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Title: Distance-dependant association of affect with pacing strategy in cycling time trials

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Abstract: The psychological construct of affect is proposed to significantly contribute to pacing decisions during exercise. Borg's Ratings of Perceived Exertion (RPE) scale, another important regulator of work-rate, is criticised as an inadequate measure of the multiple perceptual responses experienced. This study aimed to examine power output distribution and associated changes in affect, self-efficacy, perceptual cues, heart rate and respiratory gases during both 16.1 km and 40 km self-paced cycling time trials (TT). Secondly, the differentiation between physical perceptions of exertion and sense of effort in self-paced exercise was investigated. **Method:** Fifteen trained male cyclists completed 16.1 km and 40 km TT using a CompuTrainer cycle ergometer. Time, power output distribution, affect, self-efficacy, physical RPE (P-RPE),

task effort and awareness (TEA), heart rate and respiratory gases were measured throughout each TT. Linear mixed models explored associations of these variables with power output distribution, and the relationship between P-RPE and TEA. **Results:** Similar pacing strategies were adopted in the 16.1 km and 40 km TT ($p = 0.31$) and main effects were found for affect ($p = 0.001$) and respiratory exchange ratio (RER) ($p < 0.001$). Interactions between affect ($p = 0.037$), and RER ($p = 0.004$), with condition indicated closer associations with power output distribution in 16.1 km than 40 km TT. P-RPE was not significantly different from TEA ($p = 0.053$). **Conclusion:** A significant association between affect and power output distribution suggests that affective responses are task-dependent even in self-paced exercise, and a greater association is demonstrated in higher-intensity, 16.1 km TT. Furthermore, physical perceptions of exertion are not clearly differentiated from sense of effort in self-paced exercise.

Key words: exercise regulation, power output, affective valence, perceived exertion, sense of effort

INTRODUCTION

Paragraph Number 1

Pacing strategies are often defined as the distribution of work-rate during exercise (1) and are widely accepted to be an important factor influencing overall athletic performance (13). Previous experience and knowledge of the exercise endpoint are essential factors in the formation of a stable performance template for a given exercise bout and the initial setting of work-rate (14, 17), which is crucial in the development of an optimal pacing strategy. The mechanisms by which pacing strategy is continually regulated during exercise, however, have yet to be clearly identified (20, 44), despite receiving considerable attention in the literature (1, 8, 32). One important cue that has been implicated in the regulation of exercise is the conscious awareness of the sensation of fatigue (37), most commonly measured using Borg's (6) Ratings of Perceived Exertion (RPE) scale. Despite its widespread use, the appropriateness of the single-item RPE scale has recently been criticised as an oversimplification of the complex psychophysiological construct of effort perception, and that it is an inadequate measure of the multiple perceptual responses experienced during exercise (4, 18, 33-34). Recent applications of decision-making theory to pacing (33, 35), further questions the ability of the RPE scale to explain the coupling of perceptions and actions in order to establish behaviour. As RPE encompasses the sense of effort and sensations arising from afferent feedback such as pain and discomfort, it limits our ability to determine which perceptual cues are influential to the regulation of exercise intensity.

Paragraph Number 2 Swart et al. (40) recently proposed a new methodological approach, which endeavoured to separate perceptions of physical exertion from the mental sense of effort during maximal and fixed-intensity 100 km cycling time trials (TT), interspersed with 1 km sprints. A dissociation was observed between the two perceptions in the fixed-intensity trial, performed at 70% of the power output produced in the maximal TT, and during the sprints in

both trials, suggesting that the physical and mental sensations were related yet distinct perceptual cues. These findings further support the multidimensionality of perceived exertion and the complex manner in which cues interact to determine performance in exercise of different intensities (11, 18, 29, 30). Unfortunately, the inclusion of interspersed sprints and a fixed-intensity TT in Swart et al.'s (40) study, may limit the generalisability of the findings to 'real-world' self-paced TT performance, as the trained cyclists were unlikely to have acquired a strong, experience-primed performance template. Additionally, the intensity of the TT was not the only factor differentiating the trials in Swart et al.'s (40) study. Research has shown that the physiological demands of self-paced exercise are not comparable to a similar fixed-pace exercise bout (23), therefore, as the submaximal trial was enforced at 70% of the power output produced in the self-paced maximal TT, this may have had a confounding effect on the findings. Consequently, it cannot be definitively concluded that the difference in intensity was the direct cause of the distinction found between the two perceptual cues and therefore these findings need to be substantiated under more representative TT conditions using suitably experienced athletes.

