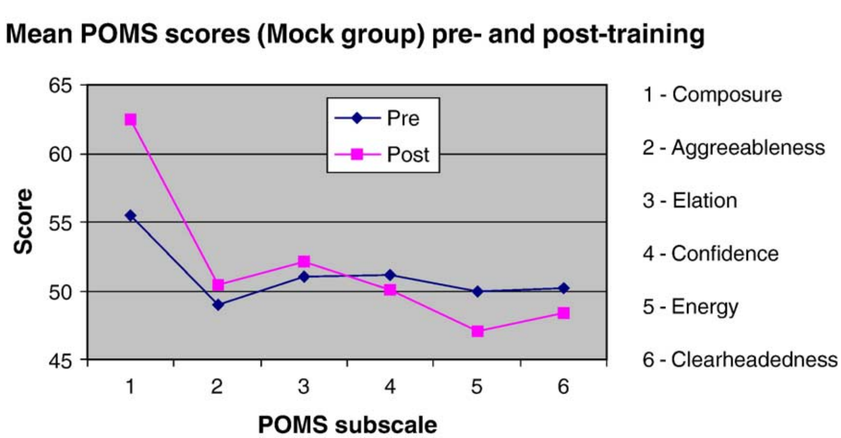

Fig. 2. Mean (±standard error of the mean) scores on POMS subscales pre- and post-training for the Mock group. A more positive score indicates feeling more composed, agreeable, elevated, etc.

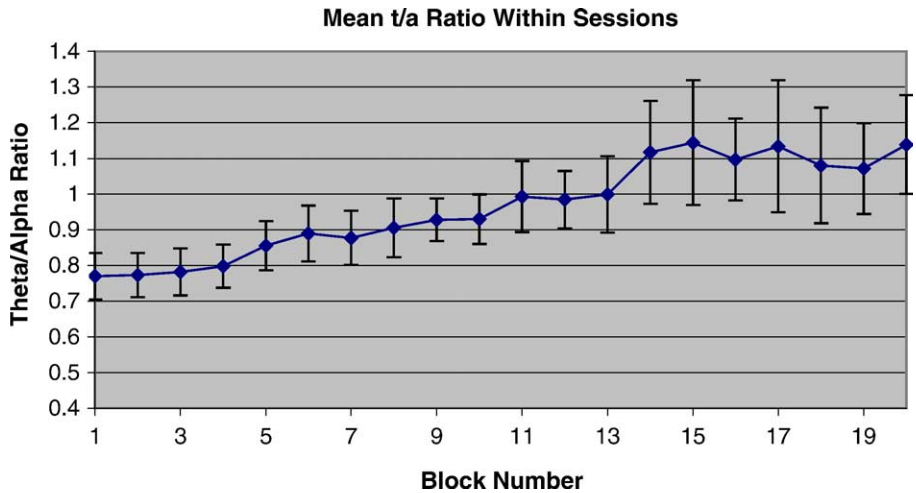

Fig. 3. Mean (±standard error of the mean) theta/alpha ratios of the Real group for 1-min periods averaged across sessions. The theta/alpha ratio rose progressively within sessions (Spearman's rho = 0.944, $P < 0.01$).

elevated. Furthermore, participants in the Real group reported feeling more composed, agreeable and confident. By contrast, the mock group reported feeling more composed but less energised, with no significant changes on the other subscales. This provides strong evidence to suggest that alpha/theta neurofeedback is a mood-enhancing and energising experience, and that this is not attributable to relaxation or the pleasant sounds alone, as these were heard in the Mock condition, after which participants reported feeling more deactivated.

Relevant to our personality hypothesis was the trend for real feedback to produce greater feelings of confidence than mock feedback, and for real feedback to increase feeling agreeable. Inasmuch as confidence and sociability can be seen as the opposite of withdrawal, an increase in feeling confident and agreeable can be seen as participants' moving towards the goal state of becoming less withdrawn. This lends support to the idea that neurofeedback is moving people towards a change in personality but that personality is simply too robust to change quickly within 5 weeks.

Both groups became more composed, but the Mock group became more composed than the Real group. This trend could be put down to a generic relaxation effect and is wholly consistent with the evidence of Egner and Gruzelier [7,10] where the enhancement in music performance specific to alpha/theta training could not be attributed to a reduction in performance anxiety because anxiety reduction was common to the range of interventions applied, including mental skills training, aerobics and the Alexander Technique, as well as beta and "sensory motor rhythm" training.

