Using Neurological Feedback to Enhance Resilience and Recuperation

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ABSTRACT

During the NATO – RTO- Human Factors & Medicine panel symposium on "Mental health and well-being across the military spectrum" we will present some recent developments in the use of bio- and neurofeedback to support and enhance recovery and recuperation after expeditory (military) deployment. Applying such technology is possible due to our rapidly developing knowledge on the neurological systems underlying stress, performance and recuperation. Parallel to the necessary scientific developments, technological developments and ever more inspiring design make it possible to use the monitored physiological an neurological signals in interactive and stimulating settings contrary to the generally dull and straight forward tasks used until recently. As such consumer, or 'gamer' compliance increases what makes it possible to transfer bio- and neurofeedback out of the laboratory and generally strictly scientific environment to a broader public. However, before taking this important step, we considered it opportune to investigate if and how bio- and neurofeedback can contribute to recovery, recuperation, stress management and well being in general. For this reason the Dutch armed forces, in cooperation with TNO, initiated a research program to investigate the potential of bio- and neurofeedback paradigms and to evaluate the developed paradigms on their usability within the military domain. For this purpose 160 soldiers of the Dutch 200 Logistic Battalion will be assigned after deployment in Afghanistan to either a biofeedback gaming intervention; neurofeedback training; or just leisure time (each 10 sessions of approximately 30 minutes). After the intervention program these groups will be compared on mental health and well-being, stress management and experience, and physiological markers of stress, anxiety and depression. During the upcoming symposium the development of the intervention protocols; preliminary results; and our experiences will be presented and discussed.

1.0   INTRODUCTION

During the past decades global political demands steadily increased the number of expeditionary military operations of NATO and its allies. Not only more military and humanitarian operations had to be deployed; these operations became more complicated as military, political and humanitarian aims are regularly combined; increasing numbers of personal are involved; missions tend to last longer (implying multiple tours on an individual level); and mission intervals consequently become shorter. This implies that both the involved defence organisations as well as their personal on an individual level get less time to recover and recuperate from on mission or tour, before they already have to prepare the next. Not surprisingly statistics show that such demands can have a devastating effect on the overall health, well-being, and motivation of the individuals involved.

Report Documentation Page		Form Approved OMB No. 0704-0188

1. REPORT DATE **APR 2011**	2. REPORT TYPE **N/A**	3. DATES COVERED **-**

4. TITLE AND SUBTITLE	5a. CONTRACT NUMBER
Using Neurological Feedback to Enhance Resilience and Recuperation	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **TNO Defence, Security and Safety 2 Kampweg 5 3769 DE Soesterberg**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
See also ADA578905. Mental Health and Well-Being across the Military Spectrum (Bien-être et santé mentale dans le milieu militaire). RTO-MP-HFM-205

14. ABSTRACT

During the NATO RTO- Human Factors & Medicine panel symposium on Mental health and well-being across the military spectrum we will present some recent developments in the use of bio- and neurofeedback to support and enhance recovery and recuperation after expeditory (military) deployment. Applying such technology is possible due to our rapidly developing knowledge on the neurological systems underlying stress, performance and recuperation. Parallel to the necessary scientific developments, technological developments and ever more inspiring design make it possible to use the monitored physiological an neurological signals in interactive and stimulating settings contrary to the generally dull and straight forward tasks used until recently. As such consumer, or gamer compliance increases what makes it possible to transfer bio- and neurofeedback out of the laboratory and generally strictly scientific environment to a broader public. However, before taking this important step, we considered it opportune to investigate if and how bio- and neurofeedback can contribute to recovery, recuperation, stress management and well being in general. For this reason the Dutch armed forces, in cooperation with TNO, initiated a research program to investigate the potential of bio- and neurofeedback paradigms and to evaluate the developed paradigms on their usability within the military domain. For this purpose 160 soldiers of the Dutch 200 Logistic Battalion will be assigned after deployment in Afghanistan to either a biofeedback gaming intervention; neurofeedback training; or just leisure time (each 10 sessions of approximately 30 minutes). After the intervention program these groups will be compared on mental health and well-being, stress management and experience, and physiological markers of stress, anxiety and depression. During the upcoming symposium the development of the intervention protocols; preliminary results; and our experiences will be presented and discussed.

