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Maintain your mind, maintain your focus: Effects of focused attention and intensity in experienced runners

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ABSTRACT

The intensity that people choose for their endurance activities has a major influence on their affective experience. Furthermore, the direction of attention (e.g., internal or external) during endurance activities may significantly influence performance and personal perceptions. Therefore, in the current study, we focus on the interaction between intensity and attentional focus. We aim to address the question of whether adopting an internal (IAF; breathing) or an external attentional focus (EAF; environment), compared to a control condition, leads in differences in speed, heart rate, and affect during running at different intensities in experienced runners. Data from 59 participants were analyzed (M_{age}: 26.95 ($SD = 4.78$) years; 34 male; 25 female). Participants ran 9 × 3 min in an outdoor park with three intensity conditions (light, somewhat hard, hard) and three attention conditions (internal, external, control). Intensity, but not attentional focus, impacted affective responses. Results revealed a significant interaction between attentional focus and intensity on heart rate ($p < 0.001$, $\omega^2 p = 0.199$): during the somewhat hard intensity, the control focus condition was significantly lower compared the internal and external attentional focus conditions. Additionally, we used exploratory multilevel models (MLM). In the best-fitting MLM of heart rate, 45% of the variance is attributed to differences between athletes, and thus 55% of the variance within athletes. Furthermore, the model indicated that athletes running at a somewhat hard intensity and maintaining an EAF ($b = 7.69$) or IAF ($b = 6.36$) had an increase in heart rate compared to the control condition. We speculate that simultaneously monitoring effort and following an attentional instruction was such a difficult task that led to a favorable effect for the control condition. In practice, this could mean that the implementation of an unfamiliar focus of attention, for example, initially requires additional energy expenditure.

1. Introduction

Researchers have shown that the focus of attention in endurance activities, such as cycling, running, and rowing, has a major impact on performance outcomes as well as subjective experiences like the perceived effort or affective experience (Bertollo et al., 2015; Brick, Campbell, Metcalfe, Mair, & Macintyre, 2016; di Fronso et al., 2018; McCormick, Meijen, & Marcora, 2015; Robazza & Ruiz, 2018; Schücker, Anheier, Hagemann, Strauss, & Völker, 2013; Schücker, Fleddermann, et al., 2016). Athletes often use various strategies to cope with discomfort, fatigue, pain, boredom, and other unpleasant reactions associated with endurance performance (Brick, MacIntyre, & Campbell, 2014, 2015; Lind, Welch, & Ekkekakis, 2009; Salmon, Hanneman, & Harwood, 2010), such as attentional association and dissociation. The focus of attention is one of several cognitive strategies to cope, among other things, with physical and mental exertion (Vitali et al., 2019). The current study investigates the relationship between attentional focus and intensity. In addition to affect, speed and heart rate are also considered. In this context, the interplay of cognitive processes and interoceptive cues, as described by Ekkekakis (2003) in the dual-mode theory, plays an important role in further understanding affective responses to exercise (e.g., pleasure-displeasure, discomfort). Both approaches (attentional focus and dual-mode theory) are discussed in more detail below.

1.1. The attentional focus in endurance activities

On the one hand, attentional focus can be seen as a strategy for self-

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monitoring or self-regulation that can be used intentionally, e.g., to better cope with discomfort or to improve performance (Brick, MacIntyre, & Campbell, 2016; Salmon et al., 2010). On the other hand, attention may also depend on incidental or non-intentional processes, such as higher workload or increased intensity (Hutchinson & Tenenbaum, 2007; Stanley, Pargman, & Tenenbaum, 2007; Tenenbaum, 2001). Morgan and Pollock (1977) first distinguished between two strategies of attentional focus among marathon runners to elucidate the concept of attentional focus in endurance activities: a task-related approach (association) and a task-unrelated approach (dissociation). This categorization was derived from the observation that experienced and runners with less experience used different attentional focus strategies. Experienced runners demonstrated a tendency to monitor sensory information closely, associate it with their performance and adjust their pace accordingly. In contrast, runners with less experience were observed to have a greater inclination toward focusing on distracting stimuli, using them as a means of dissociating from physical strain, exhaustion, pain and mental exertion.

In 2014, Brick and colleagues introduced a novel working model of attentional focus, which is divided into two dimensions (associative - dissociative: task-related, and internal - external: body-related). On the one hand, the internal associative dimension is further subdivided into internal sensory monitoring (e.g., breathing) and active self-regulation (e.g., cadence). On the other hand, monitoring the external environment is categorized as external association. Hence, in this study we adopt the terms internal focus of attention (IAF) and external focus of attention (EAF). More specifically, our IAF instruction entails internal sensory monitoring, specifically focused on breathing, while the EAF instruction, in contrast, involves distracting attention from physical activity (PA) and directing it towards the environment (Limmeroth, Schücker, & Hagemann, 2022). In general, mixed results have been reported when comparing an internal and external focus of attention in endurance activities (Brick et al., 2014). This depends on several factors, including the outcome variables (e.g., performance, well-being, perception of effort, physiological parameters; Baden, Warwick-Evans, & Lakomy, 2004; LaCaille, Masters, & Heath, 2004) and the specific focus of attention (e.g., breathing, environment; Hill, Schücker, Hagemann, & Strauss, 2017; Longman, Hutchinson, Stock, & Wells, 2014; Schücker et al., 2013). In the present study, we aim to understand whether adopting an IAF or an EAF (compared to a control condition) at various intensities leads to differences in experienced affect, heart rate and speed in experienced runners. Thus, the present study builds on the approach of Limmeroth et al. (2022). However, they focus on inexperienced runners. Therefore, we expect differences that are also due to the level of performance and experience with running, especially in dealing with the physical reactions that come along increased intensity (Brick, MacIntyre, & Campbell, 2016). In addition to extending the study by Limmeroth et al. (2022) with a focus in the present study on experienced runners, the present study fill the following research gaps: a. The previous studies in this literature were not conducted in field settings; b. The previous studies did not examine the interaction of intensity with different attentional foci; and c. There are only a few studies that examine affect experiences in combination with other dependent variables.

