Altering Pace Control and Pace Regulation: Attentional Focus Effects during Running

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Abstract

Purpose: To date there are no published studies directly comparing self-controlled and externally-controlled pace endurance tasks. However, previous research suggests pace control may impact on cognitive strategy use and effort perceptions. The primary aim of this study was to investigate the effects of manipulating perception of pace control on attentional focus, physiological, and psychological outcomes during running. A secondary aim was to determine the reproducibility of self-paced running performance when regulated by effort perceptions. **Methods:** Twenty experienced endurance runners completed four 3 km time-trials on a treadmill. Subjects completed two self-controlled pace (SC), one perceived exertion clamped (PE), and one externally-controlled pace (EC) time-trial. PE and EC were completed in a counterbalanced order. Pacing strategy for EC and perceived exertion instructions for PE replicated subjects' fastest SC time-trial. **Results:** Subjects reported a greater focus on cognitive strategies such as relaxing and optimizing running action during EC than SC. Mean heart rate was 2% lower during EC than SC despite an identical pacing strategy. Perceived exertion did not differ between the three conditions. However, increased internal sensory monitoring coincided with elevated effort perceptions in some subjects during EC, and a 10% slower completion time for PE (13.0 ± 1.6 min) than SC (11.8 ± 1.2 min). **Conclusion:** Altering pace control and pace regulation impacted on attentional focus. External control over pacing may facilitate performance, particularly when runners engage attentional strategies conducive to improved running efficiency. However, regulating pace based on effort perceptions alone may result in excessive monitoring of bodily sensations and a slower running speed. Accordingly, attentional focus interventions may prove beneficial for some athletes to adopt task-appropriate attentional strategies to optimize performance.

Keywords: Attentional strategies; perceived exertion; pacing; metacognition; endurance.

Introduction

Attentional focus during endurance activity is a dynamic process. To optimize performance, athletes must monitor both internal (e.g. bodily states) and external (e.g. environmental) stimuli and engage appropriate cognitive strategies to cope with task demands (6). Much research underpins this contention, demonstrating that a focus on task-relevant self-regulatory thoughts (e.g. relaxing, cadence/rhythm) may improve movement economy (7) or optimize pace (8). Conversely, an excessive focus directed toward bodily sensations (e.g. breathing, movement) may reduce movement efficiency (32) and diminish performance.

Alongside an appreciation of the isolated effects of attentional foci, an understanding of the situational determinants of strategy selection is also important (6). Adapting successfully to varying contexts requires cognitive control, or the intentional selection of thoughts and actions based on task demands (12,27). Situational factors may also necessitate differing forms of cognitive control; specifically proactive, goal-driven control (e.g. planning a pacing strategy) or reactive, stimulus-driven processes (e.g. responding to environmental changes) (4,6,10,27). Recently, Brick et al. (6) proposed a metacognitive framework to allow a better understanding of these attentional operations during endurance activity. Metacognition can be defined as an individual's insight into and control over their own mental processes (15). The metacognitive framework (6) highlights the importance of metacognitive skills (e.g. planning, monitoring, or reviewing one's thoughts) and metacognitive experiences (e.g. feelings of task difficulty, or judgments about effective/ineffective attentional foci) to cognitive strategy selection and implementation. Highly developed metacognitive abilities may be a feature of experience and familiarity with task demands, however (23). Accordingly, the ability of individuals to engage a focus of attention appropriate to situational constraints deserves further exploration.

During self-paced endurance activity, including individual time-trials, perceptions of exertion are considered central to pace-regulation (31,37). How perceptions of exertion are generated is a topic of debate, however. Within some models, central regulation of pacing strategy is the result of feedforward control in response to non-conscious processing of afferent feedback from physiological systems (29,31,37). However, this contention has been challenged by evidence that perceived exertion may be independent of afferent feedback (24). An alternative approach, the psychobiological model, considers the role of corollary discharge, or the conscious awareness of efferent signals believed to originate from premotor and motor areas of the cortex (11,30,33). Within this model, the conscious regulation of pace is determined by cognitive and motivational factors, including perception of effort, potential motivation, knowledge of distance/time remaining, and previous experience of perception of effort during exercise of varying intensity and duration (30,33).

Given the importance of effort perceptions to endurance performance, evidence suggesting attentional focus may alter this relationship deserves further consideration (5,26). In addition to understanding why attentional strategies are effective, recognizing situational factors which dictate when particular foci are more useful is also important. One such context relates to perception of control over pacing. In a recent review, Brick et al. (5) intimated that control over pacing may impact on attentional focus and subsequent performance outcomes. Specifically, in self-controlled pace designs performance tended to improve – without an elevation in effort perception – when subjects engaged active self-regulatory strategies (8,22). In contrast, during externally-controlled pace tasks an excessive focus on bodily sensations tended to increase effort perceptions, while distractive strategies had the opposite effect (34).

Accordingly, the purpose of the current study was to present experienced endurance runners with contexts where task constraints were modified. The primary aim was to investigate the effect of manipulating perceptions of pace control on attentional focus, physiological, and psychological measures during running. It was hypothesized that athletes would adapt attentional focus to cope effectively with task demands. The use of effort perceptions to regulate self-paced endurance activity, and the concomitant impact on attentional foci was also of interest. Therefore, a secondary aim was to determine the reproducibility of self-paced running performance when regulated by perceptions of effort.