Paragraph Number 3 Contrary to the argument that RPE is a principle regulator of exercise (42), the psychological construct of affect has been shown to be dissociated from RPE (12, 16) and proposed to contribute significantly to pacing decisions during exercise (3, 32). Through previous experience, it is suggested that affective valence (pleasure-displeasure) influences pacing strategy in relation to the goals and expectations of the task (3). Pace is said to be regulated in association with the tolerance of discomfort, with positive and negative affective responses influencing the desirability to maintain or change the exercise intensity (3). Studies measuring affect during fixed-intensity exercise (12, 16), therefore provide no further insight into the ability of affect to explain exercise regulation where complex, decision-making processes are crucial (33). As the experience of emotions are proposed to be related to goal

attainment (24), the role of self-efficacy in pacing has also been discussed as a significant situational social-cognitive variable. Positive emotions have been associated with goal attainment and negative emotions with goal failure, thus ratings of self-efficacy, which convey the level of confidence in achieving the task outcome, may influence the goal-directed regulation of exercise intensity (35). Affective valence (9) and effort perception (15) are moderated by different exercise domains (i.e. modality, intensity and duration) and between self-paced and fixed-intensity exercise, hence there is a need for future research to explore the roles of affect and self-efficacy in the decision-making processes involved in pacing strategies during self-paced exercise. Furthermore, whilst an intensity-dependent affect-exercise relationship has been theorised (9, 21), less is known about the implications of this relationship in self-paced exercise of varying distances.

Paragraph Number 4 Despite evidence supporting the importance of the interplay between cognitive constructs and interoceptive cues, such as heart rate and respiratory responses, in the regulation of exercise (29), only a paucity of research has adopted a holistic and multidimensional approach in the investigation of pacing strategies during self-paced exercise. Therefore, the main aim of this study was to examine power output distribution and the associated changes in affect, self-efficacy, perceptual responses, heart rate and respiratory gases during both 16.1 km and 40 km self-paced cycling TT. It was hypothesised that each of these variables would be associated with power output and that these associations would be dependent upon the TT distance. A secondary aim was to determine whether physical perceptions of exertion can be differentiated from the mental sense of effort during self-paced TT. We anticipated that these cues may not be easily differentiated in either 16.1 km or 40 km self-paced TT due to the close relationship demonstrated in the maximal self-paced TT in the previous study (40) in which these scales were utilised.

METHODOLOGY

Participants

Paragraph Number 5 Fifteen trained male cyclists with the following (mean \pm SD) characteristics volunteered for the study, age, 35.3 ± 8.3 yr; height, 178.5 ± 6.0 cm; body mass, 80.0 ± 11.0 kg; peak oxygen consumption ($\text{VO}_{2\text{peak}}$), 55.2 ± 8.2 ml·kg⁻¹·min⁻¹; peak power achieved in the maximal incremental test, 361.8 ± 35.2 W. The mean relative $\text{VO}_{2\text{peak}}$ value and peak power were used to classify the group of participants as performance level 3, i.e. ‘trained’, according to recent guidelines (7). All participants trained regularly (9.7 ± 5.7 h week⁻¹), had a minimum of 12 months of competitive cycling experience and had specific race experience in 16.1 and 40 km TT. Participants provided written informed consent and the study was approved by the Institutional Research Ethics Committee.

Experimental design

Paragraph Number 6 A prospective observational design was used involving the measurement of power output, affect, self-efficacy, physical perceptions of exertion, mental sense of effort, heart rate and respiratory gases consistently throughout each 16.1 km and 40 km TT. Participants visited the laboratory on five separate occasions, 2-7 days apart at the same time of day. Testing was conducted following a two hour fast and the refrainment from strenuous exercise and alcohol consumption in the prior 24 h (19). Participants were asked to maintain normal dietary practices and training routines throughout the testing period and provide nutritional and training diaries on their first trial, which were replicated in the 24 hours before each additional trial. Fluid prescription in the preceding two hours comprised a minimum of 500 ml of water. Prior to experimental testing, participants were familiarised with performing 16.1 km and 40 km TT, completed in a counterbalanced randomised-order. The familiarisation period also served to accustom participants to the analytical procedures, including detailed

instructions of how to use all scales, with repeated clarification given on each subsequent visit and a check of their understanding. Previous research has demonstrated good reliability in both 16.1 km and 40 km cycling TT performances, provided a familiarisation trial is completed (19). These distances were chosen to enhance ecological validity, as they are the most commonly ridden TT distances, and to explore the interplay between cognitive constructs and interoceptive cues across differing durations and intensities of TT exercise. An advantage of the individual TT is that, in the absence of any head-to-head confrontation, laboratory-based trials can somewhat replicate true competition, allowing performance to be accurately modelled (1).

