

Original article

# The influence of core affect on cyclo-ergometer endurance performance: Effects on performance outcomes and perceived exertion

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## Abstract

**Background:** Core affect is defined as the most general affective construct consciously accessible that is experienced constantly. It can be experienced as free-floating (mood) or related to prototypical emotional episodes. The aim of this study was to examine the influence of pleasant and unpleasant core affect on cyclo-ergometer endurance performance. Specifically, we considered the influence of pleasant and unpleasant core affect on performance outcomes (i.e., time to task completion) and rate of perceived exertion (RPE; Borg Scale, category ratio-10) collected during the task.

**Methods:** Thirty-one participants aged 20–28 years were recruited. Core affect was randomly elicited by 2 sets of pleasant and unpleasant pictures chosen from the international affective picture system. Pictures were displayed to participants during a cyclo-ergometer performance in 2 days in a counterbalanced order. RPE was collected every minute to detect volunteers’ exhaustion.

**Results:** The study sample was split into 2 groups. Group 1 comprised participants who performed better with pleasant core affect, whereas Group 2 included participants who performed better with unpleasant core affect. Mixed between-within subjects analysis of variance revealed a significant 2 (group) × 2 (condition) × 5 (isotime) interaction ( $p = 0.002$ ,  $\eta_p^2 = 0.158$ ). *Post hoc* comparisons showed that participants who obtained better performance with pleasant core affect (pleasant pictures; Group 1) reported lower RPE values at 75% of time to exhaustion in a pleasant core affect condition compared to an unpleasant core affect condition. On the other hand, participants who obtained better performance with unpleasant core affect (unpleasant pictures; Group 2) reported lower RPE values at 75% and 100% of time to exhaustion in an unpleasant core affect condition.

**Conclusion:** Findings suggest differential effects of pleasant and unpleasant core affect on performance. Moreover, core affect was found to influence perceived exertion and performance according to participants’ preferences for pleasant or unpleasant core affect.

**Keywords:** Arousal; Hedonic tone; Pleasant and unpleasant core affect; Rate of perceived exertion; Time-to-exhaustion test

## 1. Introduction

Over the last decades, research on health behavior has widely been focused on the influence of physical activity on feelings, mood, and emotions.<sup>1</sup> Regular physical activity has indeed been related to numerous mental benefits,<sup>2,3</sup> including improved mental well-being, global self-esteem, and mood states.<sup>4</sup> There is strong evidence that aerobic and resistance exercise enhance mood states.<sup>5</sup> Moreover, supporting evidence exists for the effectiveness of exercise in the treatment

of depression and in the reduction of state and trait anxiety.<sup>6</sup> Recently, there has been also a growing interest in how feelings, mood, and emotions influence physical activity and performance. Study findings have shown the impact of emotional states on human performance in many situations, including arm movement,<sup>7</sup> wrist isometric contraction,<sup>8</sup> and gait initiation.<sup>9</sup> An increasing number of experimental investigations examining the influence of emotions on performance have used systems containing standardized materials that elicit emotions.<sup>10</sup> For example, viewing emotion-eliciting pictures has been found to result in postural adjustments during balance tasks.<sup>11</sup> Additionally, emotion-eliciting pictures were found to impact performance on a visual detection task<sup>12</sup> and supramaximal cycling exercises, with better results

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caused by pleasant compared to unpleasant pictures.<sup>13</sup> Visual stimuli have also been used to better understand their moderating influence on rate of perceived exertion (RPE) during cycle exercise.<sup>14</sup>

Notwithstanding the increasing number of studies on the influence of affective constructs on performance, there is still scant research concerning core affect, especially in an endurance context. Core affect is defined as the most general affective construct consciously accessible<sup>15,16</sup> that is experienced constantly, although its nature and intensity can vary (e.g., sense of relaxation or tension, and elation or depression).<sup>15</sup> Despite the fact that it is not necessarily directed at something, it can be experienced as free-floating (mood) or related to prototypical emotional episodes.<sup>17</sup> More precisely, a person can feel happy because she or he received a gift or for unknown reasons. The first case exemplifies a prototypical emotional episode, whereas the second represents a free-floating state. Both situations involve core affect.<sup>15</sup> In other words, core affect can occur in isolate form, but it is also a state at the heart of mood and emotion. Moreover, even when free-floating, core affect is subject to different causal forces (e.g., weather)<sup>18</sup> and can be induced. Based on the “circumplex model”,<sup>19</sup> which provides a full conceptualization of the emotional responses to different stimuli,<sup>20</sup> core affect is also conceived as a 2-dimensional domain characterized by affective valence (hedonic tone) ranging from pleasure to displeasure, and perceived activation (arousal) ranging from high to low levels. The combination of different degrees of these 2 fundamental dimensions leads to various affective states: high activation—pleasant affect (e.g., excitement), high activation—unpleasant affect (e.g., anger), low activation—unpleasant affect (e.g., sluggishness), and low activation—pleasant affect (e.g., calmness).<sup>16</sup>

