RESEARCH ARTICLE

Short Bouts of Intensive Exercise During the Workday Have a Positive Effect on Neuro-cognitive Performance

Petra Wollseiffen[1], Argang Ghadiri[2], André Scholz[2], Heiko K. Strüder[1], Rainer Herpers[2], Theo Peters[2] & Stefan Schneider[1,3*†]

[1]Institute of Movement and Neuroscience, German Sport University Cologne, Cologne, Germany

[2]Bonn-Rhein-Sieg University of Applied Sciences, Sankt Augustin, Germany

[3]Faculty of Science, Health, Education and Engineering, University of the Sunshine Coast, Maroochydore, Queensland Australia

Abstract

Beside its positive impact on physical health, exercise is indicated to positively affect cognitive performance based on a relocation of cortical activity. This study examined the influence of different types of breaks on cognitive performance and related cortical activity in office-based employees. Breaks were filled with exercise, resting or a usual break and a control condition where employees continued working without any break.

Cognitive performance was assessed using the d2-R test and two commercially available cognitive tasks. Brain cortical activity was recorded using electroencephalography before and after breaks. Individual's mood was analysed using a profile of mood state.

Results indicate a positive effect of a 3-min boxing intervention on cognitive performance, mirrored by a decrease in prefrontal cortex activity. Although perceived psychological state was increased after the usual break, this is reflected in neither cortical activity nor cognitive performance. With respect to the fact that also bike activity resulted an increase in prefrontal alpha-2 activity, a positive effect of exercise on neuro-cognitive performance can be stated.

Health and economic benefits may result from brief physical activity breaks and help to maintain workplace performance and job satisfaction. Copyright © 2015 John Wiley & Sons, Ltd.

Received 25 August 2014; Revised 31 August 2015; Accepted 1 September 2015

Keywords

workday breaks; prefrontal cortex; physical activity; neuro-cognitive performance; mood

***Correspondence**

Stefan Schneider, Institute for Movement and Neurosciences, German Sport University Cologne, Am Sportpark Müngersdorf 6, 50933 Cologne, Germany.

†E-mail: schneider@dshs-koeln.de

Published online in Wiley Online Library (wileyonlinelibrary.com) DOI: 10.1002/smi.2654

Introduction

In recent years, psychiatric diseases and mental health disorders have emerged among the highest causes of absenteeism in the workplace in the industrialized countries of Europe (WHO, 2013). The diagnosis of *burnout* is increasing in prevalence and contributes substantially to the healthcare burden and costs of national economies and private health insurance companies. Burnout is a multifactorial syndrome, but repeated and prolonged stress is seen as one of the triggering factors (Maslach, Schaufeli, & Leiter, 2001; Schaufeli & Greenglass, 2001). The physiological responses to stress, including the release of 'stress hormones' such as epinephrine and norepinephrine as part of the fight or flight response, are considered important for survival. However, chronic stress such as that induced in the workplace is not appropriate and is increasingly known to be detrimental for health.

Active (exercise) breaks to interrupt the working day are generally attributed to promote health and to improve work safety (Slesina, 2008). Although to date this has mainly been considered from the perspective of physical health (especially back pain), it is also proposed that active (exercise) breaks prevent a loss of concentration and improve the maintenance of work performance (Richter & Hacker, 1998; Tucker, 2003; Ulich, 2005); (Allmer, 1996; Graf, 1927; Marschak, 2012). Several studies have demonstrated a reduction in depressive mood and psychosomatic complaints through the inclusion of sporting activities in the work setting (Bös & Brehm, 2006; Byrne & Byrne, 1993; Folkins & Sime, 1981; Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991; Ransford, 1982).

In recent years, numerous studies have shown a direct link between physical activity and cognitive performance (Anish, 2005; Brisswalter, Collardeau, & Rene, 2002; Lo Bue-Estes et al., 2008; Mierau et al., 2009). Despite this association, the underlying neurophysiological effects are yet to be identified. One of the proposed effects of sport and exercise is that physical activity is accompanied by an increase in the activity of the motor cortex and associated motor areas. As computational resources are limited (Kahnemann, 1993), this increase in activity in motor regions has been speculated to be related to a decrease in fronto-temporal brain areas, which are considered to play an important role in cognitive and emotional processing (Dietrich, 2006; Frith & Dolan, 1996; Schneider et al., 2013a; Vogt, Schneider, Anneken, & Struder, 2013) and outlasts an individual exercise session for at least 30 min (Brummer, Schneider, Abel, Vogt, & Struder, 2011; Schneider & Struder, 2009). In addition, this decrease in prefrontal activity has been shown to be accompanied by an increase in affective state (Schneider et al., 2010) and cognitive capacities (Schneider et al., 2013a)

The study presented here aims to provide a link between neurophysiological changes and improved cognitive performance and increased well-being associated with physical activity breaks during the working day. It is hypothesized that a moderate intensity exercise intervention after 2 h of office work—in contrast to a usual break—will result in an increase in cognitive performance, accompanied by a decrease in frontal cortex activity that is indicative of cortical relaxation.

Material and methods

Participants and procedures

This study was approved by the ethics committee of the Bonn-Rhein-Sieg University of Applied Sciences, Germany.

Altogether, 50 thereof [23 women (age 42 ± 10) and 27 men (age 40 ± 12)] participated in this study. All participants were recruited on voluntary basis from office employees at either the German Sports University in Cologne or the Bonn-Rhein-Sieg University of Applied Sciences in Sankt Augustin, Germany. Participants were asked to work 2 h without any break before coming to the lab. After arriving in the lab, the participants signed an informed consent and were instructed on study procedures including a familiarization task for the mental tasks and affective state assessments. The study design included pre-intervention and post-intervention measurements of cognitive performance and prefrontal brain cortical activity. Intervention consisted of different kinds of exercise, relaxation and a usual break (Figure 1).

For cognitive assessment, a mental arithmetic task (Chalkboard Challenge), a mental memorizing task (Memory Matrix) and the attention test (d2-R test) were used to determine changes in cognitive performance pre-intervention and post-intervention. To assess individual changes in mood pre-intervention to post-intervention, a profile of mood state individuals perceived physical, motivational and psychological states (MoodMeter®) was used.

Before and immediately after the randomized intervention, brain cortical activity was recorded for 3 min in a seated, rest, eyes-closed position by using a three-lead dry electroencephalography (EEG) system (Brain Products GmbH, Munich, Germany). Heart rate was determined during the first seconds of the before and after 3-min EEG recordings by manual inspection of a heart rate monitor (RCX5, Polar Electro Oy, Kempele, Finland). The overall experimental design is outlined in Figure 1.