Maximal Incremental Test

Paragraph Number 7 On the first visit, height and weight were recorded and a continuous incremental ramp test to maximal exertion was completed on a cycle ergometer (Excalibur Sport, Lode, Groningen, Netherlands) to determine $\text{VO}_{2\text{peak}}$. A 5 min warm-up was completed at 100 W, after which the resistance was increased by 20 W every 3 min, which has been shown to be a valid and reliable stage duration, until the participant could no longer maintain the required power output (5). Breath-by-breath pulmonary ventilation and gas exchange were measured throughout the test using an automated gas-analysis system (Oxycon Pro, Jaeger, GmbH Hoechburg, Germany), with the flow turbine and gas analysers calibrated using a 3 L syringe and gases of known concentration, respectively. Oxygen consumption data was averaged in 20 s time bins and normalised to pre-exercise body mass and the $\text{VO}_{2\text{peak}}$ was classified as the highest VO_2 measurement recorded over a 20 s period. Heart rate (Polar Team System, Polar Electro, Kempele, Finland) was recorded continuously throughout the test and downloaded at a 5 s sampling rate. Verbal encouragement was provided throughout each test.

Experimental Procedures

Paragraph Number 8 Following familiarisation on visits two and three, two experimental TT of 16.1 and 40 km were then completed in a counterbalanced randomised-order. Participants performed each TT on their own bicycle, which was fitted to an electromagnetically-braked cycle ergometer (CompuTrainer Pro, RacerMate, Seattle, USA) and calibrated in accordance with the manufacturer's guidelines. CompuTrainer ergometers offer reliable measurements of power output across a range of intensities (CV: 1.2-1.9 %) (31, 38, 45) and are widely used in pacing research (26, 28) as they allow the cyclists to freely alter their cadence and gear selection throughout the exercise, accurately depicting their road TT pacing strategy. After a 5 min warm-up at 70% of HR_{max} followed by a 2 min rest period, participants were instructed to complete the TT in the fastest time possible. The CompuTrainer software (RacerMate Software, Version 4.0.2, Seattle, USA) produced a synchronised graphical avatar, cycling on a flat, windless, virtual course that represented the participants' performance profile throughout the TT. Time and power output were recorded at a rate of 34Hz throughout each TT using the software and, whilst on-screen performance data except for distance covered feedback were obscured from view, these data were subsequently downloaded to x/s files following each trial.

Pre-trial measures

Paragraph Number 9 A number of measurements were assessed immediately prior to each TT to assess participants' physiological and psychological state. Willingness to invest physical and mental effort (41) were both measured on 100 mm visual analogue scales with the extremes of the scales anchored with the text 'not willing at all' to 'fully willing', and success-motivation was assessed with a 5-point Likert scale adapted from Matthews, Campbell and Falconer (25). Task-specific self-efficacy was measured using a five-item scale, adapted from Welch, Hulley and Beauchamp (43) and developed in accordance to Bandura's (2) guidelines. Participants

were asked to rate their level of confidence in their own ability to cycle at a moderate-fast pace for distances of 5, 10, 16.1, 20 and 40 km on a percentage scale from 0% (cannot do at all) to 100% (certain can do). An average value was calculated to produce an overall self-efficacy score. Fingertip capillary blood lactate (BLa; Analox Micro-Stat, P-GM7, USA) and blood acid-base status (pH, pO₂, pCO₂, ctHb, sO₂, cBase, cHCO₃⁻; Radiometer, ABL800, Copenhagen, Denmark) were analysed prior to each trial and the participants' hand was warmed prior to sampling to ensure an accurate reflection of an arterialised capillary sample (27).

During-trial measures

Paragraph Number 10 Heart rate and power output were measured continuously throughout each TT and pulmonary ventilation and gas exchange were measured at 25, 50, 75 and 100% distance quartiles. The respiratory exchange ratio (RER), minute ventilation (V_E) and pulmonary oxygen uptake (VO₂) were subsequently analysed. To allow participants to drink during the TT, a mouthpiece and nose clip were worn for only 1 km during each distance quartile. Water only was consumed *ad libitum* and drinking behaviour was monitored, with no significant individual discrepancies observed.

