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Body focus and cardioceptive accuracy are not associated with physical performance and perceived fatigue in a sample of individuals with regular physical activity

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Abstract

It is often assumed that distracting attention from unpleasant body sensations evoked by physical exertion can alleviate perceived fatigue and increase physical performance. Also, the higher acuity of perception of heartbeats was associated with less physical performance in one study with sedentary participants. The current study was designed to shed more light on these associations. In a within-subject experiment, 98 students characterized by regular physical activity completed the Schandry-task assessing cardioceptive accuracy and cycled for 15 min on a bicycle ergometer at a convenient pace, listening to their own breathing through a headset (internal attention condition) or to distracting noises (external attention condition). Physical performance (number of pedal turns), physical exertion (heart rate), and self-reported fatigue were assessed for both tasks. Frequentist and Bayesian analyses showed no impact of the direction of attention and cardioceptive accuracy on physical performance, exertion, and perceived fatigue. In fact, the lack of association between cardioceptive accuracy and performance and perceived fatigue was more probable than the alternative hypothesis. Impact of distraction and cardioceptive accuracy on subjective and objective characteristics of physical exercise in the aerobic domain may be different for physically active and sedentary individuals. Future research in this area should systematically explore the background of these differences.

KEYWORDS

cardioceptive accuracy, ECG, introspection, mental heartbeat tracking task, physical exertion

1 | INTRODUCTION

The long-term maintenance of physical exertion in endurance tasks is a difficult process, that is prominently determined by physiological factors and regulated at non-conscious levels by the brain. For example, the intensity of exertion, the proportion and condition of the involved muscles, and the capacity of the cardiovascular and respiratory systems are factors that automatically limit the duration of physical activity (Powers & Howley, 2014). The fact that the primary strategy

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of distance runners is distracting attention from the internal cues (Lohse & Sherwood, 2011; Morgan & Pollock, 1977; Razon et al., 2014) also indicates that the regulation of actual effort runs at a non-conscious level. As for the conscious level, the overall status of the organism during exertion is primarily indicated by emotional-motivational factors: sustainable physical activity in the so-called aerobic domain (i.e., the intensity of exertion at which the cardiovascular system is able to cover the oxygen demand of the muscles) is accompanied by positive affect, whereas exertion in the anaerobic domain (i.e., when lack of oxygen substantially changes the metabolism of muscles) is characterized by negative affect (Cabanac, 2006; Ekkekakis, 2003; Ekkekakis et al., 2020; Köteles, Teufel, et al., 2020). Beyond this affective evaluation, more specific body sensations, such as fatigue of the working muscles and hunger for air, also occur; these signals are unpleasant in order to catch attention and motivate the organism to decrease the intensity of exertion or to completely cease it (Köteles, 2021). From a physiological point of view, the activity of the heart is a central factor in the maintenance of physical activity; compared to the resting condition, both the frequency (heart rate, HR) and the strength of cardiac contractions increase (Powers & Howley, 2014). As the intensity of exertion shows a linear relationship with heart rate (Borg, 1982), the idea that the acuity of perception of heartbeats, called cardioceptive accuracy (Garfinkel et al., 2015), also contributes to the perception of fatigue and to the regulation of the intensity of physical activity appears feasible. In two early studies on the association between cardioceptive accuracy and aerobic training status, athletes were characterized by better cardiac perception performance than non-athletes (House, 1983; Jones & Hollandsworth, 1981). These findings were not replicated in a subsequent study (Montgomery et al., 1984), which renders the idea that self-regulation in endurance sports is influenced by cardioceptive accuracy less likely. In another study (Köteles, Éliás, et al., 2020), although participants were clearly instructed to use their perceived heart rate to replicate a certain level of physical exertion, they typically used a variety of other internal cues, for example, breathing or overall fatigue. This shows that more general indicators of the actual physiological state, such as fatigue, hunger for breath, or the actual mood state, may be more useful for the estimation and regulation of the actual level of physical effort than cardioceptive accuracy (Ekkekakis, 2009; Ekkekakis & Acevedo, 2006; Jameson & Ring, 2000; Mihevic, 1981). It is often assumed that internally focused attention amplifies somatic and affective sensations, whereas external focus, that is, a distraction from internal cues, alleviate them (Duval & Wicklund, 1972; Miller et al., 1981; Pennebaker & Lightner, 1980). For example, distraction was found to be an effective strategy to alleviate pain (Johnson, 2005; Kohl et al., 2013). These findings are explained by the so-called *competition of cues* model, which states that internal and external stimuli compete for the limited attentional resources (Pennebaker, 1982). This relationship appears valid for cardioceptive accuracy, too; however, the latter is typically assessed under resting conditions in the laboratory, and participants are instructed to focus on their heartbeat (Köteles, 2021; Schandry, 1981).