According to Tenenbaum's model, proposed in 2001, as exercise intensity increases, attention naturally shifts inwards, becoming narrow and associative. Tenenbaum and Connolly (2008) expanded on this idea by suggesting that at low or moderate intensities, attention can be consciously and flexibly switched. At higher intensities, more cognitive control is required to distract from the body's somatic reactions. This notion is supported by studies indicating that as intensity increases, thought content tends to become more associative (Hutchinson & Tenenbaum, 2007). Furthermore, Balagué, Hristovski, Aragonés, and Tenenbaum (2012) speak of a non-linear and dynamic self-regulation of attentional focus that occurs with increasing effort or intensity. They suggest that as effort/intensity increases, there is a shift towards associative thinking. This finding is further supported by another study by Balagué, Aragonés, Hristovski, García, and Tenenbaum (2014), which suggests that associative thinking occurs spontaneously during progressive and maximum bicycle ergometer tests (see also Balagué et al., 2015).

In contrast to this perspective, other researchers, such as Lind et al. (2009), argued that it is not only possible but generally beneficial to dissociate attention from bodily sensations and focus externally on something outside of oneself. They proposed that shifting attention to environmental stimuli instead of the exhausting aspects of PA, can reduce physiological stress. In line with this thinking, Schücker, Hagemann, Strauss, and Volker (2009) found that during running at moderate intensity, it is feasible to focus on the surrounding environment, and externally focused attention is associated with improved running economy compared to internally focused attention (focused on breathing and running movement). Similar findings have been observed in subsequent studies at higher intensities, during cycling activities and in inexperienced runners (Schücker et al., 2013; Schücker, Fleddermann, et al., 2016; Schücker, Schmeing, & Hagemann, 2016). The findings of Bertollo et al. (2015) indicate that individuals can experience performance benefits and increased pleasantness by either focusing their attention externally or adopting a specific internal focus, while disregarding feelings of fatigue or muscle pain. One possible explanation put forward by the authors is that the cognitive strategy of focusing on breathing (IAF) allowed participants to become more attuned to their effort levels and effectively cope with them, rather than being overwhelmed by overall bodily sensations. By focusing on the rhythm of their breathing, participants may have employed a positive approach, diverting attention away from potentially unpleasant sensations. This suggests that focusing on breathing as a cognitive strategy may contribute to a more positive exercise experience (Bernasconi, Biirki, Biihrer, Koller, & Kohl, 1995; Bernasconi & Kohl, 1993). In addition, Brick, MacIntyre, and Campbell (2016) suggested that the ability to cope with active distraction may vary with level of experience and may influence the perception of effort, particularly at lower intensities. Interestingly, experienced runners tend to view involuntary distraction as detrimental to their performance and thus perceived it in a negative light.

Furthermore, diFronso et al., 2020 recommended that performers should develop an awareness of their individual affective state during endurance activities, as this may aid self-regulation and improve performance. Moreover, cultivating the ability to switch between different attentional focus strategies may be helpful and advantageous for longer runs (Neumann, Olive, Moffitt, & Piatkowski, 2022). These findings partly challenge the prediction of Tenenbaum's model that internally focused attention is unavoidable at high intensities.

1.2. Dual-mode theory

The dual-mode theory (Ekkekakis, 2003) proposes that affective responses to exercise are influenced by the interplay between cognitive processes (e.g., reappraisals, goal setting, boosting self-efficacy, cognitive reframing) and interoceptive cues triggered by exercise (Ekkekakis, 2005a; Ekkekakis, 2009; Ekkekakis, Hall, & Petruzzello, 2005b; Parfitt & Hughes, 2009). The theory suggests that the relative influence of these factors changes systematically with exercise intensity. According to Ekkekakis. (2005a,b), cognitive appraisal processes vary between individuals and can be influenced by factors such as social context, goal achievement, self-efficacy and personality. According to the dual-mode theory, cognitive factors are most influential on affective responses at high intensities (at or around the lactate or ventilatory threshold), and interoceptive factors become more salient and ultimately dominant above the ventilatory threshold and at high intensities (Ekkekakis, 2009; Ekkekakis, Hall, & Petruzzello, 2008).

On the one hand, maintaining exercise within this range may offer advantages, such as covering longer distances in search of resources or persisting in pursuing prey. On the other hand, it also carries the risk of adverse events such as exhaustion and injury (e.g., Ekkekakis, 2003; Ekkekakis et al., 2008). It is important to note that, in samples encompassing a wide range of PA and fitness levels, chronically low-active adults typically exhibit a decline in affective valence when exercising above the ventilatory threshold (VT; Welch et al., 2010). During vigorous exercise, particularly above the respiratory compensation point (RCP), interoceptive cues become prominent and almost all individuals experience discomfort during exercise (Ekkekakis, 2005a,b).

