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Impact of 'last experience' on affect after exercise reaching the anaerobic threshold: A laboratory investigation

Impacto de la 'última experiencia' sobre el afecto después del ejercicio que alcanza el umbral anaeróbico: Una investigación de laboratorio

Impacto da 'última experiência' no afeto após o exercício atingindo o limiar anaeróbio: Uma investigação laboratorial

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ABSTRACT

The affective benefits of a single bout of exercise are widely reported, but several factors influence the affect measured after exercise. One is the *last experience* linked to the exercise session. In this laboratory study, we manipulated progressive treadmill exercise to ventilatory threshold by using cognitive tasks during and immediately after the exercise when we gauged affect and compared it to pre-exercise baseline. We assumed that the affective responses after exercise would mirror feeling states associated with the very *last experience* (i.e., the cognitive task) rather than exercise. We examined a total of 53 athletes assigned to exercise or no-exercise control group. In addition to heart rates, positive and negative affect, feeling state, and perceived arousal were measured before and after the intervention. The results revealed substantial improvements in affect in both groups, based on large effect sizes. The lack of difference in the dependent measures between the exercise and no-exercise control group may suggest that both groups responded to the same last experience (i.e., cognitive task), and the effects of exercise and sitting (control) were wiped out. These findings imply that pre- to post-intervention exercise investigations testing the psychological benefits of a single bout of exercise may not measure what they intend to measure, but merely the affective responses

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to the last experience or event before answering the questionnaire(s). In brief, many hundreds of studies' internal reliability, employing the pre/post protocols, may be questionable.
Keywords: *arousal, cognition, expectation, feeling state, placebo effect*

RESUMEN

Los beneficios a nivel emocional de un solo período de entrenamiento han sido ampliamente estudiados, pero su efecto medido después del entrenamiento está influenciado por varios factores. Uno de ellos es la última experiencia vinculada a la sesión de entrenamiento. En este estudio de laboratorio se manipula, mediante el empleo de tareas cognitivas, el ejercicio progresivo en cinta de correr hasta alcanzar el umbral ventilatorio. Tanto durante como inmediatamente después del ejercicio se evalúa la respuesta afectiva y se compara con la línea basal previa al ejercicio. Se espera que las respuestas emocionales después del ejercicio reflejarán los estados afectivos asociados con la última experiencia (es decir, la tarea cognitiva), en lugar de con el ejercicio. Además de la frecuencia cardíaca, se evaluaron un total 53 atletas asignados al grupo experimental de ejercicio o al control sin ejercicio. Se midieron el estado afectivo positivo y negativo, el estado de sentimiento, y la excitación percibida, tanto antes como después de la intervención. Los resultados revelaron mejoras sustanciales en el estado afectivo en ambos grupos, mostrando grandes tamaños del efecto. La falta de diferencia en las variables dependientes entre el grupo experimental y el control sugiere que ambos grupos respondieron de manera similar a la última experiencia, es decir a la tarea cognitiva, eliminando los efectos del ejercicio realizado. Las implicaciones de estos hallazgos son muy relevantes puesto que prueban que los resultados de los estudios realizados hasta el momento sobre los beneficios psicológicos de un solo período de ejercicio pueden no medir lo que pretenden, sino simplemente las respuestas afectivas y emocionales a la última experiencia o evento antes de responder el cuestionario que se suele aplicar. En resumen, la confiabilidad interna de cientos de estudios que emplean los protocolos pre- post en el análisis de la respuesta afectiva en condiciones de entrenamiento pueden ser cuestionable.
Palabras clave: *arousal, cognición, expectativa, estado afectivo, efecto placebo*

RESUMO

Os benefícios emocionais de um único período de treinamento têm sido amplamente estudados, mas seu efeito medido após o treinamento é influenciado por vários fatores. Uma delas é a última experiência vinculada ao treinamento. Neste estudo laboratorial, o exercício progressivo em esteira é manipulado por meio de tarefas cognitivas até que o limiar ventilatório seja atingido. Durante e imediatamente após o exercício, a resposta afetiva é avaliada e comparada com a linha de base antes do exercício. Espera-se que as respostas emocionais após o exercício reflitam os estados afetivos associados à última experiência (ou seja, a tarefa cognitiva), ao invés do exercício. Além da frequência cardíaca, um total de 53 atletas designados para o grupo de exercício experimental ou o grupo de controle sem exercício foram avaliados. Estado afetivo positivo e negativo, estado de sentimento e excitação percebida foram medidos antes e depois da intervenção. Os resultados revelaram melhorias substanciais no status afetivo em ambos os grupos, mostrando grandes tamanhos de efeito. A ausência de diferença nas variáveis dependentes entre os grupos experimental e controle sugere que ambos os grupos responderam de forma semelhante à última experiência, ou seja, à tarefa cognitiva, eliminando os efeitos do exercício realizado. As implicações desses achados são muito relevantes, pois comprovam que os resultados dos estudos realizados até o momento sobre os benefícios psicológicos de um único período de exercício podem não medir o que pretendem, mas simplesmente as respostas afetivas e emocionais à última experiência ou antes de responder ao questionário normalmente aplicado.

Em resumo, a confiabilidade interna de centenas de estudos que empregam protocolos pré-pós na análise da resposta afetiva em condições de treinamento pode ser questionável.

