Transient cardiac responses to witnessing horrible events in young adult female exercisers and non-exercisers

Helmut K. Lackner*a, Elisabeth M. Weissb, Ellen Hoferb, Andreas Rösslera, Andreas Finkb, Günter Schulterb, Ilona Papousekb

a Institute of Physiology, Medical University of Graz, Austria
b Department of Psychology, Biological Psychology Unit, University of Graz, Austria

Abstract

Objectives: It has been proposed that regular exercisers may be less vulnerable to the effects of stress and better able to cope with aversive events than people who are sedentary, but findings have not been consistent. In the present study, physiological variables indicating specific relevant psychological processes were used to objectively assess women’s responses to stressful events.

Design and method: Non-exercising (n = 56) and regularly exercising women (up to 4 h, n = 62, and more than 4 h per week, n = 50) were viewing an aversive film consisting of scenes of real injury and death, and their transient cardiac responses to sudden horrifying events happening to persons in the film were obtained, as well as changes of prefrontal-posterior coupling, measured by EEG.

Results: Compared to regularly exercising women, non-exercising women showed a clearly more pronounced second accelerative component of the transient heart rate response to the terrifying events, indicating greater sensitivity of the avoidance (defensive) motivational system and heightened sensitivity to aversive stimuli. Moreover, non-exercising women did not show the expected characteristic initial heart rate acceleration when the scene approached its fatal end, that is, more rigid responding, and EEG data indicated less susceptibility to affect-laden information at the perceptual level.

Conclusions: The findings support the notion of less adaptive coping with adverse events in sedentary compared to exercising women and add to the growing evidence suggesting a stress-buffering effect of regular exercise, therefore promoting resilience and resistance to the negative impact of stressor and trauma exposure.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

It has been proposed that regular exercisers may be less vulnerable to the effects of stress and better able to cope with aversive events than people who are sedentary. According to the cross-stressor adaptation hypothesis, an unspecific adaptation of the stress response system occurs if someone is repeatedly confronted with a stressor of sufficient intensity (Sothmann, 2006; Sothmann et al., 1996). Physical exercise may be seen as a stressor in this context (Meeusen, 2006). The adaptation process may result in generally increased stress tolerance in terms of increased resilience, referring to a greater ability to recover also from psychological stress (Sothmann, 2006; Sothmann et al., 1996).

Several neurobiological changes in the brain have been suggested to underlie the improved recovery processes (for reviews see Fleshner, Maier, Lyons, & Raskind, 2011; Harrison & Baune, 2014).

However, in empirical studies supporting the proposed positive effects of regular exercise, global self-report measures of perceived stress or mood have been used, or indirect indicators such as physical complaints and health (Aldana, Sutton, Jacobson, & Quirk, 1996; Gerber, Kellmann, Hartmann, & Pühse, 2010; Rimmele et al., 2007). Moreover, findings have not been consistent. Some studies reported no differences in self-reported stress responses between exercising and sedentary individuals or even reverse effects (Klaperski, von Dawans, Heinrichs, & Fuchs, 2013; Rimmele et al., 2009). These inconsistencies may in part be due to the great variety of largely unspecific psychological measures that were used, which are additionally influenced by participants’ expectations and their ability or willingness to accurately report on their own experience (Allen, Kuppens, & Sheeber, 2012; Blascovich, Seery,
transient cardiac responses refer to heart rate changes across a series of time frames of a few seconds. The analysis of the time course of transient cardiac responses supplies relevant information not available from coarse average values (e.g., Lackner, Batzel, Rössler, Hinghofer-Szalkay, & Papousek, 2014). Specifically, acute cardiac responses to an intense, unexpected, and aversive stimulus are typically characterized by initial fast heart rate acceleration, deceleration, and again (more gradual) acceleration, constituting the so-called cardiac defense response (Graham & Clifton, 1966; Vila et al., 2007). Particularly its second accelerative component has been interpreted as reflecting the activation of the withdrawal/avoidance (or defensive; Lang, Bradley, & Cuthbert, 1990) motivational system (Fernandez & Vila, 1989; Turpin, 1986; Turpin, Schaefer, & Boucsein, 1999). Research indicated that interindividual differences in the magnitude of the second accelerative component imply differences in avoidance-motivated behavior (Eves & Gruzelier, 1984; Lopez, Puy, Pastor, Segarra, & Molto, 2009). For instance, individuals showing stronger heart rate acceleration in the second accelerative component showed more pronounced fear learning in an aversive conditioning paradigm (Lopez et al., 2009). At the same time, studies found a positive relationship between the magnitude of the cardiac defense response and enhancement of attention to and perception of external cues (Keil et al., 2010; Papousek, Weiss, et al., 2013; Perez, Fernandez, Vila, & Turpin, 2000; Vila, Perez, Fernandez, Pegalajar, & Sanchez, 1997; Vila et al., 2007).