1.3. The present study

The main aim of this study is to gain insight into the question of whether adopting an internal attentional focus (IAF) or an external attentional focus (EAF), compared to a control condition, leads to differences in running speed, heart rate and affective responses during running in experienced runners. With this study, we are pursuing a similar question to Limmeroth et al. (2022) with the difference that we are looking at experienced runners. The study investigates these potential interactions between self-selected running intensities and attentional focus strategies. In contrast to Tenenbaum's (2001) perspective, we propose that it is possible to maintain conscious control over attentional focus even at higher intensities, in line with the findings of Schücker et al. (2013). According to some initial tendencies (see descriptive data of Schücker et al., 2013), we expect possible differences in the increase in heart rate in favor of a possibly lower heart rate in the control condition during *light* and *somewhat hard* intensity compared to IAF and EAF during these conditions. At the same time, following the dual-mode theory (e.g. Ekkekakis, 2003; Ekkekakis et al., 2005b), it can be assumed that cognitive control of the subjective experience becomes more difficult at higher intensities, which in turn may lead to an interaction between intensity and attentional focus. Following Limmeroth et al. (2022), we suppose a similar tendency in the affective experience of our sample of experienced runners. This means that during light intensity, participants' affective outcomes show improvement when their attention is not focused. Conversely, during high-intensity exercise, it appears beneficial to focus internally (on breathing) or externally (on the environment). Limmeroth et al. (2022) focused on inexperienced runners and emphasized the central importance of the affective experience, especially for novice runners. In general, however, we expect the basic affective experience of experienced runners to be more positive. With regard to speed, we expect no difference between the attentional focus conditions, mainly due to the high experience level of our participants (diFronso et al., 2020; Schücker et al., 2013; Wininger & Gieske, 2010).

2. Method

2.1. Participants

Sixty individuals took part in the study, and in the end, data from fifty-nine participants (M_{age} = 26.95 years, SD = 4.78; 34 male; 25 female) was analyzed.[1] As we have followed the same procedure (using the same attentional focus conditions [internal – breathing; external – environment; and a control condition] and the same intensity levels, which is further described below) as Limmeroth et al. (2022), we used the same sample size estimations, which were computed with small-to-medium effect sizes for the dependent variables, e.g. "affect". G*Power 3.1 analysis (input parameters: $f = 0.15$, $\alpha = 0.05$, $1\text{-}\beta = 0.95$, 1 group, 9 measurements, $r_{repeated\ measures} = 0.50$, $\varepsilon = 1$) yielded a required $n = 58$ (Faul, Erdfelder, Buchner, & Lang, 2009).

Participants spent on average M = 227.17 min per week (SD = 144.97)[2] exercising and 29 (49.15%) of them regularly participated in running competitions. In addition, the participants indicated their best time for 5 km, which was about M = 22:52 min (SD = 3:07 min).[3] Participants were recruited from the university campus, from local clubs, by means of various calls via social media and further personal contacts. The local ethics committee approved the study, and informed consent was provided from all participants. All procedures followed were in accordance with the Helsinki Declaration and its later amendments.

2.2. Measures

2.2.1. Physical activity (PA) and amount of exercise

One part of the BSA[4]-questionnaire by Fuchs, Klaperski, Gerber, and Seelig (2015) was used to receive further information about participant's exercise amount. In addition, we asked them about their best time for 5 km and if they participate on a regular basis in running competitions.

2.2.2. Affective valence

Affective valence represents one dimension of core affect ranging from pleasure to displeasure (Posner, Russell, & Peterson, 2005; Russell, 1980). The Feeling Scale (Hardy & Rejeski, 1989; Maibach, Niedermeier, Sudeck, & Kopp, 2020) with anchor points +5 (*very good*) to 0 (*neutral*) to −5 (*very bad*) was used to assess affective valence during running for each of the nine conditions. Participants had to indicate every minute on the 11-point scale how they were currently feeling. Pre-exercise affect was measured 2 min before the experimental session started (at rest). Affective valence was also measured every minute during the exercise sequences as well as during the active breaks. Because pre-exercise affective valence may vary widely and be influenced by factors other than the experimental exercise sessions, we controlled for the baseline level of affective valence.

2.2.3. Heart rate and running speed

Heart rate and running speed were measured with a chest belt (Polar H10) during the complete experimental setting. The Polar H10 was connected with a PolarBeat account of the test supervisor, which allows speed data to be recorded using the GPS signal from the connected smartphone. Later, the data were analyzed with the PolarFlow-Software and then transferred into an Excel file.

2.3. Procedure, experimental session, and attentional focus instructions

2.3.1. Procedure

Upon their arrival at the laboratory, participants were provided with information regarding the procedure (about the attentional instructions, the 3-min intervals, intensity levels, breaks, etc.) and were asked to complete a health anamnesis protocol. They were then equipped with a chest belt (Polar H10) to measure their heart rate and running speed. The Feeling Scale (Hardy & Rejeski, 1989; Maibach et al., 2020) was presented to the participants and its purpose was explained to them. After the briefing, participants engaged in an individual warm-up that

[1] We had to exclude one participant ($n = 1$) because during his runs it started to rain so heavy that his run in general but especially his affective responses were influenced more by the rain than by anything else (according to his own statement).

[2] The WHO (2020) recommends, to exercise between 75 and 150 min per week. Our participants spent on average 75 min more exercising than recommended.

[3] Two further inclusion criteria for participation in the study were to run at least two or more times a week as well as to run the 5 km in at least 30 min or faster.

[4] The questionnaire is originally developed and validated as a German version and BSA stands for „Bewegungs-und Sportaktivitäts Fragebogen“, which means questionnaire for PA and exercise.

lasted approximately 5 min. The running route consisted of a flat circuit spanning approximately 1.5 km around a large pond. The path was lined with trees and composed of gravel. Throughout the session, a test supervisor accompanied the participants on a bicycle to provide guidance and technical support. Nevertheless, the test supervisor maintained a distance during the run to minimize the influence and only approached for the minute-by-minute query of affect and for the new instruction. The entire experimental session lasted approximately 45 min. The overall length and duration led us to keep each interval at 3 min, as otherwise we would have had to expect even greater exhaustion. Additionally, we chose a design based on Limmeroth et al. (2022). Upon their return to the laboratory, participants were asked to complete a brief questionnaire concerning their PA and exercise habits during leisure time.

