Int. J. Sport Psychol., 2025; 56: 415-428
doi: 10.7352/IJSP.2025.56.415

The role of interoceptive awareness in running: Insights from the multidimensional assessment of interoceptive awareness

Yuya Maruo

[1]*Department of Physical Education, Tokyo Women's College of Physical Education, Kunitachi, Japan*

Interoceptive awareness may play an important role in self-regulation of physical exertion. This study investigated pacing strategies in endurance running among college students and explored the relationship between running performance and individual differences in interoceptive awareness. Participants completed an 800m time trial, and interoceptive awareness was assessed using the Japanese version of the 32-item Multidimensional Assessment of Interoceptive Awareness (MAIA). The 800m time was subjected to a two-way repeated-measures analysis of variance, including the factors "lap" and "group". Pearson's correlation analysis was used to examine the relationship between 800m time and MAIA scores. Results indicated that the higher-performing group adopted a positive pacing strategy, characterized by a gradual deceleration after 400m. Furthermore, faster 800m times were associated with higher scores in Attention Regulation, Emotional Awareness, Self-Regulation, and Trusting scores. These findings support the notion of an interaction between physical activity and interoceptive processes. (143 words)

KEY WORDS: Running, Pacing, The Multidimensional Assessment of Interoceptive Awareness

Introduction

The perception of fatigue, body awareness, and heartbeat, namely interoceptive awareness, could play an important role in the self-control of physical load (Herbert et al., 2007; Morgan & Pollock, 1977; Noakes, 2012; Pennebaker & Lightner, 1980; Smith et al., 2015; Takai, 1998). During endurance running, athletes must manage their energy efficiently to maintain pace (e.g., Christensen et al., 2018a). They need to regulate their physical load

Correspondence to: Yuya Maruo, Department of Physical Education, Tokyo Women's College of Physical Education, 1-40-3 Fujimidai, Kunitachi, Tokyo, Japan(E-mail: y-maruo@twcpe.ac.jp).

to avoid slowing down in the latter stages of a race. Pacing strategies can be categorized into six types: positive, negative, even, all-out, parabolic-shaped, and variable (Abbiss & Laursen, 2008; Billat et al., 2001; Edwards & Polman, 2013; Tucker & Noakes, 2009). Analysis of race data has highlighted the effectiveness of positive and even pace strategies, leading to remarkable achievements, including world records (Abbiss & Laursen, 2008; Casado et al., 2021; 2024; Comino et al., 2025; Foster et al., 1994; Hanley et al., 2019; Hanon & Thomas, 2011; Sandford et al., 2018). A positive pace strategy involves gradually reducing speed throughout the race, while an even pace strategy maintains a constant speed. Thus, pacing is crucial in endurance running.

In the context of interoceptive awareness in long-distance running, the first survey by Morgan and Pollock (1977) revealed that elite marathon runners focused on respiration and fatigue while non-elite marathon runners did not focus on respiration and fatigue. Previous studies have indicated that highly trained runners exhibit greater awareness of body signals compared to non-elite runners (Takai, 1998), and mental fatigue correlates with running performance (Smith et al., 2015). Furthermore, elite long-distance runners showed better regulation of attention to internal sensations and higher bodily trust (Seabury et al., 2023). According to the central governor model (Gibson et al., 2003; Inzlicht & Marcora, 2016; Noakes et al., 2001; Weir et al., 2006), athletes can anticipate exhaustion and regulate performance by integrating sensory inputs from the heart, respiratory muscles, and emotions related to fatigue (Behrens et al., 2023; Foster et al., 2023; Gibson et al., 2003; Inzlicht & Marcora, 2016; Noakes, 2012; Noakes et al., 2001; Renfree et al., 2012). The integration of sensory information influences perceived fatigue, which in turn regulates adjustments in exercise intensity within an individual's physiological limits. Throughout exercise, athletes anticipate and modulate their effort to sustain exercise intensity within their physiological capacity until the goal, thus avoiding maximal fatigue (exhaustion). Regulating perceived fatigue and exercise intensity facilitates optimal pacing strategies (Noakes, 2012). These results suggest that individuals with higher interoceptive awareness and fatigue sensitivity demonstrate better pacing and physical load management during middle- and long-distance running.

Interoceptive awareness encompasses not only the perception of heartbeat and bodily sensations but also emotion (Domschke et al., 2010; Paulus & Stein, 2010). Interoceptive signals have an impact on emotional processes, and individuals with high interoceptive awareness tend to experience more anxiety (Critchley & Garfinkel, 2017). Bodily and emotional awareness, or somatic markers, significantly contribute to behavioural control (e.g., Bechara, 2004; Bechara & Damasio, 2005; Bechara et al., 1997). Previous studies have shown that bodily arousal signals and emotions influence decision-making and risk-taking behaviours (Bechara, 2004; Bechara & Damasio, 2005; Wagar & Dixon, 2006). In middle- and long-distance running, athletes must balance intensity regulation to avoid exhaustion with maximizing speed to reach the finish line, accepting the risk of approaching maximal fatigue. Given the role of affective responses in guiding behaviour, awareness of body signals and emotions might be relevant in managing physical load and pacing, even in long-distance running.