Palavras-chave: excitação, cognição, expectativa, estado afetivo, efeito placebo

INTRODUCTION

Affect is a conscious momentary mental feeling state influenced by a given situation (Duncan & Barrett, 2007). It was reported that exercise improves affect (Anderson & Brice, 2011; Reed & Ones, 2006). The affect-related benefits of a single bout of exercise were demonstrated in numerous forms of exercises, including dance aerobics (Rokka, Mavridis, & Kouli, 2010), Nordic walking (Stark, Schöny, & Kopp, 2011), running (Hoffman & Hoffman, 2008; Szabo, 2003), shadowboxing (Li & Yin, 2008), swimming (Valentine & Evans, 2001), taekwondo (Toskovic, 2001), tai chi (Wang et al., 2010), walking (DaSilva et al., 2011), yoga (Streeter et al., 2010), Bikram yoga (Szabo, Nikházy, Tihanyi, & Boros, 2017), Pilates (Tolnai, Szabó, Köteles, & Szabo, 2016), spinning (Szabo, Gáspár, Kiss, & Radványi, 2015) and more. While a single bout of exercise usually yields positive feelings based a pre- to post-intervention designs, this connection is not straightforward (Ekkekakis & Brand, 2019).

The exercise intensity mediates the affective response to exercise. Indeed, high-intensity exercise, reaching and exceeding the ventilatory threshold, was related to negative affect after the exercise session (Blanchard, Rodgers, Spence, & Courneya, 2001; Ekkekakis & Petruzzello, 2002; Parfitt & Hughes, 2009). Based on these findings, Ekkekakis (2003) has forwarded a dual-mode theory to interpret the overall more negative affect reported following exercise at or above the ventilatory threshold. Based on the dual-mode theory, affective experience during exercise is affected, at least partly by the metabolic needs associated with the momentary exercise intensity. Greater metabolic demands could be related to unpleasant subjective feelings states that surface in the answers to various measures appraising the individual's exercise-induced effect. These feelings, linked to high exercise demands, trigger associative thinking (inward attention).

According to the ‘parallel-processing model’ (Rejeski, 1985), dissociative thinking (i.e., thoughts unrelated to the ongoing activity) grants a ‘time-out’ from fatigue by occupying most of one’s mental capacity of the channel connecting perception and focal awareness. Indeed, evidence from early research by Pennebaker and Lightner (1980) suggests that during exercise, external cues (e.g., environment) outcompete internal cues (e.g., ventilation). Consequently, because in high-intensity exercise, the lactic acid accumulation forces one to focus on the fatigue-induced distress, dissociative thinking is less likely. Simultaneously, the appraisal of the momentary feeling state (usually unpleasant at high workloads) culminates in negative affect.

Based on the above discussion, dissociative thinking is most likely to occur during light and moderate exercise associated with positive affective outcomes (DaSilva et al., 2011; Szabo, Gaspar, & Abraham, 2013). At a moderate intensity workload, exercisers can freely shift between associative and dissociated thinking without an effect on exercise performance (De la Vega, Rivera, Ruiz-Barquin, Ramos, & Segovia, 2016). Further, it was demonstrated that moderate exercise has a positive effect on cognitive effort with a high level of vigilance, selective attention, decision making, cognitive control, self-regulation, and motor behavior (Rodríguez, Ramos Álvarez, Segovia Martínez, Lopez-Silvarrey Varela, & De la Vega, 2017). In accord with these findings, earlier work showed that cognitive performance is raised during 20-minute progressively harder treadmill exercise (Rendi, Szabo, Szabó, 2007). Research also demonstrated that participants involved in progressively *easier* exercise showed more positive affect than those exposed to progressively increased exercise intensity (Zenko, Ekkekakis, & Ariely 2016). In contrast, progressively *harder* exercise, distracted by dissociation-inducing cognitive tasks, does not influence affect (Rendi et al., 2007).

In accord with early laboratory (Fillingim & Fine, 1986) and field research (Masters & Lambert, 1989), dissociation during exercise could enhance affect, but in progressively harder exercise, this effect may vanish (Rendi et al., 2007). Distraction used in an exercise protocol is assumed to trigger dissociative thinking. Based on the parallel-processing model (Rejeski, 1985), the distracting agent competes with internal (associative) thoughts related to exercise-induced discomfort or fatigue and, therefore, may foster affective benefits. However, based on empirical evidence (Blanchard et al., 2001; Parfitt & Hughes, 2009) and the parallel-processing model, when reaching the ventilatory threshold, the impact of the distracting agent should subside, or vanish altogether, and attention shifts from external to internal (discomfort, pain, and fatigue) awareness, triggering the change from dissociative to associative thinking. It was suggested that the evaluation of how pleasant or unpleasant the experience largely depends on past experiences associated with that experience (Zenko et al., 2016). Increasing exercise to the ventilatory threshold should then result in negative affect, but it is possible that distraction alters this expected outcome (Rendi et al., 2007). Still, soon into recovery, a shift or reversal to positive affect might be expected to occur due to earlier positive experiences. Such a shift was observed in well-trained exercisers (Hall, Ekkekakis, & Petruzzello 2002). Accordingly, the affective result of exercise (pleasant in moderate and low-intensity workouts and unpleasant after exercise performed at ventilatory or above threshold) is initially subjectively appraised according to a *momentary* feeling at the workout's termination. This appraisal emerges in the post-exercise rating of affect on various affect-gauging instruments. In pre- to post-exercise experiments, this score is compared to a baseline or pre-exercise measurement. The difference between pre- to post-exercise values is conceptualized (perhaps erroneously) as ‘exercise effect,’ but the post-intervention score only reflects the feeling state associated with the *last moment* in a specific exercise session. When exercise is performed beyond the ventilatory threshold, the person reports negative feelings because the tough and unpleasant final moments of exercise shape the momentary appraisal. However, if recovery starts, the ‘value’ of exercise and sense of accomplishment changes the subjective state associated with the earlier performed exercise. It is important to note that with the termination of the exercise beyond the ventilatory threshold, and simultaneous start of the recovery, dissociative thinking becomes possible again because the attention is no longer forcefully focussed on internal processes of fatigue and pain.

