Changes in Cognition over a 16.1 km Cycling Time Trial using Think Aloud Protocol: Preliminary Evidence.

Objectives: This study investigated cognitions of cyclists during a competitive time trial (TT) event using Think Aloud (TA) protocol analysis. Design: Single group, observational design. Method: Fifteen male and three female cyclists from the North West of England verbalised their thoughts throughout an outdoor competitive 16.1 km cycling time trial (Level 2 TA). Verbalisations were recorded using iVue Horizon 1080P camera glasses. Data was transcribed verbatim, analysed using deductive content analysis and grouped into themes: (i) Pain And Discomfort (Fatigue, Pain), (ii) External Feedback (Time, Speed, Heart Rate), (iii) Environment (Surroundings, Traffic and Other Cyclists), (iv) Pace and Distance (Pace, Distance). The number of verbalisations within each theme were analysed by distance quartile using Friedman tests to examine changes in cognitions over time. Results: Associative themes, including Fatigue and Pain, were verbalised more frequently in the earlier stages of the TT and less in the final quartile, whereas verbalisations about Distance significantly increased in the last quartile. Conclusions: This study demonstrates how a novel data collection method can capture in-event cognitions of endurance athletes. It provides an important extension to previous literature, showing how individuals may process and attend to information over time during an exercise bout. Future research should establish the relationship between performance and cognitive processes.

Keywords: Think Aloud Protocol, Cycling, Endurance, Pacing, Decision Making, Cognition.

Introduction

Within the last decade, research has started to investigate athletes' cognitions during performance. Verbal data is collected concurrently as an individual performs, for example in self-paced closed skill sports such as golf (Whitehead, Taylor & Polman, 2015; Whitehead, Taylor & Polman, 2016), and trap shooting (Calmeiro, Tenenbaum & Eccles, 2010), using a Think Aloud protocol (TA) to capture participant's cognitions and decisions. TA involves asking participants to continuously verbally report their thoughts during the performance of a task. Three levels of verbal report protocols have been identified, each requiring the participant to verbalise different depths of detail (Ericsson & Simon, 1993). Level 1 is simply the vocalization of inner speech where the individual does not need to make any effort to communicate his or her thoughts. Level 2 is most predominantly used within sport psychology research and involves the verbal encoding and vocalization of an internal representation that is not originally in verbal code. Level 3 verbalization requires the individual to explain his or her thoughts, ideas, hypotheses, or motives (Ericsson & Simon, 1993).

Recently, more focus has been directed towards examining decision-making and athletes' thought processes during endurance events. Methods for collecting this cognitive data do seem to be mainly retrospective in nature (Baker, Côté, & Deakin, 2005; Williams et al., 2015), for example, via the use of video footage to assist with the recall of cognitive information (Morgan & Pollock, 1977), or post trial interviews to highlight key thought processes during an event (Morgan & Pollock, 1977). However, such methodologies have significant limitations given that retrospective recall is associated with memory bias and added meaning (Whitehead et al., 2015).

Only a limited amount of research has examined in-event decision-making processes during endurance sports. This work has made comparisons between skilled and less skilled athletes' thought processes (Baker et al., 2005). It has previously been highlighted how elite runners are more focused on associative thoughts during their event, such as performance-related issues including tempo and relaxation, whilst non-elite runners focused on dissociative thoughts, such as the scenery (Morgan & Pollock, 1977). Although not stated as a TA protocol, researchers also assessed associative/dissociative thinking and perception of training intensity in marathon runners during their training runs by recording their thoughts on a small tape recorder (Schomer, 1987).

More recently, real time thought processes of runners during a long distance run were examined using TA (Samson, Simpson, Kamphoff & Langlier, 2015). This study identified three major themes; Pain and Discomfort, Pace and Distance, and Environment. Findings demonstrated that thoughts relating to Pace and Distance were associated with changes in the Environment. Although key factors that influence cognitions and pacing during the event were observed via the use of this novel TA protocol, it has not yet been identified how these themes may change over the duration of an exercise bout.

Using TA to capture in-event information from participants has the potential to provide an invaluable and unique insight into the theoretical understanding of how individuals make decisions regarding their pace during an endurance event. Pacing behaviour is thought to be a voluntary distribution of effort developed on the basis of afferent/efferent communication in the brain, to avoid excessive fatigue sensations and ensure task completion (Noakes, 2011). It is important that the dynamic thought processes which underpin this voluntary behaviour are examined in more detail during an exercise bout. Research suggests that performers may ignore associative information relating to fatigue during the final part of a race, in order to maintain performance and produce an end spurt (Edwards & Polman, 2012). A possible reason for the lack of empirical TA research within endurance sports could be due to the suggested challenges athletes may face in concurrently thinking aloud during an aerobically challenging event (Nicholls & Polman, 2008). Therefore, it is important for research to identify whether TA can be used as a viable method for measuring cognitions during an exertive endurance task.