4.3. Neurofeedback learning

There was a strong tendency for theta/alpha (t/a) ratios to rise within sessions in the Real group, in confirmation of Egner et al. [8,9]. This represents participants' entering a state of deep relaxation. These within-session changes do not represent falling asleep. Participants were monitored both behaviourally and with the EEG to ensure that they did not fall asleep and none of them reported having done so after any of the training sessions. There was no significant change in t/a ratios across sessions, as was also found by Egner and Gruzelier [8].

In conclusion, alpha/theta neurofeedback training over 5 weeks was not shown to alter personality in healthy participants. There were, however, differences in the POMS profile between real and mock feedback such that real feedback produced feelings of energy and confidence that mock feedback did not. Real feedback also produced a generally more positive mood than did mock feedback. This suggests that performance improvements such as those shown by Egner and Gruzelier [7,10] could be due in part to enhancements of energy and confidence caused by neurofeedback training, though these are unlikely to provide a sufficient explanation for the professionally significant enhancements they found in artistry in music performance [10].

Acknowledgment

The authors would like to thank Brainhealth for their generous support and sponsorship of this research.

References

[1] N. Birbaumer, N. Ghanayim, T. Hinterberger, I. Iversen, B. Kotchoubey, A. Koubler, J. Perelmouter, E. Taub, H. Flor, A spelling device for the paralysed, Nature 398 (1999) 297–298.

[2] E. Bodehnamer-Davis, T. Callaway, Extended follow-up of Peniston protocol results with chemical dependency, Presentation at the International Society of Neuronal Regulation, September, Houston, Texas, USA, 2003.

[3] T.H. Budzynski, Tuning in on the Twilight Zone, Psychology Today, 1977 (August).

[4] J.N. Butcher, W.G. Dahlstrom, J.R. Graham, A.M. Tellegen, B. Kaemmer, MMPI-2: Manual for Administration and Scoring, University of Minnesota Press, Minneapolis, 1989.

[5] M. Doppelmayr, W. Klimesch, T. Pachinger, B. Ripper, Individual differences in brain dynamics: important implications for the calculation of event-related band power, Biol. Cybern. 79 (1) (1998) 49–57.

[6] J. Edge, L. Lancaster, Enhancing musical performance through neurofeedback: playing the tune of life, Transpers. Psychol. Rev. 8 (2004) 23–35.

[7] T. Egner, J.H. Gruzelier, Ecological validity of neurofeedback: modulation of slow-wave EEG enhances musical performance, NeuroReport 14 (2003) 1225–1228.

[8] T. Egner, J.H. Gruzelier, The temporal dynamics of electroencephalographic responses to alpha/theta neurofeedback training in healthy subjects, J. Neurother. 8 (1) (2004) 43–58.

[9] T. Egner, E. Strawson, J.H. Gruzelier, EEG signature and phenomenology of alpha/theta neurofeedback training versus mock feedback, Appl. Psychophysiol. Biofeedback 27 (4) (2002) 261–270.

[10] J.H. Gruzelier, T. Egner, Physiological self-regulation: Biofeedback and neurofeedback, in: A. Williamon (Ed.), Musical Excellence, Wiley, Chichester, 2004, pp. 197–219.

[11] J.H. Gruzelier, T. Egner, Critical validation studies of neurofeedback, Child Adolesc. Psychiatr. Clin. N. Am. 14 (2005) 83–104.

[12] J.H. Gruzelier, G.A. Jamieson, R.J. Croft, J. Kaiser, A.F. Burgess, Personality Syndrome Questionnaire: Reliability, Validity and Experimental Evidence, 2004 (Submitted for Publication).

[13] D.M. McNair, M. Lorr, M.F. Droppleman, Profile of Mood States Manual, Educational and Industrial Testing Service, San Diego, 1992.

[14] T. Millon, Millon Clinical Multiaxial Inventory-II, 2nd ed., National Computer Systems Inc., Minneapolis, 1987.

[15] E.G. Peniston, P.J. Kulkosky, Alcoholic personality and alpha–theta brainwave training, Med. Psychother. 3 (1990) 37–55.

[16] J. Raymond, I. Sajid, L.A. Parkinson, J.H. Gruzelier, Biofeedback Improves Performance in Ballroom and Latin Dancers, 2004 (In Press).

[17] B. Rockstroh, T. Elbert, N. Birbaumer, P. Wolf, A. Duchting-Roth, M. Reker, I. Daum, W. Lutzenberger, J. Dichgans, Cortical self-regulation in patients with epilepsies, Epilepsy Res. 14 (1993) 63–72.

[18] R.E. Thayer, Measurement of activation through self-report, Psychol. Rep. 20 (1967) 663–678.

[19] D. Vernon, A. Frick, J.H. Gruzelier, Neurofeedback as a treatment for ADHD: a methodological review with implications for future research, J. Neurother. 8 (2004) 53–82.