In two seminal experiments, Pennebaker and Lightner (1980) attempted to demonstrate the impact of direction of attention on subjective and objective aspects of physical performance. In Experiment 1, participants were running on a treadmill, listening to their own previously recorded breathing (body focus condition), street noises (external condition), or without audio material (control condition). The body focus group reported a significantly higher level of fatigue and related somatic symptoms than the other two groups. However, this experiment was not without limitations. First, all participants ran at the same speed, regardless of their training status. Second, they were beginning joggers whose experience with physical exertion cannot be generalized to those with regular physical activity (see also in the discussion). Third, the rhythm of breathing they listened to was not in synchrony with their actual breathing pattern. Fourth, as the effectiveness of attention manipulation was not assessed, one cannot be sure that this manipulation actually worked. In Experiment 2, participants (also beginning joggers) were asked to run in circular laps around a small open field (internal condition) or along a cross-country course (external condition) with a freely chosen speed. It was found that participants completed the cross-country course significantly faster than the lap courses; however, no differences were revealed in perceived fatigue and physiological measures (heart rate; blood pressure). Again, it was assumed but not measured that the cross-country setting caught and distracted participants' attention from internal signals more than the lap courses (Fillingim & Fine, 1986). Moreover, physiological variables were measured before and after running only, which does not reflect participants' physiological state during exercise. The findings of these experiments were interpreted as consequences of attentional focus. In summary, street noises and the complexity of the cross-country course might have distracted attention from internal signals of fatigue (competition of cues, see above), whereas breathing-related noises and the monotony of laps favored body-focused attention.

Several years later, Experiment 2 was replicated with an improved methodology by Fillingim and Fine (1986). Their participants were experienced joggers, completing lap courses with a speed that was convenient to them. The direction of attention was manipulated by asking them to pay attention to words played from an audiotape and count the number of times a word was heard (dubbed word-cue or external condition), to focus on their body (internal condition), or they had to run without an extra task (control condition). The word-cue condition was characterized by significantly

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less exercise-relevant symptoms, including fatigue; no difference in the time of completion was found. Moreover, there was no significant difference between the internal and the control condition, which does not support the idea that body-focused attention amplifies unpleasant internal sensations and feelings. Still, these results were explained as consequences of attentional distraction. Similar to the Pennebaker-Lightner experiments, however, the actual direction of attention was not assessed.

Another factor that can possibly impact the subjective and objective aspects of physical activity, that is, cardioceptive accuracy, was taken into consideration in the experiment of Herbert and colleagues (2007). In this study, participants' training status was measured before the experiment and the physical load was individually adjusted. The task was pedaling on a bicycle ergometer for 15 min at a self-selected pace. Cardioceptive accuracy was assessed before the experiment with the mental heartbeat tracking task developed by Schandry (1981). People with good heart perception ability showed worse physical performance, less increase in HR and other cardiac variables than poor perceivers, whereas no difference between the two groups with respect to perceived fatigue was found. This finding was explained by the authors as the consequence of more precise fine-tuning of physical activity due to a more accurate perception of the internal state. It was not elaborated, however, why better interoception leads to less physical performance. Moreover, it was implicitly assumed that cardioceptive accuracy assessed at rest can be transferred to loaded conditions. In fact, cardioceptive accuracy, as assessed by the discrimination paradigm, was above the chance level during exercise for people with average cardiovascular fitness; however, it was not above random guessing at rest (Montgomery et al., 1984). Subsequent research also demonstrated that the transferability of resting cardioceptive accuracy is limited to very light physical loads, and the strength of the association is only moderate (Köteles, Éliás, et al., 2020). Also, the mental heartbeat tracking task of Schandry has received serious criticism because of its malleability to top-down influences, which limits its validity as a sensory measurement (Desmedt et al., 2018, 2020; Ring & Brener, 1996; Ring et al., 2015; Zamariola et al., 2018). Further, cardioceptive accuracy was considered an indicator of overall interoceptive ability in the study of Herbert and colleagues (2007), an assumption that is not supported by several empirical studies (Ferentzi et al., 2017, 2018). Finally, an inclusion criterion of this study was no regular participation in endurance sports, which is again problematic from the viewpoint of external validity. Table 1 summarizes the most important features of the aforementioned three experiments.

The experiment reported in this paper was designed to shed more light on the associations between physical performance, body focus, and cardioceptive accuracy. To reduce Type 2 error, we collected a comparatively large sample ($n = 98$) and

TABLE 1 Comparison of three studies with self-selected level of physical exertion

	Participants' exercise status	Sample size	Conditions/variables included	Physical performance in the task	Physical exertion, as assessed by HR	Perceived fatigue
Pennebaker and Lightner (1980), Experiment 2	Beginning joggers	$n = 13$	Internal versus external	Worse in the internal condition	No difference	No difference
Fillingim and Fine (1986)	Experienced joggers	$n = 15$	Internal versus external versus control	No difference	N.A.	Less in the external condition
Herbert et al. (2007)	No regular physical activity	$n = 34$	Poor versus good cardioceptive accuracy	Worse for good cardioceptive accuracy	Less for good cardioceptive accuracy	No difference

Abbreviation: N.A., not applicable as it was not assessed.

