



## Article

# To focus or not to focus: Is attention on the core components of action beneficial for cycling performance?

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1     **To focus or not to focus: Is attention on the core components of**  
2                   **action beneficial for cycling performance?**

3

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## 1 Abstract

2 We conducted a counterbalanced repeated measure trial to investigate the effect of different  
3 internal and external associative strategies on endurance performance. Seventeen college-  
4 aged students were randomly assigned to three experimental conditions to test the notion that  
5 different attention-performance types (optimal Type 1, functional Type 2, and dysfunctional  
6 Type 3) would influence endurance time on a cycling task. Specifically, Type 1 represented  
7 an effortless and automatic, “flow-feeling” attentional mode. Type 2 referred to an  
8 associative focus directed at core components of the task. Type 3 represented an attentional  
9 focus directed at irrelevant components of the task. Participants completed three time-to-  
10 exhaustion-tests while reporting their perceived exertion and affective states (arousal and  
11 hedonic tone). Results revealed that Type 1 and Type 2 attentional strategies, compared to  
12 Type 3 strategy, exerted functional effects on performance, whereas a Type 3 strategy was  
13 linked to lower performance, and lower levels of arousal and pleasantness. Applied  
14 implications are discussed.

15

16 *Keywords:* Attentional focus, cycling, fatigue, endurance, multi-action plan model.

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1           To Focus or not to Focus: Is Attention on the Core Components of Action Beneficial  
2   for Cycling Performance?

3           There is general agreement about the importance of studying how different attentional  
4 strategies influence performance in sport and exercise settings (Basevitch et al., 2011;  
5 Blanchfield, Hardy, de Morree, Staiano, & Marcora, 2014; Connolly & Tenenbaum, 2010;  
6 Hutchinson & Tenenbaum, 2007; Razon et al., 2010; for a review, see Brick, MacIntyre, &  
7 Campbell 2014). In this regard, previous research has shown that one’s ability to self-regulate  
8 attentional focus (e.g., attentional flexibility) is associated with the ability to sustain exertive  
9 effort in endurance tasks (for a review, see Tenenbaum, 2005). To perform optimally, athletes  
10 must be able to employ different attentional strategies in order to control external and internal  
11 distracters, while focusing on body and task-relevant cues (Tenenbaum, 2001, 2005).

### 12 **Attentional Strategies for Endurance Performance**

13           Early research suggested that there are primarily two coping strategies that can be  
14 used to enhance performance in endurance tasks (a) “association” and (b) “dissociation”  
15 (Weinberg, Smith, Jackson, & Gould, 1984). Association occurs when people monitor their  
16 body sensations (e.g., respiration rate, body temperature, muscle pain and tightness), while  
17 reminding themselves to relax and modify stride and pace to secure greater running economy.  
18 Indeed, elite performers monitor their body sensations more effectively than their less  
19 accomplished counterparts (Raglin & Wilson, 2008). Dissociation occurs when individuals  
20 ignore pain, fatigue, or boredom by directing their attention outwards or by focusing on  
21 pleasant stimuli (e.g., listening to music; Weinberg et al., 1984). In this regard, Schücker and  
22 colleagues found that external attentional focus has a significant impact on physiological  
23 performance measures of running economy (Schücker, Anheier, Hagemann, Strauss, &  
24 Völker, 2013).

1 Association and dissociation are examples of attention control, which is a topic of  
2 great interest to sport and exercise psychologists. In essence, associative and dissociative  
3 strategies represent two distinct cognitive styles that indicate where individuals allocate  
4 attention to improve adjustment to a physical task (Tenenbaum, 2005). This initial distinction  
5 between the two broad categories of attention focus (as association and dissociation) was  
6 introduced by Morgan and Pollock (1977), and has since oriented research on attentional  
7 focus and physical effort (Hutchinson & Tenenbaum, 2007; Stanley, Pargman, &  
8 Tenenbaum, 2007; Stevinson & Biddle, 1998). According to Morgan and Pollock, association  
9 is an internal attentional style used by people to monitor sensorial input while performing a  
10 physical task. Dissociation pertains to any cognitive strategy used to divert attention away  
11 from internal sensations and toward external distractions. Schomer (1986) differentiated  
12 associative and dissociative strategies by discussing the presence of “task-related” and “task-  
13 unrelated” thoughts. Specifically, associative thoughts are related to the task at hand (e.g.,  
14 bodily sensations, performance instructions, and pace monitoring), while dissociative  
15 thoughts are not relevant to the task (e.g., reflective activity thoughts, problem solving).

