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Investigating the Relationship between Cognitions, Pacing Strategies and Performance in 16.1 km Cycling Time Trials Using a Think Aloud Protocol.

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Investigating the Relationship between Cognitions, Pacing Strategies and Performance in 16.1 km Cycling Time Trials Using a Think Aloud Protocol.

Abstract

Objectives Three studies involved the investigation of concurrent cognitive processes and pacing behaviour during a 16.1km cycling time trial (TT) using a novel Think Aloud (TA) protocol. Study 1 examined trained cyclist's cognitions over time whilst performing a real-life 16.1km time trial (TT), using TA protocol. Study 2, included both trained and untrained participants who performed a 16.1 km TT in a laboratory whilst using TA. Study 3 investigated participants' experiences of using TA during a TT performance.

Method: Study 1 involved 10 trained cyclists performing a real life 16.1km TT. Study 2 included 10 trained and 10 untrained participants who performed a laboratory-based 16.1km TT. In both studies, all participants were asked to TA. Time, power output, speed and heart rate were measured. Verbalisations were coded into the following themes (i) internal sensory monitoring, (ii) active self-regulation, (iii) outward monitoring (iv) distraction. Cognitions and pacing strategies were compared between groups and across the duration of the TT. In study 3 all participants were interviewed post TT to explore perceptions of using TA.

Results: Study 1 and 2 found cognitions and pacing changed throughout the TT. Active self-regulation was verbalised most frequently. Differences were found between laboratory and field verbalisations and trained and untrained participants. Study 3 provided support for the use of TA in endurance research. Recommendations were provided for future application.

Conclusion: Through the use of TA this study has been able to contribute to the pacing and cycling literature and to the understanding of endurance athletes' cognitions.

Key words:
Pacing, Cognition, Think Aloud, Cycling, Endurance, Decision Making.

Introduction

Pacing strategies during endurance performance, and particularly within cycling exercise, has become an increasingly popular area of study within the last decade. It is widely acknowledged that setting an optimal pacing strategy is crucial in determining the success or failure of a performance (Hettinga, De Koning & Hulleman, 2012). Pacing is defined as the regulation of effort during exercise that aims to manage neuromuscular fatigue (Edwards & Polman, 2012). It prevents excessive physiological harm and maximizes goal achievement (Edwards & Polman, 2012). Strategic decisions must be made to select a work-rate that will result in an optimal performance outcome (Renfree, Martin & Micklewright, 2014). The aim of pacing research is to determine the relative importance of internal and external factors in explaining how pacing decisions are made and how performance can ultimately be improved. However, research efforts to-date have provided limited insight into the temporal characteristics of how endurance athletes engage in specific cognitive strategies which underpin these decisions.

Decisions to increase, decrease or maintain pace are made continuously throughout an exercise bout and are a dynamic and complex cognitive process that is yet to be fully understood. It has been acknowledged that athlete cognitions have an important influence on effort, physiological outcomes and accordingly, endurance performance (Brick, MacIntyre & Campbell, 2016). Recent research has applied decision-making and metacognitive theories to this pacing field to provide a framework by which these cognitive processes can be explored (see Brick et al., 2016; Renfree et al., 2014; Smits, Pepping & Hettinga, 2014). Research has supported the influence of previous experience (Micklewright, Papadopoulou, Swart & Noakes, 2010), competitor influence (Corbett, Barwood, Ouzounoglou, Thelwell, & Dicks, 2012; Williams, Jones, & Sparks, et al., 2015) and performance feedback (Jones, Williams & Marchant, et al., 2016; Smits, Polman & Otten, Pepping & Hettinga, 2016; Mauger, Jones & Williams, 2009b) on pacing decisions and provided further mechanistic support of constructs such as perceived exertion (Marcora & Staiano, 2010) and affect (Jones, Williams & Marchant, et al., 2014; Renfree et al., 2014). However, intermittent measures of such constructs do not provide the sensitivity of measurement to identify the continuous changes in cognition that occur during a competitive endurance task. Recently, more focus has been directed towards examining decision-making and athletes' thought processes during endurance events (Renfree, et al., 2014; Renfree, Crivoi do Carmo & Martin, 2015). Methods for collecting this cognitive data seem to be mainly retrospective in nature, for example, via the use of video footage to assist with the recall of cognitive information (Baker, Côté, & Deakin, 2005; Morgan & Pollock, 1977), or post trial interviews to highlight key thought processes during an event (Brick, et al., 2015; Williams et al., 2016). Nevertheless, such methodology has significant limitations given that retrospective recall is associated with memory decay bias and added meaning (Whitehead, Taylor & Polman, 2015).

Think Aloud (TA) protocol analysis (Ericsson & Simon, 1993; 1980) has been used in the last decade to collect cognitive thought processes in sports such as golf (Calmeiro & Tenenbaum, 2011; Whitehead, Taylor & Polman, 2016b), trap shooting, (Calmeiro, Tenenbaum & Eccles, 2014) and tennis (McPherson & Kernodle, 2007). However, this method has mainly been utilised in studies investigating expertise (Whitehead et al., 2015), and has seldom been used in endurance sports. TA requires participants to actively engage in the process of verbalising their thoughts throughout the duration of a task (Ericsson & Simon, 1993). Ericsson and Simon (1993; 1980) identified three distinct levels of verbalisation, with each being representative of the amount of cognitive processing required. Level one verbalisation requires vocalisation of task relevant thoughts only. Level two verbalisation requires participants to recode visual stimuli, not regularly verbalised, prior to providing verbalisation on the task. Verbalisations should reflect stimuli affecting the focus of the participant through the task, for example, a participant providing vocalisation of stimuli within a task including sight, sound and smell. Eccles (2012) indicated that level one and level two verbalisations are a result of conscious thought processing in short-term memory (STM) during the execution of a task, providing concurrent verbalisation during or immediately after a task has been completed. Verbalisations occur most often in environments where participants are provided with undirected probes' to think aloud naturally during the execution of a task (Ericsson & Simon, 1980). Lastly, level three verbalisation requires participants to provide explanation, justification and reasoning for cognitive thoughts throughout the task.

What appears to be the earliest research using TA in an endurance setting was conducted by Schomer (1986). Schomer and colleagues (Schomer & Connolly, 2002; Schomer, 1987; 1986) have previously used what was described as 'on-the-spot' data recording to collect mental strategy recordings. Using cassette recorders, mental strategies adopted by differing levels of marathon runners were investigated (Schomer, 1986). Within this study, findings revealed a relationship between associative mental strategy and perception of effort. Further research also identified gender differences in these cognitive strategies employed during marathon running, using an early version of TA (Schomer & Connolly, 2002). Although it was argued that there are limitations with the use of retrospective reports within this type of research, very little research has since employed an in-event method such as TA. More recently, having acknowledged mechanistic limitations of endurance performance research, Samson, Simpson, Kamphoff & Langlier (2015) used TA to capture real-time cognitions in long-distance running. Verbalisations were grouped under three primary themes; Pain and Discomfort, Pace and Distance, and Environment, with Pace and Distance emerging as the dominant theme. These authors concluded that the use of TA can provide a greater understanding of thought processes during an endurance activity. Although this study was novel in its application of a TA protocol in endurance performance and authors were able to identify key internal and external factors that influence during-event cognitions, it is unknown how these cognitions may change over the duration of an exercise bout. Whitehead et al. (2017) recently extended this research by using TA to monitor the cognitions of cyclists over a 16.1 km time trial (TT) and demonstrated that cyclists process and attend to different information throughout the TT. Specifically, thoughts relating to fatigue and pain were verbalised more during the initial quartiles of the event. Conversely, thoughts relating to distance, speed and heart rate increased throughout the event and were verbalised most during the final quartile. However, neither of these previous studies collected any during-event performance data (e.g. heart rate, speed, time) and therefore, the relationship between cognitions and pacing behaviour could not be determined. Cona et al. (2015) state that whilst it is possible to observe expert performance, the cognitive processes contributing to performance are less clear. Therefore, exploring how cognitions relate to pacing decisions and performance is of interest in the study of performance enhancement.

Another perspective that has yet to be fully explored within the field of endurance performance and pace regulation is the expert-novice paradigm; how experts and novices attend to and process information during an event such as cycling. Expertise differences have been consistently demonstrated across learning and performance settings, supporting differences in attentional focus strategies

(Castaneda & Gray, 2007), cognition (Arsal, Eccles & Ericsson, 2016; Baker et al., 2005; Whitehead et al., 2016b) and emotion regulation (Janelle, 2002). Evidence demonstrates how individuals in the later stages of development may centre their thoughts around external variables such as their environment and use procedural knowledge during performance, whereas novices focus on more technical, internal cognitions and use declarative knowledge (Whitehead et al., 2016b; Fitts & Posner, 1967). These findings however are specific to skill development within motor tasks as opposed to pacing strategy and regulation. Within the pacing literature, the majority of previous research has investigated pacing behaviours of expert performers solely using trained athletes (Mauger, Jones & Williams, 2009a; Micklewright et al., 2010). Furthermore, a direct comparison of cognitions and pacing behaviours between experts and novices has not been made in the pacing field to date.

Baker et al. (2005) investigated the cognitive characteristics of triathletes and identified differences in cognitive verbalisations between expert/trained and novice/untrained athletes. Trained triathletes reported a greater emphasis and focus on performance and untrained participants' thoughts were more passive and re-active. However, this study used a retrospective approach to data collection by asking participants to verbalise how they felt during different points of a race when watching a video montage of video sequences from a world championship event to cue memories of similar events participants might have experienced. The retrospective nature of the study is a key limitation due to the risk of bias and whereby recall of information may not accurately represent the situation (Hassan, 2005).

