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Stress Reduction by Technology? An Experimental Study into the Effects of Brainmachines on Burnout and State Anxiety

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Stress and burnout are widely acknowledged as major causes of societal and individual problems in the Western world. In order to reduce material and immaterial expenses, increased efforts are made to enhance relaxation and stress reduction. Based on neuropsychological findings, alternative ways have been explored, one of them being the application of so-called brain wave synchronizers, which are said to induce a relaxation response by entraining alpha brain-wave activity (8–13 Hz) through audiovisual stimulation. A double blind, quasi-experiment was conducted among employees at a Dutch addiction care center to investigate the possible effects of two distinct brainmachine programs on burnout and anxiety. Subjects in both conditions showed a significant, immediate decrease in state anxiety as assessed by Spielberger's State-Trait Anxiety Inventory (STAI) and reported a range of subjective effects. However, a long-term effect on burnout, as measured with Maslach's Burnout Inventory (MBI-NL), could not be established. A long-term effect on anxiety (STAI), as investigated by interrupted time-series measurement, could not be established either. These and other findings suggest that the major claims with respect to these machines cannot hold over time, although pleasant short-term effects do occur. Individual differences in baseline responsivity, the stable character of burnout dimensions, or the ill-defined nature of relaxation, or a combination of these, may account for these results.

KEY WORDS: relaxation; burnout; anxiety; stress; brain wave synchronizers.

INTRODUCTION

Stress has become a much discussed concept. This may be due in large part to increasing evidence of its role in the origin and development of a range of somatic disorders such as diabetes, cardiovascular illnesses, and infections. It is also clear that stress is associated with psychosomatic complaints, depression, and anxiety (Van Eck, 1996). During the last few decades, The Netherlands, like most Western countries, has witnessed an enormous increase in unfitness and absenteeism at work due to psychological disorders related to stress. According to data of the independent National Institute for Statistical Information of

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The Netherlands (CBS), a mean 10% of the Dutch working population suffers from burnout, due to emotional exhaustion. Prevalence of work-related stress problems is particularly high among employees in the educational and catering sectors as well as the health and social welfare services (Centraal Bureau voor de Statistiek [CBS], 1998). Estimates of the societal cost of stress-related unfitness and absenteeism range from $2 to 20 billion/year. These tendencies have led to increased efforts to enhance the mental and physical health of employees. In The Netherlands, relaxation, stress reduction, and the "de-acceleration" (a term coined by Dr. Borst, Minister of Health, Welfare and Sports) of modern life have become the subject of public debate.

During the seventies, the concept of *burnout* emerged in the United States. It referred to work-related mental exhaustion. Burnout especially affects employees who work in "contactual professions," referring to their intense relationship with allegedly "difficult" populations. Examples include police officers, psychiatric nurses, workers in addiction treatment settings, and general practitioners. A characteristic feature is the strong entanglement of person and profession: one's personality is one's most important working tool (Schaufeli, Maslach, & Marek, 1993). Since the 1980s burnout entered the Dutch vocabulary. Today the association between job satisfaction, workload, absenteeism and burnout is widely acknowledged.

The search for ways that reduce work stress is breaking new ground. Neuropsychological studies have shown associations between brainwave activity and relaxation (Morse, 1993). The summarized activity of groups of neurons, or neural networks, is measurable as frequency patterns of the EEG. The increase in frequency corresponds with the rise in central nervous activation, and brain-wave activity tends to relate to certain psychophysiological conditions (Niedermeyer & Lopez da Silva, 1987). The different frequencies are generated from different locations in the brain and are distributed to several other areas. Apart from such natural, endogenous activity, brain waves may be induced through exogenous, sensory stimulation (Koukou, Lehmann, & Angst, 1980; Narici et al., 1990; Regan, 1972; Rockstroh, Elbert, Birbaumer, & Lutzenberger, 1982).

