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ORIGINAL RESEARCH

Further Evidence for an External Focus of Attention in Running: Looking at Specific Focus Instructions and Individual Differences

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Although attentional focusing in sports has been broadly investigated, the findings vary when it comes to endurance sports. This study provides a comparison between relevant foci in the literature of running economy. These include two internal foci—one addressing automated processes (running movement) and the other nonautomated processes (internal body signals and perceived exertion), an external focus (video) and a control condition. Furthermore, we investigated the influence of interoceptive sensitivity on oxygen consumption within the different attention conditions. Thirty recreational runners performed a four 6-min run at moderate intensity consisting of the four counterbalanced conditions. Running economy was assessed by spiroergometry, and interoception was measured using a heartbeat tracking task. Results revealed a significantly better running economy for the external focus of attention compared with all other conditions. No significant correlations were observed between the heartbeat perception score and oxygen consumption in any condition.

Keywords: attentional focus, heartbeat perception, interoception, oxygen consumption, running economy

Attentional Focusing in Endurance Sports

The direction of attentional focus is an essential determinant of performance among different kinds of sports (e.g., Wulf, 2013). In endurance sports, an external focus of attention can be defined as directing attention toward the environment. An internal focus encompasses directing attention toward the execution of the movement or internal bodily signals and physical sensations such as breath or pain (Masters & Ogles, 1998). Although it is a broadly investigated topic, the state of research is heterogeneous when it comes to endurance sports. Starting with the seminal study by Morgan and Pollock (1977), several studies show advantages of adopting an external focus of attention, whereas others highlight a better performance when focusing internally. Studies pointing out advantages of an *external focus* of attention argue that it helps athletes to distract themselves from signs of discomfort or to tolerate them over a longer period of time (Morgan & Pollock, 1977).

Similar to Morgan and Pollock (1977), the majority of studies use self-report measures of performance. Several studies have also demonstrated a positive impact of an external focus on performance measures such as speed (LaCaille, Masters, & Heath, 2004) and duration of the endurance task (Morgan, Horstman, Cymerman, & Stokes, 1983), as well as an influence on movement economy (Schücker, Anheier, Hagemann, Strauss, & Völker, 2013; Schücker, Hagemann, Strauss, & Völker, 2009). Although all outcome variables can be regarded as important, some of them (e.g., speed or perceived exertion) can be easily influenced by participants' motivation to perform well on the task making it necessary to control for other influences (e.g., motivation). Therefore, running economy is a favorable and recently used variable (Neumann & Piercy, 2013; Schücker et al., 2009, 2013; Schücker, Knopf, Strauss, & Hagemann, 2014; Ziv et al., 2013). Running economy is strongly connected with performance (Saunders, Pyne, Telford, & Hawley, 2004) and is defined as oxygen consumption (VO_2) required to maintain a constant submaximal speed (e.g., Saunders et al., 2004). Oxygen consumption can be assessed via spiroergometry. A lower oxygen consumption represents a better economy due to a reduced consumption of physiological resources. As oxygen consumption is unlikely to be controllable by the participants and, thus, assumed to be independent of their motivation (Schücker et al., 2009, 2013), it can be regarded as an objective measurement.

Those studies that highlight advantages of an *internal focus* of attention in endurance sports mention its importance regarding active self-regulation mechanisms (Brick, Macintyre, & Campbell, 2015). By staying in contact with their body and its arising signals, athletes

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may actively regulate their physiological strain and pace (Esteve-Lanao, Lucia, deKoning, & Foster, 2008; Morgan & Pollock, 1977). Furthermore, current studies point out the role of an internal focus and the perception of somatic processes as a mediator of constant improvement: Especially when athletes get into dysfunctional habits, a conscious perception of their bodies' messages can allow somaesthetic awareness to achieve new levels of excellence (Toner & Moran, 2015).

Previous studies have already addressed the question of whether an internal or an external focus of attention can be regarded as optimal in endurance sports (e.g., Schücker et al., 2009, 2013). This study revisits this question, with an additional focus on methodological issues and inconsistent conceptualizations underlying the research area of attentional focusing in endurance sports. The latter aspect was also recently addressed by Brick, Macintyre, and Campbell (2014). Further developments derived from the conceptual and methodological inconsistencies discussed in the current study will follow.

Conceptual and Methodological Issues of Attentional Focus Research in Endurance Sports

First, the cognitive variable of attentional focus is a broadly defined term comprising different concepts with associated underlying mechanisms. In addition to the terms of an external and internal focus, Morgan and Pollock (1977) defined the terms association and dissociation. By adopting an association strategy, athletes' thoughts are connected with their bodies and the executed movement. Dissociation refers to paying attention away from the body toward the environment (Morgan & Pollock, 1977). There are also concepts that combine the terminologies internal/external and association/dissociation (Stevinson & Biddle, 1998). Brick et al. (2014) recently proposed a promising integrated conceptual framework of cognitive processes for endurance activity. The authors tried to disentangle existing concepts and terminologies by further differentiating the previously mentioned dimensions. This conceptual framework covers the attentional dimensions of active self-regulation, outward monitoring, internal sensory monitoring, and active and involuntary distraction, as well as helping to categorize and cluster different kinds of attentional strategies (see Brick et al., 2014 for an overview).