Interventions

In order to evaluate whether different kinds of interventions have different effects on changes in brain cortical activity, cognitive performance and mood, participants were randomly assigned to five different intervention groups, each group consisting of 10 participants:

(1) On the *bike* ergometer, the participants pedalled at average heart rate of 120–132 beats min^{-1} for 20 min [controlled by heart rate monitor (*RCX5*, Polar Electro Oy)] to achieve a moderate physical activation (Kashihara, Maruyama, Murota, & Nakahara, 2009). To predict the maximum heart rate, the equation of Tanaka ($208 - 0.7 \times \text{age}$) was used (Tanaka et al., 2001). For a moderate intensity, 70% of assumed HRmax was applied (Kashihara et al., 2009; Norton, Norton, & Sadgrove, 2010).
(2) The *boxing* was a short-time intervention with boxing on a freestanding punching bag. The participants were asked to do a 3-min maximum exhausting combination beginning with a warm-

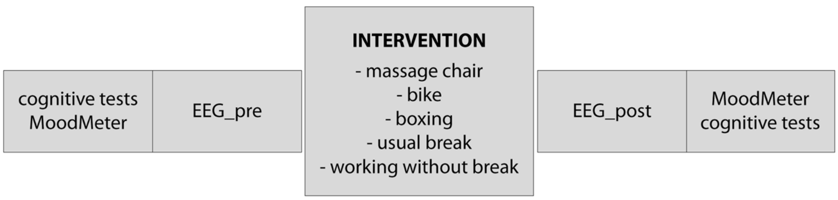

Figure 1. Experimental design: before and after the intervention, an EEG was recorded encased by cognitive tests (Memory Matrix, Chalkboard Challenge and d2-R Test) and the state of mood (MoodMeter®)

up period of 1 min from walking to running on the spot with light uppercuts followed by a period of 1.5 min of little steps and jumps surrounding the freestanding punching bag and direct punches, ending with a period of 30 s of very hard and high-frequency uppercuts out of a standing position. To control the level of activation, the heart rate was recorded by a heart rate monitor.

(3) Those doing the *usual break* were asked to do a 20-min break they normally do except going for lunch. To control their activation, the heart rate was recorded by a heart rate monitor (RCX5, Polar Electro Oy).

(4) Resting for 20 min in a supine position on a *massage chair* (brainLight relax Tower Gravity, brainLight-Mentalsystem®, brainLight GmbH, Goldbach, Germany), the participants had a massage of their back, arms, hands, legs and feet with visual and auditive stimulation. The visual stimulation was provided with spectacles producing light pulses with different colours and rhythms while the participants' eyes remained closed. The auditive stimulation was assessed with earphones serving a combined programme of music and announcements (Programme 26, brainLight-Mentalsystem®, brainLight GmbH). The heart rate was measured before and after the intervention on palpation. This intervention was conceived as passively obtaining relaxation in contrast to the physical active groups (bike and boxing). In addition, this is a commercially offered possibility of break arrangements for employers.

(5) The control group kept on working for the 20 min with *no break*, and all the measurements before and after were taken at their office. The heart rate was measured before and after the intervention on palpation.

Cognitive tests

d2-R Test of Attention

As a standardized psychological test, the d2-R Test of Attention (R Brickenkamp, 2002; Rolf Brickenkamp, Schmidt-Atzert, & Liepmann, 2010) was used. The test consists of the letters d and p, which are arranged in 14 rows of 57 characters, and the top and the bottom are marked with one to four bars. The task of the participant was to mark in each row within 20 s as many d's or p's labelled with two bars, regardless of whether the bars are below (two), on top (two) or below and on top (one each). The examiner explained in detail the testing and encouraged the participant to do it as quick and as accurate as possible. After the start signal, the examiner calls every 20 s to move on to the next line of sequences of characters.

Brain games

Following previous considerations concerning a decrease of motivation when performing standardized psychological tests within a repeated measures design (Schneider et al., 2013b), it was decided to use two commercially available mental tasks on an IPod touch™:

Chalkboard Challenge is a task assessing mental arithmetic (problem solving). Participants have to decide by tapping on the screen which of two numbers/equations presented is larger or if they are equal. With on-going levels, arithmetic gets more and more difficult [e.g. $16 * (5 - 3)$ versus 27]. Time is limited, but being accurate helps to earn more time. Each correct answer earns more points. Once the game is finished, the final score and the final level are presented.

Memory Matrix is a task assessing spatial recall addressing working memory (Dorval & Pepin, 1986; Schaefer & Thomas, 1998), where participants have to repeat a visual pattern consisting out of tiles organized on the screen. Once a pattern has been reproduced, the number of tiles to be remembered will increase by one in every subsequent level. If the participant is able to reproduce the pattern, he or she earns points, which after completion of the task will sum up to a final score and to an upgrade of one level. If the participant is not able to reproduce the pattern, he or she will be downgraded one level. The whole task consists of 15 levels. The task will end by presenting the final score and the final level reached.

For statistical analysis, the pre-intervention assessments final scores identified baseline values for each of the three tasks. Post-intervention assessments final scores were then calculated as percentage changes to the pre-intervention assessments final score.

Electroencephalographic data collection and analysis

As it was aimed to have a prompt recording after the intervention, a three-lead dry EEG was used. EEG was recorded before and immediately after the interventions with a sampling rate of 500 Hz on positions Fp1 and Fz and Fp2. Electrode positions were based on the international 10–20 system (Jasper, 1958). All electrodes were referenced to the right earlobe. Impedance was kept below 10 kΩ, which was easy to achieve as electrodes were placed on the forehead. The analogue signal of the EEG was amplified, converted to digital signals and stored using a Brain Vision amplifier and RecView software (Brain Products GmbH). A trained investigator monitored all recordings. EEG data were processed using Brain Vision Analyser 2 (Brain Products GmbH). After a first manual artefact detection, including electrooculography artefacts, Butterworth Zero Phase Filters were applied (low cutoff 0.5 Hz, time constant 0.3183099 s, 48 dB/oct, high cutoff 70 Hz, 48 dB/oct, notch filter 50 Hz). Subsequently, a systematic protocol for excluding artefacts was performed that included careful visual inspection of all EEG data and automated exclusion procedures, which were set to gradient threshold <60 µV and an oscillation amplitude between −200 and +200 µV. If applicable, defective segments were excluded from further analysis.