Thus, evidence indicates that greater transient cardiac responses to the observation of sudden horrifying events happening to other persons, in particular a more pronounced second accelerative component, reflect greater withdrawal/avoidance motivation as well as enhanced attention to negative social-emotional cues. Greater sensitivity of the withdrawal/avoidance motivational system including heightened sensitivity to aversive stimuli indicates adverse coping and related impaired recovery from stress that is characteristic in depression (Trew, 2011).

Less pronounced cardiac defense responses to the observation of awful events happening to other persons can also be associated with greater down-modulation of social-emotional input at the perceptual level (Papousek, Weiss, et al., 2013). Therefore, in addition to the cardiac defense response, we used an electroencephalographic (EEG) indicator to exclude the possibility that physically active individuals may show a more adaptive cardiac response pattern because they are generally less susceptible to the perception of other persons’ emotions. Modulation of incoming affectively laden information at the perceptual level is reflected in altered state-dependent coupling of prefrontal and posterior association cortex, indicated by changes of EEG coherence (Miskovic & Schmidt, 2010). Several studies focusing on inter-individual differences in this modulatory process demonstrated that enhanced prefrontal-posterior coupling in the right hemisphere, indicated by higher EEG coherences during the stimulation, was related to reduced perception and, thus, to reduced impact of the affectively laden input (Papousek, Reiser, et al., 2013; Papousek, Weiss, et al., 2013; Papousek, Weiss, Mosbacher, et al., 2014; Reiser et al., 2012).

Taken together, in the present study non-exercising and regularly exercising women (up to 4 h and more than 4 h per week) were viewing an aversive film consisting of scenes of real injury and death, and their transient cardiac responses to sudden horrifying events happening to persons in the film were obtained. We expected that the magnitude of the cardiac defense responses, particularly of their second accelerative components, would be greater in non-exercising than in regularly exercising participants, indicating more adverse coping and impaired recovery from the aversive experience. Since a sedentary life-style may be related to elevated depressed mood (also expected to be linked to a more pronounced second accelerative component), it was additionally examined if the effect of exercise was independent of depression levels. In addition to that, we examined whether non-exercising and regularly exercising women may differ in the modulatory process reflecting the basic susceptibility to the perception of social-emotional information by analyzing prefrontal-posterior EEG coherences. No difference was expected.

2. Material and methods

2.1. Participants

A total of n = 175 female university students were recruited. Only individuals who confirmed that they did not have traumatic experiences related to car crashes, surgery or death of a close person within the past twelve months and did not have a neuro-psychiatric or cardiovascular disease were admitted to participate. Individuals who reported using psychoactive medication, beta adrenergic receptor antagonists, or whose scores on the Beck Depression Inventory exceeded the threshold for severe depressive symptoms were excluded from the study (n = 7). The final sample comprised n = 168 women aged between 18 and 42 years, of which 62 were regularly exercising up to 4 h per week, 50 were regularly exercising more than 4 h per week, and 56 were not exercising. Please see Table 1 for descriptive of the sample groups. 47 of the group exercising up to 4 h per week and 48 of the group exercising more than 4 h per week had been doing their sport at least for 6 months. Types of sport included endurance sports such as running, hiking, cycling, skating, dancing in 55 (<4 h) and 49 (>4 h) participants, other sports were mostly ballgames (volleyball, football, tennis, badminton). Most exercising participants, particularly in the >4 h group, reported doing more than one sport. A female only sample was chosen because previous research indicated that...
women are more reactive in a lab situation to negative emotional stimulation than men, particularly if the stimulation is threatening or traumatic (Whittle, Yücel, Yap, & Allen, 2011). Participants were requested to refrain from alcohol for 12 h and from coffee and other stimulating beverages for 2 h prior to their lab appointment, and to come to the session well rested and to not use their bicycles for the journey to the laboratory. The study was performed in accordance with the American Psychological Association's Ethics Code and the Declaration of Helsinki and was approved by the local ethics committee. Participants gave their written and informed consent to participate in the study.