Research shows that affect changes during exercise as well (Hall et al., 2002), but the termination of the exercise at that *very last moment* determines the evaluation of the completed exercise session. For novel exercisers, a high-intensity exercise session will be associated with a negative or unpleasant experience because at the moment of responding to affective measures, the last feeling(s) will determine the answer. However, if there is a rest period interposed between the end of the high-intensity exercise and the assessment of the feeling state, the latter will be appraised as positive due to the pleasant feeling of recovery from exercise (Alves et al., 2021). Indeed, in his review, Ekkekakis (2009) cites several reports examining sedentary participants exercising at various workloads, which consistently found that exercisers reported unpleasant feelings on the Feeling Scale (Hardy & Rejeski, 1989) after reaching the ventilatory threshold. A lower volume or self-selected exercise favors positive feelings (Ekkekakis, 2009), which generates a positively remembered impression. Having repeatedly positive ‘finishes’ builds a positive mental association between exercise and the expectable feeling states, which is likely the dominant mechanism responsible for the large placebo effects in the consistently demonstrated psychological improvements after a single session of exercise (Lindheimer, O'Connor, & Dishman, 2015). Briefly, the last feeling states, subjectively experienced after exercise, appear to play a significant role in the appraisal of the actual (and future?) exercise sessions.

Most studies examining the affective benefits of exercise at various workloads were conducted with sedentary participants (Ekkekakis, 2009, Sudeck, Schmid & Conzelmann, 2016; Box & Petruzzello, 2021). Laboratory research addressing this question provides favorable circumstances for associative (focus on the self) thinking. On the contrary, athletic contests, often characterized by extremely high-intensity workload, usually end with a form of dissociative thinking (outside focus) in relation to self- or team performance and/or the result of the contest. Long ago, it was shown that the outcome of the contest was the determining factor in the affective states reported by the athletes (Hassmén, & Blomstrand, 1995). Therefore, athletes are a typical example in which the 'last experience' of the exercise, contest, or physical work is the crucial determinant in the post-exercise affective state. This issue might be important because both theory and research predict that at a high intensity (e.g., ventilatory threshold or above), exercise will result in negative feeling states and affect. However, if associative thinking is challenged, like in athletes who focus on the contest until the very last minute of the game, this negative effect may be voided.

The theory of last experience in determining reported affect in exercise settings, to our best knowledge, was not investigated to date, albeit there is indirect evidence for it (Hassmén, & Blomstrand, 1995; Zenko et al., 2016). In the area of food consumption, it was shown that the last memories of the food were the *most influential* in deciding how long one waits until consuming that food again (Garbinsky, Morewedge, & Shiv, 2014). In sport and exercise, the last feeling state encrypted in the memory is important in adherence and motivation, as well as a future subjective appraisal of the experience for both amateur and competitive exercisers.

In the current laboratory work, we used a progressive exercise protocol (to reach the ventilatory threshold as fast as possible) distracted by cognitive reaction-time tasks, prone to learning or practice effects, to test the hypothesis that affective experiences reported after an exercise intervention reaching the ventilatory threshold (when affect is consistently reported to be more negative than at baseline) is primarily related to the last experience, which is independent of exercise. A no-exercise control group was necessary to test this hypothesis. It was also necessary to introduce the cognitive task immediately after the termination of the exercise when the shift from associative- to dissociative-thinking becomes possible. Exercise reaching the ventilatory threshold was necessary because this is the stage in which negative affectivity is consistently reported. If the affective responses after the last cognitive task are negative, then the responses may reflect the carry-over effect of the high-intensity exercise. However, we presumed that such carry-over effects would be minimal or vanish due to the last experience manipulated with the cognitive tasks. In contrast to most past research, we tested elite athletes in open skill sports because they are used to high-intensity training involving reaction time-based decision making. Since the cognitive tasks were presented four times during exercise, they were unlikely to guess the aims of the study, which is important in attempting to avoid Hawthorne effects that might contaminate the results of laboratory experiments.

The objective of the study was to examine how distracting cognitive tasks during and immediately after progressive treadmill exercise to a ventilatory threshold change the subjective appraisal of affect. We hypothesized that the affective responses after the exercise would reflect feeling states resulting from the *very last experience* (i.e., the cognitive task) rather than from the exercise itself.