Photic stimulation (stimulation by rhythmic light impulses) is probably the most studied and most effective induction method. It entrains a "frequency following response" in cortical activity, meaning that the endogenous activity already present in this area synchronizes with the frequency offered. Since the 1930s, this phenomenon has been used to study epilepsy and has found many practical applications. Inducing alpha activity has been the main focus of interest due to its association with relaxation and its instrumental use for therapeutic purposes. Auditory stimulation has been studied as well (McCraty, Atkinson, Rein, & Watkins, 1996), although it is mostly combined with photic stimulation (Bridgewater, Sherry, & Marczynski, 1975). Not everyone naturally generates alpha activity. It is estimated that 10% show little or no activity in this bandwidth. Although most people show these frequencies with their eyes closed, a small percentage may produce 7–13 Hz with their eyes open. A relation might exist between one's capacity to generate alpha or theta activity and the extent of hypnotizability. Compulsive or neurotic personalities are assumed to be less responsive to photic stimulation (cf. Morse, 1993).

Devices to induce brain-wave activity have been made available in the commercial market under the name of "brainmachines." These typically deliver monotonous, staccato beeps through a pair of headphones, and short, monochrome light impulses are administered via a pair of goggles. The computer-generated audiovisual impulse patterns are especially designed to induce either a general or a specific relaxing effect in the alpha bandwidth. This is the frequency that is associated with relaxation, rest, or serenity, mental states that may otherwise be achieved through regular exercise or meditation (Brown, 1980). Young people may use brainmachines in a recreational and explorative way; for example, in the European rave scene, brainmachines can be found at raves to "chill out" or to experience altered states of consciousness by "digital drugs" (as they are sometimes—deceptively—called).

Empirical evidence exists for the assumption that sensory stimulation may be instrumental for relaxation. Morse (1993) cites several practical applications and positive results from obstetrics, where brain-wave synchronizers have been used to relieve pain during labor and delivery. He also mentions their use in anesthesiology and in the treatment of hypertension and migraine. Research in dental surgery (e.g., root canal procedures) showed considerable anxiety- and stress reduction among subjects experimentally exposed to a brain wave synchronizer. Through its use, patients suffering from chronic pain were able to improve their relaxation and decrease their preoccupation with pain. The attained relaxation has been established not only subjectively, but also by measuring changes in biological parameters such as blood pressure, heart rate, galvanic skin response, and neurotransmitter levels (Shealy et al., 1990). In general, negative side effects are not reported in subjects, if those possessing contraindications are excluded. These consist of the (family) presence of epilepsy, various heart conditions, the use of pacemakers, and the existence of certain psychiatric or neurological disorders.

Professional application of brainmachines marginally takes place in various treatment settings in order to reach the desired positive effects through relaxation. They have been used (experimentally) in the addiction services, in stress management, and in the treatment of headache and hypertension (cf. Bierman & Julien, 1997; Fahrion, Walters, Coyne, & Allen, 1992). Professionals working with brainmachines report positive anecdotal effects on stress, anxiety, and sleep disorders (Herreijgers, personal communication, Boumanhuis (Rotterdam Addiction Services), 1997), although scientific evidence for their efficacy is difficult to find. Available studies typically suffer from a lack of methodological rigor and scientific objectivity. From our own pilot work (Ossebaard & Van Daalen, 1996), it appeared that subjects reported significantly lower levels of state anxiety after using the brainmachine. Subjects stated they felt "better" and "more relaxed" as well. An earlier study by De Nicholas (1992) showed similar results. More substantial evidence for the potential of brainmachines may be derived from medical and psychological research concerning phototherapy, relaxation techniques (musical, subliminal, or hypnotic), and bio- and neurofeedback methods (cf. Brockopp, 1984; Brown, 1977; Dodge, 1991; McCraty et al., 1996; Morse, 1993). Results of these and other studies legitimize the assumption that brainmachine sessions may actually have a stress-reducing effect. Dutch empirical evidence against this assumption entails an investigation of the influence of brain-wave synchronizers on sleep disorders among alcohol addicts (Bierman & Julien, 1997) and a study on memory and learning tasks among students (Groeneweg, Conrad, Wolters, & Wagenaar, 1995). In both studies unequivocal effects could not be found.

The present study assessed relaxation effects following a series of sessions with a brain-wave synchronizer, among employees of a large Dutch addiction service center. Relaxation has been operationalized as a decrease in burnout and state anxiety scores as compared to pretest scores. These concepts respectively refer to a chronic, structural presence of work-related fatigue, and momentary, situational stress. It was hypothesized that after the intervention, all experimental subjects, on average, would feel more relaxed as expressed in (a) a significant decrease in mean scores on three burnout dimensions and (b) a significant decrease in mean scores on state anxiety. A second research question concerned a discriminative effect of exposure to a program that allegedly induced beta activity (13–25 Hz). Beta waves are associated with normal alertness and wakefulness. It was expected that after the intervention, the subjects in the alpha condition on the average would feel more relaxed than subjects in the beta condition, as expressed in (a) significantly lower mean scores on three burnout dimensions and (b) a significantly lower mean score on state anxiety. A nonintervention control group was included for comparison. No changes in burnout scores were expected for this condition.