2.2. Stimulus material

Please see Fig. 1 for a graphical representation of the timeline of the stimulation. Participants were exposed to a film including graphic scenes of severely injured, dying, and mourning people (approx. 10 min in length). It contained 11 clips that were used in previous studies demonstrating that withdrawal-oriented negative affective states were reliably induced from the film (e.g., Holmes, James, Coode-Bate, & Deeprose, 2009; Holmes, James, Kilford, & Deeprose, 2010). The film content was similar to that witnessed by television viewers watching programs such as news coverage of road traffic accidents, or reality programs about the police or ambulance service work. EEG and ECG were recorded during the last 5 min of the film during which there were five clips depicting a rampaging elephant injuring people at a circus and several car accidents. The last 5 min were used, because only the events in the second half were well-suited for extracting the transient cardiac responses (i.e., the scenes contained sudden, unexpected horrifying events). The film as such was used unchanged, because it had been used and validated in many studies of other labs in the context of the trauma film paradigm (e.g., Holmes et al., 2009, 2010). Each of the short stories told by the film scenes contained marked terrifying events and segments with negative content depicting the suffering of people, as well as short segments with neutral or mildly positive content that preceded the terrifying events. The film was displayed on a 21" computer monitor viewed at 100 cm and was presented without sound, so that the stimulation was dominated by the visual information for all participants. The neutral visual display, used for obtaining the reference data, showed a green circle (diameter 90 mm) at the center of the screen.

2.3. Recording and quantification of cardiac responses

The electrocardiogram was recorded using a Brainvision BrainAmp ExG Research Amplifier (Brain Products, sampling rate 500 Hz), using Ag–AgCl electrodes and a standard limb lead II electrode configuration. Interbeat intervals were derived using QRS complex detection based on Hilbert transformation (Harke, Schlögl, Anderer, & Pfurtscheller, 1999; Nygards & Sörnmo, 1983). Single artifacts were replaced by interpolation. Interbeat intervals were used for calculating mean heart rates for the reference period preceding the film and the recording while viewing the film. For the analysis of transient heart rate responses, interbeat intervals were resampled at 4 Hz using piecewise cubic spline interpolation. The third-order polynomial trend of the individual heart rate time series was removed, and heart rate time series averaged across all participants were calculated to identify local heart rate extremes within the film scenes. Heart rate time series from 10 s preceding

---

Table 1

Descriptives of sample groups: not exercising (no), regularly exercising up to 4 h per week (up to 4 h/w), regularly exercising more than 4 h per week (more than 4 h/w).

<table>
<thead>
<tr>
<th>Regularly exercising</th>
<th>No (n = 56)</th>
<th>Up to 4 h/w (n = 62)</th>
<th>More than 4 h/w (n = 50)</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>22.0 (3.5)</td>
<td>22.5 (4.5)</td>
<td>22.2 (3.2)</td>
<td>.72</td>
</tr>
<tr>
<td>Body Mass Index</td>
<td>21.8 (0.4)</td>
<td>21.6 (0.4)</td>
<td>22.4 (0.5)</td>
<td>.41</td>
</tr>
<tr>
<td>Depression (CES-D)</td>
<td>14.2 (8.4)</td>
<td>12.2 (6.8)</td>
<td>11.0 (8.2)</td>
<td>.11</td>
</tr>
<tr>
<td>Smokers</td>
<td>33.9%</td>
<td>24.2%</td>
<td>10%</td>
<td>.01</td>
</tr>
</tbody>
</table>

Note: Mean (standard deviation).