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applied a within-subject design. Besides the usual frequentist approach, Bayesian analysis was also applied to explore the probability of the alternative hypotheses compared to the respective null hypotheses. Basically, we aimed to conceptually replicate the aforementioned three studies (Table 1), with an improved methodology. To improve the internal and external validity of the results, (1) participants characterized by regular physical activity were recruited, (2) effectiveness of manipulation of attentional focus was assessed, (3) HR was continuously monitored during exertion, and (4) a stricter instruction was applied in the Schandry-task in order to reduce the impact of top-down factors. The hypotheses of the current study were as follows. Based on the findings of the previous studies, it was assumed that internal focus, compared to external focus, would be associated with lower level of physical performance (H1) and physical exertion (H2), and more perceived fatigue (H3). Moreover, a negative association between cardioceptive accuracy and physical performance (H4) and physical exertion (H5) was expected.

2 | METHOD

2.1 | Participants

98 undergraduate university students studying recreation or sports management (51 female; age: $M = 20.8$, $SD = 1.82$ yrs) participated in the study. Although these students are not elite athletes, physical exercise on a daily basis is part of their university training. Due to technical failures, data on HR during exercise were lost for 6 individuals, and ECG recording for the Schandry-task was missing for 5 people. All participants signed an informed consent form. Participation was voluntary; however, students received partial credit for partaking in the study.

2.2 | Protocol

The study consisted of three parts, participants were measured one by one in a laboratory room. First, their PWC-150 value (i.e., the load on the bicycle ergometer that corresponds to a HR of 150 bpm, see below) was determined. Second (at least one week later), they completed the Schandry-task and one of two bicycle ergometer tasks (see below; order of the cycling tasks was randomized). Third (approximately one week later), they completed the second ergometer task. The only difference between the two ergometer tasks was the audio material participants had to listen to. In the internal condition, they listened to their own breathing played back in real time. In the external condition, an audio material presenting kitchen and cooking-related noises was administered. This latter material was 15 min long and contained no repetitive sequences to maintain attention (it is available from the authors upon request). Volume of the loudspeaker of the headset was adjusted to a convenient level by the participants before each measurement.

2.3 | Self-report measures

Perceived fatigue was measured using the 3-item Fatigue scale of the Physical Activity Affect Scale (PAAS) (Lox et al., 2000). Items are rated on a 5-point scale, higher scores indicate higher levels of perceived fatigue. Internal consistency of the scale was excellent for all measurements (Cronbach's alpha indices ranged from .829 to .926).

Body focus during cycling was rated on a 10 cm visual analogue scale (VAS) right after the exercise. Participants were asked to rate to what extent they focused on their body during the task with the anchor points "*not at all*" and "*completely*".

2.4 | Sensory and physical measures

2.4.1 | Mental heartbeat tracking task (Schandry-task)

Assessment of the acuity of heartbeat perception (i.e., cardioceptive accuracy) was conducted in a seated position, with both feet on the ground. Touching the pulse or other maneuvers that enable the participant to directly sensing the beating of the heart were not allowed. Participants were asked to count their heartbeats silently during three randomly presented intervals (25, 35, and 50 s) after a 15 s long practicing phase. The counting started with a verbal START signal and stopped by a STOP signal, after which participants reported the number of felt heartbeats. Participants were explicitly encouraged to say zero if they did not feel any heartbeats, but also encouraged to count if they have a slight sensation only. Actual heartbeats (ECG) were recorded with the NeXus recording system (NeXus Wireless Physiological Monitoring and Feedback: NeXus-10 Mark II, Version 1.02; BioTrace+Software for NeXus-10 Version: V201581; Mind Media BV, Herten, the Netherlands). Individual heartbeat perception scores were calculated for each interval using the following formula: $1 - |(HB_{recorded} - HB_{counted})/HB_{recorded}|$, followed by the calculation of the average (dubbed Schandry-score). Cronbach's alpha for the Schandry-task was .948.

Determining the individual bicycle ergometer load (Physical working capacity at 150 bpm, PWC-150) (Herbert et al., 2007).

The goal of the measurement was to determine the load (in terms of Watts) on a bicycle ergometer that corresponds to

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a HR of 150 bpm. In doing so, the load during the experimental tasks was adjusted to participants' physical characteristics, such as body weight and aerobic training status. During the task, participants were asked to adjust a bicycle ergometer (Ergoline Ergoselect Viasprint 150P; ergoline GmbH, Bitz, Germany) to their body size and then pedal at a pace of 80/min. HR was continuously monitored using a Firstbeat chest belt and HR monitoring software (Firstbeat SPORTS, v4.7.2.1.; Firstbeat Technologies Oy, Jyväskylä, Finnland). The load was gradually increased by 20 W for females and 25W for males in every minute until the target HR (150 bpm) was reached. The respective load (PWC-150) was applied in the experiment.