Although some researchers have argued that asking participants to TA may result in unreliable data and affect performance (Nisbett & Wilson, 1977), more recent research has tested this potential impact in sport and found this not to be the case (Whitehead et al., 2015). Furthermore, Fox, Ericsson and Best's (2011) meta-analysis of 94 studies using concurrent verbalisation methods reported an negligible effect of think aloud and supported the protocol as a legitimate method for capturing cognitive processes. There is also a paucity of research that has looked at individual's perceptions of using TA.

In this article, we aimed to investigate the relationship between concurrent cognitive processes and pacing behaviour during cycling endurance performance using a novel TA protocol. Three separate studies are presented. In study 1, trained cyclists used TA whilst performing a real-life, outdoor 16.1

km TT and changes in cognitions were assessed over time. In study 2, both trained and untrained participants performed a 16.1 km cycling TT in a laboratory whilst thinking aloud. Cognitions and pacing strategies were compared between groups and across the duration of the TT. Finally, study 3 presents a qualitative analysis of the participants' experiences of using TA during a TT performance, via interviews conducted with the participants from study 1 and 2.

Study 1 – Investigating the relationship between cognitions, pacing strategies and performance in a 16.1 km cycling time trial in the field.

To further develop previous Think Aloud pacing research (Samson et al., 2015; Whitehead et al., 2017) this study aimed to identify changes in trained cyclists' cognitions and pacing strategies within a real-life, competitive 16.1 km TT. Previous research has yet to account for performance changes (Whitehead et al., 2017) and therefore, this study aims to determine whether athletes' verbalisations are associated with physiological responses or performance parameters, such as speed, power output and heart rate. It was predicted that the nature of the cyclists' cognitions would change over the duration of the TT.

Material and Methods

Participants

Seven male and three female cyclists (*M* age = 40.2 ± 6.6 years, *M* experience = 6.1 ± 2.7 years) were recruited from North Yorkshire cycling clubs. Participants were required to have 1) at least 12 months of experience in competitive 16.1 km TT's at the time of the study, 2) two or more years of competitive cycling experience, and 3) to have prior experience of training and/or competing with a power meter. Institutional ethical approval was secured by the first author's institution and informed consent obtained from all participants prior to testing.

Materials

An Olympus Dictaphone was used to capture in-event thoughts that were verbalised throughout a 16.1 km competitive TT. The small microphone attached to the Dictaphone was fitted to the participants' collar to ensure clarity of sound. In order to minimise the awareness of the recording device, the wire was placed inside the shirt and connected to the recording device, which was placed in the back pocket of the cycling jersey. All participants fitted a GPS device (Garmin Edge 510) and power meter (Garmin Vector 2S Power Meter, Keo Pedals) to their bikes to continuously record speed, time, distance and power output throughout the TT. A heart rate monitor (Garmin Premium Heart Rate Monitor) also recorded heart rate data for each participant.

Procedure

Participation required the cyclists to perform a single 16.1 km cycling TT in an outdoor environment. The TT was organised by a conglomerate of cycling clubs under the jurisdiction of the Cycling Time Trials Association in England and official timers and marshals were present. All participants performed this TT on the same occasion, between 19:00 and 20:00, and in dry weather conditions with a temperature of approximately 20 degrees. The wind was approximately 14 km/h and the road surface was standard asphalt material.

Prior to the day of the TT, participants were required to complete a video-based TA training exercise which was sent to all participants one week prior to the task. This included three different TA tasks to ensure that they could adequately engage in the TA protocol (Ericsson & Simon, 1993); (1) an alphabet exercise, (2) counting the number of dots on a page, and (3) verbal recall. Participants were asked to arrive at the TT location one hour before the start of the event to be briefed further using Ericsson and Kirk's (2001) adapted directions for giving TA verbal reports. This required participants to provide verbal reports during a warm-up task containing non-cycling problems (Eccles, 2012). As not to disrupt the cyclists' normal pre-race routines, they performed a self-selected warm up. Similarly, fluid and nutritional intake were not controlled. Dictaphones and power meters were fitted prior to the warm-up and checked again before the start of the TT, along with the participants' GPS device and heart rate monitor.

Once participants confirmed that they were fully comfortable with the task of thinking aloud, they were instructed to "please Think Aloud and try to say out loud anything that comes into your head throughout the trial". Stickers were also placed on visible areas of their bicycle, which stated "Please think aloud". Performance times were retrieved from official race records and power output, speed and heart rate data were retrieved from the participants' GPS devices. No technical or physical problems were reported to have occurred during the TT which may have affected performance.

Data Analyses

Think Aloud data were transcribed verbatim, analysed using both inductive and deductive content analysis and grouped into primary themes. Where deductive analysis was used, Brick et al., (2014) metacognitive framework was adopted. Using this modified version of Brick et al's (2014) metacognitive framework, these themes were then allocated to one of four secondary themes: (i) Internal Sensory Monitoring, (ii) Active Self-Regulation, (iii) Outward Monitoring, (iv) Distraction (see Table 1). The number of verbalisations were also grouped by distance quartile of the TT, for both the primary and secondary themes. In keeping with the majority of research in TA (e.g., Whitehead, et al., 2017; Arsal, Eccles & Ericsson, 2016; Calmerio & Tenenbaum, 2011; Nicholls & Polman, 2008) a post-positivist epistemology informed this study. Consistent with this, inter-rater reliability was calculated to ensure rigour. This involved a second author coding a 10% sample of the transcripts using the framework provided (Table 1). This framework was used to guide the second authors coding process, as recommended by MacPhail, Khoza and Abler (2016). An 86% agreement was found, following this a discussion regarding the following 14% difference was conducted and agreements were made.

All analyses were conducted using IBM SPSS Statistics 22 (SPSS Inc., Chicago, IL) and descriptive sample statistics for TA data are reported as frequency percentages. Two-tailed statistical significance was accepted as $p < 0.05$ and effect sizes are reported using partial eta squared (eta^2) and Cohen's d values (δ). Where data was non-normally distributed, appropriate non-parametric inferential statistical tests were conducted. To explore within-trial differences in verbalisations, Friedman's repeated-measures tests were conducted for primary and secondary themes over distance quartile. Post hoc analysis using Wilcoxon Signed Rank tests was performed where significant distance quartile effects were found. One-way repeated measures ANOVAs were conducted for speed, power output, heart rate and cadence data and Bonferroni adjusted post hoc analyses were performed where significant distance quartile effects were found.

Results

TA Data

On average, cyclists verbalised a total of 84.20 thoughts throughout the 16.1 km TT. The theme Active Self-Regulation was the most predominantly verbalised for the whole trial with 63% of the total number of verbalisations, followed by Distraction with 20% of the verbalisations (see Table 2).

Within-group analyses were conducted to explore the differences in cognitions across distance quartile (see Table 3). A main effect for distance was found for the secondary theme Outward Monitoring ($x^2(3, n = 10) = 16.79$, $p = .001$) with post-hoc analysis identifying a significant large increase in verbalisations across the duration of the TT. There were significantly fewer verbalisations at quartile 1 (Mean Rank = 1.75) than at quartile 2 (Mean Rank = 2.40) ($Z = -2.75$, $p = .006$, $\delta = 1.24$) and at quartile 3 (Mean Rank = 2.40) ($Z = -2.72$, $p = .006$, $\delta = 2.05$). No significant effects were found over quartile for the secondary themes Internal Sensory Monitoring, Active Self-Regulation, and Distraction ($p > .05$).

As evidenced in Table 3, significant effects were found over distance quartile for the primary themes Maintaining Pace, Motivation, Technique, Distance and Competition. No significant effects were found over distance quartile for the primary themes Breathing, Pain and Discomfort, Thirst, Fatigue, Temperature, Heart Rate, Cadence, Speed, Increase Pace, Decrease Pace, Controlling Emotions, Time and Course Reference ($p > .05$).

Performance Data

Speed ($F(1.32) = 24.27$, $p < .001$, $eta^2 = 0.73$), power output ($F(3) = 7.85$, $p = .001$, $eta^2 = 0.47$) and heart rate ($F(1.4) = 14.03$, $p = .004$, $eta^2 = 0.70$) all significantly changed over distance quartile with large effect sizes. Results from post hoc analyses are shown in Table 4. Cadence did not differ significantly across the distance of the TT ($p = 0.17$, $eta^2 = 0.18$) although the effect size was moderate.

Discussion Study 1

As expected the findings of this study demonstrate that trained cyclists' cognitions changed over time during an outdoor competitive 16.1 km TT. Cyclists' predominant thoughts related to the theme Active Self-Regulation (63%) followed by thoughts related to Distraction (20%). Internal Sensory Monitoring and Outward Monitoring thoughts were less common (8% and 9%, respectively) although Outward Monitoring verbalisations were found to change over time, with significantly fewer verbalisations in the first quartile.