Methods

Subjects, ethics, and informed consent

Subjects were recruited via email to local running clubs. Twenty experienced endurance runners (Table 1) volunteered to take part and were given no incentives for participation. All subjects were healthy, free from injury, engaged in regular running training, and were accustomed to treadmill running. The study was approved by the institutional research ethics committee and all participants completed a medical history questionnaire and gave written informed consent before taking part. The study requirements were outlined to subjects but they were not informed of the aims and hypotheses. Subjects were also naive to specific time-trial protocols and were requested not to discuss the study with other subjects.

[INSERT TABLE 1 NEAR HERE]

Study design and procedures

A repeated measures crossover design was used. Subjects visited the laboratory on five occasions, each separated by 3-8 days to limit fatigue and training adaptations. Trials were performed at the same time of day (+/-3 h). Subjects maintained normal training and sleep patterns throughout the duration of the study and refrained from strenuous activity in the 24 h preceding each trial. Before the first session, subjects recorded a 24 h food diary and were asked to maintain similar dietary intake before subsequent visits. Subjects were asked to avoid caffeine and food, and drink 500 ml of water in the 2 h before each session. Body mass was recorded before each trial to indicate no significant variations in hydration status.

Maximal oxygen consumption (VO_{2max})

On the initial visit, subjects completed an incremental exercise test to volitional exhaustion on a treadmill (h/p/cosmos quasar; h/p/cosmos Sports & Medical GmbH, Traunstein, Germany) with continuous measurement of respiratory gas exchange using an online metabolic cart calibrated before each test (Quark C-PET, Cosmed Srl, Rome, Italy). Following a 5 min warm-up at a self-selected pace, subjects began at a light intensity based on their ability, with the intention of reaching volitional exhaustion within 10-15 min. Stages lasted 2 min, with 2 $km \cdot h^{-1}$ increments for each of the first 3 stages followed by 1 $km \cdot h^{-1}$ increments to volitional exhaustion. Treadmill gradient was maintained at 1%. Volitional exhaustion was reached in 13.9 ± 1.4 min. Heart rate was measured continuously by wireless telemetry (Cosmed HR monitor, Rome, Italy). VO_{2max} was determined as the highest value for a 10 breath rolling average. In all tests two or more criteria for VO_{2max} were met (19).

Experimental measures

During visits 2-5, subjects completed a 3 km time-trial on the laboratory treadmill. On arrival at the laboratory, subjects were informed of the protocol for the ensuing time-trial (see *Time-trials*). Following a check for understanding, subjects completed the Brunel Mood Scale (BRUMS; 36) on which they were instructed to "*circle the answer which best describes how you feel right now*". To determine potential motivation, subjects completed an adapted state motivation questionnaire (25), and two 11-point Likert-type scales to determine willingness to invest maximal physical, and mental effort (0 = not willing, 10 = willing; 38,39). Before the warm-up, subjects' body mass (Seca 862, Hamburg, Germany) and resting blood lactate concentration were recorded (Lactate Pro 2, Arkray Inc., Kyoto, Japan).

During each time-trial recordings of running speed, heart rate (Polar RS400, Kempele, Finland), rating of perceived exertion (Borg RPE 6-20 scale; 3), and affective valence (Feeling Scale; 17) were taken at 200 m, and at each 400 m distance interval thereafter. RPE and affective valence scales were projected on a screen 3.5 m in front of the treadmill and removed once subjects had indicated their RPE and affect over the preceding 200 m. Before the PE time-trial, subjects were informed that their reported RPE could vary from the instructed RPE if they perceived their actual exertion to be different.

Time-trials

Before each time-trial, subjects warmed up for 5 min at a pace equivalent to 70% of the maximum heart rate recorded during the incremental test, followed by 2 min rest (38). To provide knowledge of distance elapsed/remaining (30,33) only the treadmill distance display was visible to the subjects. However, the user terminal was interfaced with a computer (h/p/cosmos pc software) so that all time-trial data were visible to the experimenters. A video camera was used to record data for later analysis. Subjects received no other feedback or verbal encouragement throughout each time-trial. A fan was positioned at the front right of the treadmill during each trial to ensure consistency of laboratory conditions.

Time-trials 1 and 2 were self-controlled pace trials. Before each trial, subjects were instructed how to manipulate treadmill speed on the user terminal and were informed they could pace the trial freely, but to complete it as quickly as possible. The first time-trial served as a familiarization trial. The second trial replicated the familiarization trial. Paired-sample t-tests indicated no differences between trials in running speed, completion time, heart rate, post-trial blood lactate, perceived exertion, affective valence, or on frequency ratings for any attentional focus category (see *Post time-trial measures and attentional focus interview*). The fastest trial was used as each subject's self-controlled pace (SC) trial for subsequent analysis.