---

![Fig. 1. Timeline of physiological recordings.](image-url)
the most marked heart rate minima (indicating responses to the most marked horrifying events in the scenes) to 18 s after these minima were segmented in 4-s intervals, in order to reduce breathing frequency effects. This procedure supplies a segment of the cardiac “defense” response, timed by an objective criterion. (Extraction of a longer segment was not possible, because other events interfered). Values for these 4-s intervals were referenced to the reference period (i.e., heart rate from the reference period was subtracted from these values) and were averaged across the three most marked horrifying events to obtain the transient heart rate responses (relative heart rate scores of seven 4-s intervals) used in the statistical analysis. The same procedure has been used in previous research using this film (e.g., Papousek, Weiss, Schulter, et al., 2014). The three most marked horrifying events comprised of a boy playing in the garden killed by a car veering off the street, a teenager crossing the street while writing a SMS being run over by a car, and a couple in love sitting on a wall being hit by a car out of control. In addition, a 28-s time frame with neutral/mildly positive content was selected (relative scores of seven 4-s intervals). This time frame comprised of a boy playing football in the garden and adult football players scoring a goal and celebrating in the pub. Please see Fig. 1 for a graphical representation of the timeline of the physiological recordings.

2.4. EEG recording and quantification

In a subsample (n = 120) of the total sample, EEG was recorded using a sampling rate of 500 Hz, referenced to the nose and referenced offline to a mathematically averaged ears reference (Essl & Rappelsberger, 1998; Hagemann, 2004). Artifact-free EEG data were submitted to Fast Fourier Analysis using a Hanning window (epoch length 1 s, overlapping 50%), and spectral coherence (Fisher’s z-transformed) was obtained. Only the coherences in the right hemisphere and in the beta frequency range (13–30 Hz) were used, because previous relevant research in the affective domain indicated strong right-hemisphere dominated effects and effects occurring primarily in the beta frequency range (Aftanas, Lotova, Koshkarov, & Popov, 1998; Miskovic & Schmidt, 2010; Papousek, Reiser et al., 2013; Papousek, Weiss et al., 2013; Papousek, Weiss, Mosbacher, et al., 2014; Reiser et al., 2012). Coherence pairs were grouped into anatomically valid clusters corresponding to prefrontal and posterior association cortex regions (Fp2-T4, Fp2-P4, Fp2-T6, F4-T4, F4-P4, F4-T6, F8-T4, F8-P4, F8-T6; cf. Miskovic & Schmidt, 2010; Papousek, Reiser et al., 2013; Papousek, Weiss, et al., 2013; Papousek, Weiss, Mosbacher, et al., 2014; Reiser et al., 2012). Change-of-coherence scores (Δ coh) were calculated as described in detail in Papousek, Weiss, Mosbacher, et al. (2014), Papousek, Reiser, et al. (2013). Negative scores indicate a relative decrease in prefrontal-posterior coherence during the film compared to the reference period, positive scores indicate a relative increase.

2.5. Self-report measures

Depressive affect was assessed using the Center for Epidemiologic Studies Depression Scale (CES-D; German version by Hautzinger & Bailer, 1993). It is comprised of 20 items referring to mood and attributions over the past week, designed for measuring sub-clinical depressive experiences in the general population (Wood, Taylor, & Joseph, 2010). The internal consistency reliability was α = .86 (Cronbach’s alpha) in the present sample.

For the assessment of the self-reported impact of the film, a composite mood score was calculated by summing participants’ ratings (differences of the ratings after the film minus the ratings before the film) on three 10 cm horizontal visual analogue scales for feeling “sad”, “depressed”, and “hopeless”, following previous research using the film material (Deeprose, Zhang, Dejong, Dalgleish, & Holmes, 2012; Holmes et al. 2009, 2010; Papousek, Weiss, Schulter, et al., 2014). The responses were scored in millimetres from 0 (“not at all”) to 100 “extremely”, α = .78.

Physical exercise was assessed by a short questionnaire in which participants indicated the types of sport they are practising regularly (number not limited) and, for each sport, how many hours per week they typically engage in this sport (not including the time for getting there, changing clothes, personal hygiene). We calculated the sum of hours expended for appropriate types of sports (excluding types such as motorsports, chess, or walking the dog), and divided the sample into groups of women not exercising at all, women regularly exercising up to 4 h per week, and women regularly exercising more than 4 h per week. These classification criteria were chosen because the common recommendation of the World Health Organization (2010) for achieving more substantial health benefits is to engage in 300 min of moderate-intensity physical activity or 150 min of vigorous-intensity activity per week. As most participants indicated mixed moderate- and more vigorous-intensity activities, 4 h were used as the nearest approximation to these recommendations.