The reason for describing these different focus concepts is to show that the comparability of studies is influenced by how a focus is defined. Various definitions and conceptualizations lead to a range of possible operational definitions of attentional foci, making exact comparisons difficult. Despite the promising conceptualization of Brick et al. (2014), the present study refers to the terms external and internal to better compare previous studies in the area of attentional focusing and running economy (e.g., Schücker et al., 2009, 2013). By using the same terminology, a better basis of comparison is provided. However, even within the concept of internal versus external focus, attentional foci are defined differently among studies in this research area. Schücker et al. (2014) addressed this issue by only comparing the use of different internal foci (focus on breathing, running movement, and feelings of perceived exertion), while participants ran on a treadmill. Results were in line with the constrained action hypothesis (Wulf, McNevin, & Shea, 2001), a theoretical framework usually explaining focus effects in the area of motor control. The hypothesis originally states that an internal focus on movement execution is detrimental because it interferes with automatic control processes that would naturally regulate the movement. As a result, movements are less effective (McNevin, Shea, & Wulf, 2003). Schücker et al. (2014) concluded that an internal focus on highly automated processes like breathing or running movement can be detrimental due to the constraining of automated control processes. However, an internal focus on perceived exertion should not hinder performance as measured in terms of running economy, as it is a subjective measure that does not influence the execution of automated procedures (Schücker et al., 2014). This further differentiation within the internal focus concept on the basis of the constrained action hypothesis helped to resolve the contradiction between the advantages and disadvantages of an internal focus. However, other studies could outline the influence of a focus on perceived exertion on other performance measures such as speed during self-paced running (e.g., Brick, Campbell, Metcalfe, Mair, & Macintyre, 2016). All in all, a clear differentiation between the instructed foci, and both between and within different conceptualizations, is necessary in order to draw conclusions.

A comprehensive comparison between established and proven foci in the field of attentional focus and running economy is still required, as most single studies to date have often only concentrated on isolated comparisons. For example, some studies have implemented internal foci without consideration of differences between automated and nonautomated processes, instead concentrating on just one element (e.g., Neumann & Piercy, 2013); while other studies that found effects resulting from attentional focus instructions did not always implement a control condition (Schücker et al., 2009, 2013; Ziv, Rotstein, Lidor, & Meckel, 2013). Leaving out a control condition in individual studies means that it is not possible to evaluate the effects of the focus manipulations, as it does not allow for direct comparison to a nonmanipulated data sample.

Study design is another methodological issue that can be observed in previous research, in particular the varying ways in which attentional focus is treated as a variable between studies (Okwumabua, Meyers, Schleser, & Cooke, 1983; Toner & Moran, 2014). Although various studies used attentional focus as an outcome variable, others used it as an independent variable to examine its influence on a range of other outcome variables (Brick et al., 2014; Connolly & Tenenbaum, 2010; Morgan & Pollock, 1977; Schücker et al., 2009; Tenenbaum & Connolly, 2008). It is therefore necessary to take into account the different study designs when comparing studies addressing attentional focusing. In summary, inconsistent methodologies and concepts dominate the research field of attentional focus in running, and this has led to the inconsistency and inaccuracy seen in many comparisons.

The previous explanations for the heterogeneous state of research are mainly of methodological and conceptual nature; however, the individual characteristics of the participants used in studies also warrant examination. Some studies, conducted with tests other than endurance tasks, investigated the impact of individual focus preferences on performance (Maurer & Munzert, 2013; Weiss, Reber, & Owen, 2008). These studies concluded that a change from the preferred focus could be responsible for performance decrements. For example, Maurer and Munzert (2013) showed that the most successful shots in a basketball task were made under the preferred focus, irrespective of whether it was an internal or external focus. To date, no study has dealt with the question of why participants may prefer one focus condition over others and which circumstances might be responsible for this. There is, however, one construct that addresses individual propensities toward a sensitivity to internal body signals: the construct of *interoception* (Herbert & Pollatos, 2012). Specifically, the definition of interoception overlaps with that of an internal focus of attention. It, thus, seems reasonable to investigate the connection between the two concepts. To clarify, an individual's sensitivity to inner bodily signals—interoception—could be connected with the perception and sensitivity to different attentional foci instructions, the internal focus particularly.

Interoception: The Individual Ability to Perceive Inner Bodily Signals

Interoception can be defined as the representation of afferent information from all tissues and organs—including skin, muscle, and viscera—and encapsulates the physiological condition of the entire body (Craig, 2007). According to Cameron (2001), interoception not only refers to the awareness of the internal body signals, but it may also affect behavior. Attempts to measure interoceptive ability predominantly focus on cardiac signals, which are generally regarded as quite stable indicators for general interoceptive ability. This assumption can be explained by correlations between heartbeat perception and the perception of signals of other modalities, such as gastrointestinal signals (Herbert, Muth, Pollatos, & Herbert, 2012). There is also evidence of existing differences between individuals in the awareness of interoceptive phenomena and that these differences can be conceptualized as a trait-like feature (Herbert & Pollatos, 2012; Katkin, 1985). For example, Cameron (2001) found that men are more accurate in heartbeat perception than women. Likewise, individuals with a higher fitness level demonstrate better heartbeat perception than untrained individuals (Jones & Hollandsworth, 1981).

Interoception has been investigated in various research areas (Dunn et al., 2010; Herbert, Ulbrich, & Schandry, 2007; Werner, Jung, Duschek, & Schandry, 2009). In the field of sport psychology, interoception is a less investigated subject. Only a small number of studies have addressed the relationship between interoceptive sensitivity and self-regulation in connection with physical activity. In the study of Herbert et al. (2007), participants pedaled on a bicycle for 15 min at a self-selected pace. Results showed that those with better heartbeat perception pedaled a significantly longer distance than those with poorer heartbeat perception and showed a slower increase in mean heart rate, stroke volume, and cardiac output. Performance differences in this case could not be explained by the physical fitness of the participants (Herbert et al., 2007), thus suggesting that interoceptive sensitivity may be associated with a fine-tuned self-regulation of physical workload (Herbert et al., 2007). The connection between interoceptive ability and physical activity has also been investigated among a sample of primary school children, where it was shown that higher interoceptive ability is associated with a better physical performance (Georgiou et al., 2015); in this case, using energy expenditure as the primary measure of physical performance.

The Aim and Hypotheses of the Present Study

This study had two main objectives: first, a direct comparison between established foci within the current literature; and second, developing a broader understanding of attentional focus in running with the inclusion of interoception as a variable. Reflecting on the heterogeneous results regarding attentional focus in running, there is a need for a comparison between the foci that have been shown to be important in the literature on running economy. In the current study, four relevant foci are compared objectively by measuring differences in oxygen consumption. These include two internal foci—one addressing automated processes (running movement) and the other addressing nonautomated processes (feelings of perceived exertion), as well as an external focus condition and a control condition. Based on the presented literature regarding attentional focus and running economy (Schücker et al., 2009, 2013, 2014), the following two main hypotheses were tested:

a. The external focus of attention would lead to better running economy (lower VO_2 values) when compared with the two internal foci.

b. The internal condition of focusing on body signals would result in better running economy (lower VO_2 values) when compared with the internal condition of focusing on the running movement.