A recent questionnaire study examined the relationship between interoceptive awareness and risk propensity, revealing that individuals with a greater capacity to ignore or disregard visceral signals when uncomfortable exhibited higher risk-taking tendencies (Reader & Salvato, 2024). Additionally, a few studies have demonstrated a positive association between interoceptive awareness and sports performance (Christensen et al., 2018b; Hirao et al., 2020; Mizuno & Masaki, 2023; Seabury et al., 2023). Skilled dancers and runners possess higher interoceptive awareness compared to novices (Christensen et al., 2018b; Mizuno & Masaki, 2023; Seabury et al., 2023). However, previous studies have overlooked individual differences in interoceptive awareness regarding pacing in endurance running. Since interoceptive awareness influences risk propensity (Reader & Salvato, 2024), individuals with higher interoceptive awareness are more likely to maintain a consistent pace during races.

This study aimed to investigate pacing in running among college students. Inexperienced runners often struggle to adopt optimal pacing strategies (Lambrick et al., 2013; Morgan & Pollock, 1977; Takai, 1998). Additionally, this study examined the relationship between running performance and individual differences in interoceptive awareness using 800m time trials (Lambrick et al., 2013). The Multidimensional Assessment of Interoceptive Awareness scale (MAIA scale; Brown et al., 2017; Fujino, 2019; Jones et al., 2021; Lin et al., 2017; Machorrinho et al., 2019; Mehling et al., 2012; Shoji et al., 2018) was used to measure self-reported interoceptive awareness across eight subscales: Noticing, Not Distracting, Not Worrying, Attention Regulation, Emotional Awareness, Self-Regulation, Body Listening, and Trusting. If participants attend to internal cues such as respiration and fatigue (Morgan & Pollock, 1977; Takai, 1998), those with higher scores in attention regulation and trust are expected to perform better in 800m time trials. Furthermore, we investigated individual differences in interoceptive awareness related to respiration, fatigue, emotions, and body awareness and their impact on running performance. Individuals with higher emotional awareness scores are expected to exhibit superior performance, given the association between somatic markers and decision-making as well as behavioral control (Bechara, 2004; Bechara & Damasio, 2005; Wagar & Dixon, 2006).

Methods

Participant

Eighty female participants (mean age ± SD = 20.1 ± 0.6 years) were recruited. Written informed consent was obtained from all participants. The participants were undergraduate students from the department of physical education at a women's college. One participant, a long-distance runner belonging to the college's track and field club, was excluded from the study. Ten participants did not complete questionnaires. The final sample comprised sixty-nine participants (mean age ± SD = 20.1 ± 0.6 years). This study was approved by the Local Ethics Committee (2020-03)

Questionnaire

We used the Japanese version of the 32-item MAIA scale translated by Shoji et al. (2018) from the original scale of Mehling et al. (2012). The 32-item MAIA scale measures eight psychological domains, which comprise the following subscales: Noticing (e.g., When I am tense I notice where the tension is located in my body.), Not Distracting (e.g., I do not notice physical tension or discomfort until they become more severe.), Not Worrying (e.g., When I feel physical pain, I become upset.), Attention Regulation (e.g., I can pay attention to my breath without being distracted by things happening around me.), Emotional Awareness (e.g., I notice how my body changes when I am angry.), Self-Regulation (e.g., When I feel overwhelmed I can find a calm place inside.), Body Listening (e.g., I listen for information from my body about my emotional state.), and Trusting (e.g., I trust my body sensations.). Participants were asked to indicate on a 5-point rating scale (1 = never; 5 = *VERY OFTEN).*

Procedures

Running performance consisted of 800m time trial (Lambrick et al., 2013) on a 300m outdoor track within a single day. Participants had the option to choose between two testing days, selecting the day they deemed themselves to be in the best physical condition. Measurements were conducted under sunny conditions on both days between the hours of 10:45 and 12:15 (11:00 on day 1, 45.0 °F; day 2, 45.3 °F). Participants were instructed to wear appropriate running clothes for ease of movement and were not allowed to wear timekeeping devices such as watches. Coloured cones were positioned at each 100m point of the 800m distance in the track. The 800m running test was recorded by video (JVC Kenwood, GZ-RX500-N). The total time for the 800m and the lap time for each 100m were recorded using a video. Participants selected target times from a predefined set: 2 minutes and 50 seconds, 3 minutes, 3 minutes and 10 seconds, and 3 minutes and 20 seconds. Based on their chosen target times, participants were divided into groups of 5 to 8 people. Participants were instructed that, while grouped with others who selected the same target time, performance faster or slower than that time was acceptable, and that they should complete the 800m as fast as possible. No feedback was provided to the participants until the finish line. Participants were not informed of any pacing strategy beforehand. Participants completed the MAIA questionnaire after 800m run.