Based on these assumptions, the aim of this investigation was to examine the influence of core affect on endurance performance. We grounded our investigation on the dual-mode theory,<sup>21,22</sup> which postulates that individuals involved in physical exertion proximal to anaerobic threshold may experience a range of positive (high activation—pleasant) and negative (high activation—unpleasant) affective responses, and therefore conducted a randomized, counterbalanced, and repeated measure study to examine the effect of core affect on cyclo-ergometer endurance performance. Core affect was randomly elicited by 2 sets of pleasant and unpleasant pictures, both characterized by high activation values, chosen from the international affective pictures system (IAPS).<sup>10</sup> We examined the impact of these 2 sets of pictures on perceived valence and activation, endurance performance outcomes (i.e., time to task completion), and RPE.<sup>23</sup> Drawing on the study conducted by Jaafar and colleagues,<sup>13</sup> who found better performance associated with pleasant stimuli, we expected to find better performance outcomes associated with pleasant core affect—the first hypothesis. We also expected core affect to be individually experienced as functional for performance if associated with reduced fatigue symptoms and increased task duration—the second hypothesis.<sup>24,25</sup>

## 2. Materials and methods

### 2.1. Selection of pleasant and unpleasant pictures

The first step in our study was to select 2 sets of pictures from the IAPS<sup>26</sup> capable of eliciting pleasant and unpleasant core affect. The IAPS contains a large set of standardized, emotionally evocative, internationally accessible color pictures classified in terms of hedonic tone and arousal, across a wide range of semantic categories. From the entire dataset of 1182 pictures, we selected a subset of 300 stimuli. Sport-based pictures were excluded due to their generally low values of arousal, and sexual-erotic pictures were omitted to obtain approval from the University “G. d’Annunzio” of Chieti-Pescara Ethical Committee. The subset of 300 pictures was pretested by asking 45 participants (20 women, 25 men), aged from 22 to 29 years ( $25.4 \pm 2.4$  years, mean  $\pm$  SD), to evaluate each picture in terms of perceived hedonic tone and arousal. These individuals were not included in the experimental protocol. Qualtrics software (Version 3.0, Experience Management, Provo, UT, USA) was used to display the pictures to participants positioned 1 m away from a 52-inch monitor.

The order of presentation of the pictures was randomized across the participants; each picture was anticipated by a preparation slide (“Get ready to rate the next slide”). Then, after being presented for  $\sim 10$  s and removed from the screen, each picture was rated in hedonic tone and arousal using the affect grid.<sup>27</sup> Participants could select the scores indicating one of the 81 cells of a  $9 \times 9$  grid (see Section 2.4).

Based on the 45 participants’ affect grid responses, we selected as pleasant stimuli those pictures with arousal rating values of  $>5$  and hedonic tone values of  $>5$ , and as unpleasant stimuli those pictures with arousal rating values of  $>5$  and hedonic tone values of  $<3$ . The final sample of stimuli included 50 pleasant and 50 unpleasant pictures that were incorporated as 2 sets in 2 different PowerPoint presentations aimed at eliciting pleasant and unpleasant core affect. Each set had an overall duration of  $\sim 20$  min, with pictures loop projected in a randomized order. The unpleasant pictures included semantic categories such as weapons, physical violence, death, torture, and sadness in children, whereas the pleasant pictures included semantic categories such as animals, love, landscapes, parties, and friendship. For more details concerning the semantic categories of the pictures, see the study conducted by Verschuere and colleagues.<sup>28</sup>

### 2.2. Participants

To determine the sample size, an *a priori* power analysis (effect size = 0.30, power = 0.80, and  $\alpha$  level = 0.05) was conducted using G\*Power.<sup>29</sup> The resulting sample size was 24 to perform the most stringent mixed between-within subjects 2 (group)  $\times$  2 (condition) analysis of variance (ANOVA). A total of 31 participants (10 women and 21 men), aged from 20 to 28 years ( $24.1 \pm 2.8$  years, mean  $\pm$  SD), who regularly engaged in physical activities, including cycling, completed the experimental protocol, which consisted of 4 visits to our exercise physiology laboratory. All participants were selected based on the

following 3 criteria: (1) they regularly practiced physical/sport activities, (2) they did not report psychological diseases, and (3) they were not under pharmacologic treatment. The study was conducted in compliance with the Declaration of Helsinki and received approval from the local university ethics committee (University “G. d’Annunzio” of Chieti-Pescara) with application ref. n. 10-21/05/2015. All participants signed a written informed consent form before the testing procedures.