16 Stevinson and Biddle (1998) argued that a dichotomous treatment of attentional focus  
17 was inherently simplistic, and therefore proposed a two dimensional model considering: (a)  
18 the direction of attention (internal or external), and (b) task relevance (relevant or irrelevant).  
19 Internal strategies allow an individual to monitor his/her internal states while making  
20 appropriate psychophysiological adjustments to accommodate pain and effort. Conversely,  
21 external strategies allow the performer to shift attention to exterior events, thus reducing  
22 perceptions of exertion. Task-relevant thoughts involving an internal focus (e.g., physical  
23 sensations) are classified as internal association, whereas task-relevant thoughts with an  
24 external focus (e.g., pacing) are labeled external association. Similarly, task irrelevant  
25 thoughts with an internal focus (e.g., daydreams) were categorized as internal dissociation

1 and task-irrelevant thoughts with an external focus (e.g., scenery) as external dissociation.  
2 Drawing on Stevinson and Biddle's (1998) classification, Brick et al. (2014) suggested that  
3 the associative dimension should also include active self-regulation (i.e., thoughts related to  
4 cadence, pacing, technique, strategy, or maintaining a relaxed state) and internal sensory  
5 monitoring.

6 Tenenbaum's (2005) effort-related model added the notion that associative and  
7 dissociative focus depends on workload intensity. In particular, Tenenbaum observed that  
8 people may intentionally switch their attentional focus, between associative and dissociative  
9 strategies, under low workload intensities. However, when physical symptoms of exertion  
10 reach a threshold upon which attention flexibility (i.e., ease of switching back and forth  
11 between dissociative to an associative pattern) is compromised, a final switch from a  
12 dissociative to an associative focus occurs (e.g., increased somatic awareness, and pain; see  
13 Connolly & Tenenbaum, 2010; Hutchinson & Tenenbaum, 2007; Stanley et al., 2007). In this  
14 regard, endurance athletes have reported that focusing on internal (association) cues is  
15 functional for performance unless they feel very tired and distressed, when an associative  
16 strategy is viewed as dysfunctional and unnatural (Masters & Ogles, 1998).

17 It is important to note that research on the relationship between performance and  
18 attentional focus (as associative or dissociative) has produced conflicting results. While some  
19 scholars have found a linkage between higher ratings of perceived exertion (RPE) and an  
20 associative focus (Baden, McLean, Tucker, Noakes, & Gibson, 2005), others observed a  
21 linkage between higher RPE and a dissociative focus (Beaudoin, Crews, & Morgan, 1998;  
22 Brewer, Van Raalte, & Linder, 1996). Furthermore, there is also literature suggesting no  
23 differences in performance as a function of attentional focus (Harte & Eifert, 1995; Weinberg  
24 et al., 1984). Despite these conflicting results, there is a general agreement that the  
25 optimization of attentional control may produce significant gains in endurance performance

1 and external focus strategies can also be beneficial to performance beside the internal ones  
2 (Schücker et al., 2013). The purpose herein was to investigate the effect of different internal  
3 and external associative strategies on endurance performance in cycling, using the multi-  
4 action plan (MAP) model as a theoretical basis for our experimental protocol.

### 5 **The Multi-Action Plan Model**

6         The recently proposed MAP model is based on the notion that different attentional  
7 strategies lead to different performance states, namely optimal and less than optimal  
8 (Bertollo, Bortoli, Gramaccioni, Hanin, Comani, & Robazza, 2013; Bortoli, Bertollo, Hanin,  
9 & Robazza, 2012). Specifically, an automatic attentional focus (Type 1) has been linked to  
10 optimal performance in sports. However, an attentional focus directed at a core component of  
11 a given action (Type 2) has also been associated with functional performance, which is  
12 defined within the individual zones of optimal functioning (IZOF) framework as an  
13 individual's effective recruitment and use of available resources for optimal achievements  
14 (Hanin, 2007). In contrast, over-controlled attentional focus has been found to lead to  
15 dysfunctional performance in sports. Previous research based on the MAP model revealed  
16 that attentional focus moderates performance quality in self-paced tasks (i.e., rifle and pistol  
17 shooting). In effect, Bortoli et al. (2012) observed that four performance categories result  
18 from different attentional strategies. These performance states are: (a) Type 1, optimal  
19 performance, characterized by an automatic ("flow-feeling" like) attentional mode and  
20 pleasant-functional emotions; (b) Type 2, functional performance, typified by an associative  
21 focus directed at core components of a given task/action and pleasant or unpleasant-  
22 functional emotions; (c) Type 3, dysfunctional performance, characterized by a focus directed  
23 at irrelevant components of a given task/action and unpleasant-dysfunctional emotions; and  
24 (d) Type 4, poor performance, typified by a markedly irrelevant focus and pleasant-  
25 dysfunctional emotions.