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**SAR**	**14**	

Consequently, as it may enhance (mental) recovery and decrease the necessary recuperation time between missions, interest in methods to improve stress management and relaxation skills, is quickly developing. One approach may be to use and develop the ability to control one's generally unconscious physiological and/or neurological responses to stress. In the public and scientific domains methods have been developed to apply such mental – physiological techniques (generally aimed at improving quality of life by reducing physiological tensions associated with stress). Based on promising results in these domains it might be beneficial to consider their use in the military domain as these interventions may provide soldiers with tools to enhance their recuperation. Additionally, it may reduce the risk for the development of acknowledged negative combat related outcomes like substance (ab)use; depression; aggression; and Post Traumatic Stress Disorder (PTSD) in the months-to-years following deployment. Important potential benefits on a larger scale are a significant reduction of the time needed to recover and to restore the initial (pre-deployment) levels of performance and operational ability of every individual soldier.

1.1   Neurobiological rationale

Stress responsiveness, stress management and relaxation are associated with different parts of the nervous system, as both the central as well as the autonomic nervous system might be involved, see figure 1. Some of these systems might be consciously manipulated, although awareness is fundamental and (motivated) training generally necessary to be able to do so.
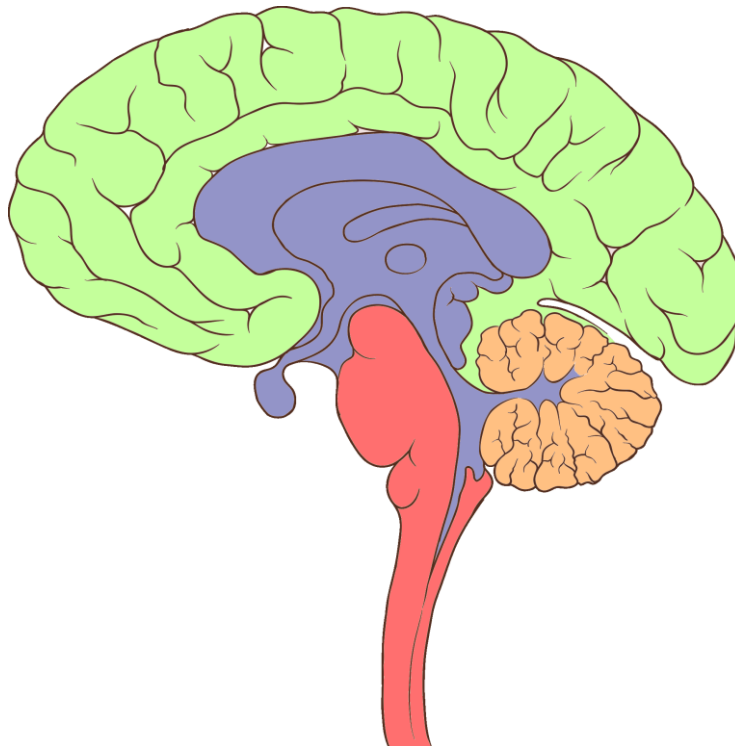

Figure 1. Saggital projection of the human brain. In red the brainstem, where the autonomic nervous system generates, providing input to be used for biofeedback; blue are mid brain involved in memory, emotion and hormonal processes; and in green the so called cortex, the structures involved in consiousness, memory, behavioral planning and reasoning. Neurofeedback is generally based on cortical signals captured using Electro-Encephalo-Graphical (EEG) techniques.