Data Analysis

By employing Kinovea (version 0.9.3), a video and motion analysis software, the time for each 100-meter split was calculated. Descriptive statics were calculated for each measure. To evaluate the final sprint, I used the time taken between 700 and 800 meters. To evaluate the participants' pacing behaviour, the slowest 100m lap time was extracted from each 800m lap time. Participants were dichotomized into a higher-performance group and a lower-performance group based on a median split of their goal times (median = 200.6 s). As a result, 35 participants were assigned to the high-performance and 34 participants were assigned to low-performance groups. 800m lap time was subjected to a two-way repeated-measures analysis of variance (ANOVA), including the factors "lap" (0-100m/100-200m/200-300m/300-400m/400-500m/500-600m/600-700m/700-800m) and "group" (Higher-performance group /Lower-performance group). The degrees of freedom of all F-ratios were adjusted using the Greenhouse-Geisser procedure. The original degrees of freedom are reported with the epsilon value where required. The Bonferroni correction was applied for post hoc comparisons. The Cronbach's α of Noticing, Not distracting, Not worrying, attention regulation, emotional awareness, self-regulation, body listening and trusting were 0.35, 0.69, 0.61, 0.96, 0.96, 0.98, 0.98 and 0.99, respectively. In the present study, three subscales did not reach an acceptable Cronbach's α (α = .70; George & Mallery, 2003) and were excluded (Seabury et al., 2023). We performed two-sided Pearson's correlation analysis to investigate the relationship between the running time in 800m (total time, lap time for 700-800m, the slowest lap time, and the difference between the 700-800m lap time and the slowest lap time) and the MAIA scores (attention regulation, emotional awareness, self-regulation, body listening and trusting). All statistical analyses were executed using JASP (0.19.0.0) for Windows.

Results

Performance Measures

Table I shows descriptive statics for each variable. The mean 800m time was 201.5 sec (±18.5 SD). Figure 1 depicts the pacing for each group. A two-way ANOVA revealed that that the interaction between lap and group was significant ($F(7, 469) = 17.39$, $p = .01$, ${}_p\eta^2 = .21$). Post-hoc test revealed that lap time for higher-performance group was faster in 0-100m than 400-500m ($p < .01$) and 500-600m ($p < .01$). Lap time for higher-performance group was faster in 100-200m than 400-500m ($p < .01$) and 500-600m ($p < .01$). Lap time for higher-performance group was faster in 200-300m than 400-500m

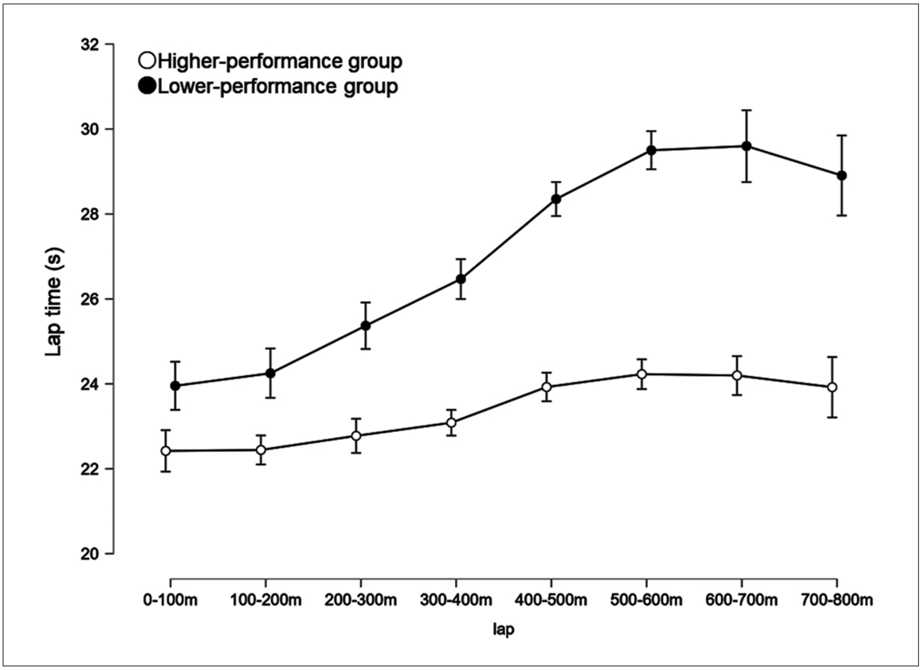

Figure 1. - The upper panel shows average time (s) for each group. The error bar shows 95% confidence interval.