METHOD

Participants

A priori sample size was determined with the G*Power (v. 3.1) software (Faul, Erdfelder, Buchner, & Lang, 2009), which indicated that the minimum required sample size for the current research design (repeated measures analysis of variance) was 52 (as based on: $f = .25$, $\alpha = .05$, $r = .40$ [minimal assumed r between repeated measures] and $1-\beta = .90$). With the help of coaches, elite athletes were recruited through personal solicitation for participation in the study. In total 53 males (mean age = 22.09 ± SD = 3.13 years, range 18-32) volunteered for the study. Their mean height was 184.91 (± 8.49) cm, mean weight was 82.82 (± 14.33) kg, and all of them trained at least five times per week for at least one hour each time in athletics, combat sports, basketball, and gymnastics. All participants agreed to take part in the study by signing an informed consent form. Ethical permission for this laboratory research was obtained from the Research Ethics Board of the Faculty of Education and Psychology at ELTE Eötvös Loránd University in Budapest, Hungary. The research was conducted in accord with the ethical regulations and guidelines of the World Medical Association's Declaration of Helsinki (World Medical Association, 2008).

Instruments

Psychological measures

Core affect (Russell, 2003) was assessed by two-single item scales, the Feeling Scale (FS; Hardy & Rejeski, 1989) and the Felt Arousal Scale (FAS; Svebak & Murgatroyd, 1985). The former measures affective valence on an 11-point Likert scale ranging from -5 (feeling *very bad*) to +5 (feeling *very good*), while the latter measures activation on a 6-point Likert scale ranging from 1 (*low arousal*) to 6 (*high arousal*). The psychometrically validated 10-item version of the Positive Affect Negative Affect Schedule (PANAS; Thompson, 2007) was also adopted to obtain reflective measures of affect that could complement the non-reflective core affect measures. Non-reflective measures correlated directly with positive affect ($p \leq .001$) in all instances, but only feeling states after the intervention correlated inversely with negative affect ($p = .001$). Each PANAS item is rated on a 5-point Likert scale ranging from 1 (*very slightly or not at all*) to 5 (*very much*). A total score is then obtained for positive (5) and negative (5) items. The internal reliability of the PANAS was reported to be (Cronbach's alpha) .78 for positive affect and .76 for negative affect (Thompson, 2007).

Physiological instruments

The incremental exercise was performed on a treadmill (Model: Marquette 2000, Pittsburgh, PA, USA). To obtain the respiration exchange rate (RER) a portable breath to-breath gas analyzer was used (Model: Master Screen CPX metabolic cart 50/60 HRz (CareFusion, Germany 234 GmbH, 97204 Hoechberg, Germany). Heart rate was measured continuously with a Polar H7 Bluetooth 4.0 smart chest band transmitter connected to the treadmill.

Maximal Graded Exercise Test

The test started with a warm-up period: 5 km/h walk (0 % slope) for 1 min. Subsequently, the velocity was increased by 1.0 km.h-1 every 1 minute from 8.0 km×h-1 to 14.0 km×h-1, then the inclination of the treadmill was increased 2 % slope every 1 minute together with speed until volitional fatigue. Our goal with the rapidly increasing load protocol was that athletes reach the anaerobic threshold (AT) relatively quickly and stay there for a long time.

Distractor (cognitive) tasks

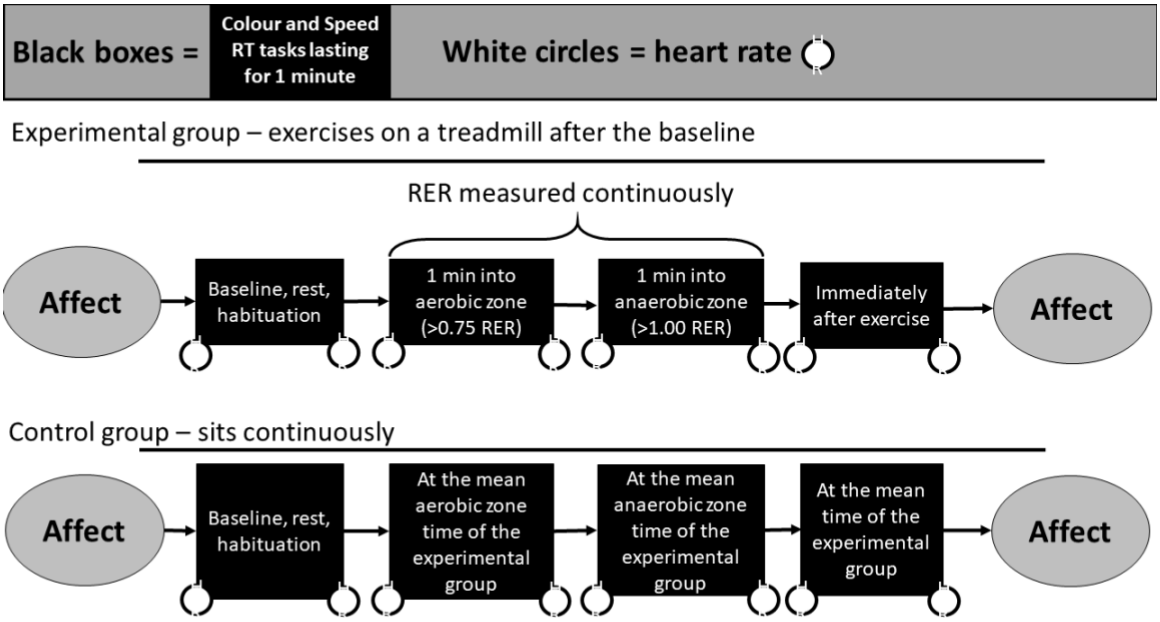
The openly available (https://webzone.ee/winpsycho) ‘WinPsycho 2000’ reaction time test system (Thomson & Watt, 2010) was used to present color and a speed discrimination task and to distract participants from attending to their feeling states. In the former, the participants had to react with the left or right mouse button to different colors, while in the latter, they had to discriminate between the faster and slower object by pressing the left or right buttons on the mouse. These tasks were presented via an Acer Extensa 5220 laptop and an Epson EB-S31 H719b Portable Projector. The participants used a wireless hand-held Hama Gaming Mouse (Model: uRage Unleashed WL) for the completion of the tasks.