Cognitions were found to change over the duration of the TT, with significant differences over distance quartile for the primary themes Maintaining Pace, Motivation, Technique, Distance and

Competition. There was a significant increase in the number of motivational thoughts over time, with the greatest number of verbalisations recorded in the final quartile which also coincided with the trend for an increase in power output, i.e. an end-spurt. The augmentation of work-rate in this final stage was exerted despite athletes' perceptions of effort known to be at their highest at this stage of an event, as previously demonstrated by a linear increase across exercise duration (Taylor & Smith, 2013). This suggests that these motivational verbalisations may represent the cyclists' use of positive cognitive strategies to cope with the increased effort perceptions whilst attempting to increase pace and optimise performance (Brick et al., 2016). This extends recent findings demonstrating how motivational self-talk can reduce perceptions of effort and improves endurance performance (Barwood, Corbett, Wagstaff, McVeigh & Thelwell, 2015; Blanchfield, Hardy, De Morree, Staiano, & Marcora, 2014). As metacognitive judgements are made throughout an exercise bout, an athlete may proactively deem their current attentional focus as no longer appropriate in-line with goal attainment and the changing demands of the task, for example the distance remaining or behaviour of a competitor (Brick et al., 2016; Bertollo, di Fronso & Filho et al., 2015). Alternatively, this may also stem from a bottom-up process driven by the increased perceptions of effort (Balagué, Hristovski & Garcia, et al., 2015) resulting in a greater need for active cognitive control to optimise pace. Consequently, as proposed by Brick et al. (2016), the data suggests a combination of reactive and proactive cognitive control becomes more evident as athletes attempt to deal with increasing demands and maintain an optimal pacing strategy to achieve goal attainment. Reflecting this, greater use of positive, motivational verbalisations was also associated with a trend for an increase in power output in the final quartile of the TT, this suggests that this proactive strategy was facilitative and supported an enhanced performance when physical and perceptual demands were highest.

Outdoor, competitive exercise with more environmental stimuli, external influences (e.g., traffic, road conditions, gradient) and the presence of competitors incur more unexpected events than respective indoor environments. Whilst participants in the current study verbalised more self-regulatory thoughts relating to their performance during the initial quartile (i.e., Technique and Maintaining Pace), unexpected events require athletes to adapt their cognitions in order to maintain positive affect and prevent suboptimal performance (Brick et al., 2016). The changing patterns of verbalisations found across the duration of the TT therefore support the cyclists' use of reactive cognitive control and the importance of this metacognition (Brick et al., 2016). For example, Outward Monitoring thoughts, relating to Competition and Distance, were verbalised more in the mid-late stages of the TT than in the initial quartile. The increased number of distance verbalisations, as also demonstrated in a recent TA study in cycling (Whitehead et al., 2017), may be indicative of the cyclists seeking information to support the effective regulation of effort. Alongside the use of motivational strategies, this attentional flexibility and reactive control supports the changing importance of performance-related information and the athlete's need to actively seek new information to inform pacing decisions once their proactive starting strategy is over.

This study uses a more novel approach (TA) to collect participant pacing data and cognitions during an endurance event. With the addition of performance data, this research has been able to support and extend previous research (Whitehead et al., 2017), by finding relationships between cognition and performance (e.g. power output). It is important to acknowledge potential external variables that may affect verbalisations, cognitions and performance during a real-life event in the comparison of these findings to laboratory-based research. Therefore, it is important that in order to develop this research further, evidence is also provided from a more contained environment, such as a laboratory.

Study 2 – Investigating the relationship between cognitions, pacing strategies and performance in 16.1 km cycling time trials with trained and untrained cyclists in the lab.

To extend the work conducted within study 1 as well as previous research by Samson et al. (2015) and Whitehead et al. (2017), this study aimed to 1) investigate the differences in cognitions between trained and untrained cyclists during a 16.1 km TT in a laboratory setting, and 2) identify changes in cognitions over time in relation to changes in pacing strategy (i.e. speed). It was predicted that cognitions would differ between trained and untrained individuals and both groups' cognitions would also change across the duration of the TT.

Material and Methods

Participants

Ten trained male cyclists (*M* age = 36.9 ± 7.0 years, *M* height = 179.2 ± 5.6 cm, *M* body mass

= 76.9 ± 10.3 kg) and ten untrained, physically active males (*M* age = 32.3 ± 9.7 years, *M* height = 179.3 ± 6.5 cm, *M* weight = 87.2 ± 14.2 kg) volunteered to participate in the study. In accordance with recent guidelines (De Pauw et al., 2013), trained participants were required to have a minimum of 2 years competitive cycling experience and a current training load of at least 5 hours and/or 60 km a week. Furthermore, trained participants were required to have a personal best time of sub 25 min in a 16.1 km road TT within the last 3 years. Untrained participants were healthy and physically active but had no prior experience in competitive cycling or TTs. Written informed consent was obtained prior to participation and the study was approved by the first author's institutional research ethics committee.

Materials

Each participant performed one 16.1 km laboratory-based cycling TT on an electromagnetically-braked cycle ergometer (CompuTrainer Pro™, RacerMate, Seattle, USA). Trained cyclists rode on their own bicycles which were fitted to the CompuTrainer rig and the untrained group performed the trial on the same, standard road bicycle with a 51-cm frame, adjusted for saddle and handlebar position. The CompuTrainer was calibrated according to manufacturer's guidelines and rear tyre pressures were inflated to 100 psi. A 240 cm x 200 cm screen was positioned in front of the participants which displayed a flat, visual TT course and performance feedback (power output, speed, time elapsed, distance covered and heart rate) was provided continuously throughout the trial. The participants' speed profile was also represented by a simulated, dynamic avatar riding the TT course using the ergometry software (RacerMate Software, Version 4.0.2, RacerMate).

As with study 1 an Olympus Dictaphone was used to capture in event thoughts that were verbalised throughout. All participants were fitted with a Polar heart rate monitor (Polar Team System, Polar Electro, Kempele, Finland) which recorded heart rate throughout the TT at a 5 s sampling rate.

Procedure

All participants were required to attend a single testing session and perform a self-paced 16.1 km cycling TT in a laboratory-based environment. As with study 1 all participants were required to complete a video-based TA training exercise which was sent to all participants one week prior to the task and were given extra TA training exercises on arrival and prior to the testing session (see Study 1 for details).

Participants' height and body mass were recorded and each was fitted with the microphone and Dictaphone before performing a 10-minute warm-up at 70% of their age-predicted maximal heart rate. Participants were instructed to verbalise their thoughts throughout the warm-up for an additional familiarisation of the TA protocol in the testing environment. As with study 1 participants were instructed to "please Think Aloud and try to say out loud anything that comes into your head throughout the trial". During the TT, researchers were positioned out of sight but if participants were silent for a sustained period of 30 seconds, the researcher prompted them to resume TA. Two signs were also placed either side of the projection screen as written reminders to TA. Water was consumed *ad libitum* and a fan was positioned to the front-side of the bike. Participants were instructed to perform the TT in the fastest time possible but no verbal encouragement was provided. A self-paced cool down was performed upon completion of the trial.

Data Analysis

Think Aloud data were transcribed verbatim, analysed using deductive content analysis and grouped into primary and secondary themes using a modified version of Brick et al. (2016) metacognitive framework, as discussed in Study 1 (see Table 1). The same analysis strategy was adopted in study 1 and a 90% agreement in coding was found between the two researchers. A 100% agreement was achieved following discussions between the researchers. The number of verbalisations were grouped by distance quartile of the TT for the primary and secondary themes for both the trained and untrained groups and descriptive data is represented as frequency percentages and absolute counts (Table 5). To explore between-group differences in the number of verbalisations for whole trial data, Mann Whitney-U tests were used. To explore within-group differences over distance quartile, Friedman's repeated-measures tests were conducted. In the event of significant differences, post hoc analysis was conducted using Wilcoxon Signed Rank tests.

Speed, power output and heart rate data were analysed over distance quartile and as whole trial averages. To normalise speed, quartile values are expressed as a percentage deviation from the individual's average trial speed. Means and standard deviations (SD) are reported for power output, speed and heart rata data and repeated-measures ANOVA's were used to explore within- and between-group differences. Bonferroni adjusted post-hoc analyses were performed where significant main and interaction effects were found. Two-tailed statistical significance was accepted as $p < .05$ and effect sizes are reported using partial eta squared (eta^2) and Cohen's d values (δ).

Results

Think Aloud Data

The total number of verbalisations did not significantly differ between the trained (*M* = 106.2) and untrained groups (*M* = 123.2) (*p* = .44). Internal associative verbalisations made up 80% of the trained groups' overall thoughts with 62% relating to Active Self-Regulation thoughts and 18% to Internal Sensory Monitoring. The untrained group also predominantly verbalised Internal Associative thoughts, with 52% and 14% of verbalisations relating to Active Self-Regulation and Internal Sensory Monitoring, respectively. The untrained group verbalised Outward Monitoring thoughts for 27% of the trial whereas this was 17% of the trained groups' verbalisations. Distraction thoughts were the least verbalised themes for both groups (see Table 5).

A between-group comparison of the secondary themes verbalised identified that the untrained group verbalised more Outward Monitoring thoughts than the trained group at quartile 1 (*M* Rank = 13.40 and 7.60; U = 21.50, *p* = .03; δ = .99) and quartile 2 (*M* Rank = 13.35 and 7.65; U = 9.50, *p* = .002; δ = 1.87). The untrained group also verbalised significantly more Distraction thoughts than the trained group at quartile 2 (*M* Rank = 14.00 and 7.00; U = 15.00, *p* = .002; δ = 1.01). All differences had a large effect size.