### 2.3. Experimental set up and procedure

#### 2.3.1. Overview of the experimental protocol

Participants visited our laboratory 4 times, with intervisit intervals of 48–72 h to allow for physiological recovery. They were instructed not to engage in vigorous exercise or consume alcohol, caffeinated drinks/foods, or ergogenic substances for  $\geq 24$  h before the commencement of data collection. Two qualified researchers collected the data. Data collection occurred in a quiet and safe environment to guarantee participants’ comfort. During the first visit, participants received standard instructions on how to rate perceived exertion on a category ratio (CR)-10 scale<sup>30</sup> and performed an incremental test to determine the cyclo-ergometer power output (Watt, W) corresponding to their anaerobic threshold. The second visit was aimed at checking the setting and at verifying the precision of the estimated anaerobic threshold to accurately proceed with the other 2 visits to our laboratory.<sup>31</sup> During the last 2 visits, participants performed a time-to-exhaustion (TTE) test on a Monark Cyclo-Ergometer (939 E; Monark Exercise AB, Vansbro, Sweden) with a randomized and counterbalanced design. The TTE interval was defined as the maximum interval for which the participant could maintain an exercise intensity equal to anaerobic threshold +5% and/or after which she or he reached volitional exhaustion. For each visit, one of the 2 sets of pictures was displayed during the constant load phase of the protocol. Each set was projected on a 52-inch monitor positioned 1 m away from participants.<sup>14</sup> Perceived exertion was collected every minute to detect the participants’ exhaustion using the CR-10 scale. Participants also rated the affect grid and completed a manipulation check immediately after exhaustion, before they knew their performance results.

#### 2.3.2. Incremental test

During the first visit, participants underwent a graded exercise test using a ramp protocol.<sup>32</sup> The test was executed on a cyclo-ergometer with a pedaling rate maintained at 70 revolution/min. After a warm-up (3 min at 50 W), the cyclo-ergometer power output was step-wise increased by 10 W every minute until exhaustion, which was detected through the CR-10 scale. Individual heart rate (HR) was continuously monitored using a BioHarness (Version 3.0; Zephyr technology, Annapolis, MD, USA) connected via wireless transmission to a laptop with Labchart software (Version 7.1; ADInstruments, Oxford, UK). Instantaneous HR was determined as the inverse of the RR duration (in milliseconds, ms), calculated as the interval between 2 subsequent R peaks

detected with an error of  $\pm 2$  ms.<sup>33</sup> HR data were collected to identify anaerobic threshold, which was measured using a non-invasive method based on HR deflection.<sup>34,35</sup> After the exhaustion, an Excel worksheet was used to depict the Watt–HR relationship obtained throughout the test. For each participant, the Watt at which the linearity of this relationship was lost (HR deflection) was defined as anaerobic threshold.

#### 2.3.3. TTE test at individual constant load

During the second visit, participants familiarized with the TTE protocol and again received instructions on the use of CR-10 Borg scale and the affect grid. After a period of 2 min of no movement and a warm-up phase of 3 min on the cyclo-ergometer at 60% of anaerobic threshold, participants underwent an exhaustive test at individual constant load (anaerobic threshold + 5%), reporting their RPE every minute during the whole protocol until exhaustion. After exhaustion (absolute maximum effort), there was a recovery period of 3 min with a free cyclo-ergometer power output. During the third and fourth visits to the laboratory, participants were assigned to one of the 2 experimental conditions (pleasant or unpleasant pictures), with each defined in a random order and occurring on different days. Anaerobic threshold values and expertise level for each participant are provided in Supplementary Table 1. As mentioned, affect grid was administered immediately after the completion of the task (i.e., exhaustion) to quickly assess the impact of the 2 sets of pictures on perceived arousal and hedonic tone, and to assess the elicited core affect. A manipulation check was also administered.

### 2.4. Measurements

#### 2.4.1. CR-10 Scale

RPE was measured through the CR-10 Scale.<sup>23,30</sup> The use of this scale is considered instrumental in diminishing ceiling effects. The scale has been used in association with various physiologic parameters, such as maximal oxygen consumption ( $VO_{2max}$ ), lactate, and HR.<sup>24,30,31</sup> It ranges from 0 (no effort) to • (maximal sustainable effort). The verbal anchors were: 0 (*nothing at all*), 0.5 (*extremely weak*), 1 (*very weak*), 2 (*weak*), 3 (*moderate*), 5 (*strong*), 7 (*very strong*), 10 (*extremely strong*), and • (*absolute maximum*) (a score of  $\geq 11$  was assigned to this anchor). No verbal anchors were used for 4, 6, 8, and 9.