Procedure

Upon volunteering for the study, participants were asked to abstain from physical exercise and drinking alcohol for one day before the experiment and drinking caffeinated beverages for at least four hours preceding the test. When arriving in the laboratory, they were familiarized with the cognitive (distractor) and the exercise task. Further, they received information about the testing. All tests were done in the afternoon (2.00 – 5.00 pm) by the same experimenter (AL). The laboratory temperature ranged between 20 and 22.8C° , while the air humidity was between 45% and 60%.

The test started with 5 km/h walk for two minutes at zero inclination, then it was increased continuously by 2 km/h and 4.0% slope inclination every two minutes until the anaerobic zone (>1.0 RER) was reached (Wasserman, Whipp, Koyl, & Beaver, 1973). Subsequently, participants exercised for another minute at >1.0 RER, after which the speed and inclination of the treadmill were gradually reduced to zero. Heart rate and gas exchange were continuously recorded with the heart rate monitor and with the gas analyzer, which was calibrated prior to each exercise test. On average, the exercise sessions lasted for 544 ± 39.5 seconds ranging from 450 to 630 seconds. During the incremental exercise, participants were continuously distracted with two cognitive tasks. One was a color reaction time task comprising the visual presentation of two colors (blue and red) at random times. The second task was a speed reaction time task in which an object approached the person at two slightly different speeds. The participant's task was to press the hand-held right mouse for one of the two possible choices and the left mouse for the other choice. The two cognitive tasks were presented four times. Reaction time, as well as error measures, were taken at baseline, after one minute into the aerobic zone (>0.75 RER), again after one minute into the anaerobic zone (>1.00 RER), and one more time after exercise (Figure 1). While before the baseline, the participants had practiced the tasks to ensure proper understanding and mastery; the baseline (habituation) session was the first task in which reaction time and the number of errors were recorded. During exercise, the tasks were presented in two phases (aerobic and anaerobic), with the pre- and post-task periods consisting of preparation for the next task and preparation for exercise intensity adjustment.

To ensure that the cognitive tasks were delivered at about the same time for the two groups, for the control group, they were presented at the mean exercise times (aerobic zone and anaerobic zone) of the exercise group (Figure 1). Heart rate was measured prior to and after each cognitive task for a total of eight times, like for the exercise group. The control participants set quietly on the treadmill throughout the study. Both exercising and control participants completed the three psychological measures (FS, FAS, and PANAS) prior to the habituation phase and after the last cognitive task, corresponding to the time of exercise-end in the experimental group. Presentation of the distracting cognitive tasks in this phase was introduced to 'disconnect' participants from the previously performed exercise or sitting and to obtain an appraisal of the momentary feeling states linked-to the last cognitive task. In fact, this last task was the most important in testing the hypothesis of the study.



Note: RER = Respiratory Exchange Ratio; RT = Reaction Time; 1 min = one minute

Figure 1. *Illustration of the experimental protocol.*

RESULTS

Changes from pre- to post-exercise/control in the four psychological measures (i.e., feeling state, felt arousal, negative affect and positive affect) were tested with a 2 (group) by 2 (time) repeated measures multivariate analysis of variance (RM-MANOVA) which only yielded a statistically significant multivariate time main effect (Pillai's Trace = .58, $F_{4, 48}$ = 16.36, p < .001, effect size: partial Eta squared [the ratio of variance; $p\eta^2$] = .58). Given that no group differences or group-by-time interactions were observed, Table 1 illustrates the combined univariate tests' results for the time main effects for both experimental and control groups, along with the effect sizes (Cohen's *d*). The change in core affect, reflected by the junction of the mean feeling state and mean arousal, from the first time of assessment (pre) to the second time of assessment (post), is illustrated in Figure 2. These results are combined for the two groups (experimental and control) because the RM-MANOVA did not yield group difference or group-by-time interaction.

Table 1. Means and standard deviations of four the psychological measures and the results of the Greenhouse-Geisser corrected univariate tests comparing them before and after exercise /sitting.