METHOD

An experimental, double blind, matched design was the framework of this study. Synchro-Energizers (model 4X Satellite) were the brain-wave synchronizers employed.

Population

The study was conducted among 42 employees of a large addiction care center in an urban area in The Netherlands. They responded to a call for participation, supported by their employer, and were briefed on the research, both orally and in writing. They cooperated on a voluntary basis after signing an informed consent form. Furthermore, they were made aware that they could immediately end their participation if they wished so. There were 29 (69%) female and 13 (31%) male participants. Mean age of the subjects was 39.7 years ($SD = 8.7$); they were employed in the addiction services for an average of 7.7 years ($SD = 4.4$). The mean percentage of their working hours spent on direct client contacts was just over 46%. Half of them worked with clients over 45% of their time. Their stress levels (i.e., burnout scores, see below) corresponded to normative scores from people in other contactual professions, such as nurses and general practitioners, and were relatively high with regard to the general population.

The response from a written survey among 185 colleagues from the same center was used to comprise a control group, made up of 16 (64%) women and 9 (36%) men, mean age 38.3 years ($SD = 6.4$), working 7 years on average ($SD = 4.2$) in the addiction care sector. Over half of them worked a mean 40% ($SD = 31.1$) of their time with clients, half of them worked over 40% of their time with clients. No significant background differences existed between the control and the experimental groups.

Instruments

Burnout was assessed by the Dutch version of Maslach's Burnout Inventory (MBI-NL). The MBI is a valid and reliable instrument, possessing good psychometric qualities and as such it serves well to measure burnout. The 20-item, self-report questionnaire is especially appropriate for people working in contactual jobs (Schaufeli & Van Dierendonck, 1993). It delivers three scores for the following dimensions: Emotional Exhaustion, Depersonalization and Personal Competence.

Emotional Exhaustion (EE) refers to the feeling of being "completely worn out," having used up all energy resources and not being able to recharge the batteries once more.

Depersonalization (D) entails feelings of estrangement expressed in a cold, cynical, and indifferent attitude towards the people one is working with (note that it does not involve the psychiatric definition of extreme alienation from oneself). The loss of Personal Competence (PC) involves the feeling of poor performance at work and related feelings of insufficiency (Schaufeli & Van Dierendonck, 1994).

Subjects indicate on a 6-point Likert type scale (never . . . –regularly . . . –daily) how often a statement applies to their working experience. For instance,

> "At the end of the day I feel empty" (EE);
> "I don't really care what happens to some of my clients" (D); or
> "I know how to adequately solve my client's problems" (PC).

To avoid any negative connotations, we renamed the MBI-NL as the "Work Perception Questionnaire" ("Werkbelevingslijst"), also adding a series of background variables.

The second instrument utilized was Spielberger's State-Trait Anxiety Inventory (STAI, Dutch version), in particular the part dealing with State Anxiety (Van der Ploeg et al., 1980). State anxiety is related to the immediate situation and the extent of a subject's relaxation. As such it discriminates from Trait Anxiety, which refers to a dispositional dimension. The self-report scale has a sufficient test–retest reliability, and it correlates well with several other instruments for stress assessment. Subjects indicate on a 4-point scale the extent (not at all . . . – . . . a lot) of relaxation at that very moment, as implied by questions like

> "I feel comfortable";
> "I am worried about nasty things that may occur"; or
> "I feel tense."

To investigate subjective experiences in a qualitative way, all participants were given a small diary and were requested to note any event they themselves related to their sessions, during the experimental 8-week period.

Procedure

Two weeks prior to the actual intervention, burnout among subjects was assessed by the MBI-NL. They were consequently matched on MBI scores and sex, and randomly assigned to the two experimental conditions. Two weeks after the experimental 8-week period, the MBI was again administered. The STAI was administered at four points during the experimental period, both immediately before and just after a session. In this way four differential STAI scores were collected for every subject.