3. Procedure

The participants completed the CES-D, detailed their exercising habits, and their height and weight were measured. After they were seated in an acoustically shielded examination chamber and electrodes were attached, they completed the mood rating scales using the computer mouse. Participants were instructed that after a short recording period during which they should watch the green circle on the screen (2 min) they would see a film to which they should direct their whole attention. They were asked to view the film as if they were really there, like a bystander at the scene of the events and to not close their eyes or look away. Two minutes after the film, the participants completed the rating scales again. The experimenter was positioned outside the examination room, and participants were monitored using a camera. All participants adhered to the instructions to not close their eyes during the film or look away. The recordings took place in the time between 9:00 a.m. and 7:00 p.m. There was no systematic bias in the recording times between groups. Before they were dismissed, participants were given the experimenter’s contact details and were encouraged to contact the experimenter if they felt distressed during the following days. A psychiatrist and trained psychotherapist (the second author) was in attendance to deal with any potentially emerging symptoms of distress.

3.1. Statistical analysis

The relationship between exercising and the transient heart rate response to the most terrifying events happening to persons in the film was examined by a two-way analysis of variance using the relative scores of the seven extracted 4-s intervals in the context of the most marked horrifying events as the levels of the within-subjects factor, and group (non-exercising, up to 4 h/w, more than 4 h/w) as the between-subjects factor. The multivariate approach to repeated measures analyses was used, which allows

---

1 Additional data were obtained for purposes related to other, non-overlapping research questions. These include effects of genetic polymorphisms on EEG responses in Papousek, Reiser, et al. (2013) and correlations between cortical decoupling and the development of intrusive memories in a smaller sub-sample (Reiser et al., 2014).
valid tests under nonsphericity conditions (Vasey & Thayer, 1987). For control purposes, an analogous analysis was performed using the relative scores of the intervals during the film period with neutral/mildly positive content as the levels of the within-subject factor.

A one-way analysis of variance was used to examine potential differences between the three groups in their depression scores. By additionally entering depression as a covariate in the initial 3 (group) x 7 (time frame) analysis of variance, the independent effect of depression on the transient heart response in the context of the most terrifying events was examined (i.e., using depression as a continuous between-subjects factor). To illustrate the effect of depression, predicted heart rate values for each level of the within-subjects factor (time frame) were calculated for one standard deviation below and one standard deviation above the mean depression score in the sample using standard regression analysis.

Additional analyses examined potential differences between the three groups in their body mass index (one-way analysis of variance) and in the rates of tobacco smokers (Chi-square test). Transient heart rate responses of smokers vs. non-smokers were compared using a 2 (smoking) x 7 (time frame) analysis of variance. Finally, self-reported mood deterioration in the three groups (non-exercising, up to 4 h/w, more than 4 h/w) was examined in a one-way analysis of variance using the composite mood score as the dependent variable.

Finally, for the analysis of potential differences between groups in the modulatory process reflecting the basic susceptibility to the perception of social-emotional information, a one-way analysis of variance was used with group as the between-subjects factor and prefrontal-posterior EEG coherences (Δ coh) as the dependent variable.

A significance level of p < .05 was used for all analyses.

4. Results

The analysis of the global heart rate differences between the 2 min reference period before the film started and the film period (average heart rates across entire recording periods) yielded a significant main effect of group ($F(2,165) = 3.0, p = .05, \eta^2_p = .04$) and condition (reference period vs. film period), $F(1,165) = 3.9, p = .05, \eta^2_p = .02$; condition x group, $F(2,165) = 2.3, p = .10$. As expected, average heart rates were lower with increasing levels of exercising. Heart rates during the reference period preceding the film and during viewing the film (coarse average values across entire recording periods) are shown in Fig. 2.

The analysis examining the transient heart rate response to the most terrifying events happening to persons in the film showed a classic triphasic pattern of initial heart rate acceleration, deceleration, and second acceleration. This was supported by the significant main effect of time frame ($F(6,160) = 29.5, p < .001, \eta^2_p = .53$) and the quadratic contrast ($F(1,165) = 64.3, p < .001, \eta^2_p = .28$; main effect of group, $F(2,165) = 2.3, p = .10$). More important, the analysis revealed that the shape of the heart rate response differed between the three groups (interaction effect of time frame by group, $F(12,322) = 2.2, p = .01, \eta^2_p = .08$). The interaction effect is illustrated in Fig. 3. It shows a markedly more pronounced second accelerative component (seconds 10 onwards) of the heart rate response in non-exercising than in regularly exercising participants, as well as a smaller heart rate increase at the beginning of the terrifying scene, with little difference between the two exercising groups.