1.1.1 The autonomic nervous system underlying biofeedback

The Autonomic Nervous System (ANS) is an early evolutionary system controlling all types of (peripheral) physiological functions that are not subject to (direct) conscious control, like heart rate; digestion; respiration rate; blood pressure; and transpiration / perspiration. Besides being important systems for sustaining primary life functions, they evoke the "Fight or flight" response when an individual is confronted with stress (Cannon, 1932). The primary aim of this response is mobilizing (energetic) resources to counter any external threat to the survival of the individual involved. Overall its advantage is that it allows a rapid and explosive response (aimed at immediate physiological safety), though as its response are based on reflexes these are generally not under direct conscious control. That means that ANS parameters have a considerably short time resolution what makes them are very useful to for short term control (e.g. while playing a game). However, the associated disadvantage might be that it takes (quite) some training to control the autonomic responses more-or-less consciously. And even so, it is only possible to control them to some extent, and only under reasonable controlled conditions (e.g. in a safe environment: startle responses will always be present and uncontrolled).

The Autonomic Nervous System consists of two branches that control the responses associated with the "Fight or flight" response, being the Sympathetic Nervous System (SNS) and the Parasympathetic Nervous System (PNS). When encountering a threat the SNS stimulates the necessary organs to increase heart rate, blood pressure, respiratory efficiency, and the production of sweat. All these actions are aimed at providing energetic resources to the skeletal muscles to make the individual able to effectively counter the threat. Contrary to the sympathetic response, the PNS generally inhibits these responses in order to bring the individual back from an aroused state in a more energetic efficient and physical less demanding condition, generally after the stressor has been dealt with. Not surprisingly, efficient recuperation and adequate stress management are generally associated with a well functioning PNS. Consequently, biofeedback based training formats will generally aim at either skills to reduce and control SNS activity, and/or an individuals ability to increase PNS activity. However, to be able to provide the necessary – real time - feedback on an individual's responses, and as such provide him or her with the opportunity to try to manipulate them, specific parameters have to be monitored and reported back as these parameters are suggested to be indicative for either sympathetic or parasympathetic activity.

1.1.1.2 Sympathetic parameters

Although Heart Rate (HR) and Blood Pressure (BP) are popular parameters of arousal (e.g. in immediate response to stress) their interpretation is limited. This is due to the fact that both HR en BP are intervened by sympathetic and parasympathetic input. Consequently, the recorded signal is the result of the reciprocal activity of the SNS and PNS. This makes these parameters at best a rough estimate of Autonomic balance. Nevertheless derivatives of both parameters can be used to describe sec SNS or PNS activity and/or change over time or conditions.

However, with regards to SNS activity, the general preferred parameter is Electro-Dermal Activity (EDA), also referred to as the Galvanic Skin Response (GSR). It is based on the notion that with the production of sweat (primarily induced by the SNS) the skin conductance for (small) electric currents (induced by a low voltage potential difference between two electrodes attached close to each other, e.g. on the same hand) increases (Dawson et al., 2000). Consequently, in response to a stressor and induced by sympathetic arousal, the Skin Conductance Level (SCL) increases. SCL in itself is considered to be a tonic variable (quite stabile within a defined period of time), whereas EDA can be described as either differences in tonic levels between well defined periods (e.g. stress and recovery periods) or (immediate) phasic responses to a presented stressor. All these parameters are quantified in micro-Siemens (μS). As the Skin Conductance Response (SCR) to a presented challenge takes approximately 4 to 6 seconds to build up from initiation to its peak value, particularly this parameter may be very useful in biofeedback methods aimed at (the suppression of) sympathetic arousal because, as a consequence feedback regarding the

triggered response can be provided within seconds. However, when considering to use this parameter in such protocols, it is relevant to take into account that the SCL after a response may need up to 15 seconds to recovery to within a reasonably range from the initial (pre-challenge) SCL (Dawson et al., 2000).