1           The MAP model was developed to orient applied interventions aimed at reaching and  
2 maintaining maximal performance in presence of distress, fatigue, and distracting situations.  
3 In detail, the MAP model is conceptualized as a function of distinct performance levels (i.e.,  
4 optimal or suboptimal) and attentional demands (i.e., automatic or controlled), thus  
5 establishing four performance categories: Optimal-automatic (Type 1), optimal-controlled  
6 (Type 2), suboptimal-controlled (Type 3), and suboptimal-automatic (Type 4). Indeed, these  
7 four types of performance have been found to rely on specific psychophysiological patterns,  
8 including skin conductance levels, respiration rate, and fronto-occipital and inter-frontal  
9 coherence in the alpha band (Bertollo et al., 2013; Comani et al., 2014). Of note, perceived  
10 arousal and pleasantness levels have also been found to predict performance in endurance  
11 tasks in general (Hanin, 2007), and in respect to the MAP model's performance  
12 categorization in particular (Bertollo et al., 2013). In fact, arousal and pleasantness underlie  
13 the notion of core affect, thus influencing one's ability to perform a given task (Russell &  
14 Weeks, 1994; Russell, Weiss, & Mendelsohn, 1989). Hence, in the present study, we were  
15 also interested in assessing whether the cyclists' core affect (i.e., arousal and hedonic tone)  
16 patterns would differ in regards to the MAP model categories.

17           It is also important to note that the MAP model is idiosyncratic in nature, thus  
18 assuming that ones' strategies and behaviors during performance are unique. In essence, the  
19 MAP model posits that individuals who focus on their idiosyncratic core components of  
20 action in conditions of distress or fatigue are likely to consistently attain high performance  
21 levels. In a recent study, for instance, cyclists identified "pedaling rate" as a core component  
22 of action linked to endurance performance (Comani et al., 2014). To this extent, Bortoli et al.  
23 (2012) suggested that an appropriate focus on one or a few core components of the action  
24 helps performers to self-regulate by maintaining optimal action tendencies. In contrast,  
25 reinvesting attention on body feelings (e.g., muscular tension, muscular stiffness, and pain) in



1 the attempt to control the whole action tends to increase the likelihood of performance  
2 breakdown (Masters & Maxwell, 2008). According to the MAP model, individuals can reach  
3 functional performance levels by directing their attention on the core components of the  
4 action (i.e., using action-centered strategies) and/or optimizing their emotional states (i.e.,  
5 using emotion-focused strategies).

## 6 **The Present Study**

7 We investigated the effect of different internal and external associative strategies on  
8 endurance performance. Drawing on the MAP model assumptions, we hypothesized that  
9 participants in a Type 1 performance condition would experience optimal performance and a  
10 “flow state” typified by pleasant affect, while externally concentrating on pacing. Type 2  
11 performance situation, in which participants’ attention was directed internally on the core  
12 component of the cycling action, was expected to result in a functional state and be  
13 accompanied by pleasant or unpleasant affect. Finally, Type 3 performance condition was  
14 predicted to augment individual’s fatigue sensations and cause a suboptimal performance  
15 state because of excessive focus on muscle feelings and pacing. Type 4 performance,  
16 characterized by unfocused attention and poor performance, was not considered in the current  
17 study because it is irrelevant to the development of applied guidelines for performance  
18 improvement in sports.

## 19 **Method**

### 20 **Design**

21 Based on the performance states delineated in the MAP model, we conducted a  
22 counterbalanced repeated measure trial to investigate the effect of different internal and  
23 external associative strategies on endurance performance. This is congruent with the  
24 importance of testing the MAP model assumptions in sport modalities other than self-paced  
25 sports (e.g., dart throwing, pistol shooting), especially endurance sports in which attentional

1 control and performance are intrinsically related. In particular, we tested participants in time-  
2 to-exhaustion trials during cycling, while collecting psychological markers of fatigue and  
3 affect (i.e., RPE, hedonic tone and arousal).

#### 4 **Participants**

5 A priori power analysis (effect size = .50, power of .95, and an alpha level of .05) was  
6 used to determine the sample size ( $N = 18$ ). In order to detect a moderate effect size (see  
7 Cohen, 1988), we recruited 21 college-aged students. Four students discontinued  
8 participation from the experiment due to either personal or health reasons. Accordingly,  
9 seventeen students (5 women and 12 men,  $M_{age} = 24.3$  years,  $SD = 4.9$  years) completed the  
10 experimental protocol, consisting of four visits to an exercise physiology laboratory. All  
11 seventeen volunteers participated regularly in different physical activities of low or moderate  
12 intensity. Assessment at baseline revealed that the fitness level of participants was generally  
13 low (men:  $\dot{V}O_2max$   $M = 39.03$  mL kg<sup>-1</sup> m<sup>-1</sup>,  $SD = 15.64$ , power peak output  $M = 231.54$ ,  $SD$   
14  $= 69.01$ ; women:  $\dot{V}O_2max$   $M = 26.31$  mL kg<sup>-1</sup> m<sup>-1</sup>  $SD = 5.32$ , power peak output  $M = 118.57$ ,  
15  $SD = 13.91$ ). After being briefed on the general purpose of the study, the participants agreed  
16 to participate and signed a written informed consent. The study was conducted in accordance  
17 with the declaration of Helsinki and received approval from the local university ethics  
18 committee.