In the first experimental condition, subjects engaged in two sessions a week, for 8 weeks, with the Synchro-Energizer standard program 4: "Deep relaxation and revitalization," a computer architecture designed to induce alpha brain-wave activity. It begins with a 5-min audiovisual stimulation at 30 Hz, followed by another at 10 Hz for 35 min. The second experimental condition consisted as well of a 40-min Synchro-Energizer session, twice a week, for of 8 weeks. This program was, however, especially designed to induce beta activity, beginning with a 5-min audiovisual stimulation at 30 Hz, followed by two more, at 25 Hz for 5 min and at 16 Hz for 30 min.

All sessions took place in quiet rooms and were accompanied by ambient music. Subjects reclined in a comfortable chair. A session leader was present to assist and to administer the STAI questionnaires four times before and after the sessions. Neither the session leaders nor the subjects were aware of the type of the experimental condition the participants were assigned to. The sessions occurred in the afternoon (during working hours) at three different locations. Attempts were made to keep other circumstances as identical as possible for the two experimental conditions.

MBI Questionnaires were sent to 185 colleagues of the subjects with the request to complete them anonymously under conditions of complete confidentiality. From the responses received (23%), a group was formed by matching independent variables (sex and age) and MBI scores with those for the two experimental groups. From this pool, a select sample was taken ($n = 25$; 9 male and 16 female persons) to compose a control group. An attempt to investigate the considerable nonresponse pool resulted in no substantial increase in the number of respondents. No intervention took place in the control group. After 10 weeks, the respondents received the MBI for the second and final time.

From the initial 42 participants (alpha condition $n = 20$; beta condition $n = 22$), those subjects who had participated in seven or more sessions were selected. An assumption made here was that at least seven sessions were required to cause any measurable effect, a premise that had been suggested by professionals experienced with brainmachines. These subjects ($n = 25$) appeared to be equally divided between the alpha condition ($n = 13$; 5 male and 8 female) and the beta condition ($n = 12$; 3 male and 9 female). They did not differ from those who participated in seven sessions or less. Thus, data analysis was limited to a selection of those subjects with the highest information density. The considerable dropout among participants (17 attended six or less sessions) could not be explained systematically and was therefore attributed to declining motivation and commitment during the long experimental period. Two persons decided to stop because of unpleasant experiences such as headache or nervousness. Each of them was assigned to a different condition. Both their MBI and STAI scores fell within the normal variance of the experimental groups.

RESULTS

Burnout

Pretest MBI scores of the employees under study were comparable with normative scores from people in other contactual professions such as nurses or general practitioners. Analysis of variance revealed only small differences in burnout dimensions between the two experimental groups and the control group at their starting position, two weeks prior to commencing the experiment. Thus, the groups were composed in a homogeneous way. The postintervention scores in all three burnout dimensions revealed no significant differences between and within the groups (Table I).

However, an interesting finding occurred with respect to the Personal Competence dimension in the alpha condition. Here, the postintervention scores were significantly lower compared to the preintervention scores and, additionally, were significantly lower than the scores for both the beta condition- and control groups. Subjects in the alpha condition thus reported feeling significantly less competent with regard to their job performance and their colleagues than before.

Unexpectedly, a small though significant decrease was observed in the Emotional Exhaustion dimension in the beta condition, whereas no significant changes occurred in the

Table I. Mean MBI Scores (M) and Standard Deviations (SD) of Experimental and Control Groups 2 Weeks Before ($t_{(-2)}$) and 2 Weeks After ($t_{(+10)}$) the Intervention

	EE $t_{(-2)}$	EE $t_{(+10)}$	PC $t_{(-2)}$	PC $t_{(+10)}$	D $t_{(-2)}$	D $t_{(+10)}$
Alpha ($n = 13$)	14.31 (7.54)	14.46 (6.19)	27.31 (3.96)	23.69** (4.29)	6.69 (4.17)	7.31 (2.69)
Bèta ($n = 12$)	15.83 (8.23)	13.83* (6.64)	27.08 (5.14)	27.08 (4.62)	7.58 (3.68)	7.42 (2.71)
Control ($n = 25$)	14.40 (7.67)	13.40 (6.51)	27.28 (5.24)	27.36 (5.45)	7.12 (4.25)	6.96 (3.55)

Note. EE: Emotional exhaustion; PC: Personal competence; D: Depersonalisation; t: start of intervention. Values in parentheses represent SD.
$^{*}p < .01$.
$^{**}p < .001$.

control condition. Weak interaction effects at specific dimensions did occur; however, they fell well below any level of significance and will not be further discussed here.