#### 2.4.2. Affect grid

Immediately after the completion of the task (i.e., at exhaustion), the affect grid was administered to assess the impact of the 2 sets of pictures on perceived arousal and hedonic tone. Affect grid is a single-item scale designed to quickly assess core affect along the dimensions of pleasure-displeasure and sleepiness-arousal.<sup>27</sup> Participants were asked to place a single X mark on a  $9 \times 9$  grid, with the horizontal dimension representing the degree of hedonic tone (from *unpleasant* to *pleasant*) and the vertical dimension representing the level of perceived activation (from *low* to *high*). Both dimensions can range from 1 to 9.

### 2.4.3. Manipulation check

Immediately after the completion of the task (i.e., at exhaustion), participants rated the following question for each set of pictures: “How much did the pictures influence your performance?” Ratings could range from 1 (*not at all*) to 10 (*entirely*).

### 2.5. Statistical analysis

Examination of histograms, skewness, and kurtosis of variable scores showed that the data were normally distributed. First, we analyzed performance outcomes in the TTE test through a within-subjects ANOVA to compare the time to complete the task associated with pleasant and unpleasant pictures (i.e., the 2 conditions). Afterwards, based on the time to complete the task in the 2 conditions, the whole sample was split into 2 groups:

- ✓ Group 1: subjects ( $n = 13$ ) who performed better with pleasant pictures rather than unpleasant pictures;
- ✓ Group 2: subjects ( $n = 14$ ) who performed better with unpleasant pictures rather than pleasant pictures.

To standardize TTE trials and to measure the temporal changes of study variables under physical exertion,<sup>36</sup> isotimes for RPE scores at 0% (the first minute of TTE), 25%, 50%, 75%, and 100% (last completed minute of TTE) were computed. It is notable that although the isotime values for 0% corresponded with the values for the first full minute of each TTE, the value of isotime at 100% was defined as the shortest TTE accomplished by each individual over her or his 2 tests. Following the procedure adopted by Blanchfield and colleagues,<sup>36</sup> the minute 100% isotime (last completed minute of TTE) was divided by 2 to obtain the value corresponding to the 50% isotime. The 25% and 75% isotimes were also derived.

RPE data collected during the first 2 min while maintaining a still position on the cyclo-ergometer and during the warm-up phase before TTE were all equal to 0. Consequently, no analysis to detect differences between conditions was performed.

Mixed between-within subjects ANOVA, 2 (group)  $\times$  2 (condition: pleasant and unpleasant pictures), was then performed on arousal and hedonic tone values to make sure the 2 sets of pictures elicited the expected core affect, and to assess the impact on performance of perceived arousal and hedonic tone across groups. A 2 (group)  $\times$  2 (condition)  $\times$  5 (isotime: 0%, 25%, 50%, 75%, and 100%) repeated measures ANOVA was conducted to identify differential effects of pleasant and unpleasant pictures on RPE values in the 2 groups. The Bonferroni correction test was used for *post hoc* pairwise comparisons.

The sphericity assumption was evaluated using the Mauchly test. Greenhouse Geisser correction for degrees of freedom was applied in case of non-sphericity. Effect sizes were calculated using partial eta square ( $\eta_p^2$ )<sup>37</sup> in the analyses of variance, with 0.01, 0.06, and 0.14 considered small, medium, and large effects, respectively.<sup>38</sup> The significance level was set at 0.05, and all statistical analyses were performed using the SPSS (Version 25.0; IBM Corp., Armonk, NY, USA).

## 3. Results

### 3.1. Manipulation check

The overall results of the manipulation check showed that participants perceived their performances to be influenced by both the pleasant and unpleasant pictures. Specifically, for performances with pleasant pictures, response ratings ranged from 6 to 8, which corresponded to ratings ranging from highly to very much ( $6.96 \pm 0.70$ , mean  $\pm$  SD), respectively, whereas for performances with unpleasant pictures, response ratings ranged from 6 to 9, which corresponded to ratings ranging from highly to almost entirely ( $7.06 \pm 0.96$ , mean  $\pm$  SD), respectively.

### 3.2. ANOVA results

Within-subjects ANOVA for TTE did not show significant differences between performance outcomes in the 2 conditions (pleasant and unpleasant pictures),  $F(1, 30) = 0.276$ ,  $p = 0.603$ ,  $\eta_p^2 = 0.009$ , power = 0.080. Means and SD regarding performance outcomes associated with pleasant and unpleasant pictures are provided in Table 1. Notwithstanding the lack of significant differences, we observed distinctive participants' performance outcome results. Representations at group level and at individual level of these results are provided in Fig. 1.