2.3.2. Experimental session

Participants engaged in a series of exercise sessions, consisting of three sets of 3-min intervals (3x3) with 2-min active breaks in between. At each intensity level, participants were given one of three attentional instructions: internal attentional focus (IAF), external attentional focus (EAF), or a control instruction. For the intensity levels we used the rating of perceived exertion (RPE) the Borg's RPE scale (Borg & Borg, 2001) to anchor participants to three intensity levels: *light* – RPE: 11, *somewhat hard* – RPE: 13, and *hard* – RPE: 15. According to, for example, Ekkekakis, Hall, and Petruzzello (2004), the change from "light'' to "somewhat hard'' could be classified as a possible marker of the aerobic–anaerobic transition.[5]

At every intensity level (3×3 min with 2 min active breaks), participants were given three distinct attentional directives: IAF, EAF, or a control condition. To mitigate potential sequencing influences, the order of these conditions was counterbalanced. First, the sequence of the three intensity levels was counterbalanced, yielding six unique order sequences. Within each intensity segment, the three attentional directives were likewise counterbalanced. However, it's important to note that every participant adhered to the same sequence of attentional focus conditions for each level of intensity. At the beginning of the test, a test supervisor started to monitor the participants' heart rate and running speed. To minimize any influence on the participants' self-selected running speed, the supervisor maintained a distance from them during the run. Every minute, the supervisor closed the gap to the participant to assess their affective valence using the Feeling Scale (Hardy & Rejeski, 1989; Maibach et al., 2020). During the 2-min breaks following each 3-min running interval, participants were asked two questions: First, they reported the percentage of time they were able to implement the instructed attentional focus condition. Second, they indicated whether their attentional focus had shifted and described their main thought during the running interval. These questions served as a subjective check of the manipulation. After 1 min of active break, participants again rated their affective valence. Shortly before the end of the break, the new focus instruction and the intensity level were repeated and named. Heart rate (in bpm) and running speed (in min/km) were continuously measured throughout the entire test.

2.3.3. Attentional instructions

The experiment involved implementing three different conditions: internal attentional focus (IAF), external attentional focus (EAF), and a control condition. In the IAF condition, participants were instructed to direct their attention to their breathing, which represents an internal sensory monitoring (Schücker et al., 2009; Schücker, Schmeing, & Hagemann, 2016). In the EAF condition, participants were instructed to focus on the environment surrounding the running course, such as the pond, trees, and the track, providing a distraction from the activity itself. In the control condition, no specific focus was given, and participants were instructed to run in their usual manner. Throughout the experiment, participants were asked to indicate their affective state every minute, and they were reminded of their respective attentional focus instructions. This approach was adapted from previous procedures and aimed to maintain consistency (e.g. Limmeroth et al., 2022; Schücker, Schmeing, & Hagemann, 2016). Notably, a unique aspect of this study was that participants performed the running tasks in a natural outdoor environment, deviating from the typical laboratory setting.

2.4. Data analyses

All planned analyses were carried out using SPSS 28 (IBM Corporation, Armonk NY, USA). Means and standard deviations were calculated as descriptive statistics. Factorial (intensity, 3 conditions & attention, 3 conditions = 9 conditions) repeated-measures ANOVAs were computed for the dependent variables (heart rate and running speed) to test for main and interaction effects. Similarly, a factorial ANCOVA with 9 conditions was used to test effects on affective valence, using pre-exercise affective valence as a covariate (controlling for baseline pre-exercise-affect). Affect, heart rate, and running speed were calculated as the mean of each condition. An alpha level of $p < 0.05$ was set throughout all analyses to indicate statistical significance. For effect sizes, $\omega 2_p$ are reported. Greenhouse-Geisser adjustments of degrees of freedom were used for violations of sphericity assumptions. Furthermore, we carried out multilevel regressions (MLM) as exploratory analyses which is a viable alternative to an ANOVA as it accounts for the nested structure of the data (i.e., the dependence of observations) and allows to investigate the within-person variance and between-person variance (e.g., Hoffman & Rovine, 2007). A further description of the used MLM and its results can be found in the supplementary material.

2.5. Transparency and openness

Following JARS (Kazak, 2018), within this study we report how we determined our sample size, all data exclusions and reasons for exclusion, all manipulations, and all measures used in the study. The data have been made publicly available at the Open Science Framework (OSF) and can be accessed at this URL: https://osf.io/6yfgd/?view_only=03f13c30ee9246f1973e091693ae8f04.

3. Results[6]

3.1. Manipulation check

First, we report the subjective manipulation check values for the six different experimental conditions (*IAF & EAF* during "light" intensity; *IAF & EAF* during "somewhat hard" intensity; *IAF & EAF* during "hard" intensity). We asked participants what percentage of time they followed instructions at each break. These descriptive results can be found in Table 1. Hence, significant differences occurred between the conditions: F (2, 116) = 19.66, p < 0.001, ω^2p = 0.239. Bonferroni-corrected pairwise comparisons showed that participants had significantly more difficulty maintaining the *EAF* during hard intensity compared to all other conditions ($p \leq 0.001$). In general, participants focused on various

[5] In any case, it should be noted that it is challenging to monitor effort and attentional instructions at the same time, but based on various studies (e.g., Vitali et al., 2019; Wulf, 2013), conscious monitoring does not necessarily influence performance outcomes negatively. Furthermore, it is a fundamental and inherent challenge of running to regulate your attention during running depending on the intensity.

[6] The exploratory results of the MLM-models can be found in the supplementary material.

Table 1
Manipulation check for the six experimental conditions.