In contrast, the analysis of the film period with neutral/mildly positive content showed no main effect of time frame ($F(6,160) = 1.0, p = .46$) and no interaction effect of time frame by group ($F(12,322) = 1.2, p = .25$). The significant main effect of group ($F(2,165) = 7.40, p = .001, \eta^2_p = .07$) was due to an increase of the heart rate during the film scene compared to the reference period in regularly exercising participants ($M = 2.8, SD = 5.1; M = 1.4, SD = 4.4$) which was absent in non-exercising participants ($M = -3, SD = 4.4$).

The three groups did not significantly differ in their mean depression scores ($F(2,165) = 2.2, p = .11$). Additionally entering the depression scores as a covariate in the analysis of the transient heart rate response to the most terrifying events did not change the interaction effect of time frame by group ($F(12,320) = 2.2, p = .01, \eta^2_p = .08$), indicating that the effect of regularly exercising on the response was independent from the participants’ depression levels. However, the analysis revealed an effect of depression on the shape

![Fig. 2. Heart rates during reference period preceding the film and during viewing the film. Note. Coarse average values across entire recording periods. Significant main effects of group and condition. Please see Fig. 1 for a graphical representation of the timeline of the physiological recordings.](image)

![Fig. 3. Transient cardiac responses to witnessing horrible events in exercisers and non-exercisers. Note. Significant interaction effect of time frame by group. Compared to regularly exercising participants, non-exercising participants showed a smaller heart rate increase at the beginning of the terrifying scene (sec. 2) as well as a more pronounced second accelerative component (progression from sec. 10 to 26). Note that the figure shows the heart rate relative to the heart rate in the neutral reference period (i.e., difference scores); positive values indicate heart rate increases as compared to the neutral reference period.](image)
of the transient heart rate response that was independent of the participants’ exercising habits (interaction effect of time frame by depression, \(F(6,159) = 2.9, p = .01, \eta_p^2 = .10\)). The effect of depression is illustrated in Fig. 4, which shows a more pronounced second accelerative component of the heart rate response in more depressed participants.

There were no differences between the groups in the body mass index (\(F(2,165) = .9, p = .41\)). Rates of smokers differed between groups (\(\chi^2(2, n = 168) = 8.5, p = .01\); see Table 1). However, there was no effect of smoking on the course of the transient heart rate response to the most terrifying events (interaction effect of time frame by smoking, \(F(6,161) = .6, p = .77\); main effect smoking, \(F(1,166) = .6, p = .44\)). The analysis of the composite mood score showed that more frequently exercising participants reported least mood deterioration by the film (\(M = 23.6, SD = 27.2\); negative mood increased from \(M = 14.9\) to \(M = 38.6\)) compared to less frequently exercising (\(M = 41.3, SD = 36.4\); negative mood increased from \(M = 16.4\) to \(M = 57.7\)) and non-exercising (\(M = 36.9, SD = 42.6\); negative mood increased from \(M = 25.3\) to \(M = 62.1\)) women (\(F(2,165) = 3.5, p = .03, \eta_p^2 = .04\)).

Of the \(n = 120\) participants for which EEG data were also available, 43 were regularly exercising up to 4 h per week, 37 were regularly exercising more than 4 h per week, and 40 were not exercising. They were aged \(M = 22.4 (SD = 4.2), M = 22.6 (SD = 3.1), M = 22.1 (SD = 3.7), \) respectively, \(F(2,117) = 1, p = .87\). The groups did not differ in their depression scores, \(F(2,117) = 2.1, p = .13\). The analysis of the prefrontal-posterior EEG coherences showed that women exercising more than 4 h per week showed the greatest decreases of prefrontal-posterior coupling, indicating greatest susceptibility to the perception of affect-laden information compared to the other groups, while the brain configuration of non-exercising women admitted the perception of social-emotional information to the least extent (Fig. 5; \(F(2,117) = 3.4, p = .04, \eta_p^2 = .05\)).