Between-within subjects ANOVA did not show significant group  $\times$  condition interactions on the 2 measures, with hedonic tone values of  $F(1, 25) = 0.099$ ,  $p = 0.756$ ,  $\eta_p^2 = 0.004$ , power = 0.061 and arousal values of  $F(1, 25) < 0.001$ ,  $p = 1.000$ ,  $\eta_p^2 < 0.001$ , power = 0.050, respectively. On the other hand, significant differences between conditions for hedonic tone were found (Fig. 2) ( $F(1, 25) = 413.675$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.943$ , power = 1.000), while arousal values did not yield significant effects ( $F(1, 25) < 0.001$ ,  $p = 1.000$ ,  $\eta_p^2 < 0.001$ , power = 0.050). Specifically, in both groups, hedonic tone values were higher for pleasant pictures (Group 1:  $7.769 \pm 1.165$ ; Group 2:  $8.000 \pm 0.887$ ) than for unpleasant pictures (Group 1:  $2.538 \pm 0.776$ ; Group 2:  $2.928 \pm 0.615$ ), whereas arousal values were high for both pleasant pictures (Group 1:  $7.230 \pm 0.926$ ; Group 2:  $7.571 \pm 0.646$ ) and unpleasant pictures (Group 1:  $7.231 \pm 1.301$ ; Group 2:  $7.571 \pm 0.647$ ) (Fig. 2).

The 2 (group)  $\times$  2 (condition)  $\times$  5 (isotime) repeated measures ANOVA revealed significant differences on isotimes ( $F(2.680, 66.991) = 321.956$ ,  $p < 0.001$ ,  $\eta_p^2 = 0.928$ , power = 1.000). Specifically, RPE values increased while approaching exhaustion, with maximum RPE values accompanying exhaustion. Means and SD regarding isotimes RPE values by groups are provided in Table 2. A significant group  $\times$  condition  $\times$  isotime interaction was also found ( $F(3.867, 96.675) = 4.691$ ,  $p = 0.002$ ,  $\eta_p^2 = 0.158$ , power = 0.936). *Post hoc* pairwise comparisons showed that

Table 1  
Performance outcomes associated with pleasant and unpleasant pictures.

Performance outcomes	Mean	SD
Pleasant pictures	19.097	8.673
Unpleasant pictures	19.839	9.041

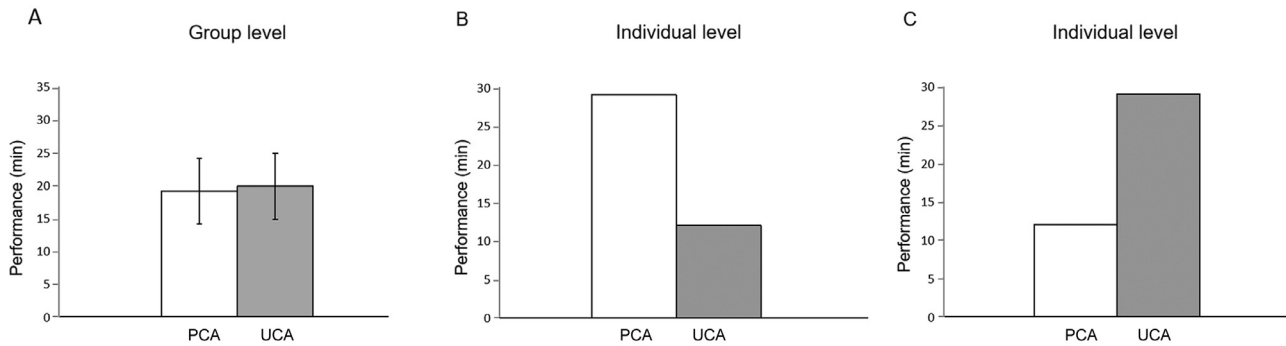


Fig. 1. Effects of pleasant and unpleasant CA on performance. (A) Effects on performance at group level. (B) A participant who performed better with PCA; (C) A participant who performed better with UCA. Error bars represent standard deviation. PCA = pleasant core affect; UCA = unpleasant core affect.

performers who obtained better performance with pleasant core affect (pleasant pictures, Group 1) reported lower RPE values at 75% of TTE in a pleasant core affect condition compared to an unpleasant core affect condition. On the other hand, participants who obtained better performance with unpleasant core affect (unpleasant pictures, Group 2) reported lower RPE values at 75% and 100% of TTE in an unpleasant core affect condition (Fig. 3). Mean differences and *p* values regarding group comparisons, conditions, and isotimes are provided in Table 3. Additional 2 (group) × 2 (condition) × 5 (isotime) repeated measures ANOVA results are included in Supplementary Table 2.