Paragraph Number 11 Affect was measured using a validated 7-point Feeling Scale (16), with participants informed that their response should reflect the affective or emotional components of the exercise and not the physical sensations of effort or strain. To measure during-task self-efficacy, only three items were recorded in order to reduce the level of interference, as other psychological measurements were also being collected (43). Participants' reported their confidence in their ability to continue at their current pace for a further 5, 10 and 20 km. Physical Ratings of Perceived Exertion (P-RPE) and Task Effort and Awareness (TEA) scales, adopted from Swart et al. (40), were used to measure the physical perceptions of exertion and

mental sense of effort, respectively. Borg's (6) 6-20 RPE scale was modified so that participants were instructed to reflect how heavy and strenuous the exercise felt, combining all physical feelings and sensations and not include the psychological effort required to continue the exercise. In contrast, a -4-10 TEA scale was described as a feeling or emotion that represents the psychological or mental effort required to continue at the chosen exercise intensity, reflecting how much attention and difficulty is experienced, as well as the level of consciousness of this effort. Responses for affect, P-RPE, TEA and self-efficacy were recorded at 25%, 50%, 75% and 100% distance quartiles, with participants instructed to point to values on the scales.

Statistical analysis

Paragraph Number 12 Statistical analyses were conducted using IBM SPSS Statistics 22 (SPSS Inc., Chicago, IL). Descriptive sample statistics are reported as the mean and standard deviation (SD) for normally distributed data and the median and interquartile range (IQR) for non-normally distributed data. Linear mixed models were used to explore the effects of condition (16.1 km vs. 40 km TT distances), distance quartile, affect, P-RPE, TEA, self-efficacy, RER, V_E , VO_2 , and heart rate on power output distribution. Covariates, interaction effects, and random effects were entered into linear mixed models separately and only left in the final model if statistically significant. To explore the linear relationships between during-trial P-RPE, TEA, affect, self-efficacy, RER, V_E , VO_2 , and heart rate with power output, within-subject correlations were first calculated for each participant for each bivariate relationship and then summarised using the median and IQR. One-sample Wilcoxon Signed Rank Tests were used to test whether the median correlations differed significantly from zero. To assess perceptual responses, a linear mixed model was performed with type of response (P-RPE and TEA) and condition entered as factors, and distance quartile (25%, 50%, 75%, and

100% of total distance) entered as a linear covariate. A two-tailed p-value of < 0.05 was considered statistically significant in all analyses.

RESULTS

Paragraph Number 13 Mean performance times in the 16.1 km and 40 km TT were $27:58 \pm 2:01$ min and $72:12 \pm 5:39$ min, respectively. Power output was significantly higher in the 16.1 km TT than the 40 km TT and significantly different across distance quartiles as demonstrated by main effects for condition ($F = 8.1$, $p = 0.01$) and quartile ($F = 10.7$, $p < 0.001$) (Figure 1A). Power output in the last quartile was significantly higher than in the other quartiles (25, 50 and 75%) in both the 16.1 km and 40 km TT ($p < 0.001$). However, no interaction was found between condition and quartile ($F = 1.3$, $p = 0.31$), indicating that a similar pacing strategy was adopted in both TT. Mean values for during-trial physiological variables are displayed in Table 1. Significant differences were found for pre- and post-trial measures in both 16.1 km and 40 km TT for BLa and blood gases, except oxygen saturation ($p < 0.05$). No significant differences were found in pre-trial ($p > 0.08$) or post-trial blood parameters ($p > 0.14$) between the two TT (Table 2).

Associations with power output distribution

Paragraph Number 14 All during-trial physiological and psychological variables were significantly associated with power output distribution (Table 3). The P-RPE, TEA, self-efficacy, and V_E were removed from the linear mixed model, as no main effects or interaction effects were observed for these variables when the other variables were entered into the model. A main effect for affect ($F = 12.1$, $p = 0.001$), and an interaction between affect and condition ($F = 4.5$, $p = 0.037$), indicated that changes in affective valence were significantly associated with changes in power output, but this response was moderated by condition. The negative

relationship between affect and power output indicates that a more negative affective valence was associated with a higher power output, and the variables were more closely associated in the 16.1 km than the 40 km TT. Similarly, a main effect was found for RER ($F = 18.1$, $p < 0.001$) and an interaction effect between RER and condition ($F = 8.9$, $p = 0.004$). The RER was significantly positively associated with power output, but the interaction shows that this association was stronger in the 16.1 km than the 40 km TT. Main effects were found for heart rate ($F = 33.5$, $p < 0.001$) and VO_2 ($F = 26.9$, $p < 0.001$), revealing that there were positive associations between heart rate and power output, and VO_2 and power output.