Attentional focus	Intensity					
	Light		Somewhat hard		Hard	
	M (SD)	95% CI	*M (SD)*	95% CI	*M (SD)*	95% CI
IAF	80.32 (13.54)	[76.84, 83.80]	79.93 (14.96)	[76.03, 83.83]	77.90 (14.54)	[74.11, 81.69]
EAF	82.08 (15.56)	[78.03, 86.14]	77.59 (11.95)	[74.48, 80.71]	59.12 (19.93) ***	[53.92, 64.31]

Note. This table includes the percentage to which participants ($N = 59$) were able to follow the instructions according to the
Six experimental conditions. ***Lower than all other conditions ($p < 0.001$)

external/internal and associative as well as dissociative aspects during the control conditions.[7]

3.2. Affect

The repeated-measures ANCOVA by controlling for pre-running affect revealed a significant main effect of intensity, F (1.32, 75.12) = 13.24, $p < 0.001$, $\omega^2 p = 0.173$. The higher the intensity, the less positive the affective valence was. No significant differences were found between the attentional focus instructions: F (1.63, 93.13) = 0.08, $p = 0.93$, $\omega^2 p = -0.016$. The interaction of "intensity" and "attentional focus" on affect showed a significant result: F (2.82, 160.91) = 2.91, $p = 0.04$, $\omega^2 p = 0.032$. However, Bonferroni-adjusted post-hoc analyses revealed no significant differences between conditions. The descriptive results for all nine conditions are presented in Table 2. It also shows that post-exercise-affect ($M = 4.07$; $SD = 1.19$) is significantly higher than pre-exercise-affect ($M = 3.34$; $SD = 1.48$): $t(58) = -2.99$, $p < 0.004$, $d = 0.389$.

3.3. Heart rate

The descriptive heart rate data with the estimated percentage of the maximum heart rate are shown in Table 2. The average heart rate differed significantly by intensity condition, F (1.78, 103.21) = 325.71, $p < 0.001$, $\omega^2 p = 0.845$, and by attentional focus instructions, F (1.81, 104.83) = 31.38, $p < 0.001$, $\omega^2 p = 0.338$. In addition, also the interaction of "intensity" and "attentional focus" was significant, F (2.71, 157.34) = 15.80, $p < 0.001$, $\omega^2 p = 0.199$. Bonferroni-adjusted post-hoc analysis showed that during somewhat hard intensity the control focus condition was significantly lower compared to both, internal ($M_{diff} = -6.64$; $SE = 1.25$; $p < 0.01$; 95% CI [−9.71, −3.57]) and the external ($M_{diff} = -7.73$; $SE = 0.99$; $p < 0.01$; 95% CI [−10.18, −5.29,]) focus of attention condition. No further significant differences were found for all other comparisons.

3.4. Speed

The descriptive speed data are shown in Table 2. The average speed differed significantly between intensity conditions, F (1.52, 88.18) = 377.16, $p < 0.001$, $\omega^2 p = 0.863$, and just failed to reach significance level for the attentional focus instructions, F (2, 116) = 3.00, $p = 0.05$, $\omega^2 p = 0.033$. The interaction of "intensity" and "attentional focus" revealed in a non-significant result, F (4, 232) = 0.68, $p = 0.61$, $\omega^2 p = -0.005$. Additionally, Bonferroni-adjusted post-hoc analyses revealed in no significant differences between the conditions.

4. Discussion

The aim of this study was to investigate the effects of attentional focus instructions of different intensities (light, somewhat hard, hard) on affective valence, running speed and heart rate in experienced runners. Previous research examining the influence of different attentional focus conditions on affective outcomes has not shown a clear preference for any of these specific attentional foci. However, new options to differentiate more precisely between different attentional focus conditions are emerging as advantageous (e.g. Bertollo et al., 2015; diFronso et al., 2020; Limmeroth et al., 2022). This is also partly due to the different conceptions and associated varying instructions regarding an internal or external focus of attention (see, . e.g., the attempt for an extended conceptualization by Schücker, Knopf, Strauss, & Hagemann, 2014). Research using speed and heart rate as dependent variables has also yielded mixed findings and no clear tendency in favor of one focus of attention (e.g. Freudenheim, Wulf, Madureira, Pasetto, & Corrěa, 2010; LaCaille et al., 2004; Schücker et al., 2013).

In this study, we did not find a main effect for attentional focus on affect. This suggests that altering attentional focus alone may not be a viable extrinsic and cognitive strategy for improving affective responses in experienced runners (Jones & Zenko, 2023). Although we found a significant interaction effect between intensity and attentional focus condition in relation to affect, controlling for baseline pre-exercise affect, Bonferroni-adjusted post-hoc pairwise comparisons showed no significant difference between individual conditions. Even though we expected the largest difference at somewhat hard intensity, we found no significant difference there. Hence, we consider the significant interaction effect to be less meaningful compared to the expected main effect of intensity on affect: affective experience was less positive with increasing intensity, with a large effect (Ekkekakis, Parfitt, & Petruzzello, 2011; Welch, Hulley, Ferguson, & Beauchamp, 2007). We suggest that this large main effect overrides the comparatively smaller influence of attentional focus. Furthermore, we assume that individual differences contribute to the lack of significance in the post-hoc tests. Therefore, we advocate a cautious interpretation of the interaction effect, especially because the main effect of intensity is substantial. Thus, we find a dependence of affective experience on intensity, but affect remains basically positive on average throughout all intensities. Therefore, the additional influence of attentional focus can be classified as rather small or negligible.