Between-group comparisons of the primary themes analysed by whole trial found that the untrained group verbalised more time (*M* Rank = 14.40 and 6.60; U = 11.00, *p* = .003; δ = 1.56), irrelevant (*M* Rank = 14.05 and 6.95; U = 14.50, *p* = .005; δ = 0.84) and pain and discomfort (*M* Rank = 13.10 and 7.90; U = 24.00, *p* = .047; δ = 0.93) thoughts. The trained group verbalised more thoughts of power (*M* Rank = 13.50 and 7.50; U = 20.00, *p* = .02; δ = 0.96) and cadence (*M* Rank = 13.40 and 7.60; U = 21.00, *p* = .02; δ = 0.73). No other significant differences in primary themes were found between the trained and untrained groups. Significant between-group differences of primary themes across distance quartile are presented in Table 6.

Within-group analyses were also conducted to explore the differences in cognitions across distance for each group. For the trained group, a main effect for distance was found for the secondary theme Outward Monitoring (x^2(3, n = 10) = 16.81, *p* = .001) with post hoc analysis identifying a significant increase in verbalisations across the duration of the TT. There were significantly more verbalisations at quartile 3 (*M* Rank = 9.15) and 4 (*M* Rank = 8.65) than at quartile 1 (*M* Rank = 7.60) (Z = -2.27, *p* = .02, δ = .98 and Z = -2.20, *p* = .03, δ = 1.25, respectively) and at quartile 2 (*M* Rank = 7.65) (Z = -2.68, *p* = .007, δ = 1.51 and Z = -2.67, *p* = .008, δ = 1.83 respectively). The untrained group verbalised significantly more Distraction thoughts at quartile 1 (*M* Rank = 10.70) and quartile 2 (*M* Rank = 11.30) than at quartile 4 (*M* Rank = 10.10) (Z = -2.04, *p* = .04, δ = 0.68 and Z = -2.03, *p* = .04, δ = .55, respectively). No significant differences were found across distance for the secondary themes Internal Sensory Monitoring, Active Self-Regulation and Internal Dissociation for either group ($p > .05$).

Within-group analyses for primary themes identified significant distance main effects for Motivation and Distance for the trained group, and Motivation and CompuTrainer Scenery for the untrained group (see Table 7). Both groups verbalised significantly more thoughts relating to Motivation across the duration of the TT and the trained group also verbalised more about Distance. The untrained group verbalised fewer thoughts relating to the CompuTrainer Scenery across the TT distance. No other significant differences were found across distance for the primary themes in either group ($p > .05$).

Pacing Data

The trained group performed the TT in a significantly faster time than the untrained group (MD = 3.88 min, *t*(10.4) = -3.68, *p* = .004, δ = 1.64) (see Table 8). As speed was analysed as a percentage of the trial average, a main effect for group was not applicable. No significant effects for quartile (F(1.9, 18) = 2.72, *p* = .08, $eta^2 = 0.13$) or group x quartile (F(1.9, 18) = 2.71, *p* = .08, $eta^2 = 0.13$) were found for speed (see Figure 1).

For power output, a significant main effect for group was found (F(1, 18) = 27.09, $p < .001$, $eta^2 = 0.60$), where the trained group's power output was significantly higher than the untrained (mean difference (MD) = 74.1, CI = 44.21, 104.05). A quartile main effect was also found (F(1.6, 18) = 4.49, *p* = .027, $eta^2 = 0.20$), with post-hoc analysis demonstrating that power output in quartile 4 was significantly higher than in quartile 3 (MD = -12.29, *p* = .001, CI = -20.34, -4.84). The quartile by group interaction was not statistically significant ($F(1.61, 18) = 1.81$, $p = .18$, $eta^2 = 0.09$).

For heart rate, there were significant main effects for group ($F(1, 18) = 4.90$, $p = .04$, $eta^2 = 0.22$) and quartile ($F(1.9, 18) = 60.36$, $p < .001$, $eta^2 = 0.78$). The trained group had a higher heart rate than the untrained group (MD = 13.3, CI = .45, 25.67) and heart rate was significantly different between each quartile ($p < .05$). There was no significant effect for the group x quartile interaction ($F(1.9, 18) = 2.48$, $p = .10$, $eta^2 = 0.13$).

Discussion Study 2

The main findings demonstrate that trained cyclists' cognitions differ from the cognitions of untrained cyclists, as demonstrated by differences in verbalisations recorded using a TA protocol. Despite no differences in the total number of verbalisations throughout the TT, the nature of the verbalisations was found to vary between the groups. On average, untrained participants verbalised significantly more Outward Monitoring thoughts (27% vs 17%) and Distraction thoughts (7% vs 3%) than the trained group. For the primary themes, the untrained group verbalised significantly more thoughts about Time, Irrelevant Information, and Pain and Discomfort than the trained group. Conversely, trained participants verbalised more about Power and Cadence than the untrained group. As expected, the trained group performed the TT in a significantly faster time although pacing strategies were not found to significantly differ between the groups, despite the appearance of their dissimilar distribution of speed.

The trained groups' thoughts were predominantly related to internal associative cues (Internal Sensory Monitoring and Active Self-Regulation) (80%) which is comparable to previous research in endurance running which found that 88% of competitive runners' thoughts were focussed internally on the monitoring of bodily processes and task-related management strategies (Nietfeld, 2003). Furthermore, Baker et al. (2005) also demonstrated that 86% of expert triathletes' thoughts related to active performance-related cues. The untrained groups' prevalence of 27% outward monitoring verbalisations is also comparable to findings of a 28% share of external thoughts for recreational runners (Samson et al., 2015).

Over the duration of the trial, the untrained group verbalised more about Pain and Discomfort than the trained group, with significant differences found between the groups during the second and third quartiles of the TT. These verbalisations from the untrained group also occurred concurrently with a drop-in pace following a faster first quartile and therefore could be a result of increasing salience of physiological disturbance causing a subsequent associative attentional focus (see Balagué et al., 2012; Hutchinson & Tenenbaum, 2007; Tenenbaum & Connolly, 2008). This supports recent evidence that recreational endurance athletes consistently report experiences of unpleasant exercise-induced sensations such as pain, fatigue, exertion and discomfort during exercise (McCormick, Meijen & Marcora, 2016). The differences between trained and untrained athletes may be in their appraisals of these experiences and this, in turn, may partially explain the resultant differences in performance. For example, Rose and Parfitt (2010) proposed that low-active exercisers have a negative interpretation of interoceptive cues, represented by perceptions of fatigue or discomfort, which causes affective responses to suffer. On the other hand, trained endurance runners will accept and embrace feelings of pain and discomfort and consider it as essential in the accomplishment of goals, instead describing discomfort as 'positive pain' (Bale, 2006; Simpson, Post & Young, 2014). Similarly, since elite performers can monitor their bodily sensations more effectively than untrained (Raglin & Wilson, 2008), the trained participants' perceptions of pain and discomfort may not have necessitated as much attention. Instead, trained athletes can effectively appraise these sensations based on previous experience which allows them to more accurately interpret and inform the active self-regulation of effort (Brewer & Buman, 2006).

The untrained group verbalised more distractive thoughts, i.e. irrelevant, task-unrelated thoughts. This dissociative attentional focus has also been demonstrated in running, whereby low-active women used more deliberate dissociative strategies compared to high-active women (Rose & Parfitt, 2010). This was suggested to be an adaptive coping strategy to make the task appear less daunting and reduce perceptions of effort. However, despite reductions in perceived effort, this type of distractive strategy has been linked with a slower-than-optimal pace (Brick et al., 2016; Connolly & Janelle, 2003), poorer performance and lower levels of arousal and pleasantness (Bertollo et al., 2015). In the current study, the untrained group's pace dropped during the second quartile of the TT where verbalisations of irrelevant thoughts were significantly greater than the trained group, supporting this possible relationship between cognitions and performance (Brick et al., 2016).

In contrast, the trained group verbalised very few irrelevant thoughts and significantly more thoughts relating to power, breathing and controlling emotions than the untrained group in the second and third quartiles. In fact no irrelevant thoughts were verbalised from any trained participant in the second quartile, further supporting that attention was instead directed to the task itself and aligned with the regulation of emotions and performance goals. Brick, et al, (2015) also demonstrated how competitive runners actively avoid distractive thoughts in order to maintain a task focus that supports the regulation of effort perceptions and the optimisation of pace during competition. The present results of the trained cyclists verbalising about associative, active self-regulatory themes (power output and control of emotion thoughts) in the middle section of the TT supports such previous demonstrations. These observations also agree with those previously found in other sporting disciplines in which high-skilled golfers verbalised more strategic, performance-related thoughts than less-skilled golfers (Arsal et al., 2016). The focus on active self-regulatory strategies has been linked with improvements in movement economy and pacing accuracy in the absence of elevated perceptions of effort (Brick et al., 2016). This pattern of verbalisations in the mid-section of the TT also coincided with a sustained exertive effort and more even pace in the trained group. On the other hand, the untrained group dropped their pace following a faster start that may have exceeded their ventilatory threshold and resulted in negative affective valence (Ekkekakis, Hall & Petruzzello, 2008). Therefore, without the experience-primed ability to regulate and effectively deal with these unpleasant sensations as demonstrated by the trained group, their behavioural response was to reduce work rate.

The second study looked to identify if cognitions changed over the duration of the TT. Both the trained and untrained groups verbalised significantly more motivational thoughts across the duration of the TT, with the percentage of verbalisations increasing by 24% and 18%, respectively. These positive motivational statements may be indicative of a self-talk strategy, warranted more towards the end of the TT where the task becomes more challenging and it becomes more salient to overcome greater levels of perceived discomfort and maintain a target pace (Brick et al., 2016). This change in verbalisations also coincides with the increase in pace in the final quartile demonstrated by both groups (i.e., an end-spurt), indicating a greater need for cognitive strategies to enable this increase in pace to achieve goal attainment. Furthermore, research has also demonstrated that long-distance runners utilise strategies such as positive self-talk, goal-setting and attentional focus strategies to maintain and manage their pace (Samson et al., 2015; Simpson et al., 2014).