Relationship between P-RPE and TEA

Paragraph Number 15 Main effects for quartile were found for P-RPE ($F = 11.1$, $p < 0.001$) and TEA ($F = 14.6$, $p < 0.001$), indicating that both perceptual responses increased over time (Figure 1C-D). A main effect was found for condition ($F = 6.3$, $p = 0.01$) and on average, responses were significantly higher in the 16.1 km TT (P-RPE: 16.6 ± 2.7 ; TEA: 7.2 ± 2.5) than the 40 km TT (P-RPE: 16.4 ± 2.5 ; TEA: 6.9 ± 2.6). The P-RPE was not significantly different from TEA as no main effect was found for type of response, although it was approaching statistical significance ($F = 4.1$, $p = 0.053$). Additionally, no interactions were found ($p > 0.23$), suggesting that both P-RPE and TEA scores increase at a similar rate across distance quartile and in both conditions (Figure 2). Significant random effects were found for intercept ($p = 0.03$) and distance quartile ($p = 0.04$) indicating that there were significant variations between individuals in the degree of perceptual responses at the start of the trials and the rate at which these perceptions increased.

DISCUSSION

Paragraph Number 16 The main aim of this study was to examine power output distribution and the associated changes in affect, self-efficacy, perceptual cues, heart rate and respiratory gases during both 16.1 km and 40 km self-paced cycling TT. The key findings support our hypothesis that all measured variables were associated with power output (Table 3), however, affect, RER, VO_2 and heart rate were shown to be the best combination of associated variables. Additionally, power output associations with affect and RER differed in strength between the TT, with both variables more closely associated with power output in the 16.1 km than the 40 km TT. As expected, the 16.1 km TT was performed at a consistently greater power output (Figure 1A) and higher intensity than the 40 km TT, supported by the accompanying mean differences in heart rate and respiratory gases (Table 1), but pacing profiles were similar in both trials. A negative pacing pattern was adopted, with a slower start followed by a significantly greater power output, or an ‘end-spurt’, exerted in the fourth distance quartile. No differences in post-trial BLa suggest that these ‘end-sprints’ were similar in both TT and support the absence of pacing differences between TT.

Paragraph Number 17 The associations of all measured variables with power output distribution supports the complex, multidimensional integration of physiological and psychological processes involved in the regulation of pacing strategies during self-paced exercise (3). The greater association between affect and power output evidenced in the 16.1 km TT in comparison to the 40 km TT, could support theory which suggests that affective responses are intensity-dependent (9, 21), even in exercise of a self-paced nature. This also provides evidence for the significance of this dose-response effect on the relationship between affect and pacing strategy. Interestingly, despite power output being greater in the 16.1 km, this was not accompanied by more negative affective valence, as demonstrated by similar trends in affect in both TT (Figure 1B). Instead, the stronger association between affect and

power output in the 16.1 km TT may be better explained by a distance-dependent relationship rather than an intensity-dependent relationship. Similar to the proposed RPE template (42), with effort perception regulated to increase linearly with the expected distance or duration of the exercise, the importance of a known endpoint may also be applicable to the affect-performance relationship. This association difference between the TT was also found with RER, which may be a product of the variance of affect that is explained by RER, which is greatest during exercise of a higher intensity (10). Thus, the stronger relationship between affect and pacing strategy in the 16.1 km TT, was moderated by resultant increases in physiological cues and supports our hypothesis that the associations between the measured variables and power output would differ between the TT. These data consequently support the role of affective valence in the regulation of self-paced exercise, extending findings from previous research (3, 32), and supporting the adjunct measurement of affect to provide clarity pertaining to the complex relationship between affective responses, perceived exertion and performance (8). On the other hand, self-efficacy was not significantly associated with power output in the model and thereby refutes our hypothesis. As self-efficacy and other cognitive parameters have been shown to have a significant influence on affective responses experienced during exercise (9), we therefore suggest that self-efficacy may have an indirect influence on pacing strategy via its determination of affective responses. What remains unclear therefore, is the nature of those moment-by-moment cognitions underpinning the resultant affective state.