Hypothetically, specific derivatives of HR and/or BP might provide insight in sympathetic arousal, and could as such (theoretically) be considered as variables useful for biofeedback protocols. Using fast Fourier transformations it is possible to use the original (time-based) ECG and BP data to calculate a frequency based power spectrum over a well defined period (e.g. 3 minutes of continues, high quality data) (Akselrod et al., 1981; Akselrod et al., 1985; Malliani et al., 1991; Task Force, 1996). This method basically describes the recorded signal within the specified period in the frequency components that together comprise the signal (see figure 2). Such power spectra (for HR and BP) typically consist of 3 distinct frequency bands: Very Low (0.00 – 0.07Hz); Low (0.07 – 0.14Hz); and High (0.15-0.50Hz). The regulatory systems underlying changes in the low frequency band of the Systolic Blood Pressure are regarded to be sympathetic in nature and could, when comparing distinct periods, be used as indication of change in sympathetic tonus (Task Force, 1996).
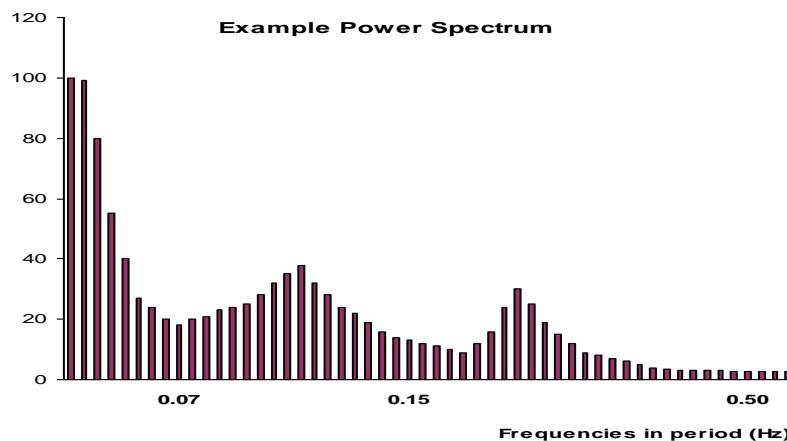

Figure 2. A typical example of an ECG-based power spectrum.

Note: The power of spectral components is the area below the relevant frequencies is presented in absolute units (square milliseconds). The total power of a signal, integrated over all frequencies, is equal to the variance of the entire signal.

Additionally, dividing the low by the high frequency power of the ECG provides the relative contribution of parasympathetic input to overall ANS activity, what is generally regarded as a gross estimate of Autonomic balance (Task Force, 1996).

1.1.1.3 Parasympathetic parameters

Although spectral analysis does provide us with the opportunity to define sympathetic and parasympathetic components in peripheral control, the usability of this method for biofeedback is significantly restricted by the mathematical necessity to use sufficiently long time series ('epochs') to be able to calculate a power spectrum. Due to the relatively low pace of heart rate (typically ranging from 60 to 180 beats per minute), epochs of at least 90 to 120 seconds are necessary to calculate reliable HRV information. This implies that feedback based on this method is always delayed and can not be used as

feedback to induce quick responses or immediate change. Consequently, this approach will not suffice as control for biofeedback-based games. Nevertheless, some biofeedback paradigms use input based on spectral analysis. Such paradigms generally use Heart Rate Variability (HRV: quantified using spectral techniques) in combination with respiratory manipulations like paced breathing. When breathing rhythmically and /or on a low frequency (< 9 cycles per minute), variations in the high frequency band of the ECG (> 0.15 Hz) are suggested to reliably indicate parasympathetic activity, information that could be feed back to the participant / patient and as such stimulate awareness and, while trying to relax, increase heart rate variability over minutes or sessions. However, do to the aforementioned temporal restrictions, and contrary to training immediate control over peripheral responses, the primary aim of such protocols is generally to enhance (overall) relaxation.

However, although spectral derivates of ECG have important restrictions that should be taken into account when considering this methodology, other ECG derivatives do provide us with very useful instruments for biofeedback based on stimulating PNS activity.

Based on beat-to-beat variations in Heart Rate (root mean squared successive difference: rMSSD) is widely used as parameter of parasympathetic activity as it is highly correlated with the high frequency component of the ECG frequency spectrum. It has the considerable methodological advantage that it can be calculated from relatively short time series (e.g. 4 to 7 beats can suffice), what makes it possible to provide reasonably direct (bio)feedback. Additionally, although it can be manipulated by breathing rate, short term changes are less sensitive for respiratory variations (what is an acknowledged disadvantage of high frequency spectral power) making the signal more robust while using a simpler algorithm that consequently needs less time and resources to calculate and process (Goedhart et al., 2007).