The additional analytical approach - the MLM - allows us to interpret the data (beyond ANOVA) by including both inter- and intra-individual differences in the analysis (e.g., Hoffman & Rovine, 2007). Moreover, the inconsistent findings (i.e., no clear preference identified for a specific attentional focus; e.g. Bertollo et al., 2015; diFronso et al., 2020; Limmeroth et al., 2022) may indicate that there is a lot of variance between as well as within participants. In exploratory analyses, we found that in the best-fitting MLM of affect (i.e., model 5), 54% of the variance is attributed to differences between athletes. Interestingly, only (a) the somewhat hard intensity ($b = -0.72$) and the hard intensity ($b = -2.68$) as compared to the light intensity as well as (b) the interaction between the hard intensity and the internal focus ($b = 0.47$) as compared to the hard intensity of the control condition significantly predict affect. Furthermore, when adding the predictors "pre-exercise affect" and "age", the model does not improve. The different findings between the ANOVA and MLM results could either show the high statistical power of MLMs to account for hierarchical data structures and individual-level variation to capture interaction effects (e.g., Quené & van den Bergh, 2004), but it could also be related to the Bonferroni correction, which is quite conservative (e.g., Armstrong, 2014). In this respect, the results of

[7] During light intensity $n = 27$ participants focused on external aspects ($n = 3$ on associative ones and $n = 23$ on dissociative ones). $N = 31$ participants said they focused on internal aspects ($n = 23$ on associative ones and $n = 9$ on dissociative ones). During somewhat hard intensity, $n = 24$ participants focused on external aspects ($n = 6$ on associative ones and $n = 18$ on dissociative ones). $N = 35$ participants said they focused on internal aspects ($n = 26$ on associative ones and $n = 9$ on dissociative ones). During hard intensity, $n = 39$ participants focused on external aspects ($n = 13$ on associative ones and $n = 26$ on dissociative ones). $N = 20$ participants said they focused on internal aspects ($n = 17$ on associative ones and $n = 3$ on dissociative ones).

Table 2
Descriptive speed, affect and heart rate data for each attentional focus condition at each intensity.

Intensity	Attentional focus	Speed (in km/h)			Affect			HR[a] (in bpm)			Approx. % of HR^{a}_{max}	
		M	*SD*	95% CI	*M*	*SD*	95% CI	*M*	*SD*	95% CI	*M*	*SD*
Light	*IAF*	9.58	1.65	[9.15, 10.01]	3.56	1.08	[3.28, 3.84]	155.65	12.20	[152.47, 158.83]	82.29	6.15
	EAF	9.60	1.71	[9.16, 10.05]	3.69	1.06	[3.41, 3.97]	155.41	13.17	[151.98, 158.85]	82.15	6.59
	Control	9.56	1.76	[9.10, 10.02]	3.72	1.08	[3.44, 4.00]	155.37	13.13	[151.95, 158.79]	82.13	6.58
Somewhat hard	*IAF*	11.47	1.69	[11.03, 11.91]	2.89	1.24	[2.56, 3.21]	166.53	11.89	[163.44, 169.63]	88.04	5.92
	EAF	11.54	1.63	[11.12, 11.97]	2.98	1.27	[2.65, 3.31]	167.63	10.87	[164.80, 170.46]	88.62	5.32
	Control	11.34	1.63	[10.92, 11.77]	3.00	1.10	[2.71, 3.29]	159.90	11.57	[156.88, 162.91]	84.53	5.78
Hard	*IAF*	13.55	1.69	[13.11, 13.99]	1.36	2.21	[0.78, 1.93]	178.54	10.30	[175.85, 181.22]	94.38	4.97
	EAF	13.51	1.75	[13.05, 13.97]	1.01	2.23	[0.43, 1.59]	178.85	10.13	[176.21, 181.49]	94.55	4.97
	Control	13.34	1.74	[12.88, 13.79]	1.05	2.30	[0.45, 1.64]	177.78	10.44	[175.05, 180.50]	93.99	5.23

Note. The estimated HR_{max} was calculated by the formula from Tanaka et al. (2001): 208 – (0.7 × age). $N = 59$ participants were taken into account.
[a] HR = heart rate

our study are certainly in line with the multi-action plan (MAP) model (Bortoli, Bertollo, Hanin, & Robazza, 2012; Robazza, Bertollo, Filho, Hanin, & Bortoli, 2016) and, in general, with approaches that focus more on monitoring than on controlling performance (e.g. Schücker et al., 2014; van Ginneken et al., 2017).

In line with previous research on affective responses before, during and, after vigorous exercise, we found a positive effect on the affective experience afterwards: participants feel better after the study (after exercise) than before. It can be suggested that affective responses during vigorous exercise show a distinct temporal pattern, characterized by initial declines and subsequent recovery, a positive rebound in affective valence (Ekkekakis, Hartman, & Ladwig, 2020).

Furthermore, the results of the ANOVA analyses of the present study show a significant interaction effect between intensity and attentional focus condition on heart rate with a large effect size. In addition, Bonferroni-adjusted post-hoc pairwise comparisons emphasize that during somewhat hard intensity both experimental (internal and external) focus of attention condition differed significantly compared to the control focus condition resulting in higher heart rate. In addition to the main effect of intensity, the main effect of focus of attention also shows a significant difference. This finding (partially) confirms our previous hypothesis: we expected possible differences in the development of heart rate in favor of the control condition during light and somewhat hard intensity. Our results showed a significant difference in relation to the somewhat hard condition and on a descriptive level also for the hard intensity.

Exploratory analyses using MLMs also partially support this hypothesis, as the MLM of heart rate indicates that intensity has a significant impact on heart rate, with higher intensities leading to higher heart rates. Athletes running at somewhat hard intensity had an estimated increase in heart rate of approximately 4.53 beats per minute compared to light intensity, while those running at hard intensity had an estimated increase in heart rate of approximately 22.41 beats per minute compared to light intensity. The specific attentional focus adopted by the athletes' during exercise does not appear to have a significant direct effect on heart rate, although this relationship may vary depending on the intensity level (i.e., the impact of attentional focus on heart rate may differ across different exercise intensities). As in the ANOVA, at the somewhat hard intensity level, the interaction between the attentional focus and intensity does show a significant effect on heart rate, specifically when comparing the internal as well as the external focus to the control condition (EAF: 7.69 bpm, IAF 6.36 bpm). 44% of the total variability in heart rate can be attributed to differences between athletes. In this context, reference can once again be made to the random effects (random intercept per person and random slope for intensity[8]): each person has its own intercept (i.e. differences between persons, e.g., Raudenbush & Bryk, 2002). In addition, the effect of intensity varies from person to person. We take this into account with the random slope in our model. For example, person 1 exhibits a lower average heart rate of 164.35 bpm, compared to person 2, whose average heart rate was at 199.58 bpm (mean intercept: 177.79). Additionally, these two people may respond differently to varying intensity levels. At moderate intensity, person 1's heart rate increased by 16.68 bpm compared to the light intensity, and by 32.23 bpm in the high-intensity scenario. In contrast, person 2 experienced an average decrease of 4.38 bpm in heart rate during moderate intensity compared to the control condition, and a decrease of 10.84 bpm in the high-intensity conditions. Possible reasons for these intra- and inter-individual differences, which can be illustrated using MLM, could be physiological as well as due to training history.