5. Discussion

The study aimed at adding novel findings to the question of whether regular exercisers may be better able to cope with aversive events than people with a sedentary life style by using objective, physiological variables that indicate specific relevant psychological processes. The most important result is that the transient cardiac responses to sudden horrifying events happening to persons in a film (the cardiac defense response) varied depending on the participants’ regular physical activity: Compared to regularly exercising women, women with a sedentary life style showed a clearly more pronounced second accelerative component of the transient heart rate response to the terrifying events.

At the same time, the analysis of the EEG data indicated that the smaller magnitude of the second accelerative component of the cardiac defense response in regularly exercising women cannot be attributed to greater down-modulation of affect-laden information at the perceptual level. According to the EEG data, regularly exercising women did not show greater increases of prefrontal-posterior coupling during viewing the aversive film than sedentary women, which would have been indicative of reduced perception and reduced impact of the affectively laden input (Papousek, Reiser, et al., 2013; Papousek, Weiss, et al., 2013; Papousek, Weiss, Mosbacher, et al., 2014; Reiser et al., 2012). Thus, the data do not provide any evidence that physically active individuals might be generally less susceptible to the perception of other persons’ emotions.

A greater magnitude of the second accelerative component of the cardiac defense response reflects greater sensitivity of the withdrawal/avoidance motivational system including heightened sensitivity to aversive stimuli (Eves & Gruzelier, 1984; Keil et al., 2010; Lopez et al., 2009; Papousek, Weiss, et al., 2013; Perez et al., 2000; Vila et al., 1997; 2007). Thus, as the greater cardiac response in sedentary women cannot be attributed to greater susceptibility at the perceptual level (as indicated by the EEG data), together, the cardiac and electroencephalographic data support the notion of less adaptive coping with adverse events in the short term and related impaired recovery from stress in sedentary compared to exercising women (Eves & Gruzelier, 1984; Keil et al., 2010; Lopez et al., 2009; Papousek, Weiss, et al., 2013; Perez et al., 2000; Trew, 2011; Vila et al., 1997; 2007). Previous research showing faster heart rate recovery after experimental stress (coarse average values) in regularly exercising than in not exercising individuals
may be in line with this finding (Forcier et al., 2006; Jackson & Dishman, 2006; Klaperski et al., 2013; Klaperski, von Dawans, Heinrichs, & Fuchs, 2014).

As was expected, higher depression scores were also related to a more pronounced second accelerative component of the transient heart rate response to the most terrifying events in the film, thereby validating the interpretation of this component: Both the sensitivity of the withdrawal/avoidance motivational system and heightened sensitivity to aversive stimuli are characteristic for depression (Eves & Gruzelier, 1984; Fernandez & Vila, 1989; Keil et al., 2010; Lopez et al., 2009; Perez et al., 2000; Trew, 2011; Turpin, 1986; Turpin et al., 1999; Vila et al., 1997, 2007). However, importantly, the effects of a sedentary life style were independent from depression levels, suggesting that the effects of depressed mood may not be compensated by exercising or vice versa. Nevertheless, the effects might possibly add up. Note that depression levels were sub-clinical in all cases.

One explanation of the stress-buffering effect of regular physical exercise is provided by the cross-stressor adaptation hypothesis according to which an unspecific adaptation of the stress response system occurs through regular exercise, which results in more adaptive stress responses, particularly in an improved ability to recover from stress (Sothmann, 2006; Sothmann et al., 1996). Recent neuroscientific studies provided evidence for neurobiological changes in the brain that may underlie the improved recovery processes in regularly exercising individuals, thus substantiating this hypothesis (for reviews see Fleschner et al., 2011; Harrison & Baune, 2014). For instance, Hoffman et al. showed that exercise trained animals exposed to acute stress provided a mechanism to promote recovery from stress (Hoffman, Ostfeld, Kaplan, Zohar, & Cohen, 2015). Additionally, endurance training increased the expression of brain derived neurotrophic factor (BDNF), neurotropic substance Y (NPY) and δ-opioid receptor (phosphor-DOR) expression in hippocampus that was associated with the more adaptive stress response seen in the trained animals. Animal experiments also pointed to the implication of changes in the responses of serotoninergic neurons in the dorsal raphe nucleus and of the nigrostriatal dopaminergic reward pathway, both of which are related to more adaptive stress responding (Fleschner et al., 2011; Wu et al., 2013).