2.4.2 | Bicycle ergometer task

Participants were equipped with the Firstbeat chest belt (see above) that continuously registered their HR and transmitted it to a laptop computer running the software component of the system. A bicycle ergometer (Ergoline Ergoselect Viasprint 150P) was adjusted to the body size of the participant and then he or she was asked to cycle at a convenient pace for three minutes, self-setting the load of the ergometer between 50 W and 80 W (i.e., a range that represents a very lightweight physical load). The function of this unloading period was decreasing the sympathetic activation evoked by the experimental setting. Following this period, participants were asked to rest for two minutes and then complete the PAAS. Then participants were equipped with a headset connected to a laptop computer, the load was set to the individually determined PWC-150 value, and they were asked to cycle at a pace that is convenient for them for 15 min. During cycling, participants were asked to pay attention to the audio material played through the headset. Right after this exercise period, participants rated the extent to which they focused on their body during cycling on a visual analog scale and completed the PAAS once again. Physical performance was characterized by the number of pedal turns, while physical exertion was characterized by the average HR.

2.5 | Statistical analysis

Statistical analysis was conducted using the JASP v0.14.2 software (JASP Team, 2021). Difference in body focus in the two conditions was checked by repeated samples *t*-test. Hypotheses were tested using both frequentist and Bayesian methods. Concerning HR and pedal turns, repeated measures (internal vs. external condition) analyses of covariance (ANCOVA) were conducted with the Schandry-score as covariant. The Bayesian analysis consisted of two steps. First, the difference between the two conditions as alternative hypotheses was compared to the null hypotheses including subjects only. Second, the superiority of the alternative hypotheses with the Schandry-score as covariant were compared to the null hypotheses including subjects and conditions. For perceived fatigue, the frequentist ANCOVA included two repeated dimensions (1: condition; 2: time of measurement, i.e., before and after cycling) and the Schandry-score as covariant. Similar to the previous analyses, Bayesian analysis was conducted in two steps. First, the difference between the two conditions as alternative hypothesis were compared to the null hypothesis including subjects and time of measurement. Second, the superiority of the alternative hypothesis with the Schandry-score as covariant was compared to the null hypothesis including subjects, condition, and time of measurement. BF_{10} values above 3 were accepted as indicators of the superiority of the alternative hypothesis; similarly, BF_{10} values below 0.33 were considered as showing the superiority of the null hypothesis (Jarosz & Wiley, 2014). Additional correlation analysis estimating the associations between body focus and cardioceptive accuracy and the three assessed outcome variables was conducted using Spearman correlation.

3 | RESULTS

Descriptive statistics of the assessed variables are presented in Table 2. Self-rated body focus was significantly higher in the internal condition than the external condition (internal:

TABLE 2 Descriptive statistics

N = 98	*M* ± *SD*	Minimum	Maximum
Schandry-score	0.54 ± 0.284	0.00	0.98
Pedal turns (internal)	949.7 ± 240.98	479.7	1,646.2
Pedal turns (external)	918.0 ± 240.21	475.0	2,018.9
Heart rate (bpm) (internal)	140.9 ± 15.82	90.0	178.0
Heart rate (bpm) (external)	139.6 ± 14.90	105.0	172.0
Perceived fatigue (internal, before)	7.4 ± 3.13	3	15
Perceived fatigue (internal, after)	7.3 ± 2.75	3	15
Perceived fatigue (external, before)	7.4 ± 3.32	3	15
Perceived fatigue (external, after)	7.6 ± 3.24	3	15

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70.5 ± 17.22, external: 61.3 ± 22.33, t(95) = 3.603, $p < .001$, $d = 0.368$). This indicates that the audio manipulation was (at least partly, see discussion) successful.

Repeated-measures ANCOVA for the number of pedal turns indicated no condition (i.e., internal vs. external) main effect (H1; $F = 0.809$, $p = .371$, $\eta^2 = 0.002$), no cardioceptive accuracy main effect (H4; $F = 0.259$, $p = .612$), and no significant interaction ($F = 0.156$, $p = .693$, $\eta^2 = 3.654e\text{-}4$) (Figure 1, left-hand graph). Bayesian repeated-measures ANCOVA supported this conclusion, as BF_{10} for condition only was 0.403, whereas BF_{10} for cardioceptive accuracy compared to the null model including condition was 0.326 (this indicates the superiority of the null hypothesis).

Similarly, frequentist ANCOVA for HR showed no condition main effect (H2; $F = 0.310$, $p = .579$, $\eta^2 = 7.913e\text{-}4$), no cardioceptive accuracy main effect (H5; $F = 1.365$, $p = .246$), and no significant interaction ($F = 1.254$, $p = .266$, $\eta^2 = 0.003$) (Figure 1, middle graph). Again, Bayesian analysis supported this conclusion, as BF_{10} for condition only was 0.119 (this means that the null hypothesis was more probable than the alternative hypothesis), whereas BF_{10} for cardioceptive accuracy compared to the null model including condition was 0.473.