This was followed by a segmentation into 4-s epochs whereby an overlap of 10% was allowed. Data then were baseline corrected and a fast Fourier transformation [spectral analysis using power output (mV^2) half spectrum, resolution: 0.24414 Hz, created using component version 2.0.5857, Brain Products GmbH] was applied on each of the 4-s intervals. Finally, data were averaged over all remaining segments and pooled over Fp1, Fz and Fp2. For statistical analysis, data were exported as raw sum of activity for alpha-1 (7.5–10 Hz), alpha-2 (10–12.5 Hz), beta-1 (13–18 Hz) and beta-2 (18–35 Hz) activity (Kirschstein & Kohling, 2009; Klimesch, 1999; Klimesch, Sauseng, & Hanslmayr, 2007).

Mood assessment

To determine changes in the affective state caused by the different interventions, the individuals' perceived physical, motivational and psychological states were assessed using a computer-based Likert scale (MoodMeter®; Kleinert, 2006; Schneider et al., 2009; Schneider et al., 2010). The MoodMeter® was configured with 32 adjectives presented to participants on a touch screen handheld computer in a quasi-random sequence. Participants were asked to indicate how well the adjective described their current physical or mental state by selecting one of six options from 0 (not at all) to 5 (completely). The response time for each adjective was limited to 5 s to discourage rational deliberation. Completion of the mood assessment (all 32 adjectives) took approximately 2 min. Before data collection, all participants were familiarized with the MoodMeter® using a small catalogue of adjectives that were not included in the experiment. The mood assessment was completed before and after the intervention. From the 32 MoodMeter® adjectives, three different dimensions were formed for assessment: perceived physical state (PEPS), psychological strain (PSYCHO) and motivational state (MOT). Each of these three dimensions was further categorized into four sub-dimensions.

The first of the four perceived physical state (PEPS) sub-dimensions was physical energy, which includes adjectives associated with lethargy and tiredness (drained, weak, weary and shiftless). The other PEPS sub-dimensions were physical fitness (well-trained, vigorous, fit and strong), physical health (healthy, groggy, battered and sick) and physical flexibility (agile, flexible, immobile and stiff). Psychological strain (PSYCHO) was broken down into the following four sub-dimensions: positive mood (positive mood and cheerful), calmness (relaxed and calm), recovery (recuperated and well rested) and relaxation (feeble and drowsy). The remaining four sub-dimensions characterized the motivational state (MOT): willingness to seek contact (open for contact and communicative), social acceptance (accepted and popular), readiness to strain (energetic and powerful) and self-confidence (experienced and self-confident).

Statistical analysis

All data were tested for normality using Kolmogorov–Smirnov normality test. Delta changes were calculated subtracting pre-values from post-values (i.e. an increase in data mirrors an increase in post-exercise values). For all statistical procedures, level of significance was set to $p < 0.05$. Data in this manuscript are presented as mean ± 95% confidence intervals. All statistical analyses were performed using STATISTICA version 7.1 (StatSoft, Tulsa, OK, USA).

Cognitive performance The effects of different exercise protocols on cognitive performance were compared calculating an analysis of variance (ANOVA) using the inter-individual factors 'intervention' (bike, boxing, usual break, no break and massage chair). Fisher Least significant difference test served for post-hoc analysis.

Frontal cortex activity Statistical analysis was performed using an ANOVA integrating the inter-individual factor 'intervention' (bike, boxing, usual break, no break and massage chair). Least significant difference test was used for post-hoc analysis if appropriate.*Mood assessment*
For each dimension, changes across time were determined using Friedman's repeated measures ANOVA. Wilcoxon paired samples test was used as post-hoc test wherever a significant measurement effect was detected so as to determine the exact location of differences.

All effect size (f) calculations (Cohen, 1988) were performed post-hoc using G*POWER 3.1 (www.gpower.hhu.de).

Results

Exercise intensity and heart rate

Statistical analysis revealed a significant effect of heart rate ($F_{(4,\ 45)} = 96.39$, $p < 0.001$, $f = 0.47$). Post-hoc tests revealed a significant increase in heart rate in the post-measurement for the two exercise interventions *bike* (pre 74.3 ± 11.6; post 102.9 ± 41.9; $p < 0.001$) and *boxing* (pre 80.3 ± 10.2; post 166.8 ± 21.6; $p < 0.001$). The *usual break*, too, resulted in a significant, albeit very moderate increase of heart rate (pre 73.0 ± 14.0; post 83.1 ± 20.1; $p < 0.05$), whereas no changes were observable during the interventions *no break* (pre 64.9 ± 10.7; post 69.5 ± 11.7; $p > 0.05$) and *massage chair* (pre 67.4 ± 11.7; post 62.4 ± 8.7; $p > 0.05$).

Cognitive data

Statistical analysis revealed a main effect for Chalkboard Challenge (decision-making task, $F_{(20,\ 140,\ 25)} = 1.92$, $p < 0.05$, $f = 0.38$, Figure 2, top) but not for Memory Matrix (working memory, $F_{(8,\ 90)} = 0.40$, $p = 0.92$, Figure 2, middle). Further post-hoc analyses revealed a significant increase from before to after the *boxing* intervention compared with the *usual break* and the *massage chair* intervention ($p < 0.05$), whereas significance was missed marginally comparing *boxing* to *biking* and *no break* ($p = 0.06$).

An improvement post-intervention could be obtained for d2-R test performance $F_{(1,\ 45)} = 91.23$, $p < 0.001$, $f = 0.46$. Further analysis revealed no differences between these five interventions ($F_{(4,\ 45)} = 0.89$, $p = 0.47$, Figure 2, bottom).

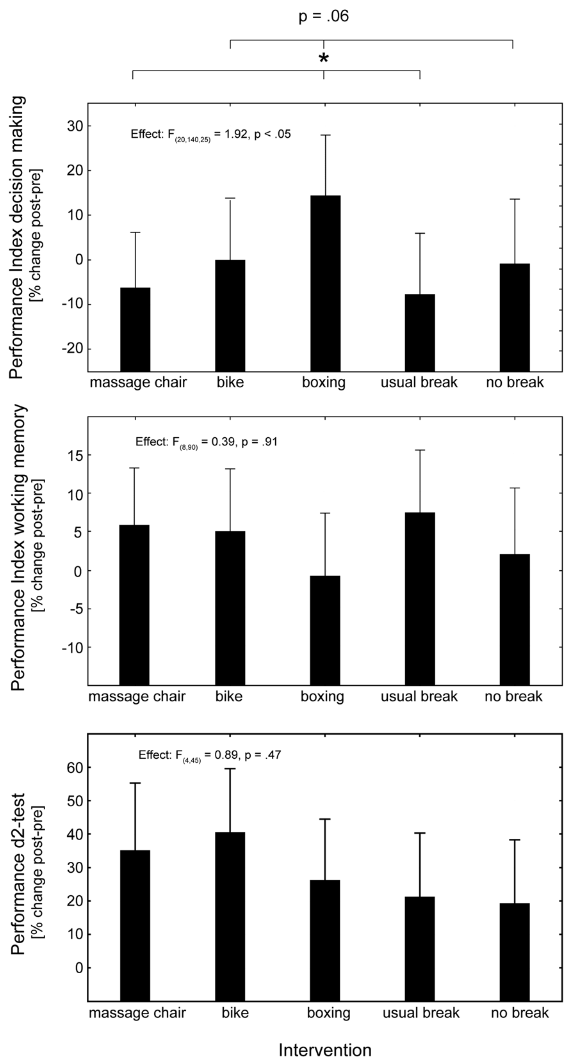

Figure 2. Percentage changes from pre-intervention to post-intervention for d2-R performance (bottom), performance index working memory (middle) and performance index decision-making task (top) across the five different interventions. Displayed are means ± confidence intervals. $*p < 0.05$