#### 4. Discussion

The aim of the present study was to examine the influence of pleasant and unpleasant core affect on cyclo-ergometer endurance performance. Overall, results demonstrated that core affect was effectively elicited by the 2 sets of pleasant and unpleasant pictures chosen from the IAPS. Core affect effect was examined on performance outcomes (i.e., time to task completion) and perceived exertion collected during the task. In particular, we investigated the influence of core affect on RPE values in 2 different groups of performers: Group 1, comprising participants who performed better with pleasant

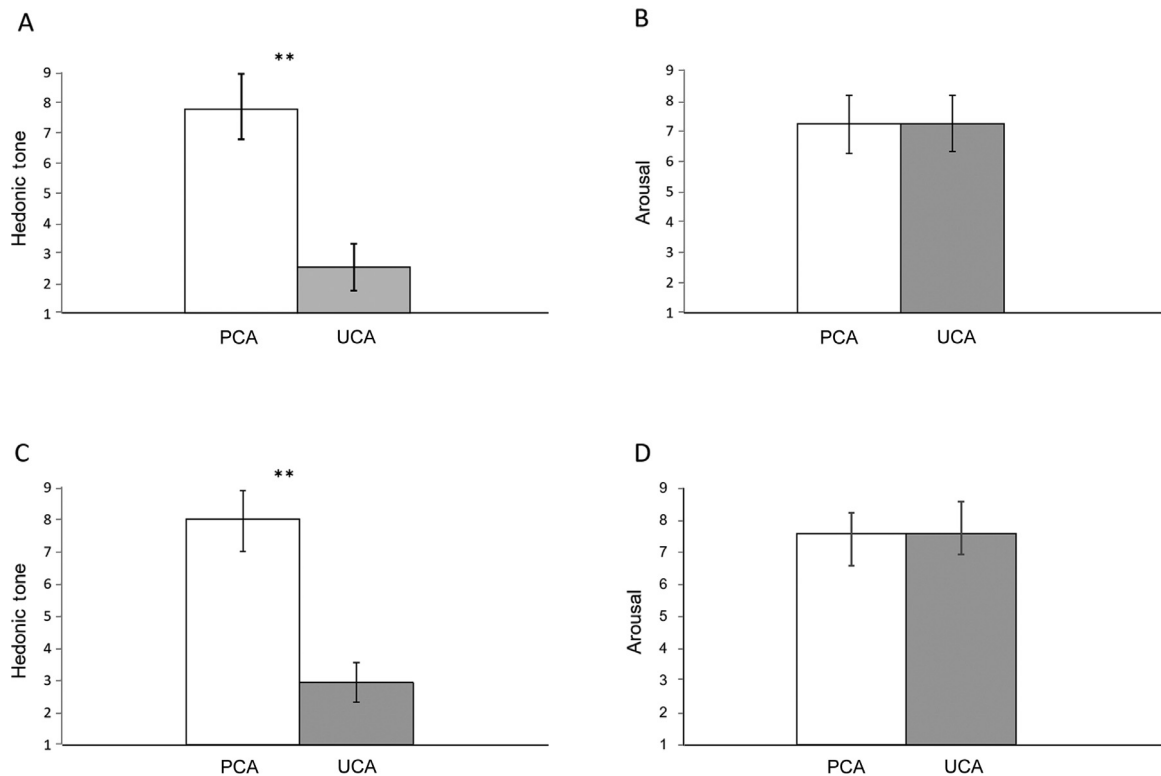


Fig. 2. Impact of PCA and UCA on hedonic tone and arousal values in the 2 groups. (A) Hedonic tone value in Group 1; (B) Arousal value in Group 1; (C) Hedonic tone value in Group 2; (D) Arousal value in Group 2. Error bars represent standard deviation. \*\*  $p < 0.001$ . PCA = pleasant core affect; UCA = unpleasant core affect.

Table 2  
Isotime rate of perceived exertion values in the 2 groups for pleasant and unpleasant core affect.

Isotime (%)	Group	Mean	SD
<b>Pleasant</b>			
0	1	1.138	1.000
	2	1.579	0.982
25	1	4.154	1.725
	2	4.214	1.978
50	1	6.380	2.022
	2	7.210	1.578
75	1	7.770	2.242
	2	9.500	1.401
100	1	11.000	0.913
	2	11.500	0.650
<b>Unpleasant</b>			
0	1	1.831	1.052
	2	1.393	0.862
25	1	4.962	2.277
	2	4.143	1.232
50	1	7.620	2.063
	2	6.140	2.248
75	1	9.690	1.750
	2	8.140	2.033
100	1	11.920	0.277
	2	10.430	1.342

Table 3  
*Post hoc* pairwise comparisons of rate of perceived exertion values among conditions, isotimes, and groups.