Finally, 2×2 repeated-measures ANCOVA for perceived fatigue indicated no condition main effect (H3; $F = 0.715$, $p = .400$, $\eta^2 = 0.002$), no time of measurement (before vs. after cycling) main effect ($F = 0.357$, $p = .552$, $\eta^2 = 5.068e\text{-}4$), and no cardioceptive accuracy main effect ($F = 0.140$, $p = .709$) (Figure 1, right-hand graph). Moreover, none of the interaction terms were significant. Bayesian analysis did not indicate the superiority of the alternative model for condition compared to the null model including measurement ($BF_{10} = 0.153$) and the superiority the alternative model for cardioceptive accuracy compared to the null model including time of measurement and condition ($BF_{10} = 7.377e\text{-}5$). Actually, both Bayes-factors show the superiority of the null hypothesis.

In the internal condition, body focus showed uniformly non-significant correlations with HR ($r_s = 0.169$, $p = .108$), the number of pedal turns ($r_s = 0.033$, $p = .750$), and change in fatigue ($r_s = 0.055$, $p = .592$) (Figure 2, first row). Similarly, associations between body focus and HR ($r_s = -0.201$, $p = .058$), the number of pedal turns ($r_s = 0.026$, $p = .804$), and change in fatigue ($r_s = 0.102$, $p = .322$) were non-significant in the external condition (Figure 2, second row).

Also, the Schandry-score was not significantly associated with HR ($r_s = -0.066$, $p = .541$; $r_s = -0.154$, $p = .154$), the number of pedal turns ($r_s = 0.065$, $p = .536$; $r_s = 0.122$, $p = .242$) and change in fatigue ($r_s = -0.033$, $p = .753$; $r_s = 0.019$, $p = .856$) in the internal and external condition (Figure 3).

4 | DISCUSSION

In a laboratory experiment with the participation of 98 young individuals characterized by regular physical activity, there was no difference between body focused and externally focused attention in terms of performance on a bicycle ergometer (pedal turns), physical exertion (HR), and perceived fatigue. Cardioceptive accuracy, as assessed with the Schandry-task, was also not associated with physical exertion, physical performance, and perceived fatigue.

Participants were individuals with a sedentary lifestyle in two previous studies that aimed to study the associations between body focus and physical activity (Herbert et al., 2007; Pennebaker & Lightner, 1980). For these people, no difference in perceived fatigue but a significant difference in physical performance were found between the two conditions (internal vs. external) or groups (good vs. poor cardioceptive accuracy); the condition/group that was more internally oriented showed inferior physical performance. It is important to see that, all other things being equal, physical exertion causes disproportionately more physiological

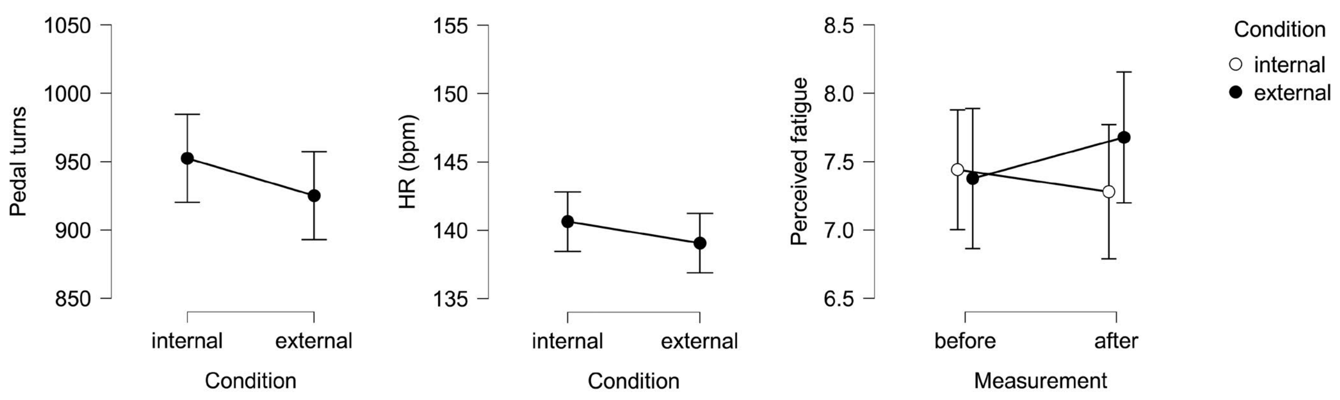

FIGURE 1 Graphical presentation of the group-level changes with respect to the three assessed variables (means and 95% confidence intervals)