As discussed, research examining cognitions within endurance sports has typically used marathon running as opposed to other endurance sports, such as cycling. In addition, there is a scarcity of research that has examined how cognitions fluctuate over time and distance within an endurance event. The different cognitions experienced between laboratory and field environments need further consideration. For example, environmental cues such as traffic are important in outdoor events but non-existent in laboratory settings (Sampson et al., 2015). With this information, athletes, coaches and sport psychologists can examine the effect of time-varying cognitions in order to develop better interventions for endurance performance. This in turn could also aid understanding of the underlying cognitions that inform pacing decisions, exercise regulation, and decision making. Therefore, the aim of this study was to examine the thought processes of cyclists over a 16.1 km time trial (TT), through the use of a real-time, concurrent, TA protocol. It was predicted that cyclists would verbalise themes based on pacing, pain and discomfort, their environment (Samson et al., 2015) and external performance-related feedback (Jones et al., 2013). Furthermore, it was hypothesised that the frequency of verbalisations within these themes would change over the duration of the TT.

Method

Participants

Participants consisted of 15 male and three female cyclists from a cycling club in the North of the UK. Participants ranged from 18-62 years of age (Mean = 40.9, SD = 11.5) and had 1-40 years of cycling experience (Mean = 11.2, SD = 12.9). As the Time Trials are club-based, there was a broad spectrum of riders participating in the trials, ranging from recreational to competitive. Participant times ranged from 19.06 – 26.48 minutes for the time trial that was completed. Institutional ethical approval was secured and informed consent was obtained from all participants.

Materials

iVUE Horizon 1080P glasses were worn by the cyclists during the TT to record all audio that was verbalised.

Procedure

The Time Trial was organised by a conglomerate of cycling clubs under the jurisdiction of the Cycling Time Trials association in England. A series of 12 separate Time Trials were advertised to riders, with times being recorded and logged onto a national database that some individual riders used to gain qualification into regional and national competitions. One week prior to the event, participants were sent a TA exercise where they watched a pre-filmed cycling video, which provided an example of thinking aloud whilst cycling. A muted video was also provided and participants were asked to practice thinking aloud. Participants were asked to attend the TT one hour before the start of the event to be briefed further using Ericsson and Kirk's (2001) adapted direction for giving TA verbal reports, which required participants to provide verbal reports during a warm-up task containing non-cycling problems (Eccles, 2012). Participants were then fitted with the iVue camera glasses and practiced giving verbal reports with feedback for approximately 30 minutes. Once participants were familiar with the task of thinking aloud, they were instructed to use level 2 TA and to verbalise as much as they naturally could throughout the 16.1 km TT. Stickers were also placed on visible areas of their bicycle, which stated, "Please think aloud".

All participants took part in this TT on the same occasion and in dry weather conditions with a temperature of approximately 15 degrees Celsius. The wind was approximately 14km/h and the road surface was standard asphalt material.

Data Analysis

Each participant's verbal reports from TA were transcribed verbatim. The transcripts were split into distance quartiles (0-4 km, 4.1-8 km, 8.1-12 km, 12.1-16.1 km) to identify thought processes across distance. Following checks for relevance and consistency, each transcript was subjected to a line-by-line content analysis. The first author identified verbalisations based on a coding scheme, which was adapted from Samson et al. (2015) and developed for this study (Table 1). The second author coded a random sample of verbal data; the inter-rate agreement was 90%. The number of thoughts verbalised were analysed for each theme over distance quartile using a Friedman Test due to a non-normal distribution of the data. Post hoc analyses for any significant effects were conducted using Wilcoxon Signed Rank Tests and δ effect sizes were calculated to establish the magnitude of differences between themes (Cohen, 1994).

INSERT TABLE 1 HERE

Results

Total Verbalisations

Table 2 provides the overall percentages of themes verbalised in the TT, demonstrating that Traffic and Other Cyclists, and Pain and Discomfort were the most prominently verbalised primary themes.

INSERT TABLE 2 HERE

A within-subject comparison of primary themes verbalised over quartile

Mean (SD) values of the primary and secondary themes verbalised across distance quartile of the TT are displayed in Table 3. Analysis to explore differences in themes over distance quartile revealed that there was a significant difference in the number of verbalisations of the primary theme Pain and Discomfort ($X^2(3, n = 17) = 16.17$, $p = 0.001$). Post hoc analysis showed there were significantly less verbalisations of this theme in quartile 4 than in quartile 1 ($Z = -3.05$; $p = 0.002$, $\delta = 1.19$), quartile 2 ($Z = -2.65$, $p = 0.008$, $\delta = .86$) and quartile 3 ($Z = -3.14$, $p = 0.002$,

$\delta = 1.33$). There were no significant differences across quartile in the number of verbalisations for the other primary themes of Pace and Distance ($X^2(3, n = 17) = 2.47$, $p = 0.48$), External Feedback ($X^2(3, n = 17) = 1.02$, $p = 0.80$) or Environment ($X^2(3, n = 17) = 6.47$, $p = 0.09$).