Time-trials 3 and 4 were completed in a randomized, counterbalanced order (www.random.org). Time-trial 3 was a rating of perceived exertion clamped (PE) trial. During PE, subjects were instructed to maintain varying perceptions of exertion, replicating those self-reported during SC. Subjects were issued with an RPE instruction at each distance interval (e.g. 200 m, 600 m, etc.) to attain by the next 200 m segment (e.g. 400 – 600 m, 800 – 1000 m, etc.). Subjects were informed beforehand and reminded during that RPE was in the context of a 3 km time-trial they were attempting to complete as quickly as possible (30,33). Subjects could manipulate the treadmill speed throughout. Time-trial 4 was an externally-controlled (EC) pace trial during which the experimenter controlled treadmill speed using the manufacturer's software controls. Before EC, subjects were informed the trial would be completed as quickly as possible but the experimenter would control the speed. Pacing replicated the self-selected strategy adopted during SC. Subjects were blind to the origin of the RPE instructions and the pacing strategy implemented during PE and EC respectively.

<u>Post time-trial measures and attentional focus interview</u>

Following each time-trial, participants completed the BRUMS, on which they were instructed to "*circle the answer which best describes how you felt during the 3 km time-trial*", and the state motivation questionnaire as retrospective measures. As a manipulation check, subjects rated their perception of control over pacing on an 11-point Likert-type scale (0 = no control, 10 = complete control). During a post-trial interview, subjects rated how frequently they focused on thoughts from attentional focus categories (5,6) during the time-trial on 11-point Likert-type frequency scales (one item per category) with verbal descriptors (0 = never, 10 = always; 40). Subjects also recounted specific foci engaged, and were able to view attentional focus category information to assist recall (see Supplemental Digital Content 1 for attentional focus scales). All interviews were digitally recorded to check for accuracy.

Statistical analysis

The effect of condition (SC, PE, EC) on pre-trial states (i.e. body mass, resting blood lactate, willingness to invest physical and mental effort, success and interest motivation), time-trial performance (i.e. completion time, running speed), physiological (i.e. heart rate, post-trial blood lactate), and psychological measures (i.e. RPE, affect, mood states), the manipulation check, and attentional focus frequency ratings were analyzed using repeated measures MANOVA. If assumptions of sphericity were violated, the Greenhouse-Geisser correction was used to report analyses. Post hoc pairwise comparisons with Sidak-adjusted *P* values were conducted where a significant F ratio was observed. Statistical significance was accepted as $P < 0.05$ (two tailed). Reporting of analyses focused on comparisons between SC and EC, and between SC and PE. Cohen's *d* (9) values are provided as an estimate of effect size where relevant. Where appropriate, 95% confidence intervals (95% CI) are reported for post hoc pairwise comparisons. All data analyses were conducted using the Statistical Package for the Social Sciences (IBM Statistics 22.0, SPSS Inc., Chicago, IL).

Results

Reporting of within time-trial distance interval measures (i.e. speed, heart rate, affect and RPE) will focus on mean time-trial values. A more detailed analysis is available on the online digital content (see Supplemental Digital Content 2 for distance interval analyses).

Pre-trial state measures

Mean duration between SC and EC was 7.9 ± 4.2 days, and between SC and PE was 9.3 ± 4.6 days. Consistency of pre-trial states (Table 2) indicated no differences for body mass, resting blood lactate, willingness to invest physical effort, willingness to invest mental effort, or success motivation. Interest motivation was higher before EC than SC (Mean difference, MD = 0.95, 95% CI = 0.03, 1.87; $P = 0.042$, $d = 0.44$). Retrospective measures indicated no differences in success or interest motivation between conditions. As a consequence, the effect of condition was further analyzed using a repeated measures MANCOVA where appropriate, with pre-EC interest motivation controlled as the covariate.

[INSERT TABLE 2 NEAR HERE]

Time-trial performance

Mean running speed (Table 2 and Figure 1a) was slower during PE than SC (MD = -1.33 km·h^{-1}, 95% CI = -2.01, -0.66; *P* < 0.001, *d* = 0.94), resulting in a slower completion time for PE (MD = 1.18 min, 95% CI = 0.57, 1.78; *P* < 0.001, *d* = 0.84). Neither mean speed nor completion time differed between SC and EC. During SC subjects made 12.1 ± 3.7 pace adjustments, most occurring within the first 600 m (5.1 ± 2.6) and the last 400 m (2.6 ± 1.2).

[INSERT FIGURE 1 NEAR HERE]

Physiological measurements

Heart rate (Table 2 and Figure 1b) was higher during SC compared with both EC (MD = 3.24 bpm, 95% CI = 1.51, 4.95; *P* < 0.001, *d* = 0.35) and PE (MD = 9.54 bpm, 95% CI = 5.96, 13.12; *P* < 0.001, *d* = 0.86). A follow up Pearson's product moment correlation revealed the difference in heart rate between SC and EC was negatively correlated with the number of pace adjustments made during SC (r = -0.513, *P* = 0.021). Blood lactate (Table 2) was lower following PE compared with SC (MD = -2.80 mmol·L^{-1}, 95% CI = -5.43, -0.159; *P* = 0.036, *d* = 0.67). There was no difference in post-trial blood lactate between SC and EC.