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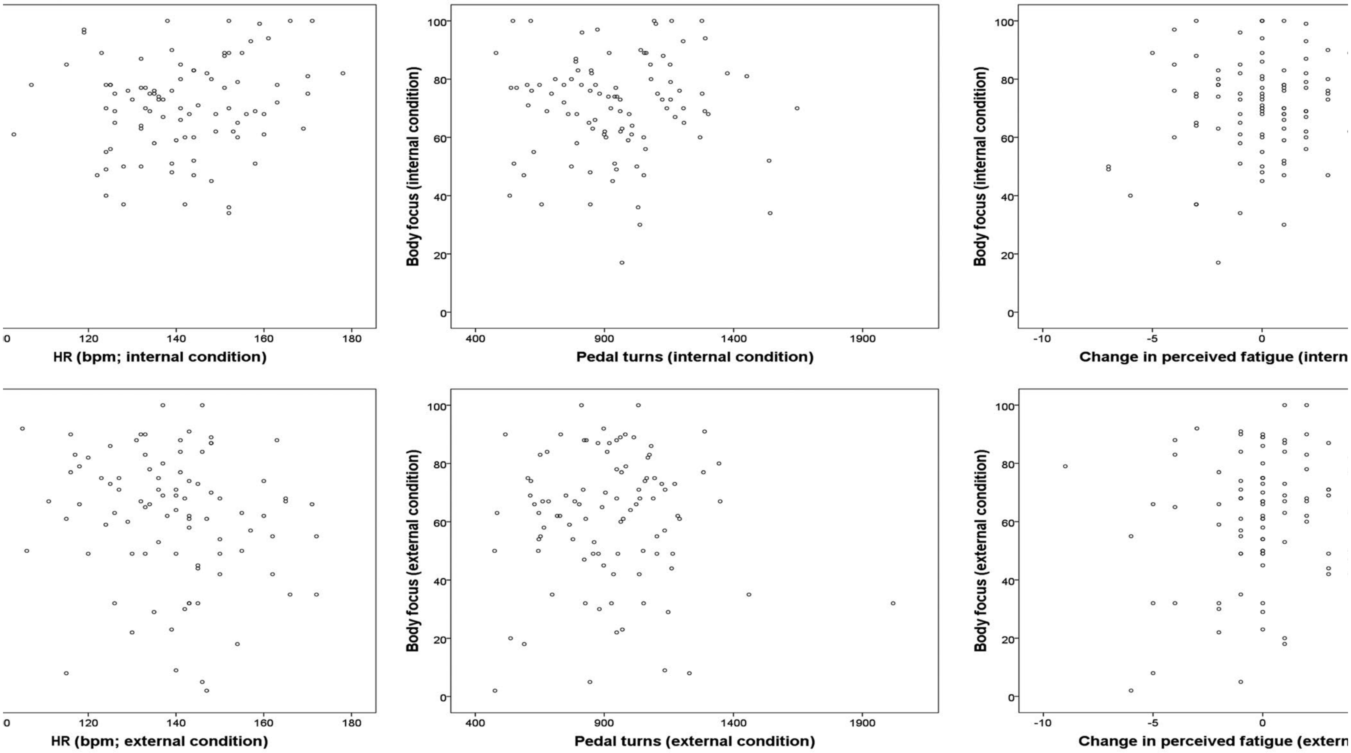

FIGURE 2 Associations between the extent of body focus (*Y* axis) and the three assessed variables (*X* axes) in the two conditions (first row: internal; second row: external). None of the correlations was significant