A within-subject comparison of secondary themes verbalised over quartile

Fatigue: There was a significant difference in the number of verbalisations of the secondary theme Fatigue over quartile ($X^2(3, n = 17) = 11.67$, $p = .009$). Post hoc analysis indicated there were significantly less verbalisations in quartile 4 than quartile 1 ($Z = -2.66$, $p = 0.008$, $\delta = 1.06$), quartile 2 ($Z = -2.68$, $p = 0.007$, $\delta = .86$) and quartile 3 ($Z = -2.79$, $p = 0.005$, $\delta = 1.33$).

Pain: Significant differences were found in the number of verbalisations of the secondary theme Pain over quartile ($X^2(3, n = 17) = 13.60$, $p = 0.004$), where there were significantly less verbalisations in quartile 4 than both quartile 1 ($Z = -1.99$, $p = 0.046$, $\delta = .62$) and quartile 3 ($Z = -2.57$, $p = 0.01$, $\delta = 1.01$). Furthermore, fewer verbalisations were recorded during quartile 2 than both quartile 1 ($Z = -2.13$, $p = 0.033$, $\delta = .65$) and quartile 3 ($Z = -2.69$, $p = 0.007$, $\delta = 1.03$).

Pace: There was a significant difference in the number of verbalisations of the theme Pace over quartile ($X^2(3, n = 17) = 15.16$, $p = 0.002$), with significantly less verbalisations in quartile 4 than quartile 1 ($Z = -2.54$, $p = 0.011$, $\delta = 1.00$), quartile 2 ($Z = -2.26$, $p = 0.023$, $\delta = .71$) and quartile 3 ($Z = -2.45$, $p = 0.014$, $\delta = .84$).

Distance: For the theme Distance, a significant difference was found in the number of verbalisations over quartile ($X^2(3, n = 17) = 17.68$, $p = 0.001$). There were significantly less verbalisations in quartile 1 than quartile 2 ($Z = -2.31$, $p = 0.021$, $\delta = .93$) and quartile 3 ($Z = -2.91$, $p = 0.004$, $\delta = 1.13$) and quartile 4 ($Z = -2.97$, $p = 0.003$, $\delta = 1.32$). Furthermore, there were significantly less verbalisations in quartile 2 than quartile 3 ($Z = -2.69$, $p = 0.007$, $\delta = .24$).

Heart Rate: There was a significant difference in the number of verbalisations of the secondary theme Heart Rate over quartile ($X^2(3, n = 17) = 9.00$, $p = 0.029$), where there were significantly more verbalisations in quartile 4 than quartile 1 ($Z = -2.26$, $p = 0.024$, $\delta = .66$), quartile 2 ($Z = -2.26$, $p = 0.024$, $\delta = .66$).

Speed: A significant difference in the number of verbalisations of the secondary theme Speed was found over quartile ($X^2(3, n = 17) = 13.25$, $p = 0.004$). Post hoc analysis showed there were significantly more verbalisations during quartile 1 than quartile 3 ($Z = -2.16$, $p = 0.030$, $\delta = .61$) and quartile 4 ($Z = -2.71$, $p = 0.007$, $\delta = 2.56$). Furthermore, speed was verbalised more in quartile 2 than quartile 4 ($Z = -2.54$, $p = 0.011$, $\delta = .82$).

Time, Surroundings, and Traffic and Other Cyclists: No significant differences were found over quartile in the number of verbalisation for the secondary themes Time ($X^2(3, n = 17) = 4.48$, $p = 0.21$), Surroundings ($X^2(3, n = 17) = 3.13$, $p = 0.37$) or Traffic and Other Cyclists over quartiles ($X^2(3, n = 17) = 4.65$, $p = 0.20$).

INSERT TABLE 3 HERE

Discussion

The main findings of this study show that TA protocol is a viable method to measure real-time, concurrent thought processes of cyclists during an outdoor, competitive 16.1 km TT. Cyclists' thought processes comprised four major themes: Pain and Discomfort, Pace and Distance, External Feedback and Environment. The number of verbalisations for the primary themes were found to vary over the distance of the TT. Furthermore, significant differences over time were found within the secondary themes Fatigue, Pain, Pace, Distance, Speed and Heart Rate. There were significantly less verbalisations of the themes Pain and Discomfort, Fatigue, and Pain in the final quartile of the TT than in the preceding quartiles. Similarly, verbalisations relating to Pace also followed this pattern, whereas verbalisations of Distance, Speed and Heart Rate increased over the duration of the TT. The findings from the present study therefore suggest that the nature of cyclist's cognitions change over the course of a real-time, outdoor TT.