($p < .01$) and 500-600m ($p < .01$). Lap time for higher-performance group was faster in 300-400m than 400-500m ($p < .01$) and 500-600m ($p < .01$). Post-hoc test revealed that lap time for lower-performance group was faster in 0-100m than 200-300m ($p < .05$), 400-500m ($p < .01$), 500-600m ($p < .01$), 600-700m ($p < .01$) and 700-800m ($p < .01$). Lap time for lower-performance group was faster in 100-200m than 200-300m ($p < .01$), 300-400m ($p < .01$), 400-500m ($p < .01$), 500-600m ($p < .01$), 600-700m ($p < .01$) and 700-800m ($p < .01$). Lap time for lower group was faster in 200-300m than 300-400m ($p < .01$), 400-500m ($p < .01$), 500-600m ($p < .01$), 600-700m ($p < .01$) and 700-800m ($p < .01$). Lap time for lower-performance group was faster in 300-400m than 400-500m ($p < .01$), 500-600m ($p < .01$), 600-700m ($p < .01$) and 700-800m ($p < .01$). Lap time for lower-performance group was faster in 400-500m than 500-600m ($p < .01$). Two-way ANOVA revealed a main effect of lap ($F(7, 469) = 68.76$, $p =. 01$, ${}_p\eta^2 =.51$) and group ($F(1, 67) = 118.05$, $p =. 01$, ${}_p\eta^2 =.64$).

TABLE I.
Descriptive Statics For Each Variable.

	0-100m	100-200m	200-300m	300-400m	400-500m	500-600m	600-700m	700-800m
Lap time (s, SD)								
Higher-performance group	22.4 (1.2)	22.3 (1.1)	22.6 (1.4)	23.0 (1.5)	23.8 (1.6)	24.1 (1.9)	24.1 (2.1)	23.8 (2.6)
Lower-performance group	23.9 (0.8)	24.3 (0.7)	25.4 (1.1)	26.4 (2.0)	28.3 (2.3)	29.4 (2.4)	29.5 (3.5)	28.8 (3.6)

TABLE II.
The Correlations Between 800m Times And MAIA Scores.

	1	2	3	4	5	6	7	8
1. 800m time (s)	-							
2. 700-800m lap time (s)	.86**	-						
3. The slowest lap time (s)	.95**	.89**	-					
4. The difference between the slowest lap time and lap time minus the 700-800m	.02	.44**	-.02	-				
5. Attention regulation	-.43**	-.39**	-.41**	-.04	-			
6. Emotional awareness	-.35**	-.25*	-.30*	.05	.64**	-		
7. Self-regulation	-.39**	-.29*	-.43**	.21	.60**	.56**	-	
8. Body listening	-.15	-.15	-.18	.04	.52**	.46**	.58**	-
9. Trusting	-.44**	-.36**	-.41**	.01	.57**	.68**	.59**	.64**

$^{**}p < .01$, $^{*}p < .05$

Correlation Between Running Performance And Maia Scores

Table 2 shows the correlations between 800m time trial and MAIA scores. The mean of Attention Regulation score was 2.9 (±0.9 SD). The mean of Emotional Awareness score was 3.2 (±0.8 SD). The mean of Self-Regulation score was 3.2 (±0.9 SD). The mean of Body Listening score was 2.9 (±0.9 SD). The mean of Trusting score was 3.4 (±1.0 SD). The individuals with higher Attention Regulation score showed faster 800m total time (r = -.43, p = .01, z = -.46), lap time for 700-800m (r = -.39, p = .01, z = -.41) and the slowest lap time (r = -.41, p = .01, z = -.44). The individuals with higher Self-Regulation score showed faster 800m total time (r = -.39, p = .01, z = -.41), lap time for 700-800m (r = -.29, p = .02, z = -.30) and the slowest lap time (r = -.43, p = .01, z = -.46). The individuals with higher Emotional Awareness score showed faster 800m total time (r = -.35, p = .01, z = -.37), lap time for 700-800m (r = -.25, p = .04, z = -.26) and the slowest lap time (r = -.30, p = .01, z = -.31). The individuals with higher Trusting score showed faster 800m total time (r = -.44, p = .01, z = -.47), lap time for 700-800m (r = -.36, p = .01, z = -.38) and the slowest lap time (r = -.41, p = .01, z = -.43). No significant correlation was found between 800m total time and Body Listening score (r = -.15, p = .24, z = -.15).

Discussion

The present study aimed to investigate pacing strategies in 800m time trials among college students. Additionally, this study examined the relationship between running performance and individual differences in interoceptive awareness. Higher-performance participants adopted a positive pacing strategy, gradually decelerating after 400m. The individuals with faster 800m total times showed higher Attention Regulation, Emotional Awareness, Self-Regulation, and Trusting scores. The individuals with faster final sprints and the time for slowest lap showed higher Attention Regulation, Emotional Awareness, Self-Regulation, and Trusting scores.