Neurophysiological data

Comparing changes in alpha-1 ($F_{(4,\ 46)} = 0.81$, $p = 0.53$), alpha-2 ($F_{(4,\ 46)} = 3.26$, $p < 0.05$, $f = 0.34$), beta-1 ($F_{(4,\ 46)} = 0.87$, $p = 0.48$) and beta-2 ($F_{(4,\ 46)} = 0.41$, $p = 0.80$) activity from pre-intervention to post-intervention, only alpha-2 activity revealed a significant difference between the interventions. Further, post-hoc test revealed that alpha-2 activity was significantly increased after *boxing* ($p < 0.01^{**}$, Figure 3) and *biking* ($p < 0.05^{*}$, Figure 3A) in comparison with the *usual break* and *no break*, although alpha-2 activity slightly increased (Figure 3A) after the *massage chair* intervention to the *usual break* and *no break* condition.

Mood data

Perceived physical and perceived motivational state showed no ($p > 0.05$, Table I, Figure 4) significant changes across the five different interventions. Perceived psychological state was found increased after the *usual break* compared with the other four interventions ($p < 0.05$, $f = 0.33$, Table I, Figure 4). Within the dimension perceived physical state, the sub-dimension physical fitness was significantly increased after the *usual break* in comparison with *bike* ($p < 0.05$), *boxing* ($p < 0.05$) and *no break* ($p < 0.01$) but not compared with the *massage chair* intervention ($p = 0.25$, Table I, Figure 4). No further changes could be obtained in any other sub-dimension.

Discussion

Active (exercise) breaks to interrupt the working day are generally recommended to promote physical health and to improve work safety. Furthermore, they are thought to decrease stress through specific neurophysiological changes and thereby improve cognitive performance and mood. Finally, these changes are believed to contribute to enhanced job satisfaction and the prevention of depression and, in the long term, further psychological disorders. The present study aimed to examine the effects of physical activity breaks within the workday on cognitive performance and mood as well as associated changes in brain cortical activity. There was a positive effect of a 3-min boxing intervention on cognitive performance and perceived psychological state that coincided with an increase in frontal alpha-2 activity. Although perceived psychological state was also increased after the usual break, which might be associated with social interactions, this is reflected in neither cortical activity nor cognitive performance. With respect to the fact that also bike activity resulted in an increase in prefrontal alpha-2 activity, this supports the positive effect of exercise on neurocognitive performance.

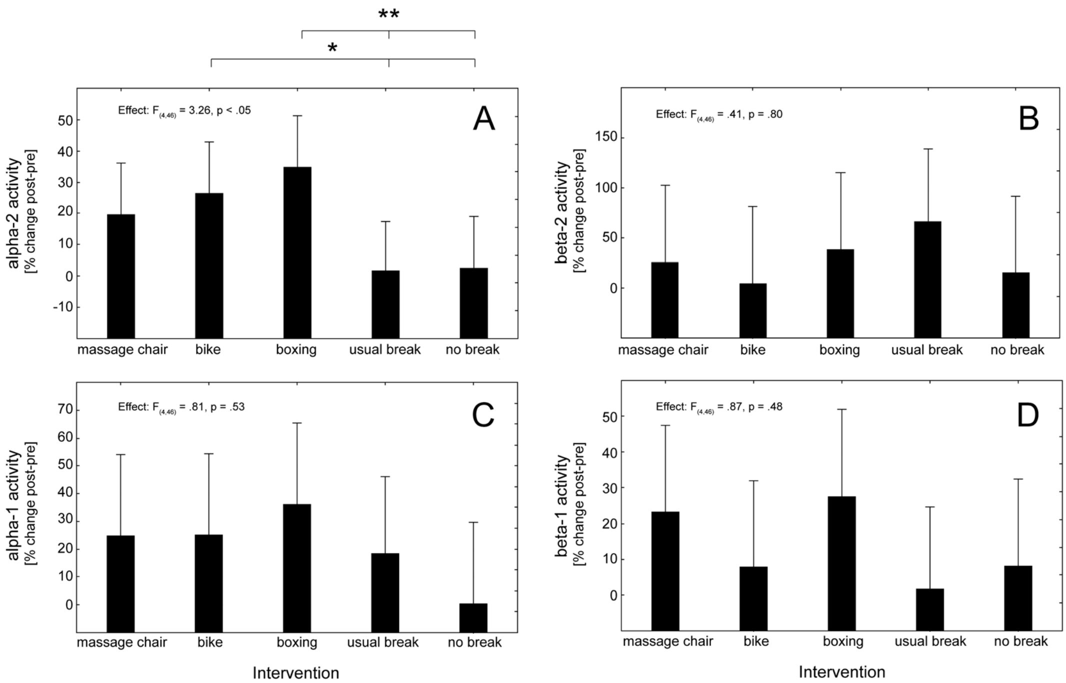

Figure 3. Changes (%)in alpha-1 activity (7.5–10 Hz, C) alpha-2 activity (10–12.5 Hz, A), beta-1 activity (12.5–18 Hz, D) and beta-2 activity (18–35 Hz, B) from pre-intervention to post-intervention, differentiated between the five different interventions: massage chair, bike, boxing, usual break and no break. Displayed are means ± confidence intervals. $*p < 0.05$, $**p < 0.01$

Table I. IANOVA results for perceived physical state, psychological state and motivational state and each of their sub-dimensions