Psychological measures and manipulation check

There was no main effect of condition for RPE on MANOVA or MANCOVA outcomes (Table 2 and Figure 1d). Mean affective valence during PE (Table 2 and Figure 1c) was more positive than SC (MD = 0.81, 95% CI = 0.06, 1.56; *P* = 0.033, *d* = 0.52). There was no main effect of condition for any mood states reported pre-trial or retrospectively on MANOVA or MANCOVA outcomes (Table 3). The post-trial manipulation check (Table 2), revealed a reduced perception of control over pacing between EC than SC (MD = -7.50, 95% CI = -9.27, -5.73; $P < 0.001$, $d = 3.64$) but not between SC and PE.

[INSERT TABLE 3 NEAR HERE]

Post time-trial attentional focus frequency rating and qualitative interviews

Attentional focus frequency ratings are provided in Figure 2. Internal body sensations were monitored more frequently during PE than both SC (MD = 1.55, 95% CI = 0.16, 2.94; $P = 0.026$, $d = 0.83$) and EC (MD = 1.45, 95% CI = 0.39, 2.52; $P = 0.006$, $d = 0.90$). There was no main effect of condition for active self-regulation ($P = 0.077$), outward monitoring ($P = 0.262$), or distraction ($P = 0.223$).

[INSERT FIGURE 2 NEAR HERE]

The primary active self-regulatory thoughts reported during SC were pacing/tactics (95% of subjects), chunking (i.e. mentally breaking the 3 km distance down to smaller segments; 80%) and improving running technique (65%). These were pacing/tactics (70%), relaxing (55%), and improving running technique (40%) during PE, while during EC subjects reported improving running technique (75%), relaxing (60%) and cadence/rhythm (55%). Bodily sensations most frequently monitored were breathing, body movement/form, and overall effort/feel. Breathing was monitored by 80% of subjects during SC, 65% during PE, and 50% during EC. Body movement was monitored by 60% during SC, 65% during PE and 45% during EC, while overall effort/feel was monitored by 55% during SC, 80% during PE and 45% during EC. The distance display was the most monitored outward source of information, reported by 95% of subjects during SC, 85% during PE and 80% during EC. Finally, 40% of subjects reported distraction during SC, 35% during PE and 55% during EC.

Individual differences in RPE responses during SC and EC time-trials

[INSERT FIGURE 3 NEAR HERE]

Further analysis of the RPE data suggested individual differences in response to the EC trial (Figure 3). Specifically, nine individuals perceived exertion during EC to be higher than SC, and eleven lower. Consequently, between-groups differences were analyzed using MANOVA with increased/decreased RPE during EC as the between-groups factor. RPE reported during SC did not differ, but there was a between-groups difference in RPE reported during EC ($F_{1, 18} = 7.83$, $P = 0.012$, $d = 0.80$). Mean RPE increased from SC (12.7 ± 1.6) to EC (13.9 ± 1.4) for those who reported EC harder, and decreased from SC (12.5 ± 1.9) to EC (11.7 ± 2.0) for those who found EC easier. Furthermore, subjects who perceived an elevated RPE during EC also reported a greater frequency of internal sensory monitoring than those who reported a lowered RPE (Mean ± SD; 7.2 ± 1.8 versus 5.6 ± 1.4 respectively; 95% CI = 0.08, 3.10; $P = 0.041$, $d = 0.99$). The groups did not differ on running experience or any other attentional focus, physiological, or psychological variable.

Discussion

The primary aim of this investigation was to determine the effects of manipulating perceptions of pace control on attentional focus, physiological, and psychological measures during 3 km time-trial running. This study was the first to compare these outcomes under self-controlled (SC) versus externally-controlled (EC) pace conditions. An important finding was that externally-controlled pace running altered the content of subjects' self-regulatory cognitions. Specifically, during EC subjects focused less attention on self-regulatory thoughts related to pacing and more on relaxation and optimizing their running action. Heart rate was also 2% lower during the EC trial than the SC trial despite an identical pacing strategy between trials. The second aim was to determine the reproducibility of self-paced running when regulated by perceptions of effort. Mean completion time was 10% slower during the perceived exertion clamped (PE) time-trial, despite identical effort perceptions to the SC trial. Subjects also reported a large increase in internal sensory monitoring during the PE trial.

Altering perceptions of pace control appeared to have a profound impact on runners' focus of attention. During SC, for example, almost all subjects focused on pacing, monitoring the distance display, and chunking (i.e. mentally breaking the 3 km distance down to smaller segments to assist pacing decisions). In contrast, during EC the majority of subjects focused on relaxing, and improving both running technique and cadence/rhythm. Furthermore, fewer subjects reported monitoring breathing and body movement during EC in comparison with SC. The altered focus of attention also coincided with a small reduction in heart rate during the EC trial which cannot be explained by treadmill manipulations or a training effect (21).

The potentially beneficial impact of focusing on relaxing and optimizing running action may have important implications for endurance running performance. Previous studies, for example, have demonstrated improved running economy and/or reduced heart rate in endurance athletes experienced at using relaxation strategies (7) or running at a preferred cadence (20). Additionally, concentrating on improved movement technique has been shown to optimize running performance (13). In contrast, monitoring highly automated processes such as breathing or movement execution may increase heart rate and the oxygen cost of running (32). The findings of the present study also emphasize the significance of metacognitive processes to attentional focus within varying contexts (6). Specifically, the data suggest that during the EC time-trial, task-relevant monitoring of situational variables (e.g. bodily sensations) stimulated cognitive control and selection of cognitive strategies more conducive to a lowered oxygen cost of running.