In addition, the trained group verbalised more distance-related thoughts across the TT which supports the previous pattern demonstrated in Study 1 and in our recent work with trained cyclists (Whitehead et al., 2017). Whilst distance was a consistently prominent theme in the untrained group, this change and adaptation of focus seen in the trained group may suggest that they are better able to appraise this distance information in a reactive manner such that it will inform their regulatory efforts (Brewer & Buman, 2006). In response to the situational characteristics of the TT, these findings suggest that the trained group demonstrated more reactive cognitive control and used this distance information to maintain goal attainment (Brick et al., 2016). On the other hand, the inexperienced group will lack effective schema to interpret this distance information and related bodily sensations, resulting in negative affect and effort withdrawal.

This study has provided evidence for differences between trained and untrained participants in both cognitive processes and pacing behaviours during TT performance. There is evidence to support that different cognitive strategies may be used to deal with the pain and discomfort experienced during endurance exercise and that experience and training level determines the types of strategies used (Bertollo et al., 2015). Trained participants were more task-focussed using active self-regulatory strategies, whereas untrained participants used distractive strategies to avert their attention from these interoceptive cues.

Study 3 – An evaluation of the feasibility of using Think Aloud protocol during a 16.1 km time trial performance from a participant perspective.

It is argued that to better understand cognition in sporting events researchers much employ the most appropriate and reliable methods (Whitehead et al., 2015). To date, very little research has examined the social validation of the use of TA with athletes. Previous research has looked at the effect of TA on performance or the difference between TA and other data collection methods within self-paced sports such as golf (Whitehead et al., 2015). Similarly, Fox, Ericsson, and Best (2011) compared performance on tasks that involved concurrent verbal reporting conditions with matching silent control conditions, concluding that instructing participants to merely verbalise their thoughts during a task did not alter performance. However, participants' thoughts and feelings about thinking aloud and their own perceptions of whether TA affects their performance is yet to be investigated. Nicholls and Polman (2008) suggested that a possible reason for the lack of empirical TA research within endurance sports is due to the challenges athletes may face in concurrently thinking aloud during an aerobically challenging event. Therefore, if the TA protocol is to be used within an endurance sport setting then it is important to investigate participant's perceptions of using this protocol. Traditionally, social validation procedures have been used to measure participant perceptions and satisfaction related to an intervention (e.g., Mellalieu, Hanton & O'Brien, 2006). However, it is also important to investigate perceptions of new and innovative methodological procedures, which in turn will inform the employment, or otherwise, of such methodologies in future research. Furthermore, social validation procedures have been suggested to strengthen the external validity of technical and practical action research by offering a personal insight into the intervention through the experiences of the participants (Newton & Burgess, 2008; Whitehead et al., 2016a).

One recent study which conducted both immediate and post eight-week social validation interviews of TA as an aid to reflective learning amongst rugby league coaches, was the aforementioned workings of Whitehead et al. (2016a). Results illustrated that coaches developed an increased awareness, enhanced communication, and perceived pedagogical development. The participants also suggested TA as being a valuable tool for collecting in-event data during a coaching session, and developing and evidencing reflection for coaches. Whilst these findings relate to the perceived utility of TA within coach education, they represent the first participant social validation of the TA protocol, implying that further research into this area is warranted across other populations. In light of the lack of research that has used TA within an endurance setting, specifically cycling, this study aimed to assess participant's perceptions of being asked to think aloud during a 16.1 km TT performance. In doing so, this study not only seeks to obtain participant views on the utility of the TA protocol in relation to their TT performance, it also provides a potential indicator of the validity and reliability of the data obtained in studies 1 and 2, reflecting whether or not participants knowingly changed their behaviours or cognitions in accordance with the TA protocol.

Material and Methods

Participants

Twenty-seven male and three female cyclists (*M* age = 36.87; *M* experience = 5.27) were recruited from North Yorkshire and Liverpool cycling clubs. All participants consisted of those who had previously taken part in study 1 and study 2. Written informed consent was attained prior to participation and the study was approved by an institutional research ethics committee.

Materials

An Olympus Dictaphone was used to record all interviews.

Procedure

Semi-structured, telephone interviews were conducted with all 30 participants within 48 hours following the completion of their TTs. These interviews lasted between 10 and 20 minutes and provided an opportunity for the participants to discuss their experiences of using the TA protocol immediately after their individual TT had taken place. Recent publications have highlighted the potential utility of telephone interviews as an alternative to the 'default mode' of face-to-face interviewing (Holt, 2010; Stephens, 2007), in that they allow for participants to control the privacy and practicalities of the conversation as they deem appropriate. In this light, telephone interviewing was deemed an appropriate method of data collection here as it allowed for contact to be established at the participant's earliest convenience following their participation in the TT.

Interview questions focussed primarily on the participants' experiences of using the Think Aloud protocol, and included questions such as; how easy or difficult was it was to articulate your thoughts during this particular time trial?; to what extent do you consider think aloud to be an acceptable means of assessing your thoughts during performance?; did your use of the protocol enable you to reflect on performance as it was occurring in any way, and if so, are there any examples you could offer? All the interviews were audio-recorded so that they could be transcribed verbatim prior to the subsequent data analysis taking place.

Data Analysis

Inductive content analysis was used as a means of analysing the interview data obtained from the participants (Scanlan, Stein, & Ravizza, 1989). Given that this is the first study to consider participant perceptions about thinking aloud and whether if affects their performance, inductive reasoning was employed with a view to allowing themes to emerge from the raw data. Biddle, Markland and Gilbourne (2001) suggested that within content analysis methodologies, raw data represents the basic unit of analysis and usually comprises of quotes that clearly identify an individual's subjective experience. The 'clustering' of these raw data extracts in turn establishes first-order themes, with the comparing and contrasting of individual quotes being undertaken to unite those with similar meanings and to separate those which differed (Scanlan et al., 1989). This same analytical process is then repeated and built upwards to create higher order themes until it is not possible to locate further underlying uniformities to create a higher theme level. In keeping with the mixed-methods design of this multi-study series, an *expansion* approach (Gibson, 2016) was adopted, with a view to exploring participant's thoughts and feelings on the use of TA during time trial cycling. A subjective epistemology and relativist ontology was adopted, recognising participant experiences as local and constructed. More specifically, a double hermeneutic was undertaken, wherein researchers tried to make sense of participants own sense making. Consistent with this position the potential limitations of inter-rater reliability, as highlighted by Smith and McGannon (2017) were acknowledged. As a result a critical friend was used, not to vouch for an objective truth but to critically ensure data collection and analysis was plausible and defendable (Smith & McGannon, 2017).

As a result of this inductive content analysis process, Table 9 depicts both first- and second-order themes for the 'general dimensions' or themes which are apparent within the interview data. As a result of this process, a total of 142 data extracts were selected and analysed (a selection of which are included within Table 9). Two general dimensions emerged from this data, the first of which was comprised of data regarding the participants' views on how TA and race performance were linked. Primary themes identified here relate to the perceived impact of thinking aloud on performance (positive, negative or neutral), and the perceived purpose of TA within the race itself (i.e. reflection, goal-setting, strategizing etc.). The second general dimension contains data regarding participants' views on the process of thinking aloud within the race, and includes data regarding perceived barriers and enablers to utilising the TA protocol. Both of these general dimensions are extrapolated further below.

Results

For the findings of Study 3, see Table 9.

Discussion Study 3

Social validation was used to explore participant perceptions of being asked to TA and the feasibility of this methodological approach within endurance exercise. Findings revealed that asking participants to TA was viewed as both a potential barrier and/or an enabler to performance. From a performance perspective, previous research by Whitehead et al. (2015) supported that using TA at level 2 does not negatively affect performance. Whitehead et al. (2015) found that thinking aloud did not pose a negative effect on performance and in fact, golfers engaged more time in actively seeking solutions and planning, which may have resulted in the development of strategies to enhance performance. This was also evident within the current study, in that participants identified how TA enabled them to think more positively in addition to providing motivation to push harder within their performance.

A number of seemingly positive functions of TA were identified which included; within-race reflection, goal-setting, strategizing and increasing focus and concentration. Previous research in sports coaching has identified how asking coaches to verbalise their thoughts in an event may increase their awareness of their own thought processes (Whitehead et al., 2016a). Coaches reported being more aware of what they were doing and in turn this enabled reflection-in-action. Gagne and Smith (1962) also demonstrated how asking participants to verbalise their reasoning when completing the Tower of Hanoi produced more efficient solutions (taking fewer moves), and suggested that the instruction to verbalise the reasons for their moves induced more deliberate planning. This raising of awareness could be a limitation when using TA during natural sporting performance as it may redirect thought processes elsewhere away from what they would usually do. However, participants in this study highlighted how this could also be interpreted as a positive influence, with TA seeming to make them more aware of their thought process, allowing for a higher level of concentration on the information that they deem most important (e.g., active self-regulatory thoughts), as evidenced in Table 1.