Isotime (%)	Group	Group	Mean		<i>p</i>
			Group 1	Group 2	
<b>Pleasant</b>					
0	1	2	1.138	1.579	0.260
	2	1	1.579	1.138	
25	1	2	4.154	4.214	0.933
	2	1	4.214	4.154	
50	1	2	6.385	7.214	0.244
	2	1	7.214	6.385	
75	1	2	7.769	9.500	0.023
	2	1	9.500	7.769	
100	1	2	11.000	11.500	0.112
	2	1	11.500	11.000	
<b>Unpleasant</b>					
0	1	2	1.831	1.393	0.246
	2	1	1.393	1.831	
25	1	2	4.962	4.143	0.251
	2	1	4.143	4.962	
50	1	2	7.615	6.143	0.089
	2	1	6.143	7.615	
75	1	2	9.692	8.143	0.045
	2	1	8.143	9.692	
100	1	2	11.923	10.429	0.001
	2	1	10.429	11.923	

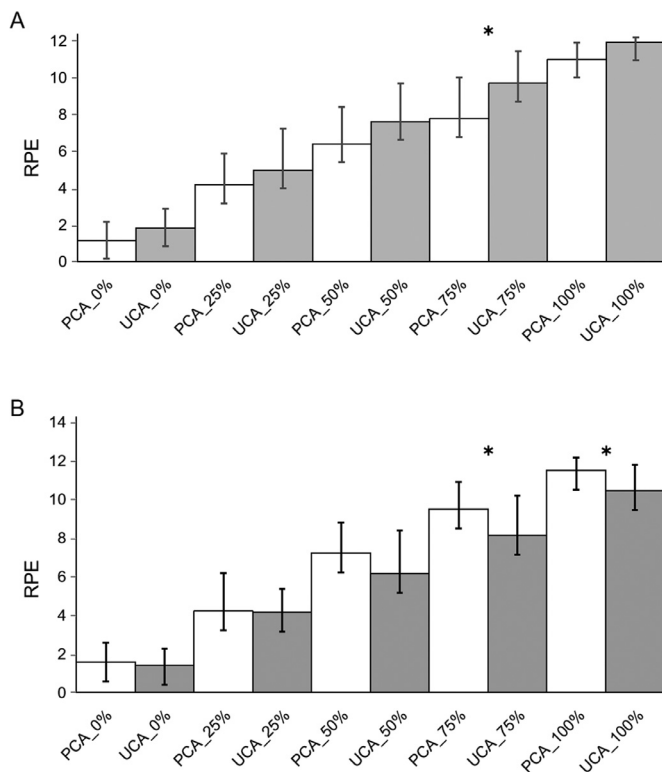


Fig. 3. Differential effects of PCA and UCA on isotime (0%, 25%, 50%, 75%, 100%) (A) RPE value in Group 1; (B) RPE value in Group 2. Error bars represent standard deviation. \**p* < 0.05. PCA = pleasant core affect; UCA = unpleasant core affect; RPE = rate of perceived exertion.

core affect; and Group 2, comprising participants who performed better with unpleasant core affect.

#### 4.1. Performance outcomes

Although significant differences did not emerge on performance outcomes (Fig. 1A), pleasant and unpleasant pictures seemed to induce differential effects.<sup>39</sup> Indeed, some participants obtained better performance with pleasant core affect (Fig. 1B), while others reached better performance with unpleasant core affect (Fig. 1C). Since core affect can be related to mood and prototypical emotions (e.g., fear, anger),<sup>17</sup> we may consider the differential effects on performance as a finding consistent with the individual zones of optimal functioning (IZOF) model assumptions.<sup>40</sup> Indeed, the IZOF model postulates that optimal performance can be associated with both pleasant and unpleasant emotions depending on the individual perception. A performer could indeed reach an individual optimal state for performance through self-regulation of pleasant and unpleasant emotions.<sup>40,41</sup> Furthermore, according to the IZOF model<sup>40</sup>, our results can be interpreted assuming valence and performance functionality as interrelated factors that underlie individual differences in relation to emotion effects on performance. For instance, anger can be related to poor performance when perceived as dysfunctional and, conversely, to good performance when perceived as functional. Consequently, while our findings concur with the idea that positively toned emotions can be associated with successful

performance,<sup>13,42,43</sup> they also concur with previous research in which pleasant emotions (e.g., happiness) were found detrimental to performance because of the low energy invested on task execution. In contrast, unpleasant emotions (e.g., anxiety) were also found helpful in sport or gross muscular tasks<sup>44,45</sup> because of a high energy investment.<sup>45</sup>

Regarding activation, the 2 sets of pictures induced high values of arousal associated with both pleasant and unpleasant core affect. Study findings suggest that arousal could moderate the effect of positively and/or negatively toned affect on performance. This finding is in line with the contention of Mella-lieu and colleagues<sup>46</sup> that arousal can change the individual appraisal of emotion, for example, when unpleasant emotions are perceived as more functional for performance, especially in amateur performers. Our results also concur with the idea that high values of arousal are positively associated with performance on aerobic tasks.<sup>45,47</sup> Indeed, high arousal values likely motivate individuals to invest greater resources on the task.<sup>48,49</sup> However, our results also suggest that high arousal is not always beneficial, especially under strenuous conditions.<sup>50</sup>

Because our first hypothesis was only partly confirmed, further research is necessary to better understand the role of mood and emotions in performance contexts. To provide a more detailed account of the influence of core affect on performance, future research might manipulate discrete moods and/or emotions,<sup>51</sup> especially in endurance contexts.