The differences in subjects' self-regulatory cognitions during the SC and EC time-trials may have further significance. Focusing on pace-related thoughts during the SC trial implies a need for proactive, goal-driven cognitive control (4,6,10). In such circumstances, sustained activation of the prefrontal cortex is required to control cognition and guide behavior, resulting in a greater demand on cognitive resources (4,27). Furthermore, study of brain activity indicates that areas including the prefrontal, premotor, and sensorimotor cortices are more active when changes in locomotion speed are prepared in advance (35), as would occur during self-paced running. In contrast, during EC an identical pacing strategy may not have required proactive cognitive control. Instead, reactive, or stimulus-driven attentional control (4,6,10) may have been more appropriate, whereby subjects could reactively employ cognitive strategies (e.g. to relax) based on periodic monitoring. While reactive cognitive control may also have been prevalent during the SC trial, it was likely the dominant form of control during the EC trial. Reactive control is considered less demanding on cognitive resources than proactive control (4). Accordingly, a reduction in central regulation (31) may represent an additional benefit of externally-controlled pace running.

While recognizing limitations of the present study (i.e. treadmill running and subjective reporting of attentional focus), the potential reduction in both cognitive and physiological demands when pace is set may have practical performance benefits. While Bath et al. (1) reported no performance effect for subjects running with a pacemaker, the second runner in that study adjusted their pace in reaction to the subject's strategy, thus not truly acting as a pace-maker. However, a study of pack running during World Half Marathon Championships (16) noted that athletes who ran in packs with similar ability opponents (i.e. pacemakers) during the entire race increased pace over the final 1.1 km more than any other group (e.g. solo runners, occasional pack runners). Whether this was a result of increased competition (16,39) or reduced wind resistance (31) demands further study. It may be that additional advantages are accrued when employing less resource demanding reactive cognitive control and cognitive strategies conducive to increased running efficiency.

While stimulus-driven attentional control may be less demanding on cognitive resources, a more in-depth analysis of the data suggests an excessive focus on some stimuli may be counterproductive. Though mean RPE did not differ between EC and SC trials, large individual differences in RPE responses were apparent (Figure 3). Specifically, nine subjects, including all five females, perceived EC to be more difficult than SC. This group also reported monitoring bodily sensations frequently during EC, while those who perceived EC to be easier monitored occasionally/often. Increased monitoring of bodily sensations has been reported to intensify perceptions of exertion (34). Thus, the findings partially support the original hypothesis in that some, but not all subjects adapted attentional focus to cope with the constraints imposed by the EC trial. This may be due to a lack of task-specific experience, for example (23,30,33), while the influence of gender warrants further research attention.

The second aim was to determine the reproducibility of self-paced running when regulated based on perceptions of effort. In this regard, a major finding was that, on average, PE was completed 10% slower than SC. This was despite no reported difference in perceived exertion or state motivation between SC and PE trials. The slower running speed (by 8.7%) during PE resulted in a reduced heart rate (by 5.8%), and a lower post-trial blood lactate concentration (by 25.5%). Affective valence was also more positive during EC, which may reflect the slower running speed and decreased blood lactate (14). Collectively, the findings support suggestions that effort perceptions may be independent of afferent feedback from cardiovascular and metabolic stress (24). However, the slower running speed during PE should, theoretically, also reduce efferent output and activity in premotor and motor areas of the cortex, regions believed to be responsible for the corollary discharges generative of effort perception (11). As with individual differences reported between SC and EC trials, however, consideration of attentional focus responses may also resolve this apparent anomaly.

During the PE trial, subjects monitored bodily sensations most of the time as opposed to often/frequently during SC (Figure 2). In addition, a greater number of athletes reported monitoring overall effort/feel (80%) and body movement (65%) during PE. From an attentional focus perspective (6) the findings suggest excessive internal sensory monitoring without task-appropriate self-regulatory (8,22), outward (38,39) or distractive (34) foci may amplify feelings of task difficulty. This may result from an increased conscious awareness of corollary discharge and an attendant elevation in effort perceptions. Consequently, during PE a decreased intensity was required to maintain the instructed RPE. The findings emphasize the importance of a context-appropriate focus of attention during endurance activity (5,6).

Conclusions and future recommendations

This is the first study to directly compare self-controlled (SC trial) and externally-controlled (EC trial) pace endurance tasks. An important finding was that subjects employed attentional strategies (e.g. relaxing, optimizing running action) conducive to improved running efficiency during the EC trial. Attentional control during externally-controlled pace running may also be less demanding on cognitive resources. However, increased internal sensory monitoring coincided with elevated effort perceptions in some runners during the EC trial. Compared with the SC trial, excessive monitoring of bodily sensations (e.g. overall effort/feel, body movement) was also accompanied by a slower running speed and completion time during the perceived exertion clamped (PE) trial. This study highlights the need for a task-appropriate focus of attention during running and supports suggestions that attentional focus may be an important determinant of endurance performance (2,26).