In addition to acknowledging the perceived links between TA and subsequent performance outcomes, participants also provided their thoughts on the process of utilising the TA protocol within the race itself. Some of the barriers included those regarding the physically demanding nature of the sport and how it impacted on their ability to articulate their thoughts (cf. Nicholls & Polman, 2008), as well as personal preferences for remaining quiet during a race and not wanting to be seen talking out loud. In contrast to this however, a number of participants also suggested that they adjusted well to the process of TA, with some stating a willingness to continue to utilise the protocol outside of the research study itself, mirroring the findings of similar research by Whitehead et al. (2016a). Furthermore, and in accordance with the positioning of this data within this current multi-study project, participants also offered a range of perspectives regarding their perceived awareness of the ongoing data collection that was occurring during the TA process. Whilst there was no direct influence of any members of the research team during either the lab or field studies described in this paper, a number of participants discussed how their awareness that they were being recorded during the race impacted on what was said. For some participants, there was no perceived change in articulated thoughts as a result of being recorded, however, others suggested that they felt a pressure to speak during the ride as they knew they were being recorded. These findings seemingly indicate that further social validation research regarding participant perceptions of being asked to TA during performance are warranted as research into the area continues to develop in the future.

Conversely, some participants highlighted that TA could have a potentially negative effect on their performance, as they reported holding back in terms of energy expenditure in order to enable them to TA. This is an important point to consider and relates to the suggestion that a possible reason for the lack of empirical concurrent TA research within endurance sports is due to the challenges athletes may face in concurrently thinking aloud during an aerobically challenging event (Nicholls & Polman, 2008).

Although this study found TA to have both positive and negative perceived effects on participants' performance, it is important to acknowledge that this is the first time this kind of protocol has been evaluated to inform the future utilisation of TA. Through recommendations of how to develop the methodology further, this will create a more robust and valid method of data collection. One potential area for development could be the amount of time and tasks dedicated to the training of TA. Although Ericsson and Simon (1980) recommend specific guidelines, which were followed within this collection of studies, more specific training could be employed within an endurance activity. For example, allowing participants to become more familiar and comfortable with the process may lead to a more naturalistic set of data. Research often includes familiarisation periods for the exercise protocols adopted (Williams et al., 2014; Wass, Taylor & Matsas, 2005) therefore it is reasonable to expect that methodological protocols may also need this same level of familiarisation. Consequently, future research using TA protocol should consider extending the length of the TA training process to ensure familiarisation with the protocol.

Although it is evident that not all participants view engaging in TA positively, it is important to acknowledge the growing body of research that has used this method of data collection. The TA protocol is a means of collecting concurrent data, where other methods (e.g., retrospective interviews) cannot. This social evaluation study provides evidence that the data obtained in study 1 and 2 are valid and reliable.

General Discussion

Given the limited insight into the temporal characteristics of endurance athletes' specific cognitive strategies, this research provides valuable insight using TA. This discussion will bring together both study 1 and 2 in order to make valuable comparisons between the results found in both the lab and field based studies.

Lab Vs Outdoor Environmental Conditions

In both laboratory and field TT conditions, Active Self-Regulation was the most verbalised theme. Given the goal-directed nature of the task this is to be expected, but that participants were able to verbalise these cognitive efforts supports the utility of TA in these settings. Further similarities were seen in the use of motivational strategies as the trend for an increase in verbalisations across the TT was evident for all participant groups regardless of environmental condition. These findings support Blanchard, Rodgers and Gauvin (2004) who demonstrated that cognitions and feeling states during running in a track environment were comparable to those observed in a laboratory. In contrast however, there were more verbalisations relating to the distraction thoughts during the field TT than the lab TT. This is in support of Slapsinskaite, Garcia and Razon et al., (2016) findings that outdoor environments result in a greater prevalence of external thoughts and use of a dissociative attentional strategy compared to indoor environments. Future research should consider the transferability of these findings and acknowledge the importance of environmental differences.

Expertise Differences

Both the lab and field studies included groups of trained cyclists with TT experience. Similar trends in verbalisations were observed between these groups, with an increasing number of verbalisations relating to external associative cues, Motivation and Distance across the TT. There were differences observed in the prevalence of Outward Monitoring themes of Distance and Time, with Distance verbalised less during the field TT than the laboratory TT.

Although distance was a consistently prominent theme in the untrained group in Study 2, distance-related verbalisations increased across the TT for the trained cyclists in both the lab and field groups. This is a similar finding to that observed in previous cycling TT research (Whitehead et al., 2017) and could support the assertion that trained athletes employ both proactive and reactive cognitive control of focus of attention to facilitate performance, and most specifically near the end of the race (e.g., Brick et al., 2016). This change and adaptation of focus was not present in the untrained group and is suggestive of the ability of experienced athletes to self-regulate attentional focus in response to internal and external distractors during performance (Bertollo et al., 2015).

Overall, it is clear that expertise influences thought processes and use of cognitive strategies during TT performance. In particular, expertise appears to be associated with the ability to cope with negative feedback information (e.g., in relation to fatigue and pain). Having an experience-derived pacing schema better enables effective cognitive control through accurate appraisal of pain and discomfort in relation to the remaining distance and task goals (Addison, Kremer & Bell, 1998; Brewer & Buman, 2006).

Limitations

Whilst TA has been used to provide evidence for during-task changes in individual cognitive processes, it is not possible to measure what is unconscious due to an inability for individuals to verbalise decisions that are made unconsciously. Therefore, studies can only measure what is in the conscious thought process. Similarly, and as suggested previously by Nicholls and Polman (2008), individuals may also report a greater number of verbalisations for what they believe is expected or perceive is of importance to the investigation. Further limitations, relating to familiarity must be acknowledged, as Study 3 highlighted how some participants may have benefitted from further training, therefore better familiarisation of the protocol may have allowed them to feel more comfortable with the TA process. Furthermore, gender differences were not taken into account within this research. A previous study identified how female runners are more likely to engage in 'personal problem solving' during marathon training (Schomer & Connolly, 2002). Kaiseler, Polman and Nicholls (2013) identified cognitive differences in stress and coping between males and females using TA, therefore it would be of interest to investigate cognitive differences between males and females within cycling and pacing.

Although the data analysis of study 1 and 2 involved inter-rater reliability to ensure rigor, it is important to acknowledge the potential limitations of this, in that different coders may unitize the same text differently (Campbell, Quincy, Osserman, & Pedersen, 2013). For example, during the data analysis some themes experienced this subjectivity of coding, indicated by the 10-14% discrepancies found between coders, specifically with the theme distraction. In addition to the conceptual clarity provided by Brick et al. (2014), the present study has highlighted that the task itself is a critical consideration in thought categorisation. For example, some thoughts within a laboratory setting (e.g., "eyes on the road") would be considered active distraction due to the arbitrary information provided by the road simulation, whereas the same thought when cycling on the road would be task-relevant outward monitoring. Therefore, for future reflection, we would like to acknowledge the recommendations of Smith and McGannon (2017) surrounding the analysis approach taken with the TA data. In studies 1 and 2, we, like others in TA literature, have taken a post-positivist/cognitivist perspective approach. Future TA researchers could however consider adopting a constructionist lens. As Eccles and Arsal (2017) quite rightly suggest, the results from these positions would be different, albeit not better or worse. Thus, TA is an area that offers opportunities and would benefit from researchers with different theoretical and philosophical lenses.

Conclusion

The findings of this study extend previous research within pacing and endurance athlete cognitions through utilising TA. In addition, it has extended previous work by accounting for performance data (speed, power, time, heart rate), which has allowed for inferences to be made between participant verbalisations and the performance parameters. As previously recommended by Whitehead et al., (2017), this study has acknowledged participant perceptions of thinking aloud on pacing performance and has also adopted a more thorough coding scheme (Brick et al., 2014). It is hoped that this data can support the use of TA in future pacing and endurance research. Further, this study provides further evidence that thought processes change throughout an event and gives an insight into how athletes may respond cognitively to different performance and physiological experiences. This in turn could inform coaches, athletes and psychologists in understanding how their athletes pace during performance, and what variables they attend to at difference stages. Importantly, the third study provided evidence that TA is a valid and reliable methodology to collect in-event data during endurance activities. Providing participants with enhanced practice prior to performance might help in making TA easier to execute. In addition, more studies are required to compare the different levels of TA with no TA in TT performance.