State Anxiety

State anxiety in both conditions significantly decreased immediately after each single session (Table II). A repeated-measures ANOVA showed neither significant differences in STAI scores between alpha- and beta conditions nor changes over time (before session: $F(3, 15) = 1.013$ n.s.; after session: $F(3, 15) = 0.926$ n.s.). There were no indications for long-term effects. Every next session where state anxiety was measured, subjects started at approximately the same level as before.

Diaries

From a qualitative content analysis of the diaries, it appeared that subjects attributed a range of subjective experiences to the brainmachine sessions. The perceived effects varied from almost psychedelic and cosmic experiences, via slumbering, to nervous irritation and headache. No systematic relations could be established between such reported effects and the test scores on both inventories.

DISCUSSION

The results of this study suggest that brainmachines may cause immediate relaxation effects. Situational anxiety apparently decreased directly after the sessions and a qualitative content analysis of the diaries showed that subjects associated strong (after-) effects with the

Table II. STAI Mean Scores, Before (Pre) and After (Post) Sessions

	Pre (SD)	Post (SD)	t	df	p
STAI 1 (pre) vs. STAI 1 (post)	42.16 (6.76)	33.40 (7.53)	−7.57	24	<.001
STAI 2 (pre) vs. STAI 2 (post)	38.82 (7.24)	33.00 (7.75)	−4.58	21	<.001
STAI 3 (pre) vs. STAI 3 (post)	38.50 (6.82)	34.08 (7.75)	−4.61	23	<.001
STAI 4 (pre) vs. STAI 4 (post)	39.55 (6.17)	31.86 (5.99)	−5.72	21	<.001

brain-wave synchronizer sessions. This implies a near-immediate, short-term effect related to the intervention. Various uncontrolled variables and artifacts probably played a role as well, such as the subject's expectancy or the hour of the day.

Relaxation effects were not exhibited for the burnout scores. The outcomes suggested that a decreasing influence on burnout dimensions was negligible in the long term. This is consistent with evidence that the stable and chronic character of burnout is difficult to change. From a meta-analysis of autocorrelates of burnout (Van Dam, 1997), it appears that the MBI dimensions show considerable stability when measured over an average time interval of 9.52 months ($SD = 6.9$).

This might have masked possible relaxation effects of the brain-wave synchronizer. The complex nature of burnout probably thwarts the efficacy of simple technologies such as brainmachines. This may be true for relaxation as well, which is an ill-defined concept in the sense that few instruments are available to objectively quantify it. Relaxation itself is made up of several biological, psychological, and social components. The established observation that relaxed subjects show increased alpha wave activity may have inspired the idea that the presence of alpha activity equals relaxation. This is a reductionist circularity that denies the intricate nature of relaxation.

From their study into the effects of a specific type of brainmachine, Rosenfeld, Reinhart, and Srivastava (1997) concluded that individual differences in responsivity may decisively determine the extent of entrainment. Persons with a low spontaneous (baseline) alpha activity appeared to respond stronger to alpha stimulation compared to subjects with a high baseline alpha activity. Such individual differences may have played a role in the present study. Entrainment might not have occurred in those subjects in the alpha condition whose feelings of Personal Competence had not decreased.

The decrease in Personal Competence in the alpha condition is noteworthy. Although speculative, it may be that those subjects who perceived an increased workload during the experimental period were more inclined to continue their participation in the study. Contra-intuitively, from this study, it seems that alpha stimulation negatively affected feelings of Personal Competence and even burnout in general. If alpha stimulation would enhance relaxation, brainmachine sessions may not be a useful method to reduce burnout. Activation through beta stimulation might even be more appropriate with regard to the decrease of the Emotional Exhaustion dimension in the beta condition. Finally, the resultant small sample sizes for the experimental groups reduce the power of the study and may have masked a potential effect of the Synchro-Energizer.

In general, these outcomes undermine major claims concerning the (long-term) stress reduction effects of the brain-wave synchronizer. The added value of the brainmachine compared to other relaxation methods, such as listening to music, has not become clear. Other claims concerning alpha brain wave induction may need to be viewed with caution as well.

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