The secondary objective was to obtain a broader view of attentional focus in running by including the variable of interoception. Thus, this study seeks to shed light on the role of internal body signals and the relationship with sensitivity to different attentional foci. Specifically, it was explored, whether people with a higher interoceptive ability are more inclined to adopt an internal focus of attention when free to choose. It is possible that possessing a stronger sensitivity toward inner bodily signals might push these inner signals to the center of attention, prompting an internal attentional focus. In addition, possible correlations between interoceptive sensitivity and the amount of oxygen consumption within the four different focus conditions were explored. It is assumed that highly interoceptive individuals perceive internal body signals more intensely, which might lead to changes in oxygen consumption during physical activity.

Methods

Participants

A total of 30 recreational runners (19 men and 11 women) with a mean age of $M = 23.23$ years ($SD = 2.29$) voluntarily participated in this study. They were recruited via social networks as well as advertisements. With the help of G*Power 3.1 (input parameters: $f = .40$, $\alpha = .05$, $1 - \beta = .80$, one group, four measurements, $\varepsilon = 1$; Faul, Erdfeleder, Lang, & Buchner, 2007), a required sample size of 25 was computed to reach a large effect size of $\eta_p^2 = .14$ (e.g., Schücker et al., 2009, 2013). The inclusion criteria specified that participants should be able to run for 30 min and be able to run on a treadmill. Participants' average running experience was $M = 4.47$ years ($SD = 3.48$), with an average of 12.84 km/week ($SD = 7.17$) and 1.73 hr/week ($SD = 1.17$). All participants were informed about the experimental protocol and possible risks before they signed the informed consent. The ethics committee of the Faculty of Psychology and Sport Sciences, University of Münster, Germany approved the informed consent form and study protocol. Participants either received 15 euros or 2 hr of course credit for their participation.

Apparatus

Participants ran on an h/p/cosmos pulsar 3p treadmill (h/p/cosmos sports & medical GmbH, Traunstein, Germany). Videos were projected on a movable projection screen (Vario 64, 3.80 × 2.90 m; AV Stumpfl, Wallern, Austria) via a video projector (Optoma 505M, London, UK). Respiratory gas exchange was measured by a MetaMax cardiopulmonary exercise testing system (CORTEX Biophysik GmbH, Leipzig, Germany). The system was calibrated on each day of testing to provide reliable results, and participants were required to wear a breathing mask that was adapted individually to head size. The MetaMax measured VO_2 as well as further respiratory parameters including respiratory rate, respiratory volume, ventilation rate, respiratory quotient, and energy expenditure. Heart rate was measured continuously with a chest belt (Polar Electro, Kempele, Finland), which transmitted the signal to the MetaMax system. The heartbeat tracking task was conducted with a Prince 180B Easy ECG Monitor (Heal Force, Shanghai, China).

Procedure

Participants were told that the experiment was about "attention and running performance." Heartbeat perception was not mentioned to avoid influencing participants' expectations about interoception. The experiment consisted of two sessions, carried out on different days. During both sessions, participants had to fill out two questionnaires assessing their actual health condition and sports history after arriving at the laboratory. They were informed beforehand that an acute illness or injury (e.g., respiratory disease) could lead to an exclusion from the study. Assessing participants' sport experience by the help of the sports history questionnaire was important as it was intended to only include recreational runners. Figure 1 represents an overview of the test procedure and time course of the two test sessions.

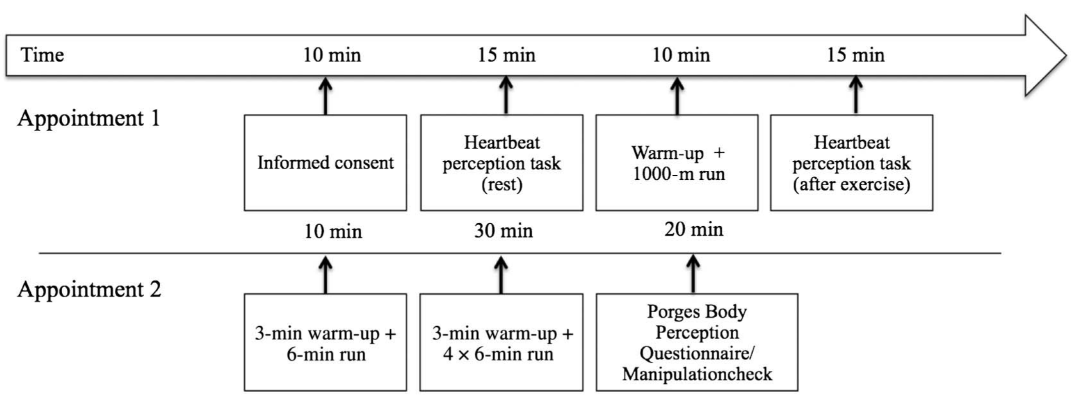

Figure 1 — Overview of the time course and test procedure of the two sessions.

Session 1. Participants were asked to eat normally before conducting the first test session and to not drink coffee at least 2 hr before the experiment in order to prevent the influence of caffeine on the cardiovascular system (Smith, Clark, & Gallagher, 1999). Upon arrival at the laboratory, participants completed the approved informed consent form and questionnaires assessing demographic data and sports history. After filling out the questionnaires, heart rate was measured in the resting condition using a heart rate monitor watch to define the heart rate baseline. Participants did not receive feedback about their heart rate and were asked to remove the heart rate monitor afterward to avoid influencing the following heartbeat perception task (Schandry, 1981). Participants were then asked to find a comfortable upright seated position in preparation for the heartbeat perception task (Schandry, 1981), initially completed in a resting condition for a baseline measurement. They were asked to count their heartbeats within different time intervals (30 s, 45 s, and 60 s) without feeling for their pulse or any other physical manipulations that could facilitate the perception of their heartbeats. Time intervals for this task were initiated and ended by the experimenters' use of the words "Start" and "Stop," respectively, and were separated by 20-s pause intervals. Electrocardiogram recordings were taken for each trial, and participants were asked to report the number of counted heartbeats for each interval. The three different time intervals were completed three times each, the order of the intervals was randomized and counterbalanced to avoid order effects. Participants neither received information about the length of the intervals nor their performance. The accuracy of heartbeat perception was quantified using the heartbeat perception score (e.g., Knoll & Hodapp, 1992; Schandry, 1981) with a maximum score of 1 indicating absolute accuracy (i.e., heartbeat perception score = $\frac{1}{3}\Sigma[1 - (|\text{recorded heartbeats} - \text{counted heartbeats}|)/\text{recorded heartbeats}])$.