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Table 1: Primary and secondary themes identified from TA data

Secondary Themes	Primary Themes	Description	Example of raw data quotes
Internal Sensory Monitoring	Breathing	Reference to breathing or respiratory regulation	"Pretty smooth, just keep the deep breaths" (S1 P4) "Control my breathing" (S2 Trained P3) "Breathe in and breathe out" (S2 Untrained P5)
	Pain and Discomfort	Reference to physical injury, pain or general discomfort during the task	"Just my legs burning a bit." (S1 P3) "This is hurting now" (S2 Trained P7) "The saddle is getting a bit uncomfortable" (S2 Untrained P3)
	Hydration	Reference to taking or needing a drink	"Going to use this opportunity to get a drink." (S1 P6) "Thirsty again" (S2 Trained P1) "Taking a drink, realised I forgot" (S2 Untrained P4)
	Fatigue	Reference to tiredness, including mental and physical fatigue but not associated with pain or discomfort	"I just feel exhausted" (S1 P1) "Legs getting tired" (S2 Trained P10) "Oh I'm exhausted" (S2 Untrained P7)
	Temperature	Reference to the temperature of the room, feeling hot/cold, sweat rate.	"I'm hot" (S1 P9) "I'm sweating now" (S2 Trained P7) "It's too hot to be above 190" (S2 Untrained P9)
	Heart Rate	Increasing or decreasing of heart rate, or statement of heart rate value.	"Heart rate's at 94 already" (S1 P9) "Pulse is rising to 170" (S2 Trained P9) "My pulse is going down" (S2 Untrained P6)
Active Self-Regulation	Cadence	Verbalisations relating to pedal stroke	"Cadence staying up so that's good." (S1 P1) "Steady cadence, just keep turning the wheel" (S2 Trained P4) "Get my cadence up" (S2 Untrained P8)
	Speed	Reference relating specifically to speed	"Steady between 33 and 34. Try and pick it up to 35" (S1 P2) "Speed is still down a bit" (S2 Trained P10) "Kilometres still over 30, that's good" (S2 Untrained P10)
	Power	Reference relating to power output or watts	"Watts below 300" (S1 P3) "Bring the power down a touch" (S2 Trained P1) "Definitely got less power at this point" (S2 Untrained P4)
	Pace	Reference to purposeful strategy or action-based changes to pace	"Nice long straight to come off. Keep pushing constantly." (S1 P6) "I'll settle for a mile and then push up because that will be 8k" (S2 Trained P6) "I'm conscious that I don't want to go too fast too early" (S2 Untrained P9)

	Increase Pace	Direct reference to actively increasing pace	"Last two kilometres I'll try and pick it up." (S1 P2) "Take it up nice and easy, not too much" (S2 Trained P2) "A sprint then to the corner" (S2 Untrained P4)
	Maintain Pace	Direct reference to maintaining current pace	"Don't let it drop. Keep pushing. Try and keep it constant." (S1 P6) "Trying to keep this pace now" (S2 Trained P9) "Just look to maintain this now" (S2 Untrained P8)
	Decrease Pace	Direct reference to purposefully reducing pace or involuntarily slowing down	"It has cost speed and power" (S1 P3) "Come on, you're letting the power drop" (S2 Trained P7) "My pace is dropping to 23 now" (S2 Untrained P2)
	Controlling Emotions	Reference to controlling emotions	"Come on, just focus." (S1 P2) "Relax. That's it relax" (S2 Trained P2) "Stay in control, stay in control" (S2 Untrained P7)
	Gear use	Reference to gear change or gear selection	"Ease off the gears just a little bit." (S1 P10) "Just trying to get in the right gear to start with" (S2 Trained P1) "I've found another gear, it's a lot easier" (S2 Untrained P4)
	Motivation	Verbalisations relating to self-motivation or positive encouragement	"Keep going, keep going, it's looking good" (S1 P7) "That's it, you can do this" (S2 Trained P2) "Come on, you can do it" (S2 Untrained P6)
	Technique[a]	Reference to technique including body position and coaching points	"Keep my head down. Relax shoulders." (S1 P1)
Outward Monitoring	Time	Reference to time, time elapsed or expected finish time	"Half way, just, aiming for 20 minutes" (S1 P4) "Another minute, just turning it over" (S2 Trained P6) "Ok, we're up to 3 minutes 30" (S2 Untrained P10)
	Distance	Any reference to distance covered or distance remaining	"Two kilometres done." (S1 P2) "Distance is ticking away slowly" (S2 Trained P1) "6.15 completed" (S2 Untrained P6)
	Competition[a]	Reference to both the performance of other cyclists or being caught/catching another cyclist	"On target though slightly over, but more prepared to catch him" (S1 P4)
Distraction	Irrelevant Information	Verbalisations not relevant to the given task	"I need a haircut, it's getting in my way." (S1 P2) "My watch has fallen on the floor" (S2 Trained P8) "I can't wait for lunch" (S2 Untrained P1)

CompuTrainer Scenery[b]	Reference to the visual display of the simulated course, avatar or scenery.	"There's a big mountain over there" (S2 Trained P3) "That's a nice tree on the right" (S2 Untrained P8)
Course Reference[a]	Any reference identifying specific distractions from the course.	"There's a lot of cars about today" (S1 P6)

[a] *Field study only*. [b]*Lab study only*
S1 = Study 1, S2 = Study 2.

Table 2: Percentage (absolute count) of verbalisations for secondary themes for a field-based time trial

Secondary Themes	**Whole-trial verbalisations**	**Verbalisations per quartile**			
		1	**2**	**3**	**4**
Internal Sensory Monitoring	8% (77)	9% (23)	10% (19)	9% (21)	6% (14)
Active Self-Regulation	63% (573)	71% (179)	56% (113)	58% (144)	62% (137)
Outward Monitoring	9% (81)	2% (6)	11% (22)	10% (24)	13% (29)
Distraction	20% (179)	18% (43)	20% (38)	24% (58)	18% (40)

Table 3. A within-group comparison of the significant secondary themes verbalised over distance quartile for a field-based time trial

Secondary theme	**Primary theme**	**Post-hoc analysis**			
		Quartile difference	**Wilcoxon Rank Z**	**Cohen's δ**	**Sig. Diff *P***
Active Self-Regulation	Maintaining pace	Quartile 1 * – Quartile 2	-2.46	1.18	.014
		Quartile 1 * – Quartile 4	-2.26	1.18	.024
	Motivation	Quartile 1 – Quartile 4 *	-2.72	0.37	.007
		Quartile 2 – Quartile 4 *	-2.51	0.48	.012
		Quartile 3 – Quartile 4 *	-2.15	0.25	.031
	Technique	Quartile 1 * – Quartile 2	-2.26	0.86	.024
Outward Monitoring	Distance	Quartile 1 – Quartile 4 *	-2.81	1.93	.005
	Competition	Quartile 1 – Quartile 2 *	-2.53	0.93	.011
		Quartile 1 – Quartile 3 *	-2.23	-1.10	.026

* denotes significantly more verbalisations

Table 4. Mean (SD) time-trial performance data across distance quartile for the field-based time trial

	Quartile 1	**Quartile 2**	**Quartile 3**	**Quartile 4**
Speed	39.00 (4.02)	38.41 (4.83)	34.94 (2.78) *	32.97 (2.70) **
Power	261.51 (64.62) ¥	245.77 (63.70)	245.46 (63.73)	255.34 (63.49)
Heart Rate	164.29 (11.44) ϴ	170.27 (9.84)	171.49 (8.99)	172.99 (8.20)
Cadence	86.42 (7.87)	83.90 (10.25)	84.33 (9.80)	83.85 (7.50)

*denotes significantly lower than quartile 1 ($p = .007$)
**denotes significantly lower than all other quartiles ($p \leq .009$)
¥ denotes significantly higher than quartile 2 ($p = .01$)
ϴ denotes significantly lower than all other quartiles ($p \leq .047$)

Table 5. Percentage (absolute count) of verbalisations for secondary themes for trained and untrained participants during a lab-based time trial

Secondary Themes	**Whole-trial verbalisations**		**Verbalisations per quartile**							
	Trained	**Untrained**	**Trained**				**Untrained**			
			1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Internal Sensory Monitoring	18% (196)	14% (194)	21% (50)	23% (55)	17% (51)	13% (40)	14% (43)	13% (51)	16% (57)	12% (43)
Active Self-Regulation	62% (670)	52% (704)	62% (146)	63% (151)	61% (184)	63% (189)	43% (137)	49% (186)	51% (180)	56% (201)
Outward Monitoring	17% (183)	27% (186)	13% (30)	12% (28)	19% (58)	22% (67)	28% (88)	25% (96)	25% (90)	27% (96)
Distraction	3% (33)	7% (98)	4% (10)	3% (7)	3% (9)	2% (6)	10% (30)	10% (36)	5% (18)	3% (14)

Table 6: A between-group comparison of primary themes verbalised across distance quartile during a lab-based time trial

Secondary theme	**Primary theme**	**Quartile**	**Mann-Whitney U**	**Cohens δ**	**Sig. diff *P***	**Mean Rank data** Trained	Untrained
Internal Sensory Monitoring	Breathing	2	23.00	0.76	.021	13.20 *	7.80
	Pain and Discomfort	3	47.00	1.01	.038	7.85	13.15 *
	Fatigue	3	30.00	1.09	.029	8.50	12.50 *
Active Self-Regulation	Cadence	3	27.50	0.77	.044	12.75 *	8.25
	Speed	3	21.00	1.00	.024	7.60	13.40 *
	Power	2	24.00	0.79	.039	13.10 *	7.90
		3	22.00	0.99	.029	13.30 *	7.70
		4	24.00	0.77	.040	13.10 *	7.90
	Pace	2	22.50	0.92	.034	7.75	13.25 *
	Controlling Emotions	2	28.50	0.99	.044	12.65 *	8.35
Outward Monitoring	Time	1	14.50	1.36	.005	6.95	14.05 *
		2	6.00	2.19	<.001	6.10	14.90 *
		3	20.00	1.00	.020	7.50	13.50 *
		4	24.50	1.05	.004	7.95	13.05 *
	Distance	2	18.50	1.24	.016	7.35	13.65 *
Distraction	Irrelevant information	2	15.00	1.01	.002	7.00	14.00 *

** denotes significantly more verbalisations than the other group*

Table 7: A within-group comparison of primary themes verbalised across distance quartile during a lab-based time trial