The interaction between lap time and group demonstrated significant differences in pacing strategies between the two groups. Higher-performance group employed a positive pacing strategy, while lower-performance group employed an all-out pacing strategy. Previous studies suggested that for 800m positive pacing is the optimal strategy to achieve a fast time (Abbiss & Laursen, 2008; Casado et al., 2021; Foster et al., 1994; Hanon & Thomas, 2011; Sandford et al., 2018). In the present study, for high-performance group there was little deceleration every 100m up to 400m; for instance, no significant deceleration occurred from the 0-100m section to the 100-200 m. Statistically significant deceleration was observed in the 400-500m section, but no significant deceleration occurred in subsequent sections until reaching the finish line. The results suggest that participants achieved their maximum sustainable speed within physiological constraints during the initial phase of the 800m race (Casado et al., 2021), subsequently maintaining a pace within these limits to avoid exhaustion before the finish (Noakes, 2012). On the one hand, Lower-performance group showed a significant decrease in speed after the first 100m. These results are partially consistent with those of a previous study (Lambrick et al., 2013). Lower-performance group may have overestimated their initial pace, suggesting a need to refine their pacing strategy. The observed rapid deceleration after the 100m mark suggests a misjudgment of physiological capacity in the first half of the race, possibly resulting in overpacing. Lower-performance group may improve through enhanced pacing strategies (Lambrick et al., 2013). These results reflect the group differences that higher-performance participants paced well while others did not.

The abovementioned pacing was found to be associated with individual differences in interoceptive awareness. We found that participants with faster 800m times and final sprint demonstrated higher scores of attention regulation and self-regulation. These results suggest that participants who can consciously focus on their body and breathing without distraction demonstrate faster final sprints and better running performance. Furthermore, participants with a high ability to regulate pain through focused on bodily sensations demonstrate faster final sprints and better running performance. Our findings extend previous findings that physical activity interacts with interoceptive processes (Christensen et al., 2018b; Gibson et al., 2003; Inzlicht & Marcora, 2016; Wallman-Jones et al., 2021; Weir et al.,2006). Previous studies have shown that skilled dancers and elite runners are sensitive to interoceptive awareness (Christensen et al., 2018b; Seabury et al., 2023), and that superior runners tend to focus on their breathing and fatigue (Morgan & Pollock, 1977). The brain integrates various signals including respiration, fatigue, bodily sensations, and emotions to predict and control physical load (Gibson et al., 2003; Noakes et al., 2001; Smith et al., 2015; Renfree et al., 2012). It is likely that participants adept at bodily awareness and controlled breathing may achieve better performance under self-regulated physical load.

In addition, participants who demonstrated faster 800m times exhibited higher scores on Emotional Awareness. This finding is consistent with the notion that somatic markers may facilitate optimal decision-making and self-control in risky situations (Bechara, 2004; Bechara & Damasio, 2005; Wagar & Dixon, 2006). Emotional Awareness is demonstrated by statements such as "I notice how my body changes when I am angry" and correlate with awareness to emotional changes. During 800m running, participants must manage both effort within physiological limits and increasing discomfort and fatigue (Noakes, 2012). Present study revealed that emotional awareness is also essential for achieving superior running performance and final sprint. Previous studies reported that fatigue caused by emotion regulates exercise performance (Gibson et al., 2003; Noakes, 2012; Renfree et al., 2012). According to the findings of the central governor model (Gibson et al., 2003; Inzlicht & Marcora, 2016; Noakes et al., 2001; Weir et al., 2006), discomfort and fatigue sensations increase to prevent exhaustion before the goal. Our results suggest a connection between emotional awareness and self-regulated physical load and pacing.

Faster running performance was correlated with high trusting scores. Trusting score is associated with experience of one's body as safe and trustworthy (Mehling et al., 2012). Trusting bodily sensations is considered an important component of pain management (Steen & Haugli, 2001). Endurance running can cause physical and psychological discomfort due to the stain it places on breathing and the body. Individuals who feel safe and trust their bodies may handle greater physical loads. Seabury et al. (2023) found that athletes reported higher trusting to their own bodies than non-athletes. Our result suggested that even participants not specialized in running, faster-performance participants felt safe and trusting of their bodies. Running fast might require heightened awareness to trusting one's body, enduring intense physical loads, and effectively managing discomfort without slowing down.

It should be noted that our study included some limitations. First, the current study focused on the measurement and analysis of running time, neglecting the physiological assessment of anaerobic and aerobic capacities. Physical condition and fatigue could be monitored by measuring heart rate and lactate levels. Furthermore, interoception could also be physiologically measured, such as through the heartbeat counting task (HCT; Herbert et al., 2007; Schandry, 1981). Future research could clarify the relationship between interoceptive awareness and running performance through physiological assessments. Second, more detailed data regarding participants' running experience and current physical activity levels should have been collected. Third, this study examined only women's college students. Future research could include a more diverse sample, such as male students and highly trained endurance athletes, to enhance the generalizability of the findings.