	Massage chair	Bike	Usual break	Boxing	No break
Perceived physical state $F_{(4,\ 46)} = 1.23$, $p = 0.31$	6.83 ± 18.48	9.69 ± 27.81	23.41 ± 30.79	6.11 ± 24.66	1.73 ± 10.26
Physical energy $F_{(4,\ 46)} = 1.67$, $p = 0.73$	8.18 ± 20.83	30.45 ± 71.60	53.94 ± 71.99	9.89 ± 47.05	3.43 ± 20.73
Physical fitness* $F_{(4,\ 46)} = 2.86$, $p = 0.05$*	31.42 ± 54.31	9.17 ± 33.31	51.88 ± 53.59*	8.22 ± 31.15	−0.65 ± 14.44
Physical flexibility $F_{(4,\ 46)} = 1.43$, $p = 0.24$	−1.45 ± 15.69	25.64 ± 29.13	15.66 ± 38.81	15.02 ± 26.21	7.17 ± 17.87
Physical health $F_{(4,\ 46)} = 0.10$ $p = 0.98$	3.16 ± 26.24	−0.94 ± 33.49	6.17 ± 26.22	2.58 ± 27.33	1.04 ± 11.91
Psychological state* $F_{(4,\ 46)} = 2.75$, $p < 0.05$*	14.55 ± 24.48	5.44 ± 34.16	43.33 ± 48.39*	12.45 ± 18.60	3.89 ± 15.45
Calmness $F_{(4,\ 46)} = 0.92$, $p = 0.46$	9.33 ± 24.33	5.76 ± 24.82	52.41 ± 99.29	38.10 ± 122.40	2.44 ± 16.74
Positive mood $F_{(4,\ 46)} = 0.48$, $p = 0.50$	6.19 ± 13.09	−1.58 ± 31.90	10.90 ± 21.09	8.11 ± 19.85	7.25 ± 16.23
Recovery $F_{(4,\ 46)} = 3.56$, $p < 0.05$*	49.58 ± 81.37	19.80 ± 71.47	240.66 ± 354.70*	20.41 ± 43.22	2.86 ± 32.55
Relaxation $F_{(4,\ 46)} = 1{,}18$, $p = 0.33$	38.44 ± 76.30	10.44 ± 59.29	64.98 ± 97.12	23.63 ± 36.05	13.29 ± 37.15
Motivational state $F_{(4,\ 46)} = 0.16$, $p = 0.95$	2.58 ± 17.56	3.97 ± 33.50	4.01 ± 17.13	7.16 ± 19.36	−0.01 ± 7.08
Social acceptance $F_{(4,\ 46)} = 0.23$, $p = 0.92$	−9.01 ± 11.34	−12.03 ± 21.99	−9.58 ± 33.99	−7.03 ± 18.69	−3.50 ± 10.08
Willingness to seek contact $F_{(4,\ 46)} = 0.66$, $p = 0.62$	−0.77 ± 42.11	18.52 ± 68.24	−7.45 ± 17.65	5.56 ± 25.93	−2.40 ± 15.92
Self-confidence $F_{(4,\ 46)} = 1.19$, $p = 0.33$	3.89 ± 10.96	9.42 ± 27.03	15.45 ± 27.35	18.37 ± 27.09	0.50 ± 10.31
Readiness to strain $F_{(4,\ 46)} = 0.59$, $p = 0.67$	34.72 ± 66.76	18.93 ± 72.22	51.14 ± 65.39	26.29 ± 46.12	13.98 ± 46.81

Displayed are percentage changes from pre-intervention to post-intervention for each of the five interventions. Displayed values are means ± standard deviations.
ANOVA: analysis of variance.
$*p < 0.05$.

Cognitive performance

Performance index of a decision-making task (chalkboard challenge) showed improved results after the 3-min boxing intervention compared with a usual break and 20 min in a massage chair, whereas neither the d2-R test (attention) nor working memory (Memory Matrix) results were improved. In comparison with the 20-min bike-exercise intervention as well as the no-break group, there was a strong tendency ($p = 0.06$) for the performance index of this decision-making task to improve with the boxing exercise. This indicates that the short but very high intensity boxing intervention is effective for

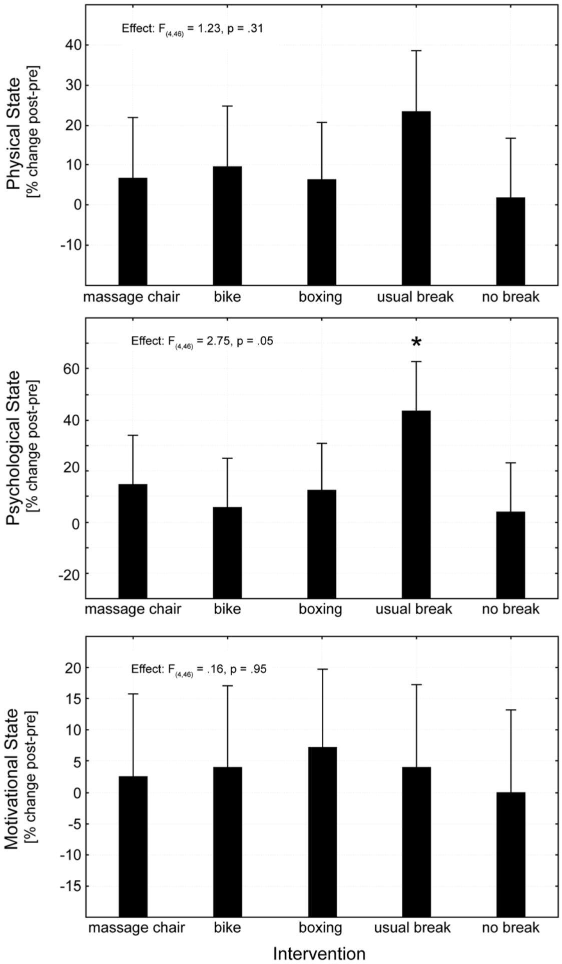

Figure 4. Changes (%) in perceived motivational state (bottom), psychological state (middle) and physical state (top) from pre-intervention to post-intervention, differentiated according to the five interventions: *massage chair*, *bike*, *boxing*, *usual break* and *no break*. Displayed are means ± confidence intervals. $^{*}p < 0.05$

enhancing cognitive performance, albeit limited to a very specific aspect of cognitive performance. That performance during the decision-making task after the usual 20-min break and the 20 min of massage chair intervention was impaired, indicating a lack of effectiveness of such break activities. While the usual break activity might at least have a positive effect on social interaction at the workplace, the 20-min massage chair intervention in this study induced doziness and had a clear negative impact on the decision-making task.