The next part of the first test session took place in an indoor athletic sports hall to keep weather and light conditions stable and to avoid influencing attentional focus. Participants warmed up for 5 min and then ran 1,000 m (five 200-m laps) as fast as possible on a running track. This served as a reference time to calculate 60% of their speed for the ergometer running task in the second test session. After running, participants received information about three different attentional foci: (a) attention toward inner bodily signals such as heart rate, pain, and feeling of exertion; (b) attention toward running movement; and (c) attention toward the running environment. Then, they were asked to describe what they had focused their attention on during the first, third, and last rounds of the run to gather initial information about self-selected focusing styles. The reason for introducing these three foci was to give the participants an overview of different possible attentional styles and to clarify terms and definitions. This information was given to them after the run, so that the participants were not able to create theories about their preferred styles beforehand. Furthermore, they were asked to rate the level of perceived exertion for the three laps mentioned (ratings of perceived exertion [RPE]; Borg, 1998). After returning to the laboratory, the heartbeat perception task was conducted a second time (3× each interval: 30 s, 45 s, and 60 s, in randomized and counterbalanced order) for a postexercise measurement. Before every set of trials, participants were required to run or jump in place in the laboratory in order to reach an individually calculated moderate heart rate (60% of theoretical maximum). Theoretical maximum heart rate for each participant was calculated using the formula 220–age; a moderate target heart rate was then calculated based on individual heart rate maxima. After the participant's heart rate had remained stable in the target range for 1 min, the heartbeat perception task was conducted once for every interval (30 s, 45 s, and 60 s) in randomized order. If the heart rate dropped three times during the heartbeat perception task, the process of raising the heart rate was carried out in order to return it to the target range before the next two sets of trials began. Applying the heartbeat perception task during the two different conditions (i.e., resting and after moderate intensity) served to increase the reliability of the heartbeat perception score. Some studies point out that the heartbeat perception task in the resting condition can be influenced by the perception of time (e.g., Dunn, Dalgleish, Ogilvie, & Lawrence, 2007; Knoll & Hodapp, 1992). A high correlation between the heartbeat perception score in the resting condition and after moderate intensity—in which the participants should sense the heartbeat more easily—would refute the argument of a sole estimation of time in the resting condition. After finishing the last part, the participants received either five euros or 1 hr of course credit. The appointment for the next session was then also made.

Session 2. The second part of the study took place in the university motion laboratory with the same participants. After reading the instructions for the next part and getting acquainted with the following procedure and instruments, participants were asked to step on to the treadmill. First, the participants ran for 3 min to warm up at 50% of their maximum speed and to get familiarized with the treadmill. They then ran for 6 min on the treadmill at 1% incline and a moderate intensity of 60%. Running speed was adjusted individually to ensure each participant was performing at a comparable level of exertion. During the 6-min run, a video of a jogging track from the runners' perspectives was presented on a projection screen in front of them. This video was shown in order to simulate natural running conditions as much as possible. During the run, participants' self-chosen attentional focus was assessed every minute and the level of perceived exertion every 3 min (RPE; Borg, 1998). Participants were asked to describe their perceptions of physical exertion ("How hard is running for you at the moment?") using the exertion perception rating scale (6–20 with six being the lowest and 20 being the highest). Attentional focus was measured on a one-dimensional 10-point scale with the two extremes *internal focus* and *external focus* at opposing ends. At the conclusion of the initial running task, the participants were asked which external or internal cues they actually focused on during the run.

After a short recovery break, during which the experimenter prepared the spiroergometric system, participants were equipped with the breathing mask and stepped back on to the treadmill. Participants were then secured to the treadmill with a protective belt for safety reasons. Before the second task commenced, the participants were asked to wait for 2 min, during which time their heart rate and respiratory gases were recorded and adjusted in order to calibrate the spiroergometry machine. Participants again completed a 3-min warm-up (50% of their maximum speed) to get familiarized with running on a treadmill while wearing a breathing mask and were asked about their well-being at the completion of this phase. In the second phase of this running task, the participants performed a 24-min run consisting of four 6-min blocks, where they were explicitly instructed to focus their attention on (a) internal body signals and perceived exertion, (b) a video showing an outdoor running track, (c) their running movement, and (d) whatever cues they would normally use in training. Instructions were standardized (e.g., "concentrate on the movement of your legs" or "concentrate on your internal bodily signals and perceived exertion") and were repeated every 30 s via loudspeaker (audible instructions) and simultaneously appeared at the bottom of the screen (visible instructions). Participants were instructed beforehand on what each focus condition required. With respect to the focus on internal body signals and perceived exertion, it was explained that this focus solely covered internal body signals in connection with the feeling of perceived exertion, such as pain, muscular tension, or sweat. It was important to mention this as this focus should only refer to nonautomated processes. In the external focus condition, participants were asked to count symbols (red circles) appearing intermittently on the screen to make sure they were concentrated on the video. In all other conditions, the video of a running track was shown without added symbols to keep all conditions constant. Participants completed each condition once, the order of conditions was counterbalanced and randomized among the participants. Each condition was conducted one after the other with no formal transition period between. That means the blocks of foci conditions passed over continuously, which is a new aspect allowing investigation of the transitions between the different attentional foci, as previous studies separated the foci conditions by breaks in between. During this task, participants were asked to rate RPE every 3 min. Running economy (VO_2, $ml \cdot min^{-1} \cdot kg^{-1}$) was assessed via spiroergometry throughout the entire run. After completion of the 24-min run, the testing phase was concluded by a 3-min cool-down phase at 50% of the participants' maximal speed.