The current study found that a faster running time in the 800m was associated with higher Attention Regulation, Emotional Awareness, Self-Regulation, and Trusting scores. The results of the present study are consistent with the idea that physical activity interacts with interoceptive processes (Gibson et al., 2003; Inzlicht & Marcora, 2016; Wallman-Jones et al., 2021; Weir et al., 2006). Additionally, the trust of the body and distraction from discomfort may lead to faster endurance performance. The present findings may provide further evidence that interoceptive awareness, in addition to physiological factors (e.g., maximal oxygen uptake), is positively associated with endurance running performance. Endurance runners should continuously focus on their interoceptive awareness. Coaches and athletes can improve training by focusing on interoceptive cues, such as breathing and heart rate, and using subjective fatigue to gauge exercise intensity.

Generated for this study are available on request to the corresponding.

REFERENCES

Abbiss, C. R., & Laursen, P. B. (2008). Describing and understanding pacing strategies during athletic competition. *Sports Medicine*, 38(3), 239-252. https://doi.org/10.2165/00007256-200838030-00004

Bechara, A. (2004). The role of emotion in decision-making: Evidence from neurological patients with orbitofrontal damage. *Brain and Cognition*, 55(1), 30-40. https://doi.org/10.1016/j.bandc.2003.04.001

Bechara, A., & Damasio, A. R. (2005). The somatic marker hypothesis: A neural theory of economic decision. *Games and Economic Behavior*, 52(2), 336-372. https://doi.org/10.1016/j.geb.2004.06.010

Bechara, A., Damasio, H., Tranel, D., & Damasio, A. R. (1997). Deciding advantageously before knowing the advantageous strategy. *Science*, 275(5304), 1293-1295. https://doi.org/10.1126/science.275.5304.1293

Behrens, M., Gube, M., Chaabene, H., Prieske, O., Zenon, A., Broscheid, K. C., Schega, L., Husmann, F., & Weippert, M. (2023). Fatigue and human performance: an updated framework. *Sports medicine*, 53(1), 7-31. https://doi.org/10.1007/s40279-022-01748-2

Billat, V. L., Slawinski, J., Danel, M., & Koralsztein, J. P. (2001). Effect of free versus constant pace on performance and oxygen kinetics in running. *Medicine & Science in Sports & Exercise*, 33(12), 2082-2088. https://doi.org/10.1097/00005768-200112000-00017

Brown, T. A., Berner, L. A., Jones, M. D., Reilly, E. E., Cusack, A., Anderson, L. K., Kaye, W. H., & Wierenga, C. E. (2017). Psychometric evaluation and norms for the Multidimensional Assessment of Interoceptive Awareness (MAIA) in a clinical eating disorders sample. *European Eating Disorders Review*, 25(5), 411-416. https://doi.org/10.1002/erv.2532

Casado, A., Hanley, B., Jiménez-Reyes, P., & Renfree, A. (2021). Pacing profiles and tactical behaviors of elite runners. *Journal of Sport and Health Science*, 10(5), 537-549. https://doi.org/10.1016/j.jshs.2020.06.011

Casado, A., Ranieri, L. E., Díaz, J. J., Hanley, B., & Foster, C. (2024). Pacing strategies in men's and women's world record marathon performances and Olympic Games and World Championship's winning performances. *Kinesiology*, 56(1), 153-162.

Christensen, D. A., Brewer, B. W., & Hutchinson, J. C. (2018a). Psychological predictors of performance in a 161 km ultramarathon run. *International Journal of Sport Psychology*, 49(1), 74-90. doi:10.7352/IJSP.2018.49.074

Christensen, J. F., Gaigg, S. B., & Calvo-Merino, B. (2018b). I can feel my heartbeat: Dancers have increased interoceptive accuracy. *Psychophysiology*, 55(4), e13008. https://doi.org/10.1111/psyp.13008

Comino, P., Foster, C., Renfree, A., & Casado, A. (2025). Tactical behaviors in men's and women's middle-distance global championship track finals. *International Journal of Sports Physiology and Performance*, 1, 1-11. https://doi.org/10.1123/ijspp.2024-0393

Critchley, H. D., & Garfinkel, S. N. (2017). Interoception and emotion. *Current opinion in psychology*, 17, 7-14. https://doi.org/10.1016/j.copsyc.2017.04.020

Domschke, K., Stevens, S., Pfleiderer, B., & Gerlach, A. L. (2010). Interoceptive sensitivity in anxiety and anxiety disorders: an overview and integration of neurobiological findings. *Clinical psychology review*, 30(1), 1-11. https://doi.org/10.1016/j.cpr.2009.08.008