Although non-exercising women showed a more pronounced second accelerative component of the transient cardiac response than exercising women, they responded with smaller initial heart rate increases in the context of the aversive scenes. In fact, in contrast to regularly exercising participants, non-exercising women did not show the expected characteristic initial heart rate acceleration at all when the scene approached its fatal end. Thus, the cardiac responses of sedentary women to witnessing the terrifying events seemed to be more rigid overall whereas more beneficial cardiac responses were already observed with relatively low levels of exercising (up to 4 h per week), with little difference to those who were exercising more. The finding provided by the EEG analysis that the brain configuration of non-exercising women seemed to admit the perception of affect-laden information to the least extent might be in line with the diminished initial heart rate acceleration in the transient cardiac response. It was suggested that regular exercise produces adaptive changes in cerebral pathways that are associated with improved efficacy to respond to altered circulatory demands (Michelini & Stern, 2009), as well as that it triggers processes facilitating neuroplasticity in general, thereby enhancing the capacity to respond to changing demands with behavioral adaptations (Hötting & Röder, 2013; for reviews see Fleschner et al., 2011; Harrison & Baune, 2014). However, as only little research on physiological processes mediating the effects of regular physical activity on emotional responding is available to date, the specific neurophysiological mechanisms underlying the observed effect are an issue for future research.

In opposition to the cardiac responses, only more frequently (but not less frequently) exercising women reported less mood deterioration after the aversive film compared to non-exercising women, suggesting that the transient cardiac response is more sensitive than are self-reported mood ratings, which may be influenced by conscious or unconscious regulatory controls and other influences hampering the accurateness of the reports, and are less suitable to capture more subtle and fleeting changes (Allen et al., 2012; Blasovich et al., 2004; Schwerdtfeger, 2004). Several studies reported dissociations between physiological and psychological indicators of stress responses, particularly in depressed or alexithymic individuals (Dan-Glauser & Gross, 2013; Nandrino et al., 2012; Papousek, Schulte, & Premsberger, 2002; Schwerdtfeger, Schmukle, & Egloff, 2006). Importantly, the higher sensitivity can be achieved by analyzing transient cardiac responses only (but not coarse average values) once more demonstrating that information that is important for interpreting effects may be lost when only average values are used (Childs & de Wit, 2014; Lackner et al., 2010, 2013, 2014; Papousek, Weiss, Schulte, et al., 2014).

A limitation of the study is that levels of exercising were only assessed by self-report but not, for instance, by behavioral observations or diary measures. However, the differences in the resting heart rates between the three groups, with highest heart rates in sedentary women and lowest heart rates in women having indicated to exercise more than 4 h per week may provide some indication of validity of the self-reported data (Fig. 2). In addition, although only physiological variables were used that are well-established in the psychophysiological domain and the interpretation of which is substantiated by extensive empirical evidence, and although the data of the cardiac defense response seems to provide a clear picture, the interpretation of the complex interaction effect with three groups and seven points of measurement may not be completely unequivocal. Effect sizes are not large, which somewhat questions the actual practical relevance of the findings. The findings, acquired in a female-only sample may not fully generalise to men. Furthermore, it cannot be excluded that psychological characteristics that are linked to exercising and that were not assessed in the present study might explain the different responses in exercisers and non-exercisers. Finally, due to the cross-sectional nature of the study, no cause-effect relationship can be inferred from the results.

Taken together, the study demonstrated that the innovative approach of the combined use of cardiac (electrocardiographic) and brain (electroencephalographic) data can provide valuable information that may allow more conclusive interpretations than when they are analyzed separately. This is particularly true if variables are used for which the interpretation in terms of specific relevant psychological processes is empirically substantiated and well-established. Notwithstanding the limitations of the study, practical implications may be derived from the findings, which certainly will have to be explicitly examined or replicated in further studies. For instance, there is evidence that lasting sequelae of witnessing negative events such as intrusive memories and avoidance can occur in healthy individuals after observing disaster through televised images that are similar to those used in the present study (Breslau et al., 2010; Durham et al., 1985; Holmes & Bourne, 2008; Schlenger et al., 2002; Schuster et al., 2001). Greater sensitivity to aversive social-emotional cues should also predict greater impact of observed horrible events on the individual (e.g., Hender et al., 2003). In the current study, regularly exercising women showed more flexible responding to sudden horrifying events happening to persons in a film compared to not exercising individuals, and therefore better adaptive coping with adverse events in the short term, while women with a sedentary life style showed response