1.1.2   Cortical systems underlying Neurofeedback

In neurofeedback paradigms, individuals receive (close to) online feedback about their brain signals. A range of (brain-computer interface) studies showed that neurofeedback enables individuals to adjust their brain signals in the desired manner (Birbaumer et al., 1992; Birbaumer, 2006; Lubar & Shouse, 1976; Weiskopf et al., 2003; Heinrich et al., 2007). A critical review paper by Heinrich et al. (2007) indicates that there is now solid evidence for chances of behaviour following neurofeedback, and that there is strong evidence for e.g. the treatment of ADHD and epilepsy neurofeedback to help to improve the symptoms. The latter is recently confirmed through a meta-analysis by Tan et al. (2009). Recent studies published in solid scientific journals indicate that EEG neurofeedback can improve certain types of memory (Keizer et al., 2010a; Vernon et al., 2003), intelligence (Keizer et al., 2010b), attention (Egner & Gruzelier, 2001; Egner & Gruzelier, 2004) and mood (Raymond et al., 2005). These studies all involved healthy individuals. Neurofeedback aimed at relaxation has been shown to modify EEG signals (Egner et al. 2002; Egner & Gruzelier, 2003) and resulted in improvement of performance (Egner & Gruzelier, 2003) even though self-reports did not show beneficial effects as compared to control groups (Egner et al. 2002; Egner & Gruzelier, 2003). Several authors claim a reduction of PTSD symptoms after neurofeedback (Peniston & Kulkolsky, 1991; Peniston et al. 1993; Hammond, 2005; 2006). However, up till now, there is a lack of solid (double-blind, placebo controlled) research on the effects of neurofeedback with respect to stress-related symptoms. However, given the recent achievements in neurofeedback and brain-computer interface research, as well as the existence of neural and biological correlates we (and others; e.g. Gruzelier, 2009; Sokhadze et al., 2007) think there is potential for neurofeedback to help prevent and treat stress-related symptoms.

Neurofeedback training represents a sophisticated form of biofeedback based on specific aspects of cortical activity. It forms part of an operant conditioning paradigm in which a person can learn how to modify the amplitude and/or frequency of the electrophysiological aspects of his/her own brain. The aim of such a technique is to teach the individual what specific states of cortical arousal feel like and how to activate them voluntarily. The training typically involves recording an individual's electrical brain activity, as measured by the electroencephalogram (EEG), filtering this to isolate a target frequency component and then feeding back information relating to this component to the participant in the form of audio and/or visual information. For example, the goal of neurofeedback training may be to enhance the amplitude of a particular frequency component of the EEG, the level of which can be depicted using audio feedback, with higher amplitude related to higher volume of sound and lower amplitude to lower volume. The aim then for the individual is to recall and recreate states associated with periods when the amplitude/sound is higher, and in this way learn to associate specific changes in mental states with changes in brain activity.

However, it has been shown that during neurofeedback training, the context alone and the subject's perceived success in controlling their electrical brain activity can behave as powerful placebos in influencing subsequent responses on the phenomenological level, independently of changes in the EEG (Plotkin & Rice, 1981). The best way to control for these placebo effects is using a double blind paradigm. However, it is unclear if there have been double blind studies examining neurofeedback training in healthy subjects, leading to the conclusion that double blind studies of the effectiveness of neurofeedback in healthy subjects are at least scarce. The use of controlled trials in which both the participant and the neurofeedback trainer are blind to the study conditions is critical for evaluating the effectiveness of neurofeedback because expectancy effects may be a considerable source of potential bias in interpreting the effects of neurofeedback training.

1.1.2   Bio- & neurofeedback applied in military populations

About 1.800 Dutch soldiers were serving in Uruzgan, as part of a NATO International Security Assistance Force (ISAF) operation. As of August 1 (2010), the deployment is scheduled to start a redeployment phase. This implies that last rotations of military personnel will be active in Uruzgan, preparing for departure. Deployed military personnel are at risk for the development of stress and posttraumatic symptoms, potentially cumulating in syndromes like anxiety, depression and post traumatic stress disorder (PTSD). Within US marines and soldiers, PTSD prevalence after deployment to Iraq and Afghanistan is estimated at 6 to 13% (Hoge et al., 2004). Despite some adjustment problems in the first months after return, only a small part of trauma-exposed individuals develop full blown disorders like PTSD (Engelhard et al., 2007).