Edwards, A. M., & Polman, R. C. J. (2013). Pacing and awareness: brain regulation of physical activity. *Sports Medicine*, 43, 1057-1064. https://doi.org/10.1007/s40279-013-0091-4

Foster, C., Schrager, M., Snyder, A. C., & Thompson, N. N. (1994). Pacing strategy and athletic performance. *Sports Medicine*, 17(2), 77-85. https://doi.org/10.2165/00007256-199417020-00001

Foster, C., De Koning, J. J., Hettinga, F. J., Barroso, R., Boullosa, D., Casado, A., Cortis, C., Fusco, A., Gregorich, H., Jaime, S., Jones, A. M., Malterer, K. R., Reinschmidt, P., Skiba, P., Splinter, A., St Clair Gibson, A., St Mary, J., Thiel, C., Uithoven, K., & van Tunen, J. (2023). Competition between desired competitive result, tolerable homeostatic disturbance, and psychophysiological interpretation determines pacing strategy. *International Journal of Sports Physiology and Performance*, 18(4), 335-346. https://doi.org/10.1123/ijspp.2022-0171

Fujino, H. (2019). Further validation of the Japanese version of the Multidimensional Assessment of Interoceptive Awareness. *BMC Research Notes*, 12, 1-6. https://doi.org/10.1186/s13104-019-4556-x

George, D., & Mallery, P. (2003). SPSS for Windows Step by Step: A Simple Guide and Reference. 11.0 Update (4th ed.). Boston: Allyn & Bacon.

Gibson, A. S. C., Baden, D. A., Lambert, M. I., Lambert, E. V., Harley, Y. X., Hampson, D., Russell, V. A., & Noakes, T. D. (2003). The conscious perception of the sensation of fatigue. *Sports Medicine*, 33, 167-176. https://doi.org/10.2165/00007256-200333030-00001

Hanley, B., Stellingwerff, T., & Hettinga, F. J. (2019). Successful pacing profiles of Olympic and IAAF World Championship middle-distance runners across qualifying rounds and finals. *International Journal of Sports Physiology and Performance*, 14(7), 894-901.

Hanon, C., & Thomas, C. (2011). Effects of optimal pacing strategies for 400-, 800-, and 1500-m races on the [Vdot] O2 response. *Journal of Sports Sciences*, 29(9), 905-912. https://doi.org/10.1080/02640414.2011.562232

Herbert, B. M., Pollatos, O., & Schandry, R. (2007). Interoceptive sensitivity and emotion processing: an EEG study. *International Journal of Psychophysiology*, 65(3), 214-227. https://doi.org/10.1016/j.ijpsycho.2007.04.007

Hirao, T., Vogt, T., & Masaki, H. (2020). Difference in interoception between long-distance runners and sprinters: An Event-related Potential Study. *Medicine & Science in Sports & Exercise*, 52(6), 1367-1375. https://doi.org/10.1249/MSS.0000000000002248

Inzlicht, M., & Marcora, S. M. (2016). The central governor model of exercise regulation teaches us precious little about the nature of mental fatigue and self-control failure. *Frontiers in Psychology*, 7, 656. https://doi.org/10.3389/fpsyg.2016.00656

Jones, A., Silas, J., Todd, J., Stewart, A., Acree, M., Coulson, M., & Mehling, W. E. (2021). Exploring the Multidimensional Assessment of Interoceptive Awareness in youth aged

7-17 years. *Journal of Clinical Psychology*, 77(3), 661-682. https://doi.org/10.1002/jclp.23067

Lambrick, D., Rowlands, A., Rowland, T., & Eston, R. (2013). Pacing strategies of inexperienced children during repeated 800 m individual time-trials and simulated competition. *Pediatric Exercise Science*, 25(2), 198-211. https://doi.org/10.1123/pes.25.2.198

Lin, F.-L., Hsu, C.-C., Mehling, W., & Yeh, M.-L. (2017). Translation and psychometric testing of the Chinese version of the multidimensional assessment of interoceptive awareness. *Journal of Nursing Research*, 25(1), 76-84. https://doi.org/10.1097/jnr.0000000000000182

Machorrinho, J., Veiga, G., Fernandes, J., Mehling, W., & Marmeleira, J. (2019). Multidimensional assessment of interoceptive awareness: Psychometric properties of the Portuguese version. *Perceptual and motor skills*, 126(1), 87-105. https://doi.org/10.1177/0031512518813231

Mehling, W. E., Price, C., Daubenmier, J. J., Acree, M., Bartmess, E., & Stewart, A. (2012). The multidimensional assessment of interoceptive awareness (MAIA). *PLoS One*, 7(11), e48230. https://doi.org/10.1371/journal.pone.0048230