After completing the running task, the participants completed a manipulation check for each condition, assessing to which degree they actually followed the instructions (e.g., "For what percentage of time did you concentrate on the movement of your legs?") and what they focused on when not concentrating on the instruction. The manipulation check for each condition was conducted all at once retrospectively. In the external focus condition, a question ("How many symbols did you count?") was added. Subsequently, they had to fill out the German version of the Porges Body Perception Questionnaire (Porges, 1993), which can be regarded as an additional subjective method of assessing the sensing of bodily signals. The questionnaire consists of 45 items and is available in the German language.

Statistical Analysis

All data analyses were computed with IBM SPSS Statistics for Macintosh (version 23.0; IBM Corp, Armonk, NY). Repeated-measures analyses of variance with the factor attention condition (a) internal focus on body signals and perceived exertion, (b) internal focus on running movement, (c) external focus, and (d) control were computed and the significance level was set at $p < .05$. Greenhouse–Geisser adjustments of degrees of freedom were used for violations of sphericity assumptions. For effect sizes, partial η^2 and Cohen's *d* were calculated. For post hoc tests, pairwise comparisons with Bonferroni adjustments of alpha level were employed. Cronbach's alpha was used to assess internal consistency in the Porges Body Perception Questionnaire.

Results

Oxygen Consumption

Average oxygen values of every condition (each 6 min) were calculated using average values of every 15 s. The starting and cool-down phase, each 3 min, were excluded from the analysis. Mean oxygen consumption was $M = 32.78$ $ml \cdot min^{-1} \cdot kg^{-1}$ ($SD = 5.33$) for the internal focus on perceived exertion, $M = 32.08$ $ml \cdot min^{-1} \cdot kg^{-1}$ ($SD = 5.27$) for the external focus condition, $M = 32.88$ $ml \cdot min^{-1} \cdot kg^{-1}$ ($SD = 5.25$) for the focus on running movement, and $M = 32.65$ $ml \cdot min^{-1} \cdot kg^{-1}$ ($SD = 5.32$) for the control condition. Repeated-measures analyses of variance showed a significant difference between the four conditions in terms of VO_2, $F(3, 87) = 11.29$, $p < .001$, $\eta_p^2 = .28$. As can be seen in Figure 2, post hoc comparisons with Bonferroni adjustment revealed significantly lower VO_2 values for the external focus compared with all other conditions (all ps $< .01$), and Cohen's (1988) effect size shows a medium effect for these differences ($d = 0.54$–0.76).

Ratings of Perceived Exertion

Repeated-measures analyses of variance revealed a significant difference between the four conditions for the

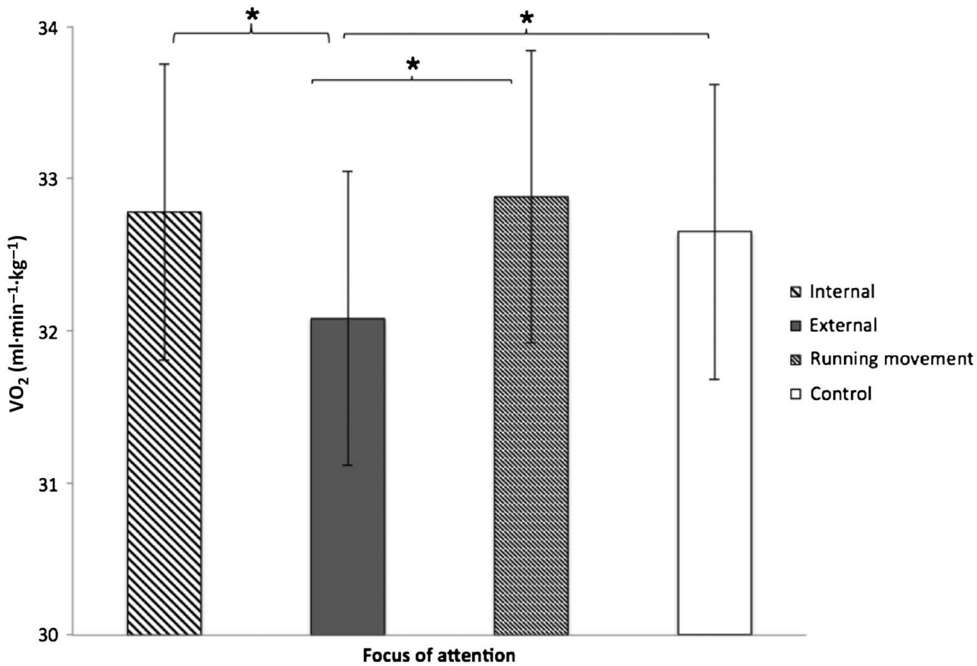

Figure 2 — Oxygen consumption (mean and *SE*) within the four test conditions. Asterisks represent significant differences.

RPE, $F(3, 87) = 6.06$, $p < .001$, $\eta_p^2 = .17$. Post hoc tests with Bonferroni adjustment showed significantly higher values for the focus on inner bodily signals ($M = 13.95$, $SD = 1.82$) compared with the external focus ($M = 12.57$, $SD = 2.08$) and the control condition ($M = 12.87$, $SD = 1.89$) with $p = .00–.019$ and $d = 0.53–0.83$. The internal focus on running movement ($M = 13.15$, $SD = 2.46$) did not differ from the internal focus on perceived exertion. Figure 3 represents RPE within the four conditions.