#### 19 **Measurements**

20 **Ratings of Perceived Exertion (RPE).** RPE was measured through a CR-10 Scale®  
21 ranging from “0” (*no effort*) to “●” (*maximal sustainable effort*). The verbal anchors were: 0  
22  $=$  *nothing at all*, 0.5  $=$  *extremely weak*, 1  $=$  *very weak*, 2  $=$  *weak*, 3  $=$  *moderate*, 5  $=$  *strong*, 7  
23  $=$  *very strong*, 10  $=$  *extremely strong*, ●  $=$  *absolute maximum*. No verbal anchors were used  
24 for 4, 6, 8 and 9. Of note, the CR-10 Scale® is instrumental in diminishing ceiling effects as

1 its ratings are linearly related to various physiological parameters such as  $\dot{V}O_2$ max, lactate,  
2 and heart rate (Borg, 1998).

3 **Affect grid.** This is a single-item scale designed to quickly assess core affect along  
4 the dimensions of pleasure-displeasure and sleepiness-arousal (Russell et al., 1989). In our  
5 study, the participants were asked to place a single “X mark” on the 9x9 grid, which columns  
6 represent pleasantness and arousal scores. Hence, both the pleasure-displeasure and  
7 sleepiness-arousal can range from 1 to 9.

8 **Manipulation check questionnaire.** The participants were asked to rate, using a 10-  
9 point frequency scale with anchors 1 (*never*) and 10 (*always*), one of the following questions:  
10 “How often did you focus your attention on the metronome?” (Type 1 performance  
11 condition), “How often did you focus your attention on your feet to maintain individual RPM  
12 pacing?” (Type 2 performance condition), and “How often did you focus your attention on  
13 the tension of your muscles and body or fatigue?” (Type 3 performance condition).

#### 14 **Procedures**

15 Four visits to the laboratory were planned, with inter-visit intervals of 48 to 72 hours.  
16 Two trained scholars collected the data. Data collection occurred in a quiet (no music playing  
17 and no other people allowed in the laboratory) and safe environment to ensure the comfort of  
18 the participants. During the first session, the cycle ergometer was set-up and adjusted to each  
19 participant’s needs. The participants used the same cycle ergometer set-up during the  
20 subsequent visits. They were allowed to ask questions at any time during the study.

21 **Incremental test.** During the first visit to the laboratory, participants received  
22 standard instructions about the use of the Borg CR-10 RPE scale (Borg & Borg, 2001) and  
23 the affect grid (Russell et al., 1989). They also performed an incremental test to determine  
24 their anaerobic threshold or second ventilatory threshold (VT2). Specifically, after a warm-up  
25 (4 min cycling at 25 watt),  $\dot{V}O_2$  and  $\square CO_2$  were measured using an incremental protocol on

1 a Monark Cycle Ergometer (939 E). Heart rate,  $\dot{V}O_2$  and  $\dot{V}CO_2$  were continuously monitored  
2 during the exercise using a Schiller CS 200 system. VT2 was determined through the V-  
3 Slope method (Wasserman, Stringer, Casaburi, Koike, & Cooper, 1994). Pedal rate was set at  
4 70 revolutions per minute (rpm) and the workload power output was initially set at 25 W.  
5 Subsequently, the power output was incrementally increased by 25 W every 2 min until  
6 exhaustion. After the completion of the incremental test, the participants were given a 20 min  
7 rest period. After this period, participants were asked to pedal at VT2+5% for ten minutes in  
8 order to identify their preferred pedaling rate (PPR), while familiarizing themselves with the  
9 study's procedures. Overall, this initial assessment indicated that participants were not trained  
10 athletes but rather recreational exercisers and, in some instances, arguably unfit individuals.  
11 Lastly, the participants were assigned to three different experimental conditions to be  
12 undertaken separately during the subsequent three meetings. These conditions required that  
13 the participants kept their focus of attention on either: (a) a metronome that reproduced their  
14 PPR (external associative strategy) aimed at eliciting a Type 1 performance state, which is  
15 typified by movement automaticity and optimal-pleasant affect; (b) their PPR (i.e., internal  
16 associative strategy on pacing representing the core component of action) aimed at eliciting a  
17 Type 2 performance condition typified by focused attention on the relevant aspects of action  
18 and pleasant or unpleasant affect; or (c) muscle fatigue feelings and difficulties in  
19 maintaining pacing (dysfunctional associative strategy on internal feelings) aimed at inducing  
20 Type 3 dysfunctional performance state and unpleasant affect (see Figure 1).