In the study by Schücker et al. (2013), a descriptive tendency related to differences in heart rate across different attentional focus instructions in favor of the control condition was observed. A significant effect of focus on heart rate also occurred in Schücker et al. (2014): heart rate was higher for the focus on movement than for all other foci (though it is important to keep in mind here that this is a different focus condition). Further, in the present study, it was a difficult cognitive task to monitor at the same time the intensity and the attentional instruction. In this sense, Lohse (2012) holds a possible explanation why heart rate was lower in the control condition (at somewhat hard intensity). They proposed that "explicitly attending to one's body mechanics leads to less effective movement outcomes, [and] less efficient movement patterns" (p. 23). It is possible that an initially conscious monitoring became more of a controlled monitoring with increasing intensity. Various studies, like mentioned in Vitali et al. (2019) have shown that controlled monitoring could have a negative effect on endurance performance, which is why both experimental focus conditions with somewhat hard intensity possibly led to a higher heart rate.

Taking now a closer look to the subjective assessment of the intensity in relation to heart rate, it appears that our sample of experienced runners may have already exerted themselves excessively at light intensity with a mean heart rate of 155.48 bpm ($SD = 12.54$). This was already evident with inexperienced runners (Limmeroth et al., 2022). Even if we can only approximate the maximum heart rate (see table 2; Tanaka, Monahan, & Seals, 2001), it is clear that the subjectively rated intensity "light" cannot be considered as "moderate" and must already be classified higher. Based on the American College of Sports Medicine Guidelines (Garber et al., 2011), the "light" intensity was actually vigorous.

As expected, there was no interaction effect on speed. However, it is of interest that during "hard intensity" participants ran 47 s faster projected to their personal best times on 5 k on average. Therefore, this suggests, as stated before, that they clearly strained themselves too intensively for the targeted intensity ranges, even though the sample consisted of experienced runners. However, previous research has shown that RPE is not necessarily related to experience or fitness level

[8] This is described in more detail in the supplementary material.

(Braun-Trocchio, Williams, Harrison, Warfield, & Renteria, 2021). Those findings are as well supported by the MLM models predicting speed, as the best fitting model (i.e., Model 4) does not include the interaction effects. The model indicates that 48% of the variance is attributed to differences between athletes.

To better understand the findings of our study results, Bryan et al.'s (2007; 2011) holistic perspective on the subjective experience of exercise is helpful. To some extent this perspective suggests that the subjective experience involves a psychological understanding of physiological changes occurring in the body (e.g., heart rate, lactate concentration) during exercising: e.g. perceiving pain as the affective response due to lactate increase. For our study, this could be of special interest because we found differences referring to the development of heart rate while speed and affect remain largely unaffected from the focus instructions. Therefore, it may be more important for experienced runners to keep the running experience basically positive in order to improve more performance-relevant parameters like heart rate (in our study) or VO_2 (Schücker et al., 2013).

4.1. Limitations

The current research has certain limitations that need to be acknowledged. First, it was a highly complex task to maintain a specific attentional focus instruction while simultaneously monitoring and controlling the intensity ranges. The complexity of following attentional instructions and monitoring intensity at the same time max have confounded specific attentional focus effects on the outcome variables. The lower heart rate in control at somewhat hard intensity can be explained by an effect of less complexity rather than an effect of intensity and focus. Previous studies, including the work of Radel, Tempest, and Brisswalter (2018), have demonstrated the impact of endurance performances with varying intensities on sustained attention. Specifically, Radel et al. (2018) suggest that at low intensities, the potential monotony of the task could negatively affect attention maintenance. However, at moderate intensities, increased arousal may offset the attentional costs associated with dual-task performance. The specific effects of high intensities on sustained attention remain unclear. This overall influence of endurance performance on attention could have potentially influenced our own study results.

Second, the manipulation check revealed discrepancies between the conditions, indicating that the participants did not implement all the instructions equally well. Specifically, they had more difficulty in implementing the external instruction during hard intensity compared to all other attentional focus instructions. This underpins the general assumption that it becomes more challenging to maintain an external focus of attention as intensity increases (e.g., Hutchinson & Tenenbaum, 2007). Presumably, according to dual-mode theory (Ekkekakis, 2009), the interoceptive cues become more salient, making it more difficult to externalize the focus. For future studies, a prior training of attention could help to better implement the instructions even at hard intensity. Furthermore, in line with Limmeroth et al. (2022), as the intensity increased, it became progressively more challenging for the participants to adhere to the attentional focus instructions. However, it is important to note that during the control condition, internal (48.59 %) and external (50.85 %) as well as associative (46.89 %) and dissociative (52.54 %) aspects were mentioned equally often. It is worth considering that the manipulation check relied solely on subjective ratings, which holds a potential for bias. Thirdly, due to the absence of an incremental treadmill test until volitional exhaustion prior to the study, we lack information regarding the individual aerobic-anaerobic transitions for participants in each condition. This means that the specific physiological thresholds for each participant were not measured. Nevertheless, it is worth emphasizing that the present study was conducted in a field setting, which is much closer to the real experiences of runners than a more controlled laboratory setting. Especially, for field settings, the use of the RPE scale is recommended as a practical marker (e.g. Bok, Rakovac, & Foster, 2022; Cochrane-Snyman, Housh, Smith, Hill, & Jenkins, 2019).