Further Respiratory Parameters

To gain a more detailed picture of the respiratory gas analysis, descriptive results and statistical analysis of the respiratory parameters breathing rate, respiratory volume, respiratory quotient, ventilation rate, and energy expenditure are presented in Table 1. To summarize, in the external focus condition, heart rate was significantly lower than in the focus on running movement condition. Furthermore, participants expended significantly less

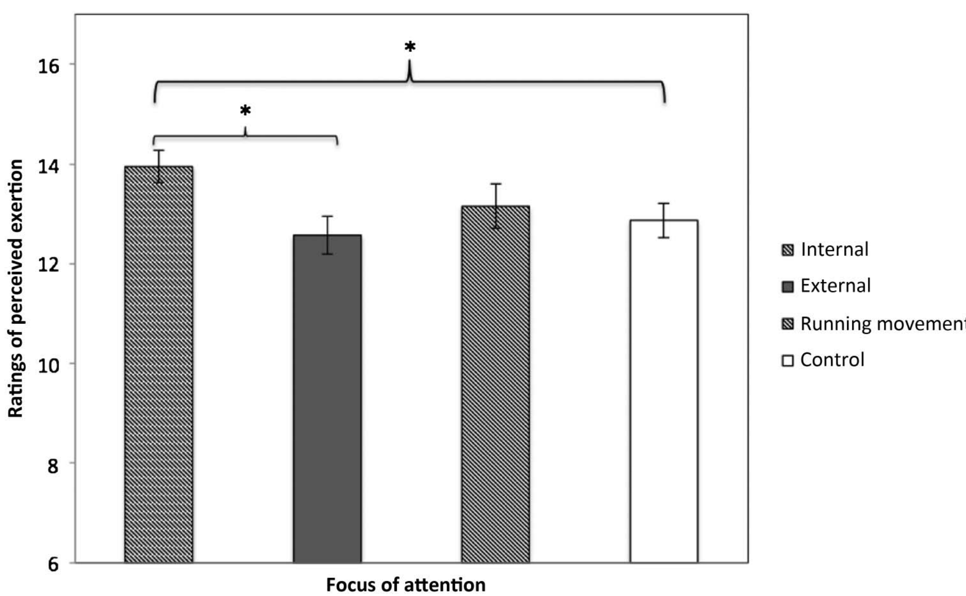

Figure 3 — Ratings of perceived exertion (mean and *SE*) within the four test conditions. Asterisks represent significant differences.

Table 1 Differences Between the Four Attention Conditions Regarding Further Respiratory Parameters

	Focus on Perceived Exertion	External Focus on Video	Focus on Running Movement	Control Focus	p	Partial η^2	Post Hoc Analysis[a]
Heart rate (beats/min)	159.69 (12.20)	158.12 (12.81)	160.89 (11.27)	158.63 (13.11)	.05	.09	External < running movement
Respiratory rate (breaths/min)	36.34 (6.78)	37.79 (5.88)	36.64 (7.64)	37.04 (7.07)	.24	.12	—
Ventilation rate (L/min)	64.68 (18.98)	65.01 (20.15)	65.15 (19.72)	64.11 (18.17)	.62	.02	—
Energy expenditure (kcal/hr)	658.91 (216.92)	645.64 (213.08)	660.38 (215.89)	656.22 (215.13)	<.01	.251	External < all others
Respiratory quotient[b]	.96 (.05)	.97 (.05)	.95 (.05)	.96 (.05)	.04	.09	External > running movement

Note. Mean values and *SD* for every 6-min block. p values and effect sizes based on repeated measures analyses of variance with the factor attention condition. "<" indicating significant differences with $p < .05$.
[a]Post hoc analysis with Bonferroni adjustment.
[b]Respiratory quotient calculated from the ratio CO_2 produced/O_2 consumed.

energy in the external focus condition compared with all other conditions. Likewise, the respiratory quotient was significantly higher in the external focus condition compared with the focus on running movement condition.

Transitions Between the Foci Conditions

As the four attention conditions merged without a break, the transitions between them were analyzed. To examine how long it took for a focus to be adopted, mean VO_2 values within the first 15 s of each condition were compared with the conditions' mean VO_2 level. No difference was found between the VO_2 level for the first 15 s and the overall mean VO_2 value for the external focus (mean 15 s: $M = 32.83$, $SD = 6.05$; conditions mean: $M = 32.06$, $SD = 5.28$), for the focus on internal body signals and perceived exertion (mean 15 s: $M = 32.60$, $SD = 5.51$; conditions mean: $M = 32.78$, $SD = 5.33$), as well as the usual training focus (mean 15 s: $M = 32.73$, $SD = 5.43$; conditions mean: $M = 32.64$, $SD = 5.32$). Thus, these three foci were adopted within the first 15 s of each condition. A significant difference was shown for the running movement condition (mean 15 s: $M = 32.23$, $SD = 5.22$; conditions mean: $M = 32.89$, $SD = 5.27$) with $t(29) = -2.39$ at $p = .02$, disappearing after another 15 s, $t(29) = -0.71$, $p = .48$. This means that the focus on running movement was adopted within the first 30 s.

Manipulation Check

Mean scores for the percentage of time the participants indicated they complied with the actual condition were calculated. For the internal focus on perceived exertion, participants indicated $M = 74.31\%$ ($SD = 14.49\%$), for the external focus condition $M = 88.23\%$ ($SD = 11.15\%$), and for the focus on running movement condition $M = 71.88\%$ ($SD = 12.73\%$). For the control condition, participants were asked if their focus was identical with their usual training focus. A total of 24 participants (74.2%) agreed to this question, whereas seven participants (19.4%) answered that the focus differed from their usual training focus. The analysis of answers for control condition revealed that four participants focused on internal cues exclusively (e.g., breathing, pain in the legs), whereas 13 participants only focused on external cues (e.g., the video, environment). Thirteen participants stated that their attentional focus varied between internal and external cues. Exactly, 77.7% of those, who reported a focus deviating from than their usual one, focused more on external cues, such as the laboratory environment as well as the unfamiliar breathing mask and apparatus. On the other hand, 22.2% focused more on internal cues, such as breathing and their running movement. On the 5-point scale (1 = *very good*; 5 = *not at all*) assessing the subjective feeling of how well each of the four conditions were implemented, mean scores were $M = 2.19$ ($SD = 0.78$) for the internal focus on perceived exertion, $M = 1.35$ ($SD = 0.49$) for the external focus of attention, and $M = 2.38$ ($SD = 0.91$) for the focus on running movement.