Based on the present findings, further research is required to explore the performance implications of externally-controlled pace running in an ecologically valid setting (e.g. running with pacemakers). Given that all five female subjects reported increased effort perceptions during the EC trial, the potentially moderating influence of gender should also be investigated. Future research is also needed to determine the cortical activity involved during externally-controlled versus self-controlled pace endurance tasks. Finally, from an applied practice perspective, the findings suggest attentional focus interventions may prove beneficial for some athletes to adapt successfully to task demands. Performance advantages may be accrued by those athletes adopting a context-appropriate focus of attention.

Conflicts of interest, source of funding and acknowledgements

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Table 1. Demographic and training characteristics of subjects (*n = 20*).

Table 2. Measures for pre-trial variables, time-trial data, and manipulation check for SC, PE and EC.

Table 3. Mean ± SD for mood states (BRUMS) reported pre-trial and retrospectively post-trial.

Figure 1. Running speed (a), heart rate (b), affective valence (c), and ratings of perceived exertion (d) during 3 km time-trials. Error bars illustrate SEM. Symbols denote main effect of condition: (#) Mean speed slower for PE than SC ($P < 0.001$). (*) Heart rate higher for SC than both EC ($P < 0.001$) and PE ($P < 0.001$). (^) Affective valence more positive for PE than SC ($P = 0.033$).

Figure 2. Attentional focus frequency ratings for each condition. Error bars illustrate SEM. Symbol denotes Sidak-adjusted pairwise difference: (*) ISM higher during PE than SC ($P = 0.026$) and EC ($P = 0.006$).

Figure 3. Individual subject data (*grey lines*) for differences in RPE reported during SC and EC time-trials. Thicker black lines represent mean RPE ± SEM for subjects perceiving EC easier (full lines), and more difficult (dashed lines) than SC. (*) Difference between groups in mean RPE reported during EC ($P = 0.012$).

Supplemental Digital Content 1. Attentional focus rating scales and checklist (.pdf)

Supplemental Digital Content 2. Distance interval analyses (.pdf)

Table 1. Demographic and training characteristics of subjects (*n = 20*).

Variable	
Age	40.3 ± 8.1 yr
Gender	15 M, 5 F
Body Mass (Session 1)	69.2 ± 10.8 kg
Height	1.73 ± .09 m
VO_{2max} (all) **Males (*n = 15*)** **Females (*n =5*)**	53.1 ± 5.0 $mL \cdot kg^{-1} \cdot min^{-1}$ 54.3 ± 4.3 $mL \cdot kg^{-1} \cdot min^{-1}$ 49.5 ± 5.5 $mL \cdot kg^{-1} \cdot min^{-1}$
Running experience	9.7 ± 10.6 yr
Weekly training volume	62.9 ± 15.6 km
Training intensity* **(No. sessions p.w.)**	2.2 ± 0.6 high, 3.0 ± 0.8 medium/low
Primary events	Ultra-distance (*n = 3*) 10km – Marathon (*n = 7*) 800m – 10km (*n = 10*)

**Note: training intensity self-reported by participants. High intensity training identified as high-intensity interval and tempo running*

Table 2. Measures for pre-trial variables, time-trial data, and manipulation check for SC, PE and EC.

	SC	**PE**	**EC**
Pre-trial variables			
Body Mass (kg)	69.4 ± 10.8	69.2 ± 10.5	69.5 ± 10.7
Resting Blood Lactate ($mmol{\cdot}L^{-1}$)	1.6 ± 0.5	1.8 ± 0.8	1.8 ± 0.8
Willingness to invest effort			
Physical	9.4 ± 0.9	9.6 ± 0.8	9.7 ± 0.6
Mental	9.3 ± 1.1	9.6 ± 0.6	9.6 ± 0.7
Motivation (Pre-trial)			
Success	20.2 ± 5.4	20.1 ± 5.1	20.4 ± 4.9
Interest	24.9 ± 2.3	25.6 ± 2.5	25.9 ± 2.0[a]
Motivation (Retrospective)			
Success	21.3 ± 4.0	20.4 ± 5.3	20.1 ± 5.0
Interest	25.7 ± 2.4	26.2 ± 2.2	25.9 ± 2.5
Time-trial data			
Completion Time (min)	11.8 ± 1.2	13.0 ± 1.6[b]	11.9 ± 1.2
Mean Speed ($km{\cdot}h^{-1}$)	15.3 ± 1.4	14.0 ± 1.5[b]	15.3 ± 1.4
Mean Heart Rate (bpm)	163.3 ± 9.3[c]	153.8 ± 12.6	160.1 ± 9.2
Post-trial Blood Lactate ($mmol{\cdot}L^{-1}$)	11.0 ± 4.2	8.2 ± 4.2[d]	10.2 ± 3.7
Mean RPE	12.6 ± 1.7	12.8 ± 1.6	12.7 ± 2.1
Mean Affect	1.7 ± 1.6	2.6 ± 1.5[e]	1.8 ± 1.9
Manipulation check			
Perceived control pacing	8.7 ± 1.8	8.2 ± 2.0	1.2 ± 2.3[f]

Data are presented as Mean ± SD. Symbols denote significant pairwise differences: [a] Higher than SC ($P = 0.042$). [b] Slower than SC ($P < 0.001$). [c] Higher than PE ($P < 0.001$) and EC ($P < 0.001$). [d] Lower than SC ($P = 0.036$). [e] More positive than SC ($P = 0.033$). [f] Lower than SC ($P < 0.001$).