However, despite the growing body of evidence that bio- and neurofeedback may be potential useful tools to relief symptoms of tension and stress (see figure 3), as yet only few studies have described biofeedback protocols to be investigated in soldiers. Ginsberg et al. (2010) incorporated five combat veterans (Iraq or Afghanistan) with PTSD with five non-affected peers in a protocol providing HRV based biofeedback. The intervention was supported by resonance frequency breathing and stimulation of positive emotions by cognitive means and was conducted once a week for 4 consecutive weeks. In all participants cognitive performance improved significantly,

what was related to increased cardiac coherence, an index of parasympathetic cardiac control. These findings are supported by Zucker et al (2009) who report significant reductions in PTSD and depressive symptoms following a biofeedback (RSA) based intervention in 38 PTSD patients. Lande et al. (in press) reported no additional improvement of HRV based biofeedback on top of 'treatment as usual' in an exploratory study incorporating 38 PTSD diagnosed military service members after serving in either Iraq or Afghanistan.

In recent years the focus has shifted from studies on core features of PTSD to secondary prevention of stress-related problems and complaints. For example in 2009, Othmer & Othmer found combat veterans with several posttraumatic stress symptoms such as flashbacks, panic attacks, phobias, daily headaches, hyper vigilance, mood swings, anxiety and depression, fatigue, anger, chronic body pain, poor memory and concentration, poor sleep (sleep fragmentation), nightmares, and night sweats. In their study neurofeedback (alpha and theta, 4-8Hz) was used to train the combat veterans. After 25 sessions, they found symptom decrease and quality of life increase, and veterans mastered traumas they could not even overcome in other therapies.
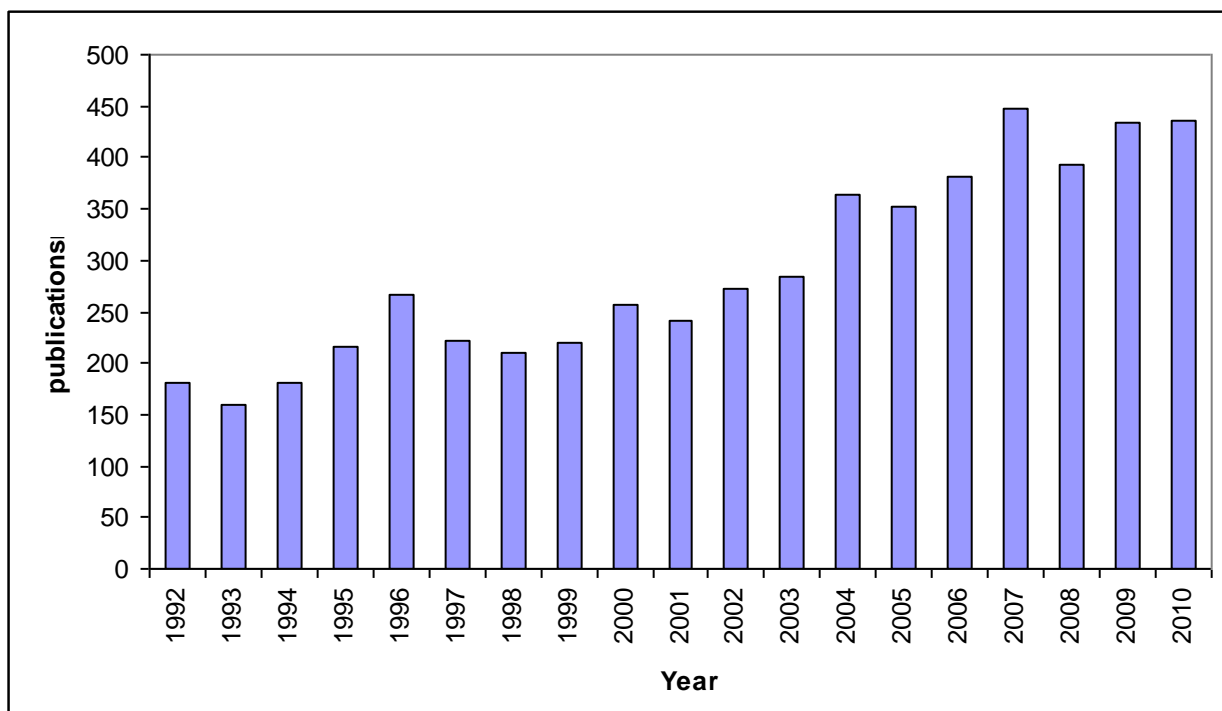