#### 4.2. Perceived exertion

Overall, significant differences among isotimes clearly account for the general increase of exertion through the endurance cycling task, with maximum perceived exertion characterizing exhaustion in both conditions and groups. Interestingly, we observed a between-groups difference in RPE values when compared across conditions (i.e., pleasant and unpleasant pictures). In particular, individuals who obtained better performance with pleasant core affect (Group 1) reported RPE values lower at 75% of TTE in a pleasant core affect condition compared to an unpleasant core affect condition. On the other hand, participants who obtained better performance with unpleasant core affect (Group 2) reported RPE values lower at 75% and 100% of TTE in an unpleasant core affect condition. This finding suggests that at specific stages of TTE (i.e., 75% and 100%), participants perceived the task as less fatiguing,<sup>14</sup> depending on the core affect they experienced to functionally influence their performance. These results are in line with the study of Bertollo and colleagues,<sup>24</sup> where RPE scores associated with suboptimal performances were higher compared to RPE values in optimal performances at 75% of a TTE test. From a broader theoretical perspective, notwithstanding the fact that between groups differences were not observed on earlier stages of TTE (i.e., 25% and 50%), our findings can be understood in light of a top-down psychobiological account of endurance fatigue.<sup>25</sup> According to this account, exhaustion is viewed as a volitional choice influenced by psychological factors rather than a process determined by afferent feedback from the muscular and cardiovascular systems. In our study, psychological factors

influencing exhaustion seem to be related to the participants' preference for pleasant or unpleasant core affect. This core affect was associated with reduced perceived exertion and increased duration of the constant load phase of the task, and thus experienced as functional for performance.<sup>41</sup> Moreover, it is worth considering that our experimental procedure induced high physiological duress similar to performance conditions in which cyclists are often required to make important decisions (e.g., whether or not to drop out of a demanding race).<sup>50</sup> The effect of core affect is particularly evident at the end of the endurance task, which is considered to be the moment when the highest physiological duress can be experienced and the most important phase for decision making.<sup>44</sup> Also, our findings confirm that a more positive affect might reduce the perception of exertion<sup>52</sup> and that a performer experiencing negative affect does not exclusively achieve poor performances.<sup>50</sup>

Although our second hypothesis was supported, more studies are necessary to further explore the complex interactions between affect and fatigue during endurance tasks. For example, when adopting a psychophysiological perspective, heart rate variability parameters should also be considered to contribute to a more nuanced differentiation of affect and to a deeper investigation of their impact on fatigue.<sup>53</sup> Moreover, changes in brain cortical activity measured by electroencephalogram techniques should be examined to broaden the knowledge about emotional processing and physical activity/exercise.<sup>54,55</sup>

To attain more generalizable findings, research should also be extended to different endurance tasks and to a larger sample of experienced performers. Additionally, studies considering the influence of pleasant and unpleasant core affect on RPE values during active and passive recovery phases would be beneficial to address the topic of stress/recovery balance.<sup>56,57</sup>

## 5. Conclusion

This study revealed differential effects of pleasant and unpleasant core affect on the examined endurance cycling task, and, at a group level, influences of core affect on perceived exertion according to the participants' preferences for pleasant or unpleasant core affect in terms of functionality toward performance. From a practical standpoint, these findings suggest that performers should be aware of their affective/emotional state and reactions under demanding performance conditions to self-regulate and improve performance. Carefully tailored training programs should help participants become aware not only of the intensities of their affects and/or emotions but also of the related content (pleasant/unpleasant, functional/dysfunctional). Once awareness is attained, performers should be trained to improve, refine, and expand their own routines and psychological skills to recover emotional feelings associated with their best performance and to either increase or decrease their levels.<sup>58</sup> Moreover, this study provides some evidence in support of the efficacy of visual stimuli in modulating the emotion–performance relationship. Accordingly, in the sport context, coaches could use visual stimuli to help athletes self-regulate their emotional states during endurance tasks.

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## Authors’ contributions

SdF conceived and carried out the study, performed the analyses, prepared figures and tables, and drafted and revised the manuscript; AA carried out the study, performed the analysis, and revised the draft of the manuscript; RZB prepared figures and tables and revised the draft of the manuscript; CM prepared figures and tables; CR performed the analysis and revised the manuscript; MB conceived the study and revised the manuscript. All authors have read and approved the final version of the manuscript, and agree with the order of presentation of the authors.

## Competing interests

The authors declare that they have no competing interests.

## Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.jshs.2019.12.004.

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