Secondary theme	**Primary theme**	**Group**	**Quartile difference**	**Post-hoc analysis**		
				Wilcoxon Rank Z	**Cohen's δ**	**Sig. diff *p***
Active Self-Regulation	Motivation	Trained	Quartile 1 – Quartile 3 *	-2.81	1.44	.005
			Quartile 1 – Quartile 4 *	-2.81	1.99	.005
			Quartile 2 – Quartile 4 *	-2.20	0.76	.028
		Untrained	Quartile 1 – Quartile 2 *	-2.33	0.05	.020
			Quartile 1 – Quartile 3 *	-2.00	0.57	.046
			Quartile 1 – Quartile 4 *	-2.71	1.23	.007
			Quartile 3 – Quartile 4 *	-2.15	0.60	.031
Outward Monitoring	Distance	Trained	Quartile 1 – Quartile 3 *	-2.45	1.12	.014
			Quartile 1 – Quartile 4 *	-2.45	1.58	.014
			Quartile 2 – Quartile 3 *	-2.53	1.16	.011
			Quartile 2 – Quartile 4 *	-2.68	1.66	.007
Distraction	CompuTrainer Scenery	Untrained	Quartile 1 * – Quartile 4	-2.04	0.68	.041
			Quartile 2 * – Quartile 4	-2.03	0.55	.042

**denotes significantly more verbalisations*

Table 8: Mean (SD) whole-trial performance data for trained and untrained groups during a lab-based time trial

	Trained	**Untrained**
Time (mins)	25.94 (0.89)*	29.82 (3.22)
Speed (km.hr^{-1})	37.46 (1.41)*	32.63 (2.97)
Power Output (W)	267.90 (24.07)*	195.68 (37.52)
Heart Rate (beats.min^{-1})	165.62 (9.64)*	151.20 (15.67)

**denotes significantly faster/greater values than the untrained group*

Table 9. Primary and secondary themes identified from the TA social validation interviews.

General Dimension	Secondary Themes	Primary Themes	Example Raw Data Extracts
TA and Performance	Perceived Impact on Performance	**Negative Impact on Performance: "It slowed me down slightly"**	"…you had to hold yourself back a little bit more to make sure you could actually speak." (L3) "…it slowed me down slightly simply because I'm having to do something that I don't normally do" (L7) "…when I was thinking aloud…I had less concentration in my legs so all my speed dropped" (L8) "I underperformed a little bit. I don't know what I would have done if I hadn't been thinking aloud" (L19)
		No Perceived Impact on Performance: "It was probably as per normal"	"I don't think thinking aloud per se actually affects performance" (L17) "I wouldn't say it hindered me and I wouldn't say it helped me, it is probably, you know, it was probably as per normal I would think." (F8) "I'm not too sure if it benefited me in my race yesterday " (F9)
		Positive Impact on Performance: "Made me push a bit more	"…maybe made me push a bit more because I was like shouting…or concentrating more on my speed." (L11) "…it made me push myself, sort of as someone else was talking to me but it was me in my head." (L11) "…the think aloud, I think, was helping me to maybe sustain as I wasn't sure whether I was going to finish" (L15) "…my performance definitely improved…thinking out loud made me much more aware." (F3)
	Perceived Purpose of TA	**Within-Race Reflection: "You are giving yourself feedback almost"**	"…it can be positive because you're self-assessing…but it can be negative because you are thinking about it and concentrating on it too much." (L13) "…verbalising it is a way of synthesising that and then turning it into something a bit more concrete." (L17) "…you are giving yourself feedback almost…about how you can correct some of that." (F1) "…it certainly encouraged me, I would say, to reflect a little bit more on what I was doing at the moment." (F9)
		Goal-Setting: "Create little goals for myself"	"… when you say a goal…you are more motivated to do it than just thinking that and let it fade away." (L10) "…it made me sort of in a way create little goals for myself as I knew I had to say something." (L12) "…I had a 2Km goal, a 4Km goal…So, I was using the think aloud I suppose as a way to re-affirm goals" (L15)
		Strategizing: "It helped me to pace myself better"	"I was also working out a strategy…it helped me to pace myself better than I expected." (L8) "I seemed to kind of almost regulate it a little bit better cos I was talking it through in my mind and talking it out loud…so it made me kind of think through a strategy as I was doing it really." (L19) "…you're kind of committing yourself to a strategy and when you see that strategy going you have to talk yourself right…So it does keep you more focussed." (L5)
		Increased Focus and Concentration: "It puts you in the present doesn't it?"	"…verbalising it just keeps that focus…the more you got into that habit the more useful it would become." (L4) "…it puts you in the present doesn't it? There's a lot of stimuli and…actually I think think aloud just gets rid of a lot of that and moves it to the back…" (L15) "I suppose you take in more what you're thinking because you're saying it out loud…" (L16) "…by thinking aloud I think it tends to kind of relax you a little bit." (F1) "I think doing the think aloud made me actually more aware…whereas sometimes I think you just switch off" (F3)

General Dimension	Secondary Themes	Primary Themes	Example Raw Data Extracts
Process of TA	Perceived Barriers	**Personal Preferences: "I like to shut up and get on with it"**	"…in a race with others you probably would look quite odd…I think it is the self-conscious aspect" (L4) "I'm probably quite quiet on the bike…it's a bit weird talking to yourself." (L6) "I don't talk a lot anyway…I have that commentary in my head." (L7) "I like to shut up and get on with it." (L18)
		Perceived Difficulties: "You can't verbalise sometimes because you under so much strain"	"…you are sort of pushing that hard that you can't really speak anyway." (L3) "…it was kind of hard to think out loud then as I was catching my breath" (L11) "…by virtue of needing to breathe, you talk less…" (L14) "I had all these thoughts going all at the same time so obviously you can't say them all..." (L17) "…you can't verbalise sometimes because you are under so much strain because of the exertion" (F1) "It was quite hard at some points because I was literally blowing out of my backside" (F7) "…it felt like quite an effort to keep talking and thinking about things to talk about" (F11)
	Perceived Enablers	**Prior Tendencies: "I talk to myself a lot when I'm on there anyway"**	"I'm always thinking in my head when I'm on my bike…it does help when you're thinking whether it is out loud or in your head" (L5) "I found it quite good actually but I talk to myself a lot when I'm on there anyway." (L8) "…I would have done it but the only difference is that I am speaking it out loud" (L17)
		Adjusting to the Process: "It came fairly naturally"	"…it came fairly naturally…more naturally than I thought it probably would have done." (L4) "…it made it a bit more interesting to just cycling and having thoughts in my head…" (L16) "… when I actually started doing the bloody thing, I felt it was quite good." (L17)
		Openness to TA: "I'll try it at the weekend"	"I think it works really well for cycling and I think that would be really quite useful" (L8) "…it wasn't intrusive in any way and I think that would be important, to retain that element" (F9) "I'll try it, at the weekend I'll try it and see what happens." (L14) "I personally wouldn't use it but I think…it can be used as an internal coaching mechanism" (F7) "I think that I would use it on the training side but not use it in a race." (F8) "…I'd be happy to do it again without it having a detrimental effect to my performance." (F9) "I'd be happy to do it again, erm, primarily for the reason I don't see why not. " (F10)
		Social Desirability: "You know you're being recorded"	"…it's a strange one because you know you're being recorded…" (L11) "…I don't think there is any particular change in the way I approached it. I sort of went about it how I would normally, it was just obviously talking out loud." (L11) "You could argue that maybe a lot of it is forced under the circumstances." (F2) "I think I was thinking more about the fact that I should be sort of speaking…" (F4) "…I think also when you realise you are being recorded you tend to be a bit more positive…" (F7) "…I was a bit quiet and I was thinking I should be saying something" (F8)

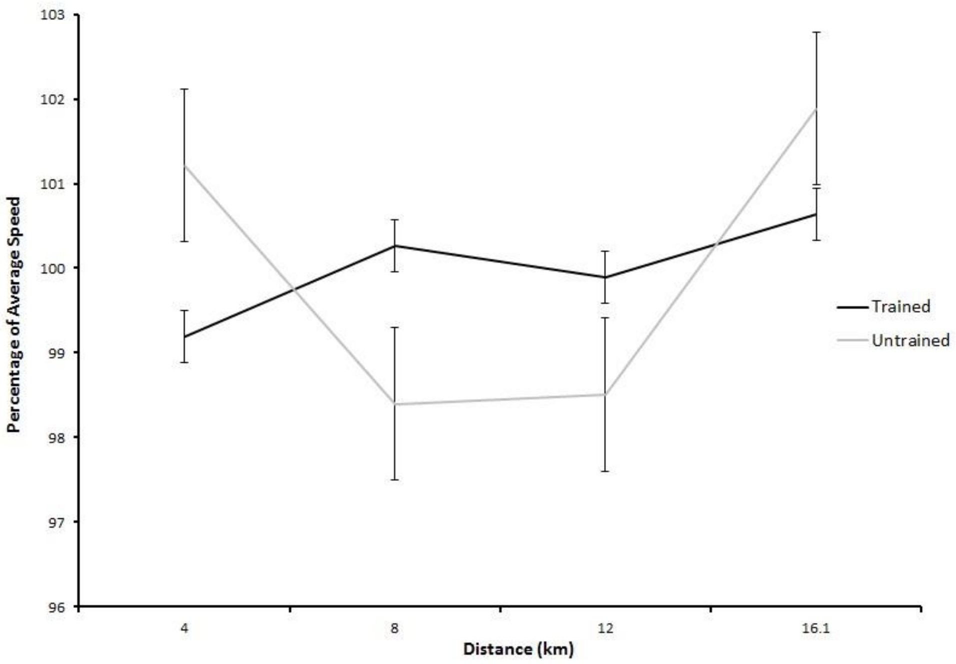

Figure 1: Mean (standard error) pacing profiles for both trained and untrained groups during a lab-based time trial.