Furthermore, there are two additional limitations that should be noted: The utilization of a field setting in our study, rather than a controlled laboratory environment, provides a notable advantage. However, it also sets it apart from the majority of previous studies that focused on manipulating attentional focus within laboratory settings. As a result, the presence and variety of external cues from the environment were significantly greater in our study compared to a typical laboratory setup. In general, environmental factors such as weather conditions, noise, or unexpected distractions, could introduce variability in participants' affective as well as physiological responses, making it challenging to discern the specific impact of attentional focus and intensity. Finally, our experimental conditions lasted only 3 min, which is considerably shorter than the durations implemented in other studies within the same research area (e.g. Ekkekakis et al., 2020; Schücker et al., 2013). It is essential to consider this discrepancy when interpreting the results and making any comparisons with these aforementioned studies. Nevertheless, we followed the same procedure as Limmeroth et al. (2022), as we wanted to compare our findings with those of unexperienced runners. Furthermore, a test duration of 45 min is already very long, which we did not want to extend further to keep the participation feasible in terms of time economy of the participants. This approach also allowed us to implement a within-subjects, single-session research design effectively.

4.2. Strengths

While all these limiting aspects should be considered when interpreting the findings and making comparisons to other studies, they were deliberate choices made to ensure the practicality and feasibility of the research design, particularly within a field-setting (compared to a more controlled, but less realistic and externally valid laboratory environment). Implementing the same research design as Limmeroth et al. (2022) with experienced runners in the present study shows that experience or expertise seem to shift the importance of affect or respectively the effect of it. Instead, other aspects become more meaningful, for example, how to train more economically, etc. According to Sheeran and Webb (2016), the frequency of a specific behavior is important, as its repetition tends to establish a state of "routine behavior." This state integrates behavior as an integral aspect of one's personal identity and sense of self. In addition, the general expectations of the affective experience are also shaped by positive past experiences and can therefore be assumed to be more positive in experienced, regularly exercising individuals (Lee, Emerson, Bohlen, & Williams, 2018; Limmeroth & Hagemann, 2020; Williams et al., 2008). Compared to inexperienced runners (see descriptive data by Limmeroth et al., 2022) the affective valence was on average clearly more positive at all intensity levels and standard deviations (except for the hard intensity level) are higher. It is supported by numerous studies that the more predisposed a person is to tolerate the symptoms of exercise and, then, to continue it, the more positive affect is (Ekkekakis, Hall, & Petruzzello, 2005a).

Including MLMs as an additional method of analyzing the data is a promising approach to advance research in various fields. Unlike traditional ANOVA, where observations within the same condition are typically averaged, MLMs offer the advantage of incorporating the variability of several measurements within each condition (Hoffman & Rovine, 2007; Raaijmakers & Schrijnemakers, 1999). By allowing multiple observations per participant per condition, MLMs significantly enhance statistical power (Brysbaert, 2019). Another advantage of multilevel models is their ability to handle dependencies among observations, which is often present in real-world data (Hoffman & Rovine, 2007), while ANOVA typically assume independence of observations (Field, Miles, & Field, 2012).

4.3. Implications

Looking at the results of affect and speed, we would be cautious about making a direct recommendation for experienced runners and believe that further research, particularly in the field, is needed to make a clear recommendation. In contrast, for heart rate, it seems to be more beneficial during somewhat hard intensity to stay with the own learned attentional focus. We speculate that it was difficult to monitor effort and an attentional instruction at the same time which is why we see this effect on heart rate. For further research, we would suggest including a measure of running economy by using of mobile spirometry. This would allow a better monitoring of participants' individual aerobic-anaerobic transitions and results could be interpretated more specifically (e.g. Aghdaei, Farsi, Khalaji, & Porter, 2021). Combining physiological measurements like the VO_2max, with psychological, parameters like affect could be a promising strategy for future research in this field. In this regard, as a main advantage of this study, we would like to highlight the outside setting because it is simply closer to the real running experience, and to naturally occurring attentional foci. At least, comparing inexperienced with experienced runners could help to differentiate practical instruction guidelines by taking into account the level of running and the experience level. Furthermore, we assume, that the MAP-model (e.g. Bortoli et al., 2012), designed to explain athletes' diverse performance states, especially for high standards during training and competition, could mark a promising explanatory approach. Shared among this and other discussed viewpoints is the belief that adopting a monitoring attitude, characterized by mindfulness and attention to action core components, is advantageous, while exerting control over automated motor processes is counterproductive.

For further research approaches as well as for practical implications, we recommend focusing more on the individual experience in combination with already learned (attentional focus) strategies. The large interindividual variability that we wanted to illustrate, for example, in our additional approach of multilevel models, underlines this. For future research, MLM could help to show much more specifically to what extent and whether inter- and intrapersonal differences exist. If so, these can be analyzed more specifically (e.g. random intercepts/slopes for certain variables). This also means that differences in individual variables can be included into the model, which in turn means that groups/individuals with different preferences/values can be considered and individual- and group-related implications can be given.

In conclusion, it could be brought to the fore that it is becoming increasingly clear for experienced runners that it is particularly important to be able to switch flexibly between different attentional foci (e.g., Neumann et al., 2022).

CRediT authorship contribution statement

Julia Limmeroth: Writing – review & editing, Writing – original draft, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Hannah Pauly:** Visualization, Formal analysis, Data curation. **Linda Schücker:** Writing – original draft, Supervision, Methodology, Conceptualization. **Zachary Zenko:** Writing – review & editing, Writing – original draft, Supervision. **Norbert Hagemann:** Writing – review & editing, Writing – original draft, Supervision, Project administration, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

We have provided a link where data can be found online.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.psychsport.2024.102616.

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