(N = 53)	Pre-exercise /sitting	Post-exercise /sitting	*F*	*p*	*d*
Feeling state	3.43 (1.12)	3.98 (1.00)	13.12	= .001	.52
Felt arousal	4.17 (0.87)	4.85 (0.82)	29.34	< .001	.80
Negative affect	6.68 (1.68)	6.04 (1.87)	4.39	= .04	.32
Positive affect	19.75 (2.35)	21.43 (2.42)	55.14	< .001	1.09

Note: *F* = ratio of two variances; *p* = probability level (α ≤ .05); *d* = effect size (Cohen's *d*)

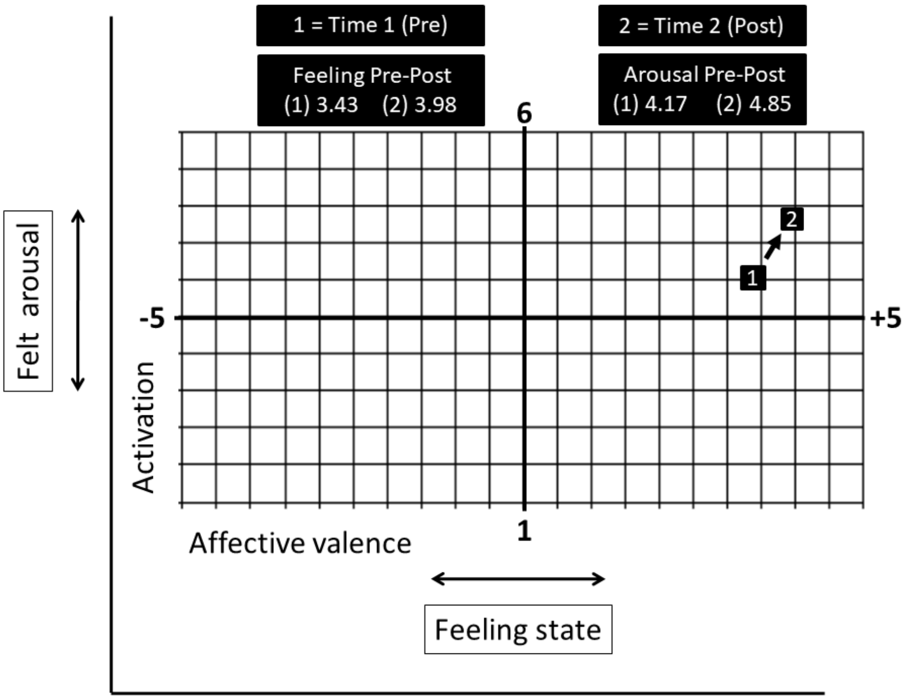


Figure 2. *Change in core affect (defined as the junction of perceived feeling state [affective valence / horizontal axis] and felt arousal (activation / vertical axis) from pre(1) to post(2) assessment.*

Heart rate data of the two groups, obtained at eight assessment times, were analysed with a group by time repeated measures analysis of variance. This test was done primarily as a manipulation check, and hence, as expected, it resulted in a statistically significant group by time interaction after the Greenhouse-Geisser correction for the degrees of freedom ($F_{4.24,\ 216.38}$ = 378.36, p < .001, $p\eta^2$ = .88). The interaction is illustrated in Figure 3.

Further, again as a manipulation check, the reaction time and the errors were examined for the distraction tasks with repeated measures analyses of variance. No group difference or group-by-time interaction was noted for the speed detection task either in reaction time or in the number of errors. However, the latter decreased over time as shown by the Greenhouse-Geisser correction-based ANOVA test ($F_{2.83,\ 133.92}$ = 9.09, p < .001, $p\eta^2$ = .15), with the last (in recovery) assessment showing significantly (p < .001) lower number of errors than during the previous three assessments, which did not differ from each other. Similarly, a time main effect was noted for the colour reaction time task ($F_{1,47,\ 75.11}$ = 11.80, p < .001, $p\eta^2$ = .19), indicating that reaction time decreased after the first trial and differed from all subsequent trials (p < .001), which did not differ significantly from each other. Finally, while there was no group by time interaction in the examination of the number of errors in the colour reaction time task, there was a time main effect ($F_{1,85,\ 94.52}$ = 15.25, p < .001, $p\eta^2$ = .23), showing that the number of errors decreased after the first trial (p = .02 to p < .001), and also a statistically significant between-groups difference revealing that control participants committed less errors across the four trials than the exercising participants ($F_{1,51}$ = 4.44, p = .04, $p\eta^2$ = .08), as it is illustrated in Figure 4.

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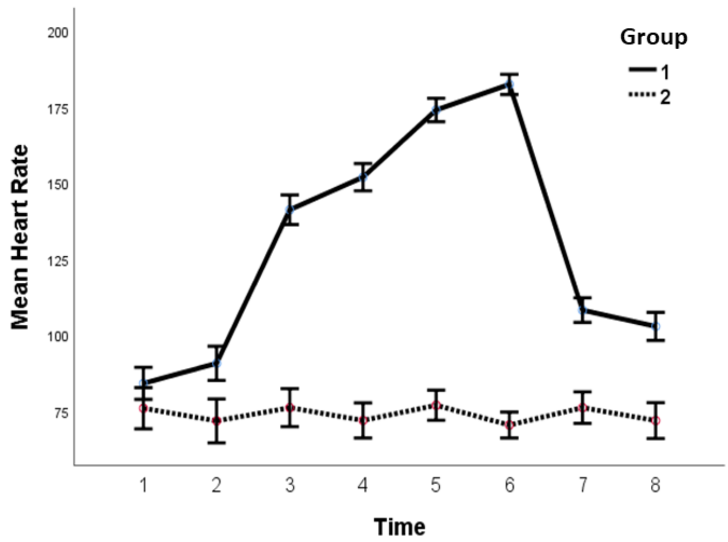