Table 3. Mean ± SD for mood states (BRUMS) reported pre-trial and retrospectively post-trial.

		Tension	Depression	Anger	Vigor	Fatigue	Confusion
SC	Pre-trial	1.7 ± 1.8	0.2 ± 0.4	0.2 ± 0.7	10.0 ± 3.2	2.0 ± 2.1	0.5 ± 0.8
	Post-trial	1.3 ± 1.9	0.01 ± 0.3	0.1 ± 0.3	12.5 ± 2.8	2.0 ± 2.4	0.5 ± 1.2
PE	Pre-trial	1.9 ± 2.0	0.0 ± 0.0	0.0 ± 0.0	9.7 ± 3.7	1.2 ± 1.5	0.6 ± 1.1
	Post-trial	1.3 ± 2.4	0.2 ± 0.5	0.1 ± 0.2	11.4 ± 3.9	1.2 ± 1.5	1.0 ± 2.0
EC	Pre-trial	2.7 ± 2.8	0.2 ± 0.5	0.01 ± 0.5	9.8 ± 3.9	2.0 ± 2.5	0.8 ± 1.2
	Post-trial	1.5 ± 1.8	0.3 ± 1.1	0.0 ± 0.0	10.8 ± 3.3	1.4 ± 1.8	0.9 ± 1.4

No main effect of condition for mood states reported pre-trial or retrospectively on MANOVA or MANCOVA outcomes.