Neurophysiological data

Cognitive processes necessary for goal-directed cognition and behaviour (underlying perception, memory and action) are related to executive functioning and executive control (Best, 2010; Hillman, Kramer, Belopolsky, & Smith, 2006; Schneider et al., 2013b), and the prefrontal cortex is postulated as an important contributor to cognitive control (Ridderinkhof, van den Wildenberg, Segalowitz, & Carter, 2004). The fact that alpha-2 activity, being the neurophysiological marker of a relaxed cortical state, showed an increase of more than 20% in the frontal cortex after physical exercise, both boxing and biking, in comparison with a usual and no break, respectively, underlines the initial hypothesis that exercise is accompanied by a transient hypofrontality (Dietrich, 2006; Schneider et al., 2013b). Although the ~20% increase in alpha-2 activity after the 20-min massage chair intervention was not statistically significant ($p = 0.15$), this suggests that this is a very relaxing break activity. Nevertheless, it is necessary to differentiate between a general increase in cortical relaxation and cognitive performance. Whereas exercise interventions seem to improve cognitive performance (at least in some subdomains such as a decision-making task), less physically active breaks tend to have no effect. With respect to the data obtained in this study, it can only be speculated that this effect is due to a general activation of the cardiovascular system and a concomitant increase in arousal. With respect to the model of transient hypofrontality (Boecker, Hillman, Scheef, & Strüder, 2012) proposed first by Dietrich (2003), exercise is accompanied by a redistribution of cortical activity to regions involved in the planning, programming and execution of motor control and therefore reducing activity in cortical areas not involved in these tasks, especially fronto-temporal areas. Interestingly, this 'frontal relaxation' seems to be temporary and does not seem to affect cognitive tasks, whereas the doziness caused by traditional relaxation methods such as the massage chair seems to be more global. Unfortunately, using only three electrodes located on positions Fp1, Fp2 and Fz does not allow for further discrimination between the different cortical areas. analysis.

Mood

Various studies suggest that exercise is positively linked to mental health (Deslandes et al., 2009; Penedo & Dahn, 2005) and leads to a heightening of the state of mood and psychological well-being (Berger, 1996; Fox, 1999). Interestingly, none of the measured dimensions of mood in the present study showed significant changes after both the biking and boxing exercise interventions. With respect to the sub-dimensions of mood, physical fitness and physical recovery both increased after the usual break (Table I).

Although perceived psychological state was increased after the usual break compared with all other interventions, this is reflected in neither cortical activity nor cognitive performance, indicating that the individuals' perceptions of mental recovery, which might be due to social interactions, differ to the objective measurement of physiological functions. The latter is recognized to benefit cognitive performance (Chmura, Nazar, & Kaciuba-Uscilko, 1994; Kashihara et al., 2009; McMorris & Keen, 1994).

Conclusions

The results of this study correspond with previous neurophysiological research proposing beneficial effects of physical exercise on cognitive performance (Schneider et al., 2013a; Vogt, Abeln, Struder, & Schneider, 2014). Although individual preferences might exist, brief active breaks are suggested to enhance or promote the recovery of workplace performance in office workers, whereas physical relaxation does not show this effect.

It has been shown previously that the effect of exercise on cortical activity (Brummer et al., 2011; Ohsugi, Ohgi, Shigemori, & Schneider, 2013; Vogt, Schneider, Brummer, & Struder, 2010) and neuro-cognitive performance (Schneider et al., 2013a) are dependent on exercise intensity and biased by individual preferences. The results presented here, namely, an increase in alpha-2 activity, which is a marker of cortical relaxation, as well as an increase in performance index in the decision-making task, could be caused by the exercise intensity, as heart rate was significantly increased compared with all other interventions after the boxing intervention, but might also be affected by the positive bias towards boxing, mainly caused by the novelty of intervention. Further research is necessary to distinguish between the effects of duration, intensity and the content of breaks relating to exercise preferences. Furthermore, future research activities should try to differentiate between different kinds of cognitive performance and should test outcomes that are specific to work activities of employees.

This study contributes to the general idea that breaks interrupting the daily work time lead to enhanced productivity and reduced fatigue (Dababneh, Swanson, & Shell, 2001; Galinsky, Swanson, Sauter, Hurrell, & Schleifer, 2000). They can provide positive psychosocial effects and promote work satisfaction, which may turn to lead to stress reduction and buffering effects (Tucker, 2003). This would ultimately have a positive influence on the growing prevalence of work-related mental health conditions, such as burnout. These beneficial influences can be reinforced by physical activity, coupled with the positive impact of exercise on stress reduction, decreased anxiety and the alleviation of depression (Salmon, 2001).

Active breaks not only are a potential fatigue countermeasure, and hence a means of controlling risk, but also may have beneficial effects on job performance, with associated economic and socio-economic significance. Health and economic benefits may result from brief physical activity breaks and help to maintain workplace performance and job satisfaction and finally reduce the loss of productivity. The boxing intervention is of particular interest for employers as it is a high-intensity but short-time intervention leading to a quick recovery from a high workload with minimal set-up time and costs.

Limitations and outlook

This study was only able to determine effects on the behavioural aspect of cognitive performance. Further studies should aim to identify possible underlying neurophysiological changes, e.g. effects of exercise interventions on event-related potentials. This might help to further understand the importance and mechanisms of active breaks on work performance.

Further studies should also try to identify other sources affecting neuro-cognitive and neuro-affective performance, e.g. changes in neurotransmitters or an activation of the autonomic nervous system including baroreceptor control, ventilation and changes in pCO_2, which might be considered as potential mediators underlying the relationship between exercise and post-exercise cortical activity (McMorris et al., 2006; McMorris et al., 2009). In addition, a differentiation between gender, especially with regard to exercise intensity and exercise mode, should be taken into account in future studies.

What this paper adds

- Although it is well known that work breaks improve cognitive performance, no study to date has examined the influence of alternative break activities on cognitive performance and related cortical activity in office-based employees.
- Results of this study indicate a positive effect of short bouts of exercise on neuro-cognitive performance.
- This study bridges the gap between phenomenological and empirical research by describing (1) the underlying neurophysiological effects of breaks and (2) combining subjective and objective data.
- Although exercise is widely regarded to be an effective ‘neuro-enhancer’, many companies and employees still rely on traditional sedentary break activities, mainly because implementing exercise regimens into workday routines is difficult. Small bouts of exercise, as proposed here, might offer a valid alternative.

Acknowledgments

We would like to express our thanks to the participants and to the German Sports University Cologne as well to the Bonn-Rhein-Sieg University of Applied Sciences for support. The massage chair was provided by brainLight GmbH.

REFERENCES

Allmer, H. (1996). Erholung und Gesundheit Grundlagen, Ergebnisse, Maßnahmen (Vol. *6*). Göttingen: Hogrefe.

Anish, E. J. (2005). Exercise and its effects on the central nervous system. *Curr Sports Med Rep*, *4*(1), 18–23.

Berger, B. G. (1996). Psychological benefits of an active lifestyle: What we know and what we need to know. *Quest*, *48*(3), 330–353.