Figure 3. Overview of the number of scientific publications describing bio- and/or neurofeedback protocols. The number of publications is steadily growing every year since the late 80's

2.0 METHOD

Of the Dutch redeployment force, operational in Afghanistan (ISAF) during 2010, 160 soldiers of the 200 Bevo & Tbat (age 18 – 55 years) are recruited to participate in our study. It is important to emphasis that these are not combat troops, though generally engineers and logistic specialisst

assigned to redeploy Dutch equipment. These soldiers are randomly assigned to either: 'Treatment as usual' (TAU); Biofeedback gaming (BIO); Neurofeedback training (NEU); or a mock neurofeedback training added to validate the neurofeedback paradigm (NEU-m). Consequently 40 participants will be assigned to every condition. Every condition contains 10 session of 20 to 30 minutes. These 10 sessions are generally conducted every other day, though should be completed within 3 weeks. To investigate the effects of the different formats before (T0), immediately after a participant finished an intervention (T1), and three months later (T2) every participant is tested on:

- Self efficacy

- Subjective effects of the followed training

- Quality of life

- Quality of sleep and Fatigue

- Psychosomatic complaints and Anxiety

- Depression and Burn-out

- Physiological and neurological markers of (continuous) stress: QEEG, baseline HRV and early morning cortisol concentrations

- Cognitive functioning

2.1   Treatment As Usual (TAU)

The participants assigned to the TAU condition Are provide with the opportunity to spend 30 minutes per day on (additional) leisure time. During this period they have to sit and relax in a comfortable chair, read a paper or magazine, and if they like listen to some music.

2.2   Biofeedback gaming (BIO)

The participants following the biofeedback protocol play a 20 minute computer game (a modified version of the Biofeedback game developed for medical professionals by the Utrecht Medical Centre (UMC: Kato et al., 2010)), including 6 chapters (tasks). The game is situated in Kamp Holland, Afghanistan, during which multiple tasks have to be performed using Heart Rate Variability (HRV) and Skin Conductance Levels(SCL) as controls. These tasks resemble the actual task these soldiers used to do during their deployment in this region like loading trucks, driving in a convoy, controlling helicopters and constructing sanitary facilities. The Wild Divine biofeedback console (ww.wilddivine.com) continuously monitors SCLs and changes in HRV what will be used to control the machines necessary to successfully fulfil the designated task. The

first session will start with a general introduction and instructions how SCL and HRV can be manipulated by controlled breathing. After this introduction, the participant is connected to the console and the first gaming chapter is used to train basic skills: the participant has to perform simple up-and-down control tasks to get familiar with the game controls. Following this start-up session, six chapters have to be played to complete the procedure. During these sessions, the sensitivity of the biofeedback console is regularly adjusted to the performance of the participant, to ensure steadily increasing skill and avoid a ceiling effect that might reduce commitment. The complete intervention consists of 10 sessions being played in two consecutive weeks.

2.3   Neurofeedback training (NEU)

The participants assigned to the NEU condition will provide a MP3 / iTunes list with there favourite music. During each session the participant will be listening to this music for 30 minutes. However, based on specific components of the EEG signal, the music is filtered. When subjects are relaxed, the EEG alpha frequency level will be high, and all tones can pass the filter. This will result in music that contains high and low tones and therefore generates qualitative excellent music. However, when subjects are stressed, the relative alpha level drops, and only tones above 2kHz are allowed to pass the filter. As a result, the music only contains high tones because the low tones will be filtered out, and this causes significantly less satisfaction while listening to the music.