Mizuno, K., & Masaki, H. (2023). The effects of internal focus of attention and interoceptive abilities on golf putting performance. *Japanese Psychological Research*, 65(4), 277-293. https://doi.org/10.1111/jpr.12478

Morgan, W. P., & Pollock, M. L. (1977). Psychologic characterization of the elite distance runner. *Annals of the New York Academy of Sciences*, 301(1), 382-403. https://doi.org/10.1111/j.1749-6632.1977.tb38215.x

Noakes, T. D. (2012). Fatigue is a Brain-Derived Emotion that Regulates the Exercise Behavior to Ensure the Protection of Whole Body Homeostasis. *Frontiers in Physiology*, 3, 82. https://doi.org/10.3389/fphys.2012.00082

Noakes, T. D., Peltonen, J. E., & Rusko, H. K. (2001). Evidence that a central governor regulates exercise performance during acute hypoxia and hyperoxia. *Journal of Experimental Biology*, 204(18), 3225-3234. https://doi.org/10.1242/jeb.204.18.3225

Paulus, M. P., & Stein, M. B. (2010). Interoception in anxiety and depression. *Brain structure and Function*, 214, 451-463. https://doi.org/10.1007/s00429-010-0258-9

Pennebaker, J. W., & Lightner, J. M. (1980). Competition of internal and external information in an exercise setting. *Journal of Personality and Social Psychology*, 39(1), 165-174. https://doi.org/10.1037/0022-3514.39.1.165

Reader, A. T., & Salvato, G. (2024). Investigating the relationship between self-reported interoceptive experience and risk propensity. *Cognition and Emotion*, 38(1), 148-162. https://doi.org/10.1080/02699931.2023.2279160

Renfree, A., West, J., Corbett, M., Rhoden, C., & Gibson, A. S. C. (2012). Complex interplay between determinants of pacing and performance during 20-km cycle time trials. *International Journal of Sports Physiology and Performance*, 7(2), 121-129. https://doi.org/10.1123/ijspp.7.2.121

Sandford, G. N., Pearson, S., Allen, S. V., Malcata, R. M., Kilding, A. E., Ross, A., & Laursen, P. B. (2018). Tactical behaviors in men's 800-m olympic and world-championship medalists: a changing of the guard. *International journal of sports physiology and performance*, 13(2), 246-249. https://doi.org/10.1123/ijspp.2016-0780

Schandry, R. (1981). Heart beat perception and emotional experience. *Psychophysiology*, 18(4), 483-488. https://doi.org/10.1111/j.1469-8986.1981.tb02486.x

Seabury, T., Benton, D., & Young, H. A. (2023). Interoceptive differences in elite sprint and long-distance runners: A multidimensional investigation. *Plos one*, 18(1), e0278067. https://doi.org/10.1371/journal.pone.0278067

Shoji, M., Mehling, W. E., Hautzinger, M., & Herbert, B. M. (2018). Investigating multidimensional interoceptive awareness in a Japanese population: validation of the Japanese MAIA-J. *Frontiers in Psychology*, 9, 1855. https://doi.org/10.3389/fpsyg.2018.01855

Smith, M. R., Marcora, S. M., & Coutts, A. J. (2015). Mental fatigue impairs intermittent running performance. *Medicine & Science in Sports & Exercise*, 47(8), 1682-1690. https://doi.org/10.1249/mss.0000000000000592

Steen, E., & Haugli, L. (2001). From pain to self-awareness–a qualitative analysis of the significance of group participation for persons with chronic musculoskeletal pain. *Patient Education and Counseling*, 42(1), 35-46. https://doi.org/10.1016/S0738-3991(00)00088-4

Takai, K. (1998). Cognitive strategies and recall of pace by long-distance runners. *Perceptual and motor skills*, 86(3), 763-770. https://doi.org/10.2466/pms.1998.86.3.763

Tucker, R., & Noakes, T. D. (2009). The physiological regulation of pacing strategy during exercise: a critical review. *British Journal of Sports Medicine*, 43(6), e1. https://doi.org/10.1136/bjsm.2009.057562

Wagar, B. M., & Dixon, M. (2006). Affective guidance in the Iowa gambling task. *Cognitive, Affective, & Behavioral Neuroscience*, 6, 277-290. https://doi.org/10.3758/CABN.6.4.277

Wallman-Jones, A., Perakakis, P., Tsakiris, M., & Schmidt, M. (2021). Physical activity and interoceptive processing: Theoretical considerations for future research. *International Journal of Psychophysiology*, 166, 38-49. https://doi.org/10.1016/j.ijpsycho.2021.05.002

Weir, J., Beck, T., Cramer, J., & Housh, T. (2006). Is fatigue all in your head? A critical review of the central governor model. *British Journal of Sports Medicine*, 40(7), 573-586. https://doi.org/10.1136/bjsm.2005.023028

Manuscript submitted November 2024. Accepted for publication on March 2025.