Interoception

The mean heartbeat perception score in the resting condition was $M = 0.63$ ($SD = 0.17$) and after the exercise was $M = 0.65$ ($SD = 0.19$). Correlations between the heartbeat perception task at rest and after moderate intensity was $r = .81$ and $p < .001$. No significant correlation was found between the heartbeat perception score and the self-selected focus (scale: 1 = *internal*, 10 = *external*) of the 6-min run at moderate intensity during the second appointment ($r = -.172$, $p = .362$). Furthermore, no significant correlations were observed between the heartbeat perception score and oxygen consumption within the four attention conditions at moderate intensity ($r = .08$ to .14, $p = .47$–.68). The relation between the heartbeat perception score and the manipulation check answers was also investigated to see if heartbeat perceivers subjectively perceived differences in the implementation of the three instructed foci. No significant correlation could be found ($r = -.08$ to .25, $p = .19$–.88). However, the retrospective assessment of RPE in the first, third, and fifth round of the 1,000-m run at the first appointment revealed a significant correlation between the heartbeat perception task at rest and RPE in the first lap of the run ($r = .388$, $p = .034$). The heartbeat perception score did not correlate with the Porges Body Perception Questionnaire ($r = -.069$, $p = .718$). Internal consistency indicated by Cronbach's alpha was .95.

Discussion

The aim of this study was to provide a comprehensive comparison between the foci conditions that have been proven to be important in the literature concerning running economy (Neumann & Piercy, 2013; Schücker et al., 2009, 2013, 2014). In this study, the researchers implemented an external focus, a control condition, and two different internal foci, where the latter differentiated between automated and nonautomated processes. Previous studies have concentrated on single comparisons making it difficult to draw universally valid conclusions. The results replicated and extended the findings of Schücker et al. (2009, 2013). It was shown that an external focus of attention leads to a better running economy than both internal foci and the control focus. By comparing the previously mentioned crucial foci in one study, the advantage of an external focus of attention gains even more importance. It should be highlighted that the external focus is more beneficial than the internal focus on nonautomated processes, although the latter focus proved to be advantageous in a previous study as well (Schücker et al., 2014). The significant results of the further respiratory parameters also support a better running economy for the external focus of attention in terms of less energy expenditure, a lower heart rate, and a higher respiratory quotient. Particularly, the lower heart rate indicates a more efficient oxygen supply for the body as muscles do not consume as much oxygen. Moreover, the external focus was connected with a better running economy than the usual training focus. However, in the study of Schücker et al. (2013), the external focus did not differ from the control condition in terms of running economy. According to the authors, the participants mostly paid attention to the video in the control condition and, thus, directed their attention on the same aspects as in the external condition, which accounts for the missing difference. In the present study, the external focus did differ from the control condition in terms of running economy. The difference can be explained with the answers of the manipulation check. It was revealed that the participants' focus fluctuated and were not solely set to either internal or external cues (13 participants reported an external focus, four participants an internal focus, and 13 switched between internal and external cues). Another difference is that in the external condition, participants had to count the red circles, whereas in the control condition, the video played without additional symbols. An active task such as counting could be more attention demanding than just watching the video, which could account for the differences revealed here. One reason for the different attentional foci in the control condition might be the different expertise levels of both samples. Although Schücker recruited trained runners (Schücker et al., 2009, 2013, 2014), the participants of the present study can be regarded as recreational runners. It is possible that elite runners already established functional attentional strategies in their training. They may have applied these strategies in the control condition where they may have adopted their usual training focus. In contrast, recreational runners might not yet have established a functional attentional focus that they steadily concentrate on. This assumption could explain the fluctuating focus in the control condition and is in line with the state of research and findings of different focus effects according to the expertise level of the participants (Brick et al., 2014; Ziv et al., 2013).

It is interesting to note that no significant difference between both internal foci could be found. According to Schücker et al. (2014), it could have been expected that a focus on perceived exertion, as a nonautomated process, leads to a better running economy than a focus on running movement, as a highly automated process (Schücker et al., 2014). However, the descriptive values point out the same trend. The mean VO_2 values for the focus on running movement were slightly higher than for the focus on internal body signals and perceived exertion. It is possible that the sample of recreational runners of the present study reacted differently to the instructed foci compared with the sample of trained runners in the study of Schücker et al. (2014). Recreational runners might feel their internal body signals more intensely compared with trained runners who might rather be used to internal body signals under physical load. Accordingly, the focus on internal body signals (nonautomated process) might not be as advantageous as the focus on running movement (automated process) in the sample of recreational runners. This is also confirmed by the RPE as the focus on internal body signals is rated as equally exhausting as the focus on running movement. Even though the difference in terms of running economy did not reach significance in this study, the differentiation between automated and nonautomated processes should be kept in mind for future studies to further examine the significance of the constrained action hypothesis.

The novelty of this approach compared with previous studies (e.g., Schücker et al., 2009, 2013, 2014) was that the four attention conditions merged without a break, making it possible to examine the transitions between them. It was shown that the external focus, the focus on internal body signals and perceived exertion, and the control condition were adopted within the first 15 s of the condition. Contrarily, it took the participants longer to concentrate on their running movement. These results are in line with the participants' responses in the manipulation check. They regarded the focus on running movement as the most difficult focus to adopt.

In summary, it can be concluded that the external focus of attention resulted in better running economy when compared with all foci that have been proven to be important in relation to running economy. The constrained action hypothesis was confirmed by the advantage of the external focus of attention and not confirmed for the distinction between both internal foci. Only the descriptive values highlighted a slight advantage for the focus on internal body signals compared with the focus on running movement. It would be interesting to conduct the study with a different sample, as well as at a different task intensity. That would help to generalize the results and to achieve an even broader view.