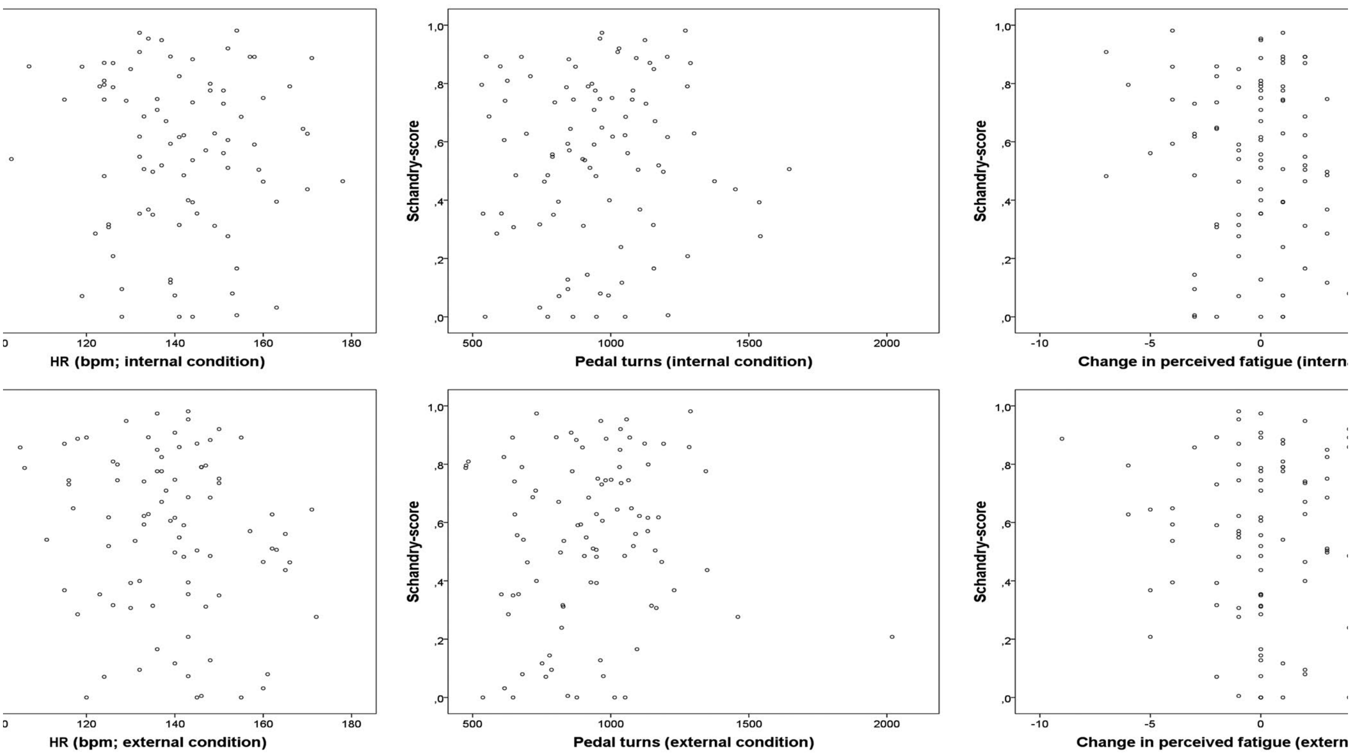

FIGURE 3 Associations between the Schandry-score (*Y* axis) and the three assessed variables (*X* axes) in the two conditions (first row: internal; second row: external). None of the correlations was significant

activation and somatic sensations for beginners than for those with regular physical activity (Fisher et al., 2015; Powers & Howley, 2014). As these are unpleasant feelings, beginners are more motivated to decrease the actual level of activity to alleviate them. However, these findings are not generalizable to individuals with regular physical activity.

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In the study of Fillingim and Fine (1986), as well as in the current study, participants were physically active individuals. For them, keeping a convenient pace during cycling or jogging does not require voluntary effort and continuous self-monitoring. It is an automatic process, the result of integration of information from multiple internal channels. Under such circumstances, factors impacting conscious functioning, including direction of attention, do not seem to play an important role. Moreover, exercising at a convenient pace is not a particularly demanding activity for such people, either physiologically or psychologically. Thus, there is no need to down-regulate the actual level of activity. In consequence, their physical performance showed no specific differences with respect to the direction of focus/heartbeat perception ability.

In the Fillingim and Fine (1986) study, significant differences in the subjective experience among conditions were reported. The word-cue (aka external) condition was characterized by less negative sensations, including fatigue. As mentioned, the direction of attention during exercise was not directly measured in the Pennebaker and Lightner (1980) and the Fillingim and Fine (1986) studies. In the present study, participants' self-report indeed indicated a significant difference between the two conditions. However, the effect size of this difference was in the small to medium domain only. This shows that manipulation of attention was far from complete despite the real-time playback of own breathing noises, an exercise-related internal signal. The effect of manipulation in the aforementioned two studies (asynchronous breathing sounds and simple verbal instruction, respectively) might have been even weaker. This fact further weakens the body focused attention hypothesis. Taken together, it is more reasonable to assume that differences in perceived fatigue can be attributed to certain characteristics of the word-counting task rather than to the direction of attention. For example, the word-cue condition were characterized by an increased cognitive load (in terms of sustained attention and memory) and the use of language too. The latter components might have reduced participants' capacity to assess and verbalize non-verbal cues, such as body symptoms, which led to a lower level of self-reported fatigue. Concerning the direction of attention, its malleability to manipulations is an interesting question in itself. Physical activity automatically catches attention to some extent; however, complete body focus or complete distraction from internal cues appear to be theoretical extremities that cannot be reached under everyday or even laboratory conditions.

It is important to note that these conclusions are valid only for self-selected and convenient physical exertion. Studies with a predetermined intensity or high levels of exertion usually report better performance when attention is distracted from internal cues (Hill et al., 2017; Lohse et al., 2010; McCormick et al., 2015; Razon et al., 2010). Also, empirical findings support the idea that movement economy (in terms of oxygen consumption) in endurance tasks, such as running and cycling, can be improved via external attentional focus (Hill et al., 2017; Schücker, Fleddermann, et al., 2016; Schücker, Schmeing, et al., 2016). Overall, the impact of distraction on unpleasant body feelings and physical performance might be influenced by a number of various factors, including the intensity of exercise and the training status of the participants. Similarly equivocal findings were reported in other areas of research. For example, distraction by music was helpful in the alleviation of dyspnea and improved functional performance in patients with COPD in some studies (Bauldoff et al., 2002; Thornby et al., 1995), whereas it was not effective in others (Brooks et al., 2003; Pfister et al., 1998). It is also worth mentioning, however, that our findings are relevant for a very large population, that is, those who exercise on a regular basis for recreational purposes. Empirical evidence shows that letting the body automatically set the actual level of exercise is a well-working strategy in recreational endurance activities, which can substantially contribute to the maintenance of the regularity of exercise (Ekkekakis, 2009; Ekkekakis et al., 2011). Exercising on a regular basis is a more prominent factor from the viewpoint of health-related benefits than the intensity of the exercise. Under these circumstances, distraction as a strategy is neither necessary nor useful. Biological organisms are "lazy," that is, they always attempt to spare energy and resources, which acts against physical activity. On the other hand, slight physical activation is rewarding even for animals (Greenwood & Fleshner, 2019); in humans, it is accompanied by pleasure (Ekkekakis, 2003; Ekkekakis et al., 2020), most likely because of its adaptive consequences, such as exploration or play (Panksepp & Biven, 2012). These antagonistic factors, which show well-known individual differences at both the physiological and psychological levels (Ekkekakis et al., 2011), determine the actual level of physical exertion and perceived fatigue.