To be able to do so, EEG activity during the intervention is recorded continuously using an audio-headset with seamlessly integrated sensors (AgAgCl electrodes). To amplify the measured signal a NeXus10 (TMSI, Netherlands) is used. EEG activity is recorded at P3-A1 and P4-A2 following standardized 10/20 system, and sampled at 512 Hz.

2.4   Neurofeedback -mock- training (NEU-m)

The set-up of the mock condition is completely comparable with the NEU condition, with one prominent difference: the quality of the presented music is *not* based on specific components within the EEG, though randomly adjusted.

3.0   RESULTS

- To be able to validate the Neurofeedback paradigm the neurological components, training progression and outcome variables (QEEG, others) will be compared between the NEU and NEU-m conditions.

- The participants following the biofeedback training will be compared on the outcome variables with the TAU. We hypothesise that the soldiers following the biofeedback training will show lowered baseline HRV as compared to the TAU; healthier cortisol increases after awakening; and better scores on Quality of Life, Self efficacy and the Burn-out / depression / anxiety scales. The software makes it possible to track the performance of every individual player (the tasks can be played at 5 different levels), so potential lack of progression can be included as covariate in our analyses.

- Finally cross comparisons of the Neurofeedback intervention with TAU and the outcomes of the biofeedback are possible as well. We hypothesise that biofeedback might do better on baseline HRV and specifically Burn-out / depression / anxiety / perceived stress; whereas NEU may do better on QEEG and Quality of Life. As Brouwer et al. (2011) and Kallen et al. (2010) have shown that in response to (virtual) stress EEG, endocrine (cortisol) and cardiovascular (HRV) components may be associated (as they together comprise the human stress management system), potential correlations with the cortisol rise after awakening will be investigated as well. These associations might be modified by feelings of depression, stress and anxiety as well (Kallen et al., 2010).

The biofeedback game will be demonstrated during the NATO RTO HFM-205 Symposium "Mental health and well-being across the military spectrum" (April 2011 Bergen, Norway).

4.0   CONCLUSIONS

Based on the underlying neurological processes, investigated during an extensive literature study, we conclude that applying either biofeedback protocols and/ or neurofeedback interventions may be beneficial in different stages previously to, during and after deployment. Given the neurological backgrounds, biofeedback seems to be very useful for increasing stress management and coping; whereas neurofeedback may primarily be beneficial for relaxation, recovery and recuperation. Consequently, biofeedback training might be provided during the early stages of a military career, or pre-deployment. This will make it possible for any individual soldier to train these particular skills, that can from that point onwards be applied when stressful circumstances are encountered or extra attention for quick recovery is necessary. The easy-to-apply format (a very 'consumer friendly' game) makes biofeedback gaming easy to implement on e.g. bases and ships, what will provide the opportunity to train and sustain the developed skills. From that perspective the post deployment / stress application might then appear to be specifically beneficial when the necessary skills are already trained / improved to some extent, e.g. by pre-deployment gaming, though future studies may want to investigate such hypothesised outcomes in more detail.

Neurofeedback seems to be less obvious with regards to the optimal time to provide. Although literature suggests that it might be specifically beneficial *after* stressful periods or experiences. This may have to do with the fact that, contrary to the skills used when applying biofeedback, the used physiological control skills are hard-to-impossible to apply without direct EEG based feedback. Additionally, the optimal environment for controlling neurological processes appears to be a quite controlled environment in which an individual can lockout external stimulation (e.g. noises) and close his or her eyes to relax. Biofeedback skills can, after training, be applied in any environment.

Nevertheless the potential beneficial outcomes of engaging in neurofeedback training seem obvious, as promising results have been reported in relation to stress related psychopathology, like anxiety and PTSD. However, although hypothesised and intuitive likely, it has yet to be empirically proven that neurofeedback training may reduce the risk for the development of such disorders after traumatic events.

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