The construct of interoceptive ability was used to investigate its influence on the focus of attention in running. The idea was based on Herbert and Pollatos (2012) who determined that people with a better interoceptive sensitivity covered a shorter distance on the ergometer and regulated the physical load according to their feeling of their bodies. In this study, it was first examined whether there was a relationship between the heartbeat perception score and the self-chosen attentional focus in the 6-min run at the second appointment. However, no correlations were found in the current study. This leads to the conclusion that regardless of the heartbeat perception score, participants do not favor a certain focus of attention when they are free to choose. Furthermore, no correlation was found between the heartbeat perception score and oxygen consumption within the four attention conditions. According to the results, it appears that interoceptive ability does not interact with oxygen consumption. There are several reasons that can possibly explain the findings. First, it has to be mentioned that most participants in this study had a medium heartbeat perception ability. Only two participants were classified as very poor heartbeat perceivers (score lower .40) and only three participants could be regarded as very good heartbeat perceivers (score above .80). Therefore, it was not possible to create groups of participants with high and low values on the heartbeat perception score. A further study should be conducted with a larger sample size and a higher variety on the continuum of heartbeat perception ability. Another reason for the missing finding could be the moderate task intensity. It is possible that the selected speed might be too low for the internal body signals to influence the participants' attention, or in a further step have an impact on their behavior. An indication for this assumption is provided by the 1,000-m run during the first appointment of this study. Participants were asked to run as fast as possible to calculate their maximum speed. After that, they rated their subjective perceived exertion via Borg scale for the first, third, and last round retrospectively. The results revealed a significant positive correlation between the values on the heartbeat perception task at rest and RPE in the first lap of the run. The better the participants perceived their internal body signals, the higher they rated their level of exertion at the beginning of the run. It is possible that these participants regulated their speed according to their feeling of internal signals. This aspect can be regarded as a promising future research opportunity as higher intensities could also be investigated.

It should also be taken into consideration that people with a higher interoceptive ability might be used to the feeling of their internal body signals when doing sports. Especially at medium intensity, a stronger feeling of internal body signals does not necessarily impair effects of different cognitive strategies like attentional focusing. This is an important hypothesis when it comes to training. If good heartbeat perceivers found it hard to distract themselves from their inner bodily signals, it would be more difficult for them to adopt and train an external focus of attention respectively. The results point out that people, regardless of their interoceptive ability, should be equally able to adopt different attentional foci and underline the possibility and effectiveness to teach and train suitable attentional strategies.

This study goes beyond a simple comparison between different focus conditions with the aim of finding the optimal focus of attention with respect to running economy. Specifically, this study aimed to search for the most optimal focus among those that had already been shown to be important in the specific research field of attentional focusing and running economy. Furthermore, to our knowledge, this study is the first to examine the influence of trait-like factors that could influence attentional focus in endurance sports. Although the present study did not reveal a relationship between interoception and attentional focus, it should be emphasized that individual factors can be regarded as important factors to implement in future studies. Another auspicious approach within the search for the optimal focus of attention is the role of self-regulation mechanisms. As previously mentioned, Brick et al. (2014), proposed a new working model of attentional focus in endurance sports. The researchers expand the internal and external focus dimensions by the category of active self-regulation mechanisms. In that study, Brick et al. (2014) address not only the cognitive-behavioral act of adopting a certain focus as it was done in the current study, but subsequently take into account the metacognitive approach of dealing with the adopted focus connected with its arising thoughts and evaluations. Further studies should also concentrate on self-regulation mechanisms as a coping mechanism when adopting a certain focus in order to find the optimal focus of attention.

Limitations

A number of limitations should be considered in the present study. The first limitations refer to the implementation of the different attentional foci. First, in the 6-min run during the second appointment, participants were free to choose their attentional focus. At this point, the term "free to choose" should be reflected critically as the participants were provided with information about different attentional foci beforehand. Providing them with specific information beforehand could have biased their responses. Even though these foci were only defined broadly, it would have been more advantageous to simply ask open questions about their focus of attention. A second critical aspect is that participants were asked for their self-chosen focus every minute. It is possible that they were biased because this suggested that the focus is supposed to change every minute. Otherwise, it could have been asked only once. Due to this procedure, the self-chosen focus could be less natural. In the second part of the second appointment, the participants had to run under four attention conditions. It may be noted that in every condition, participants received the instructions visually, as well as audibly via loudspeakers. Thus, while receiving the focus instruction, the participants were forced to focus externally, albeit momentarily. Furthermore, in contrast to other studies (e.g., Schücker et al., 2013), a difference in oxygen consumption between the external focus of attention and the control condition was found in the present study. In this regard, another critical aspect of note is that in the external focus condition the participants had to count symbols, which was not the case in the control condition. As this differed from the procedure followed in previous studies, the different implementations can potentially be regarded as a limitation as well. Moreover, the present study also investigated the transitions between the attention conditions, further diverting from the procedures followed by previous studies; as this is a new aspect, it needed to be treated with caution. For example, switching between conditions was prompted by the perception of the new instruction. Thus, participants could be distracted within the first few seconds of each focus period before actually adopting the new focus.

There are also limitations related to the manipulation check performed in the present study. It must be noted that assessing the manipulation check for all four conditions retrospectively should be regarded as a limitation due to a compromised memory of earlier blocks. Also, the manipulation check showed that not all instructions were implemented equally well, especially the focus on running movement, which appeared to be difficult to adopt. Therefore, the difficulty of adopting a specific focus should also be regarded as a limiting factor.

The following limitations refer to the measurement of interoceptive ability. Although the heartbeat tracking task is an often-applied method, it should be reflected upon critically. In a previous study, Knoll and Hodapp (1992) stated that the performance in the heartbeat perception task might be confounded with the perception of time. This argument is supported by some studies (Pollatos, Yeldesbay, Pikovsky, & Rosenblum, 2014), while others do not support it (Knoll & Hodapp, 1992; Schwarz, Winkler, & Sedlmeier, 2013). Also, the suitability of the ability to perceive one's own heartbeat accurately as an encompassing indicator for the general interoceptive ability is questionable (e.g., Ceunen, van Diest, and Vlaeyen, 2013). The notion that the heartbeat perception task only measures one facet of interoceptive ability is also supported by the present study. Porges Body Perception Questionnaire (Porges, 1993) was conducted to display self-report statements of interoceptive phenomena; however, the questionnaire responses and the Heartbeat perception score did not correlate with each other, supporting the notion that both might measure different aspects of interoceptive sensitivity.

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