Figure 1

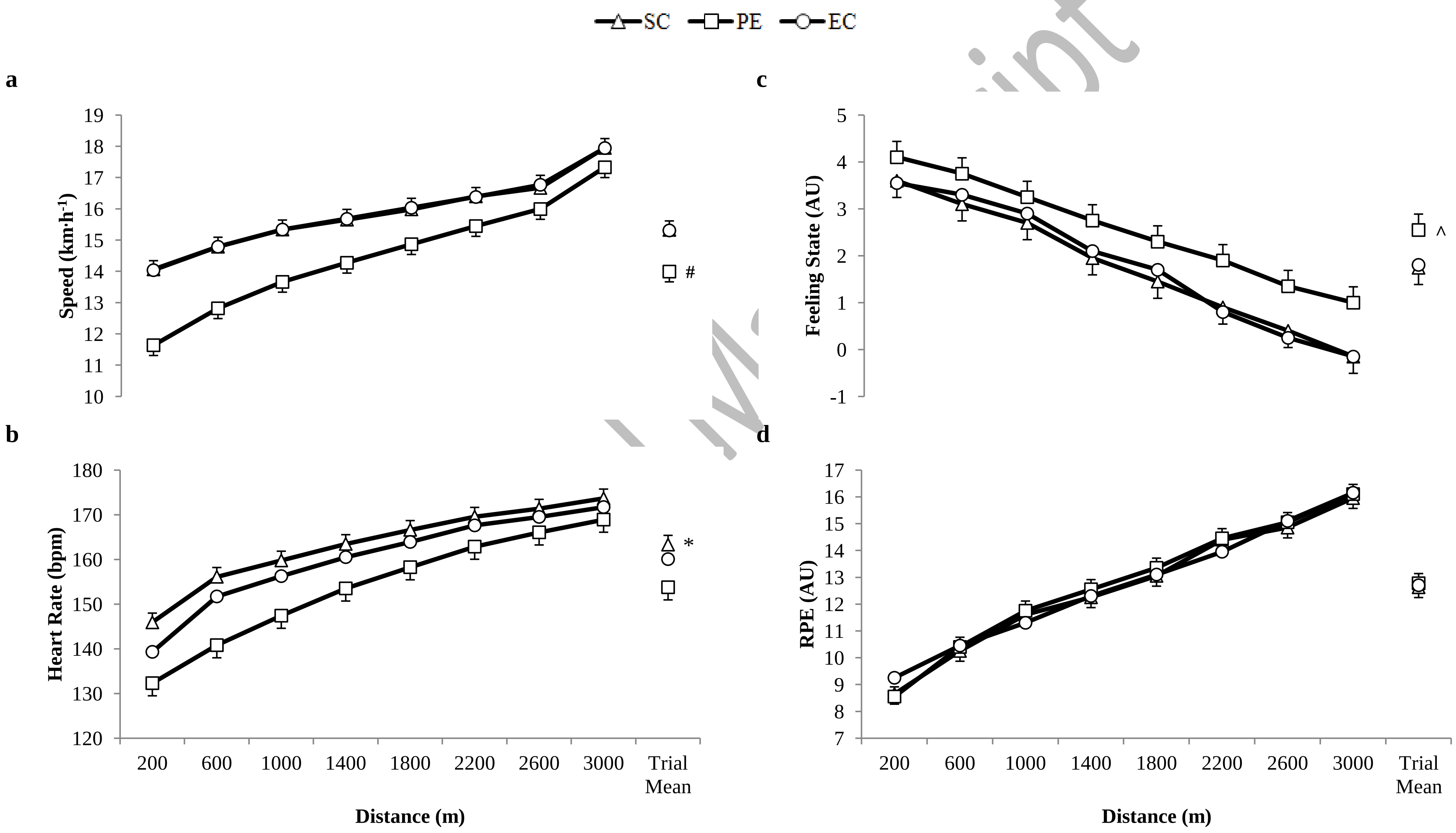
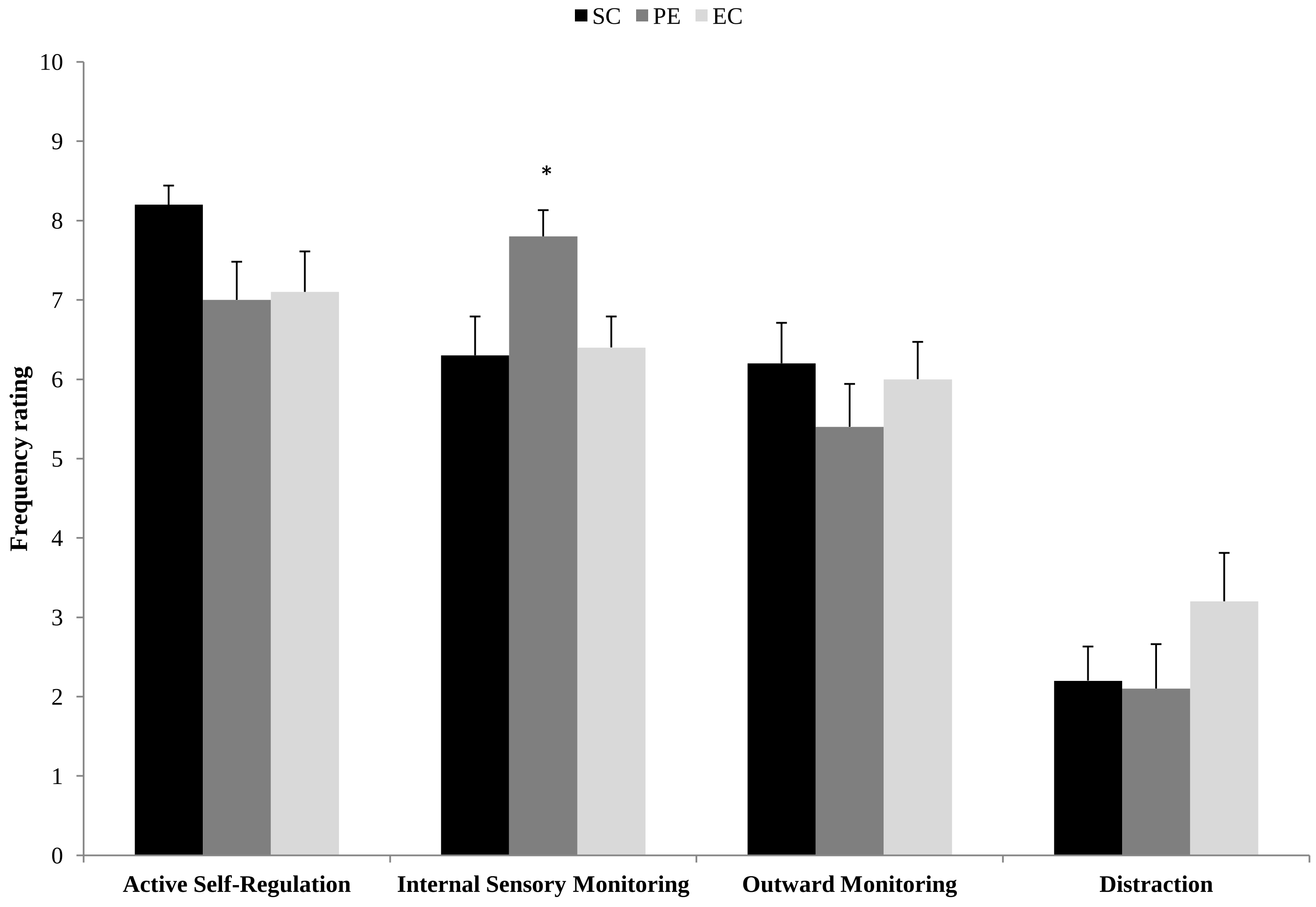

SC
PE
EC
a
Speed (km·h-1)
19
18
17
16
15
14
13
12
11
10
#
b
Heart Rate (bpm)
180
170
160
150
140
130
120
*
200
600
1000
1400
1800
2200
2600
3000
Trial Mean
Distance (m)
c
Feeling State (AU)
5
4
3
2
1
0
-1
^
d
RPE (AU)
17
16
15
14
13
12
11
10
9
8
7
200
600
1000
1400
1800
2200
2600
3000
Trial Mean
Distance (m)

Figure 2



SC
PE
EC
Frequency rating
10
9
8
7
6
5
4
3
2
1
0
*
Active Self-Regulation
Internal Sensory Monitoring
Outward Monitoring
Distraction

Figure 3