Figure 3. *Heart rate profiles in two groups during the experimental interval (means ± 95% confidence intervals). Group 1 (solid line) represents the progressive exercise group, while Group 2 (dotted line) represents the control group.*

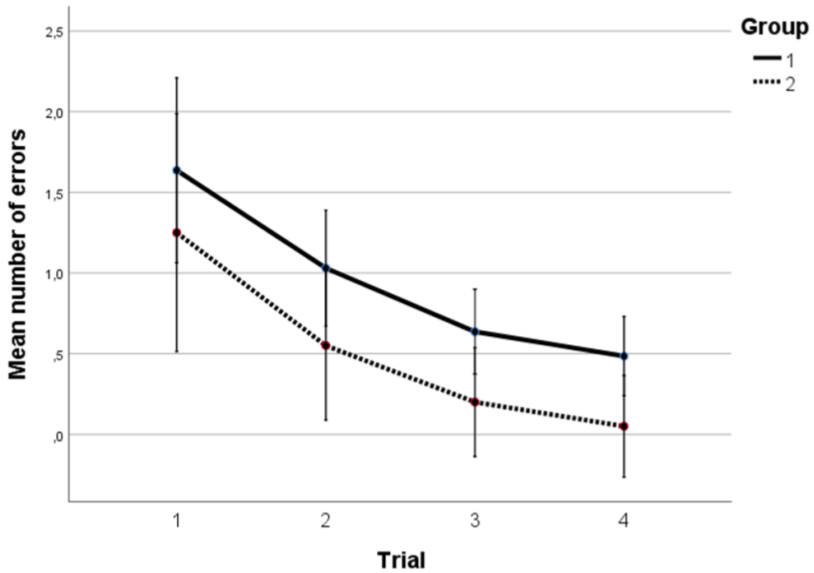

Figure 4. *Number of errors across the four trials in the experimental and control group (means ± 95% confidence intervals). Group 1 (solid line) represents the experimental group,while Group 2 (dotted line) represents the control group.*

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DISCUSSION

Compared to the pre-intervention baseline core- and positive affect increased while negative affect decreased in both the exercise group, running a treadmill until the level of the ventilatory threshold was reached, and the sitting control group. The finding that there were no interaction effects or group main effects suggests that the two groups responded equally. The question is, however, what does this response reflect? Given that the bulk of time (about 9-10 minutes) differed drastically in the two groups, one exerting no energy beyond the basal metabolic rate and one running with progressively greater intensity, the similar changes in the dependent measures support the hypothesis that the after-exercise and after-control measures reflect the affective responses to the last event, which was identical in the two groups (i.e., the cognitive reaction time tasks). So, what is the big deal about these findings?

In accord with the recent literature synthesis by Ekkekakis and Brand (2019), during high-effort exercise affect exhibits a quadratic decline over time, but it rebounds very quickly upon the cessation of exercise. These authors argue that the bidirectional dynamics in affect contaminate the findings of pre-post assessment protocols but do not elaborate on the reason for the rebound. They argue that *"... given the robust post-exercise affective rebound, by the time the post-exercise assessments were taken, participants typically tended to report feeling better than they did before the bout began, thus falsely appearing to confirm the "feel-better" effect in most cases (e.g., regardless of exercise intensity).* (pg. 132). We agree that the post-exercise assessments may falsely be interpreted as the 'overall' exercise effect; however, not because of the rebound in affect but because of the momentary responses to the *actual* (last) experience. State measures require participants to indicate their feelings at that *very moment*. While that moment is the end of a continuum (i.e., exercise) and therefore is not independent of the preceding events, the affect ratings cannot be correctly generalized to the preceding events since a momentary assessment is a snapshot of a precise moment. Therefore, the pre- to post-intervention research designs measure the *difference* between the moment of the commencement of exercise and *moment assessment* after the termination, and, in accord with Ekkekakis and Brand (2019), they do not reflect the 'overall' effect of exercise.

Affect, by definition, is a conscious momentary mental feeling state influenced by a given situation (Duncan & Barrett, 2007). Clearly, the last experience or the event before the assessment of affect has the largest effect on subjective ratings. The often reported rebound in affect after high-intensity exercise (Ekkekakis & Brand, 2019) can be justified by the relief in effort and instantaneous muscle relaxation, which, in general, is experienced as a tranquilizing effect (deVries, 1981). However, if this rebound, caused by a shift into the recovery zone after exercise, is distracted by an unrelated event like the reaction time task in the current work, the affective responses will mirror the feeling states associated with this *last experience* while the effects of hard exercise may vanish. The lack of difference in reported affect between exercise and control group, both improving after the last cognitive task, may suggest that this task could be responsible for the results and supports the last experience theory.