Concerning the Herbert et al. (2007) study, we could not replicate the reverse association between cardioceptive accuracy and physical performance. Regardless of the direction of attention, participants with better cardioceptive accuracy did not differ from those with poor perception performance. Actually, the results of Bayesian analysis indicated the independence of these factors for physical performance and perceived fatigue. The lack of association between cardioceptive accuracy and physical performance can be explained by multiple ways (which are not mutually exclusive though). We used the Schandry-task with an instruction that reduces the impact of top-down factors on measured performance and applied a continuous approach to cardioceptive accuracy instead of comparing two extreme groups. The mental tracking task by Schandry requires participants to count their heartbeats for a number of time intervals; if they are not explicitly instructed to avoid estimation and count only really felt heartbeats, they

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usually tend to overestimate the number of heartbeats which leads to seemingly higher accuracy (Desmedt et al., 2018). In other words, the Schandry-score is a blend of accuracy and bias (Pohl et al., 2021; Witthöft et al., 2020); the latter can be reduced by more strict instruction but cannot be completely eliminated. It can be argued that those with more positive bias in the Schandry-task will be more biased in the exercise setting too, that is, they overestimate their actual exertion, and this is why they set a more lightweight load for themselves in the experiment of Herbert and colleagues (2007). As this bias was reduced in the current study, the association between cardioceptive accuracy and physical performance disappeared. Also, as mentioned above, physically inactive individuals participated in the study of Herbert and colleagues; physical activity might have caused unusually high physiological and psychological activation to them, which led to a tendency to decrease exertion.

As discussed, the present study involved individuals characterized by regular physical activity; therefore, findings cannot be generalized to sedentary individuals. Furthermore, the use of more attracting audio material in the external condition could have made the difference between body focused and externally focused attention bigger. Overall, the comparatively small difference between the two conditions can partly explain the lack of significant associations. Also, a different manipulation in the internal condition (e.g., real-time feedback on heartbeat instead of breathing) may have led to different results. Concerning the intensity of physical activity, there might have been individual differences in the interpretation of the instruction "to cycle at a convenient pace"; this factor can increase error variance which can impact the results. Finally, the aforementioned issues with the Schandry-task also limit the validity of the conclusions. As the outcome of the task depends on the instructions (Desmedt et al., 2018; Ehlers et al., 1995) and on the extent to which participants follow them (Murphy et al., 2018), it clearly involves top-down factors beyond interoceptive input (Ring & Brener, 1996).

According to our findings, the direction of attention (internal vs. external) and cardioceptive accuracy assessed at rest do not contribute to the objective and subjective characteristics of cyclic physical activity for physically active individuals if the intensity of the activity is freely chosen. An important question raised by these null-findings is that what factors might be at work behind the substantial differences in effort, performance and perceived fatigue we found. To answer this question, qualitative studies would be needed. Also, further experimental studies with the participation of both physically active and sedentary individuals and with systematic manipulation of the intensity of exercise would be desirable to better understand the factors that impact the effectiveness of distraction.

5 | CONCLUSION

For physically active individuals cycling at a convenient and self-selected pace, the actual level of physical exertion, physical performance, and perceived fatigue are not associated with the direction of attention and cardioceptive accuracy. The actual level of exertion might be regulated by non-conscious processes.

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CONFLICT OF INTEREST

All authors declare that there is no conflict of interest.

AUTHOR CONTRIBUTIONS

Lili Kósa: Investigation; Project administration; Writing-original draft. **Alexandra Mikó:** Investigation; Project administration; Supervision. **Eszter Ferentzi:** Conceptualization; Methodology; Writing-review & editing. **Zsuzsanna Szabolcs:** Conceptualization; Investigation; Methodology; Supervision. **Tamás Bogdány:** Data curation; Formal analysis; Investigation. **Ferenc Ihász:** Supervision; Writing-review & editing. **Ferenc Köteles:** Conceptualization; Data curation; Funding acquisition; Supervision.

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