Best, J. R. (2010). Effects of physical activity on children’s executive function: Contributions of experimental research on aerobic exercise. *Developmental review: DR*, *30*(4), 331–551.

Boecker, H., Hillman, C. H., Scheef, L., & Strüder, H. K. (2012). Functional neuroimaging in exercise and sport sciences. Heidelberg, New York: Springer.

Bös, K., & Brehm, W. (2006). Handbuch Gesundheitssport (Vol. *2*). Schorndorf: Hofmann.

Brickenkamp, R. (2002). Bickenkamp Handbuch psychologischer und pädagogischer Tests (Vol. *3*). Göttingen Bern Toronto Seattle: Hogrefe.

Brickenkamp, R., Schmidt-Atzert, L., & Liepmann, D. (2010). Attention and concentration test d2—revised version. Göttingen: Hogrefe Verlag für Psychologie.

Brisswalter, J., Collardeau, M., & Rene, A. (2002). Effects of acute physical exercise characteristics on cognitive performance. *Sports Med*, *32*(9), 555–566.

Brummer, V., Schneider, S., Abel, T., Vogt, T., & Struder, H. K. (2011). Brain cortical activity is influenced by exercise mode and intensity. *Medicine and Science in Sports and Exercise*, *43*(10), 1863–1872. doi: 10.1249/MSS.0b013e3182172a6f

Byrne, A., & Byrne, D. G. (1993). The effect of exercise on depression, anxiety and other mood states: A review. *Journal of psychosomatic research*, *37*(6), 565–574.

Chmura, J., Nazar, K., & Kaciuba-Uscilko, H. (1994). Choice reaction time during graded exercise in relation to blood lactate and plasma catecholamine thresholds. *International journal of sports medicine*, *15*(4), 172–176. doi: 10.1055/s-2007-1021042

Cohen, J. (1988). Statistical power analysis for the behavioral sciences. Oxon: Psychology Press.

Dababneh, A. J., Swanson, N., & Shell, R. L. (2001). Impact of added rest breaks on the productivity and well being of workers. *Ergonomics*, *44*(2), 164–174. doi: 10.1080/00140130121538

Deslandes, A., Moraes, H., Ferreira, C., Veiga, H., Silveira, H., Mouta, R., … Laks, J. (2009). Exercise and mental health: many reasons to move. *Neuropsychobiology*, *59*(4), 191–198. doi: 10.1159/000223730

Dietrich, A. (2003). Functional neuroanatomy of altered states of consciousness: The transient hypofrontality hypothesis. *Conscious Cogn*, *12*(2), 231–256. doi: 10.1016/S1053-8100(02)00046-6

Dietrich, A. (2006). Transient hypofrontality as a mechanism for the psychological effects of exercise. *Psychiatry research*, *145*(1), 79–83. doi: 10.1016/j.psychres.2005.07.033

Dorval, M., & Pepin, M. (1986). Effect of playing a video game on a measure of spatial visualization. *Perceptual and motor skills*, *62*(1), 159–162.

Folkins, C. H., & Sime, W. E. (1981). Physical fitness training and mental health. *The American psychologist*, *36*(4), 373–389.

Fox, K. R. (1999). The influence of physical activity on mental well-being. *Public health nutrition*, *2*(3A), 411–418.

Frith, C., & Dolan, R. (1996). The role of the prefrontal cortex in higher cognitive functions. *Brain Res Cogn Brain Res*, *5*(1-2), 175–181. doi: 10.1016/S0926-6410(96)00054-7

Galinsky, T. L., Swanson, N. G., Sauter, S. L., Hurrell, J. J., & Schleifer, L. M. (2000). A field study of supplementary rest breaks for data-entry operators. *Ergonomics*, *43*(5), 622–638. doi: 10.1080/001401300184297

Graf, O. (1927). Die Arbeitspause in Theorie und Praxis. *Psychologische Arbeiten*, *9*, 563–681.

Hillman, C. H., Kramer, A. F., Belopolsky, A. V., & Smith, D. P. (2006). A cross-sectional examination of age and physical activity on performance and event-related brain potentials in a task switching paradigm. *International journal of psychophysiology: official journal of the International Organization of Psychophysiology*, *59*(1), 30–39. doi: 10.1016/j.ijpsycho.2005.04.009

Jasper, H. H. (1958). The ten–twenty electrode system of the international Federation. *Electroencephalogr Clin Neurophysiol Suppl*, *35*(Supp 10), 371–375.

Kahnemann, D. (Ed.) (1993). Attention and effort. New Jersey: Prentice-Hall.

Kashihara, K., Maruyama, T., Murota, M., & Nakahara, Y. (2009). Positive effects of acute and moderate physical exercise on cognitive function. *Journal of physiological anthropology*, *28*(4), 155–164.

Kirschstein, T., & Kohling, R. (2009). What is the source of the EEG? *Clin EEG Neurosci*, *40*(3), 146–149.

Kleinert, J. (2006). Adjektivliste zur Erfassung der wahrgenommenen körperlichen Verfassung (WKV): Skalenkonstruktion und erste psychometrische Befunde [Adjective list for assessing Perceived Physical State (PEPS). Scale construction and psychometric results]. *Zeitschrift für Sportpsychologie*, *13*(4), 156–164.

Klimesch, W. (1999). EEG alpha and theta oscillations reflect cognitive and memory performance: A review and analysis. *Brain research reviews*, *29*(2-3), 169–195.

Klimesch, W., Sauseng, P., & Hanslmayr, S. (2007). EEG alpha oscillations: The inhibition-timing hypothesis. *Brain Res Rev*, *53*(1), 63–88. doi: S0165-0173(06)00083-X[pii]

Lo Bue-Estes, C., Willer, B., Burton, H., Leddy, J. J., Wilding, G. E., & Horvath, P. J. (2008). Short-term exercise to exhaustion and its effects on cognitive function in young women. *Percept Mot Skills*, *107*(3), 933–945.

Marschak, M. E. (2012). Experimentelle Untersuchungen über den Einfluss der aktiven Erholung auf die Arbeitsfähigkeit des Menschen. *European journal of applied physiology and occupational physiology*, 664–680. doi: 10.1007/BF02010222

Maslach, C., Schaufeli, W. B., & Leiter, M. P. (2001). Job burnout. *Annual review of psychology*, *52*, 397–422. doi: 10.1146/annurev.psych.52.1.397

McMorris, T., Davranche, K., Jones, G., Hall, B., Corbett, J., & Minter, C. (2009). Acute incremental exercise, performance of a central executive task, and sympathoadrenal system and hypothalamic–pituitary–adrenal axis activity. *Int J Psychophysiol*, *73*(3), 334–340. doi: 10.1016/j.ijpsycho.2009.05.004

McMorris, T., & Keen, P. (1994). Effect of exercise on simple reaction times of recreational athletes. *Perceptual and motor skills*, *78*(1), 123–130.