Paragraph Number 18 The second aim of this study was to examine whether physical perceptions of exertion and the mental sense of effort could be differentiated during self-paced exercise. There was a linear trend in the increase of P-RPE and TEA responses (Figure 1C-D) and, despite the TT varying in total distance, the perceptual cues increased as a function of the relative exercise duration and not the intensity or total distance to be completed (39). Although approaching significance, the findings between the P-RPE and TEA scales (Figure 2),

including an absence of any interactions, support our hypothesis that the physical perceptions of exertion may not be clearly differentiated from the mental sense of effort in either TT distance (8). These findings are less supportive of previous results in which these scales were utilised (40), but the disparity between these investigations may be a function of the varying research designs. Firstly, the use of 16.1 km and 40 km self-paced TT allowed full decision-making control of pacing behaviours in response to homeostatic challenges during the trials and to prevent deviance from the anticipatorily-set performance template, which would have resulted in suboptimal performance. Secondly, the trained cyclists used in this study will have acquired experientially-developed performance templates from previous exposure to the specific TT distances, and are able to successfully regulate their work-rate in order to prevent the surpassing of acceptable limits of automaticity and resultant rise in severe sensory cues (7). These differences between the current study and that of Swart et al. (40) may therefore explain why a significant differentiation between P-RPE and TEA was not found in the present study. Consequently, the role of sense of effort in the regulation of pacing strategies may not provide any additional contribution to self-paced exercise in which individuals have previous experience of performing.

Paragraph Number 19 Whilst theory has claimed that perceived exertion is the primary source of exercise regulation, most of these previous studies (22, 42) have used the RPE scale whilst the present study adopted a newly proposed, alternative method of measurement; the P-RPE and TEA scales (40). This may explain why neither the P-RPE nor TEA were found to be amongst the strongest predictors of pacing strategy in the current study, being left out of the final linear mixed model as they became non-significant when other physiological and cognitive variables were included. Therefore, these findings are not corroborative with previous proposals (42) that these perceptions are the most crucial factors in the regulation of pace. The scientific examination of ‘consciousness’ creates difficulty due to the subjectivity of

the phenomenon, which differs between individuals and is entirely unique to the individual experiencing it (36). This is supported by the finding of significant random effects, indicating variations between individuals' initial perceptual responses and the rate of change of these perceptions throughout the trials. A limitation therefore, of the TEA scale may be the process of asking participants to consciously report a perceptual response that may be unconscious at the time of asking. As with other measurements of perceived exertion, and the arguments surrounding the subconscious or conscious manner in which exertion is perceived (8), the action itself of prompting participants at set time points during an exercise bout forces attention to these sensations. Accordingly, caution is warranted in terms of the use of the P-RPE and TEA scales in the endeavour to separate these perceptual cues and more research is needed to determine whether experimentally, more appropriate measures of perceptions of physical exertion and the sense of effort can be developed.

Paragraph 20 An observational design was used in this study to investigate the relationships between variables involved in pacing strategy selection without the manipulation of an independent variable which may confound the true nature of these relationships. However, any cause-and-effect relationships from the results discussed should be interpreted tentatively. Future research may wish to explore the use of experimental approaches to further examine these relationships under different exercise conditions.

CONCLUSION

Paragraph Number 21 The results from this study demonstrate that a combination of psychological and physiological factors are associated with the regulation of power output during 16.1 km and 40 km self-paced cycling TT. The finding of a task-dependant association between affective valence and power output distribution extends support for the role of affect in exercise regulation and warrants future consideration as an important construct of pacing

strategies in exercise of varying intensities or distances. Furthermore, a clear dissociation between physical perceptions of exertion and mental sense of effort was not found in self-paced exercise and is not supportive of the previous study in which the P-RPE and TEA scales were utilised. Together with other recent investigations of the multidimensionality of the construct of perceived exertion, it is hoped that this study will also serve as a catalyst in the exploration of the usefulness of the RPE in our understanding of pacing.

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Figure captions

Figure 1. Mean (SD) power output (**A**), affect (**B**), P-RPE (**C**) and TEA (**D**) across distance quartile in 16.1 km and 40 km TT.

* significantly greater than the 25, 50 and 75% distance quartiles ($p < 0.001$)

significantly greater than the 40 km TT ($p < 0.05$)

Figure 2. Mean (SD) P-RPE and TEA responses across distance quartile in 16.1 km and 40 km TT.

Table 1. Mean (SD) heart rate, RER, V_E , VO_2 and across distance quartile in 16.1 km and 40 km TT.

Table 2. Mean (SD) pre- and post-trial blood lactate and blood gas parameters in 16.1 km and 40 km TT.

Table 3. Median (IQR) within-subject correlation coefficients for the relationships between power output and all exploratory variables.