21 **Time-to-exhaustion test at individual constant load.** During the subsequent visits to  
22 the lab, participants were assigned to one of the three experimental conditions, each defined  
23 in a random order and occurring on different days. They performed a time-to-exhaustion test,  
24 at individual VT2 power intensity, while reporting their RPE and affective states. Time-to-  
25 exhaustion was determined as either (a) the maximum interval in which the participants could

1 maintain exercise intensity ( $VT2 + 5\%$ ), and/or (b) the moment in which participants'  
2 reached volitional exhaustion. The first criterion, in particular, was established to prevent  
3 excessive lengthening of the experimental condition, especially with well-trained individuals.  
4 Individual  $VT2$  and PPR of each participant was set during test. After a resting period (no  
5 movement) of 2 min, and a warm-up period of 4 min on the cycle ergometer at individual  
6 power (calculated as the 40-50% of the individual  $\dot{V}O_{2max}$ ), the participants performed a  
7 constant load until exhaustion at their individual power (i.e.,  $VT2 + 5\%$  with a PPR) while  
8 maintaining their PPR. After exhaustion, the participants engaged in an active recovery  
9 period of 4 min (at the same power used during warm-up) followed by a resting period of 2  
10 min (no movement). RPE and affect grid scores were collected in the last 5 s of every 1 min  
11 period throughout the entire test. The manipulation check questionnaire was administered at  
12 the end of data acquisition to verify adherence to the experimental conditions.

### 13 **Statistical Analysis**

14 Analysis of variance with repeated measures (RM-ANOVA), with an alpha level set  
15 at .05, were computed to compare participants' time-to-exhaustion test, RPE, and affective  
16 scores across the three experimental conditions. Bonferroni post-hoc test was used to identify  
17 potential differences among the three experimental conditions. Furthermore, condition  $\times$  time  
18 RM-ANOVAs were performed for RPE and affect grid scores at 0% (first minute), 25%,  
19 50%, 75%, and 100% (last completed minute) in the time-to-exhaustion test. This is aligned  
20 with the importance of measuring temporal changes in affective states in general (Hanin,  
21 2007), and in fatigue in particular (Blanchfield et al., 2014). These iso-times were measured  
22 at the selected time-points, thus allowing for the identification of affective (i.e., arousal and  
23 pleasantness) and perceptual (RPE) changes throughout the exhaustion tests. Specifically,  
24 iso-time values for 0% corresponded to the values for the first full minute of each time-to-  
25 exhaustion test. The value of iso-time at 100% was defined as the shortest time-to-exhaustion

1 accomplished by each individual over their three tests. The minute 100% iso-time was  
2 divided by two to obtain the value corresponding to 50% iso-time (see Blanchfield et al.,  
3 2014). The 25% and 75% iso-times were derived accordingly.

## 4 **Results**

### 5 **Manipulation Check**

6 Manipulation check results showed that participants adhered satisfactorily to the  
7 experimental conditions. During the Type 1 performance condition, response ratings ranged  
8 from 5 to 9, which corresponded to an adherence frequency from *often* to *almost always* ( $M =$   
9  $6.82$ ,  $SD = .87$ ). In the Type 2 performance state, the response ratings ranged from 6 to 9  
10 (*very often* to *almost always*;  $M = 7.29$ ,  $SD = .89$ ), whereas in the Type 3 performance state  
11 the response ratings ranged from 7 to 9 ( $M = 7.82$ ,  $SD = .74$ ). The levels of arousal, affect,  
12 and perception of effort were also analyzed prior to the time-to-exhaustion test. RM-ANOVA  
13 results on the affect grid and RPE data collected during the rest and warm-up phases revealed  
14 no differences among the experimental conditions before the time-to-exhaustion test in  
15 regards to arousal level,  $F(2, 32) = 0.89$ ,  $p = .41$ , hedonic tone,  $F(2, 32) = 2.32$ ,  $p = .11$ , and  
16 RPE,  $F(2, 32) = 0.76$ ,  $p = .48$ .

### 17 **Experimental Manipulation**

18 **Descriptive analysis.** Descriptive statistics for all measures are reported in Table 1.  
19 High standard deviation scores on time-to-exhaustion indicate large individual differences in  
20 the efficacy of the Type 1 and Type 2 strategies. Two examples of idiosyncratic trends for  
21 RPE during the entire experimental phase are presented in Figure 2. Panel A shows the RPE  
22 trend of a cyclist who reached best performance using Type 1 performance strategy. On the  
23 other hand, panel B shows the RPE trend of a cyclist who sustained a longer time in cycling  
24 performance through Type 2 performance strategy. Both participants showed poorer  
25 performance under the Type 3 performance condition.

1           **Inferential analysis.** In RM-ANOVA, the assumption of sphericity was violated, and  
2 thus the Greenhouse-Geisser correction was applied to the degrees of freedom for subsequent  
3 *F* statistic calculation. RM-ANOVA on overall scores showed differences across the three  
4 experimental conditions in regard to the duration of the time-to-exhaustion test,  $F(1.81,$   
5  $29.03) = 11.41, p < .01, \eta_p^2 = .41, \text{power } .98$ . Bonferroni post-hoc test showed differences in  
6 the duration of time-to-exhaustion test between Type 1 ( $M = 18.35$  min) and Type 3 ( $M =$   
7  $14.12$  min) performance states ( $p < .01$ ), and between Type 2 ( $M = 17.65$  min) and Type 3 ( $M$   
8  $= 14.12$  min) performance states ( $p < .01$ ).