However, one may ask why affect would improve after two cognitive reaction tasks when it was reported that affect does not change from pre- to post-exercise in progressive exercise protocol (Rendi et al., 2007)? These tasks were new to the participants, and with repeated practice, there was a clear learning effect, as confirmed by the results. The learning effect, as revealed by the decreased number of errors in the current work, is, in fact, a mastery effect that is usually associated with positive feelings. Even though the number of mistakes was consistently higher in the exercise than in the control group, the learning pattern was similar (refer to Figure 4). Improvement occurred in both groups. The mastery hypothesis states that the

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completion of a challenging task brings about a sense of accomplishment, self-fulfilment, or achievement, thereby improving affect (Simons, Epstein, McGowan, Kupfer, & Robertson, 1985). Not expecting this effect, we did not assess how participants felt about their performance on the cognitive task, which became a limitation of the study. Despite this limitation, a similar increase in affect (compared to the baseline) in both the control and experimental group might suggest that the affective responses gathered in this work are responses to the cognitive tasks, which were the last events prior to the assessment of the affective states.

Clearly, the effort, as demonstrated by the heart-rate data, was different between the two groups, yet this difference was not reflected in the post-session assessment of affect, suggesting that the impact of the exercise on affect (if any) was wiped out by the cognitive tasks. It should be stressed that in the current research, we were not focusing on the affective benefits of exercise, but rather on *how the last experience determines affective responses* after exercise in contrast to a control group having a similar last experience. Our findings may lend support to Ekkekakis and Brand (2019), suggesting that pre- to post-intervention research designs are inadequate for assessing the 'overall' effect of an exercise session. The results can also be aligned with an earlier study by Bixby and colleagues (2001), demonstrated that while appraisal of pleasure–displeasure was not significantly different pre- and post-cycling below or at the ventilatory threshold, the exercise below the ventilatory threshold increased pleasure, but at the ventilatory threshold decreased it significantly. However, the pleasure returned to the baseline level after the cycling. Accordingly, the last event, which was the *termination* of the exercise, resulted in a feeling of relief or accomplishment and triggered a shift in affect, yielding positive post-exercise feeling states ascribable to the last event.

Our results also agree with another recent work in which the authors tested the 'peak-end rule' (feelings determined by the peak and last experience) for appraising high-intensity interval training (HIIT; Alves et al., 2021). Thirty minutes into recovery after a short and a long, but progressively made easier, a bout of HIIT participants' affect and enjoyment did not differ between the sessions. In contrast to the authors' hypothesis, the peak-end rule could not be demonstrated, but the 'end' rule (reflected by the last experience) was apparent perhaps due to the positive experience of recovery from exercise.

Our study expands the conjecture of Ekkekakis and Brand (2019), by demonstrating that not the post-exercise assessment of the affect *per see* is the main factor that falsifies the interpretation concerning the exercise-induced affect, but the last event that reflects *a very limited momentary feeling state* and that, perhaps most importantly, may not necessarily be connected to the exercise experience. Thus, we argue that any event after the exercise session is capable of changing affect, such a last moment goal in a team contest which then wipes out (or at least it reduces drastically) the effects of the preceding event (i.e., a hard effortful physical contest; Hassmén, & Blomstrand, 1995), In pre- to post-intervention designs the last (or post-treatment) assessment yields trustworthy measures of affect, but that is determined by the moment of assessment. Although in exercise settings no similar research results were reported to date, our findings agree with works from the area of food enjoyment where the memories of the last experience with a given food mediated the interval one waits until consuming that food again (Garbinsky et al., 2014). Our results also agree with findings from sports science in which the outcome (and not the game) mediated the affective response after a sporting contest (Hassmén, & Blomstrand, 1995).

Limitations

There are certain limitations in this laboratory work that calls for cautious interpretation of the results. One limitation is an exercising control group, not performing any cognitive tasks, was not included in the study. Another limitation is that these findings are based on elite athletes who are used to demanding exercise; therefore, the generalizability to other populations may be limited. Further, the effect of the last experience was not complemented with a structured interview (qualitative method) that could have strengthened the interpretation of the findings.

CONCLUSIONS

The current study results suggest that despite a large difference in physical effort between an exercise and a control group, the two exhibited similarly (i.e., not different from each other) more positive affect after the intervention/control session. This finding suggests that the groups did not respond to the intervention (exercise) or control (sitting), but to the very last event identical in the two groups, two cognitive reaction time tasks prone to learning. We argue that pre- to post-intervention protocols, aimed at measuring the (overall) impact of an exercise session on affect, should not be used because, in contrast to the pre-exercise baseline, post-measures will reflect what happens in that very moment. This momentary 'snapshot' of affect can trap the relaxation effect starting in the moment of recovery (i.e., the rebound from negative affect after challenging exercise) and any other impactful event(s) happening just before the psychological assessment measures.

PRACTICAL APPLICATIONS

The fundamental application of our research focuses on the importance of evaluating affective states at the precise moment, emphasizing methodological difficulties. In this sense, it is pertinent to suggest to coaches, physical trainers and sports psychologists the possibility of carefully planning the collection of information related to affective experience and fatigue processes, and ensure that the last experience in training or competition is as positive as possible. For example, even after a loss, a coach can comfort players in some way to reduce the psychological pain associated with the loss.

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