McMorris, T., Swain, J., Smith, M., Corbett, J., Delves, S., Sale, C., … Potter, J. (2006). Heat stress, plasma concentrations of adrenaline, noradrenaline, 5-hydroxytryptamine and cortisol, mood state and cognitive performance. *Int J Psychophysiol*, *61*(2), 204–215. doi: 10.1016/j.ijpsycho.2005.10.002

Mierau, A., Schneider, S., Abel, T., Askew, C., Werner, S., & Struder, H. K. (2009). Improved sensorimotor adaptation after exhaustive exercise is accompanied by altered brain activity. *Physiol Behav*, *96*(1), 115–121. doi: 10.1016/j.brainresrev.2006.06.003

Norton, K., Norton, L., & Sadgrove, D. (2010). Position statement on physical activity and exercise intensity terminology. *Journal of Science and Medicine in Sport/Sports Medicine Australia*, *13*(5), 496–502. doi: 10.1016/j.jsams.2009.09.008

Ohsugi, H., Ohgi, S., Shigemori, K., & Schneider, E. B. (2013). Differences in dual-task performance and prefrontal cortex activation between younger and older adults. *BMC neuroscience*, *14*, 10. doi: 10.1186/1471-2202-14-10

Penedo, F. J., & Dahn, J. R. (2005). Exercise and well-being: A review of mental and physical health benefits associated with physical activity. *Current opinion in psychiatry*, *18*(2), 189–193.

Petruzzello, S. J., Landers, D. M., Hatfield, B. D., Kubitz, K. A., & Salazar, W. (1991). A meta-analysis on the anxiety-reducing effects of acute and chronic exercise. Outcomes and mechanisms. *Sports medicine*, *11*(3), 143–182.

Ransford, C. P. (1982). A role for amines in the antidepressant effect of exercise: A review. *Medicine and science in sports and exercise*, *14*(1), 1–10.

Richter, P., & Hacker, W. (1998). Belastung und Beanspruchung (Vol. *3*). Heidelberg: Asanger.

Ridderinkhof, K. R., van den Wildenberg, W. P., Segalowitz, S. J., & Carter, C. S. (2004). Neurocognitive mechanisms of cognitive control: The role of prefrontal cortex in action selection, response inhibition, performance monitoring, and reward-based learning. *Brain and cognition*, *56*(2), 129–140. doi: 10.1016/j.bandc.2004.09.016

Salmon, P. (2001). Effects of physical exercise on anxiety, depression, and sensitivity to stress: A unifying theory. *Clinical psychology review*, *21*(1), 33–61.

Schaefer, P. D., & Thomas, J. (1998). Difficulty of a spatial task and sex difference in gains from practice. *Perceptual and motor skills*, *87*(1), 56–58.

Schaufeli, W. B., & Greenglass, E. R. (2001). Introduction to special issue on burnout and health. *Psychology & health*, *16*(5), 501–510. doi: 10.1080/08870440108405523

Schneider, S., Abeln, V., Popova, J., Fomina, E., Jacubowski, A., Meeusen, R., & Struder, H. K. (2013a). The influence of exercise on prefrontal cortex activity and cognitive performance during a simulated space flight to Mars (MARS500). *Behav Brain Res*, *236*(1), 1–7. doi: 10.1016/j.bbr.2012.08.022

Schneider, S., Abeln, V., Popova, J., Fomina, E., Jacubowski, A., Meeusen, R., & Struder, H. K. (2013b). The influence of exercise on prefrontal cortex activity and cognitive performance during a simulated space flight to Mars (MARS500). *Behavioural brain research*, *236*(1), 1–7. doi: 10.1016/j.bbr.2012.08.022

Schneider, S., Askew, C. D., Diehl, J., Mierau, A., Kleinert, J., Abel, T., … Struder, H. K. (2009). EEG activity and mood in health orientated runners after different exercise intensities. *Physiology & behavior*, *96*(4-5), 709–716. doi: 10.1016/j.physbeh.2009.01.007

Schneider, S., Brummer, V., Carnahan, H., Kleinert, J., Piacentini, M. F., Meeusen, R., & Struder, H. K. (2010). Exercise as a countermeasure to psychophysiological deconditioning during long-term confinement. *Behav Brain Res*, *211*(2), 208–214. doi: 10.1016/j.physbeh.2008.09.002

Schneider, S., & Struder, H. K. (2009). Monitoring effects of acute hypoxia on brain cortical activity by using electromagnetic tomography. *Behav Brain Res*, *197*(2), 476–480. doi: 10.1016/j.bbr.2008.10.020

Slesina, W. (2008). Workplace health promotion in the Federal Republic of Germany. *Bundesgesundheitsblatt, Gesundheitsforschung, Gesundheitsschutz*, *51*(3), 296–304. doi: 10.1007/s00103-008-0460-6

Tanaka, H., Monahan, K. D., & Seals, D. R. (2001). Age-predicted maximal heart rate revisited. *J Am Coll Cardiol*, *37*(1), 153–156.

Tucker, P. (2003). The impact of rest breaks upon accident risk, fatigue and performance. *International Journal of Work, Health & Organisations*, *17*(2), 123–137. doi: 10.1080/0267837031000155949

Ulich, E. (2005). Arbeitspsychologie (Vol. *6*): Germany: Schäffer-Poeschel Verlag, Freiburg.

Vogt, T., Abeln, V., Struder, H. K., & Schneider, S. (2014). Artificial gravity exposure impairs exercise-related neurophysiological benefits. *Physiol Behav*, *123*, 156–161. doi: 10.1016/j.physbeh.2013.10.020

Vogt, T., Schneider, S., Anneken, V., & Struder, H. K. (2013). Moderate cycling exercise enhances neurocognitive processing in adolescents with intellectual and developmental disabilities. *Res Dev Disabil*, *34*(9), 2708–2716. doi: 10.1016/j.ridd.2013.05.037

Vogt, T., Schneider, S., Brummer, V., & Struder, H. K. (2010). Frontal EEG asymmetry: The effects of sustained walking in the elderly. *Neurosci Lett*, *485*(2), 134–137. doi: 10.1016/j.bbr.2010.03.034

WHO. (2013). Depression in Europe: facts and figures. 2013. Retrieved 20.06.2013, 2013, from http://www.euro.who.int/de/what-we-do/health-topics/noncommunicable-diseases/mental-health/news/news/2012/10/depression-in-europe/depression-in-europe-facts-and-figures (Accessed 15 August 2015)