9           To explore the effect of internal and external associative strategies on RPE, based on  
10 the MAP model assumptions, we calculated the slope of RPE for the time-to-exhaustion test.  
11 Subsequently, we performed a RM-ANOVA on the overall slope scores to explore the impact  
12 of RPE, and affect trend during task. Results revealed differences among the three  
13 experimental conditions on the slope scores of RPE during time-to-exhaustion-test,  $F(1.67,$   
14  $26.86) = 4.01, p = .03, \eta_p^2 = .21, \text{power } .62$ . In particular, Bonferroni post-hoc test showed  
15 difference between Type 1 ( $M = 0.67$ ) and Type 3 ( $M = 0.88$ ) performance states ( $p < .01$ )  
16 and Type 2 ( $M = 0.73$ ) and Type 3 ( $M = 0.88$ ) performance states ( $p = .04$ ). No differences  
17 were found with regards to the RPE slope during the recovery period, and scores of arousal  
18 and hedonic tone.

19           Condition  $\times$  iso-time RM-ANOVAs on RPE, arousal, and hedonic tone were also  
20 performed. Specifically, we compared the three experimental conditions over iso-time for  
21 RPE. Results revealed an effect on condition,  $F(1.89, 30.24) = 462.46, p < .01, \eta_p^2 = .97,$   
22  $\text{power } 1.00$ , on time,  $F(2.32, 37.13) = 74.29, p < .01, \eta_p^2 = .82, \text{power } 1.00$ , and in the  
23 interaction between condition and time,  $F(2.78, 44.53) = 6.57, p = .01, \eta_p^2 = .29, \text{power } .95$ .  
24 These differences are graphically depicted in Figure 3 (Panel A), in which higher RPE levels  
25 are more evident for Type 3 performance state at the 75% and 100% iso-times.

1 Furthermore, when comparing the three experimental conditions over iso-time on  
2 Arousal level, we found an effect on condition,  $F(1.34, 21.55) = 10.47, p < .01, \eta_p^2 = .39,$   
3 power .93, time,  $F(3.11, 39.49) = 3.80, p < .01, \eta_p^2 = .34,$  power .99, and in the interaction  
4 between condition and time,  $F(3.47, 55.60) = 6.57, p < .01, \eta_p^2 = .19,$  power .83. These  
5 differences can be seen in Figure 3 (Panel B), in which lower levels of arousal accompanied  
6 Type 3 performance throughout the entire test. Finally, significant differences were observed  
7 for hedonic tone on condition,  $F(1.55, 24.80) = 21.64, p < .01, \eta_p^2 = .57,$  power 1.00, and  
8 time,  $F(2.52, 40.85) = 4.92, p < .01, \eta_p^2 = .23,$  power .84, but not for the interaction (Figure 3,  
9 Panel C).

## 10 Discussion

11 We conducted a counterbalanced repeated measure trial to investigate the effect of  
12 different internal and external associative strategies on endurance performance. Based on the  
13 MAP model, we differentiated among an external focus associated with a fluent performance  
14 (Type 1), an internal focus linked to optimal performance regulation (Type 2), and an internal  
15 focus hindering automatic execution of motor performance (Type 3). Results reinforced the  
16 notion that fatigue is a natural psychobiological process related to attentional focus and  
17 motivation (Blanchfield et al., 2014; Schücker et al., 2013). Specifically, both external (Type  
18 1) and internal (Type 2) associative attention strategies, in comparison with internal  
19 attentional focus (Type 3), were found to be functional, whereas intense internal attentional  
20 focus (Type 3) was found to be dysfunctional to performance. Of note, the functional effects  
21 of Type 1 and Type 2 performance states observed herein have also been identified in  
22 shooters (Bertollo et al. 2013; Bortoli et al., 2012). Furthermore, findings pertaining to Type  
23 3 performance states are consistent with the *reinvestment hypothesis*, in which automatic  
24 movements are disrupted when individuals try to consciously monitor and over control both



1 feedback input (e.g., feelings of fatigue) and movement execution (Masters & Maxwell,  
2 2008).

3         Our results showed that cyclists were able to reach and maintain optimal performance  
4 when using an external associative strategy by focusing attention on metronome (Type 1  
5 performance). Similarly, the cyclists were able to perform optimally when using an internal  
6 associative strategy with attention focused on the core component of the action (i.e., PPR,  
7 Type 2 performance). However, when the cyclists focused their attention on internal and  
8 irrelevant features of the task (e.g., disruption of PPR or muscle tension), they performed  
9 poorly (dysfunctional performance). These results suggest that in the absence of flow-like  
10 performance states, individuals may still perform well by adopting a Type 2 strategy.  
11 Therefore, applied sport and exercise psychologists should assist individuals in identifying  
12 and focusing on their (idiosyncratic) core components of action linked to functional  
13 performance patterns. In essence, by learning how to focus on core components of action  
14 individuals may be able to perform well while ignoring unpleasant feelings of fatigue (e.g.,  
15 muscle pain).

16         Our findings pertaining to Type 2 performance are in agreement with the notion that a  
17 functional internal focus (internal association) may also lead to functional performance  
18 experiences. To this extent, Masters and Ogles (1998) noted that an internal associative  
19 strategy is neither dysfunctional nor unnatural. Accordingly, individuals may benefit from  
20 internal associative strategies, especially under high workload intensities when the ability to  
21 switch between association and dissociation is compromised (Tenenbaum, 2005). In this  
22 regard, it is important to note large interindividual differences among the cyclists, with some  
23 individuals being remarkably unfit/sedentary. The differences were in the intensity,  
24 variability, and magnitude of the cyclists' subjective and psychophysiological recordings.  
25 Overall, these results are in accordance with the *individuality principle* and reflect the

1 idiosyncratic nature of maximal performance in sports (Hanin, 2007). In effect, some  
2 individuals may perform better using external strategies while others experience maximal  
3 endurance performance when adhering to internal strategies (Bortoli et al., 2012). In fact,  
4 although applying different methodological approaches various scholars have emphasized the  
5 importance of identifying individual difference of performance-related states (Bortoli et al.,  
6 2012; Filho, Moraes, & Tenenbaum, 2008). There is also a general agreement on the  
7 importance of identifying the fundamental variables and mechanisms linked to peak  
8 performance in sports (Hanin, 2007).

9         Although internal strategies may be functional from an idiosyncratic standpoint, our  
10 nomothetic (group level) analysis echoed the notion that (a) external attentional focus is best  
11 for performance gains in economy of effort (Schücker et al., 2013), and (b) associative-  
12 dissociative dimension is the main determinant of RPE (Stanley et al., 2007). In this regard,  
13 exergaming technology can be used to create “dissociative environments” (e.g., gym,  
14 physical therapy clinics) aimed at diverting attention from feelings of fatigue. In addition to  
15 gaming technology, sport and exercise psychologists may use bio-neurofeedback multimedia  
16 modalities to help people to divert attention away from unpleasant fatigue sensations (Perry,  
17 2012).

18         We also measured core affect throughout the time-to-exhaustion-tests. The results  
19 revealed that affective value means (arousal and hedonic tone) did not differ across  
20 conditions. However, when comparing iso-times across conditions, we observed differences  
21 for both arousal and pleasantness trends. Thus, the relationship between iso-time and RPE  
22 was found to be influenced by attentional strategies, with an internal dysfunctional  
23 associative focus leading to lower levels of arousal and pleasantness. The fact that Type 3  
24 performance was associated with lower levels of pleasure and arousal, suggests that focusing  
25 on fatigue feelings is related to energy demobilization. Indeed, Hanin (2007) posited that

1 optimal performance is likely to occur when energy matches task demands (i.e., energy  
2 matching hypothesis). The flow-feeling theory also reflects the notion that optimal  
3 performance is likely to occur when one's psychosocial skills are "a good match" for a given  
4 challenging task (Csikszentmihalyi & Csikszentmihalyi, 1993). It is also important to note  
5 that individuals have different arousal and hedonic tone levels linked to optimal and less than  
6 optimal performance (Robazza, Pellizzari, Bertollo, & Hanin, 2008). In this regard, Hanin  
7 (2007) has noted that there is interindividual variability in the intensity and content of  
8 idiosyncratic functional and dysfunctional affective states.

9 Overall, three main conclusions derive from our study: (a) both internal and external  
10 attention strategies, namely Type 1 and 2 performance states, can exert functional effects on  
11 performance compared to attentional focus on feelings of fatigue (Type 3 performance); (b)  
12 internal attention can be functional if the attentional focus is directed toward the core  
13 component of action (Type 2 performance) rather than on feelings of fatigue (Type 3  
14 performance); and (c) attentional focus on feelings of muscle fatigue leads to poor  
15 performance and low pleasant states and arousal levels (thereby causing energy  
16 demobilization) during high intensity exercise (iso-time > 50%). These conclusions are  
17 congruent with the MAP model performance categorization, particularly with the notion that  
18 individuals can perform well when directing their attentional focus to the core components of  
19 action related to a given exertive task. From a broader theoretical standpoint, these findings  
20 support a top down psychobiological account of endurance fatigue (Marcora, 2009) in which  
21 exhaustion is viewed as a volitional choice influenced by psychological factors (e.g.,  
22 attentional and motivational strategies) rather than a process determined by afferent feedback  
23 from the muscular and cardiovascular systems. In fact, this new psychobiological model has  
24 been seen as an alternative to the tradition peripheral afferent feedback framework (i.e.,  
25 inhibitory feedback triggered by increased concentration of metabolites such as lactate and

1 urea; Gandevia, 2001) in trying to explain exhaustion in humans (Blanchfield et al., 2014;  
2 Marcora, 2009).

3         It is also important to acknowledge the limitations of our study in attempt to better  
4 orient future research efforts. First, it is difficult to induce Type 1, flow-like performance in  
5 both laboratory and ecological settings (Csikszentmihalyi & Csikszentmihalyi, 1993; Hanin,  
6 2007). Peak performance experiences are rare, and thus pose a challenge to scholars and  
7 practitioners interested in its antecedents and outcomes. Longitudinal assessment may be an  
8 alternative to this limitation, as it allows for the recording of a larger data set with a  
9 correspondingly larger sample of peak-performance records (Filho et al., 2008). The use of a  
10 mixed-method approach, involving the measures of core affect used in this study and surveys  
11 on flow and qualitative assessments, may allow the researcher to triangulate participants'  
12 perceived flow states with bio- and neuro-feedback data, thus yielding a more comprehensive  
13 assessment of peak performance experiences in laboratory settings. A second limitation of  
14 our study is related to our convenience sample, which was comprised primarily of college  
15 students and novices. In this regard, caution should be taken in generalizing the present  
16 findings across endurance sports (e.g., road cyclists), given that participants of this study  
17 were mostly sedentary individuals. Comparing sedentary individuals with elite athletes (i.e.,  
18 the expert-novice paradigm), and elite athletes among themselves (i.e., the expert  
19 performance approach) may reveal the nomological network pertaining to the attention-  
20 performance linkage in endurance and motor tasks. Third, it could be argued that the lack of a  
21 control group may limit the generalizability of our findings. However, we opted by a  
22 counterbalanced design because a true neutral effect is somewhat unrealistic in sport and  
23 exercise psychology contexts. In this regard, extant empirical evidence suggests that attention  
24 flexibility is ultimately compromised in time-to-exhaustion trials (for a review see  
25 Tenenbaum, 2005). Notwithstanding, future studies could consider alternative experimental

1 protocols to advance research on exertion. Finally, although a manipulation check confirmed  
2 the validity of our experimental protocol, the participants did not receive training on attention  
3 control to reach and maintain Type 1 and Type 2 performance states. Hence, the participants'  
4 ability to adeptly control their attentional focus might not have been ideal. Future research  
5 should test the effect of systematized mental skills training on individuals' ability to increase  
6 the likelihood of optimal-automatic performance (Type 1), focus on their core components of  
7 action (Type 2), and prevent dysfunctional performance states (Type 3).

8 Experimental trials testing the MAP model predictions in regards to other mental  
9 processes and skills (e.g., imagery, self-talk, and goal setting) are also warranted. Qualitative  
10 retrospective reports are important in the study of experts' mental processes, including meta-  
11 emotional and meta-cognitive fatigue and performance experiences (Hanin, 2007). Moreover,  
12 the implementation of the IZOF probabilistic methodology may generate more information  
13 regarding the idiosyncratic nature of optimal performance states, as previously demonstrated  
14 in other studies (e.g., Bertollo et al., 2012; Filho et al., 2008). Studying perceived exertion  
15 through multi-sensorial approaches (e.g., audio and scent) may continue to advance our  
16 understanding of the mechanisms underpinning fatigue in humans.

17

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- 21

## 1 Table 1

2 *Descriptive Statistics of Physiological, Performance, and Affective Data*

| Variable   | <i>M</i> | <i>SD</i> |
|--|----------|-----------|
| VT2- $\dot{V}O_2$ (mL kg <sup>-1</sup> m <sup>-1</sup> ) | 23.08    | 9.88      |
| VT2-Power (Watt)   | 138.82   | 54.84     |
| VT2-HR   | 142.06   | 24.74     |
| PPR (rpm)  | 75.41    | 15.06     |
| Time to exhaustion (min)                                 |          |           |
| Type 1 performance                                       | 18.35    | 6.93      |
| Type 2 performance                                       | 17.65    | 6.52      |
| Type 3 performance                                       | 14.12    | 5.95      |
| Arousal  |          |           |
| Type 1 performance                                       | 5.44     | 1.89      |
| Type 2 performance                                       | 5.90     | 1.70      |
| Type 3 performance                                       | 5.56     | 1.90      |
| Hedonic tone   |          |           |
| Type 1 performance                                       | 5.25     | 1.88      |
| Type 2 performance                                       | 5.33     | 1.72      |
| Type 3 performance                                       | 4.87     | 1.59      |

3 *Note.* VT2 = second ventilatory threshold;  $\dot{V}O_2$  = oxygen consumption; HR = heart rate; PPR

4 = preferred pedaling rate.