Overall, more thoughts were verbalised during the first quartile of the TT in comparison to the final quartile. Being able to pace an event correctly is generally at the forefront of a performer's thought process, especially during the start of an event (Zakowski et al., 2001). In addition, other factors unaccounted for may have contributed to this higher number of verbalisations earlier in the race. For example, the perceptions of stressors could result in certain verbalisations being more evident in earlier stages. The perceived importance of the event may have contributed to these findings (Nicholls et al., 2011); given that this was a real-life TT event, it could be suggested that this was perceived as more important than other training events or a laboratory-based study. The initial verbalisations could be the result of a stress response, however as the TT progresses, participants may employ specific coping strategies and develop perceptions of control over the event (Billat et al., 2001). This also supports the proposal that there is less uncertainty relating to performance and pacing optimisation towards the end of exercise (St Gibson et al., 2006) and that the number of verbalisations decreases as the level of complexity of a task decreases (Arsal et al., 2016). Our study suggests that cyclists' cognitions change over the duration of a TT and therefore should be considered in the exploration of how an athletes' conscious decision-making will influence pacing during an event.

Our results showed that in the first quartile of a TT, cyclists' verbalisations centred on Fatigue, and Traffic and Other Cyclists. Verbalisations of fatigue in the early stage of the TT is perhaps surprising, as athletes often feel more fatigued towards the end of an event, regardless of how long the event actually is (Baden, Warwick-Evans & Lakomy, 2004).

However, verbalisations such as, “my legs feel full (of lactic acid) already” and “I’m feeling a little tired already”, are consistent with a cyclist’s initial assessment of their physiological conditions based on afferent feedback (Billat, Slawinski, Danel, & Koralsztein, 2001). During the initial phase of the race, cyclists may experience feelings of uncertainty, which occur immediately following any change in muscular work rate (Billat et al., 2001). It has been suggested that, especially amongst novices, inappropriate pacing can lead to overestimations of individual capabilities and result in an optimistically high initial power output (Edwards & Polman, 2012). Therefore, the cyclists may think more associatively about the pain and fatigue related to the metabolic disturbance in relation to how this may affect their overall pacing strategy and ability to perform the remaining distance of the TT at an optimal intensity. This also supports the proposal that athletes self-regulate performance in an anticipatory manner in order to prevent premature fatigue and an associated reduction in work-rate (Tucker, 2009). However, without performance data such as speed and power output, we are unable to determine whether verbalisations influenced pacing strategies.

Verbalisations relating to distance were found to increase over time, which is especially interesting given that overall verbalisations decrease over quartiles. This may indicate that cyclists focus more on distance information near the end of a race, e.g. “2.5 km to go”, and “the end is in sight, last push”, which could be a strategy to suppress pain or fatigue-related thoughts. Alternatively, athletes may base their pacing decisions on metabolic ‘set point’ values, where the brain will calculate the degree of response required to prevent excessive homeostatic disturbance throughout an event (Billat et al., 2001). If the distance or duration of the task is known, athletes will regulate physiological systems to keep them within ‘norms’. If a cyclist is familiar with the task and has distance ‘set points’, then distance may be important in a cyclists thought processes, especially in the later stages of a time trial.

Whilst the number of verbalisations within the theme Environment did not significantly change over time, this was the most frequently verbalised theme overall. Patterns in other verbalisations further support that thoughts relating to internal and external cues vary in dominance over the course of the TT, with more internal cues (Pain, Fatigue) verbalised initially and more task-related external cues (Distance) verbalised towards the end. These findings build on the laboratory based work of Bertollo et al. (2015) who found that internal focused attention can be functional if the attentional focus is directed toward the core component of action (e.g. pedalling rate) instead of fatigue or muscle pain. The present study extends this work since it examines changes in thoughts during a field based time trial using TA rather than prescribing an attentional focus strategy.

The limitations of this study should be acknowledged in the consideration of the findings. As no performance data was collected within this study, it is not possible to determine whether a participants' verbalisations were directly associated with physiological responses or performance parameters, such as speed, cadence or power output. Furthermore, it is important to acknowledge that the effect of thinking aloud on cycling performance is unknown, however all participants were thoroughly briefed and asked to terminate thinking aloud if they felt that the process hindered them in any way. Further research needs to incorporate other performance measures in order to fully examine the relationship between cognitions and pacing behaviour.

Another area for development within this research could be the difference between male and female cognitions. Kaiseler, Polman and Nicholls (2013) were able to use TA to identify cognitive differences in stress and coping between males and females, therefore it would be of great interest to investigate cognitive differences between males and females within cycling and pacing. Furthermore, whilst the wide range of experience and age among the participants gives a representative sample of club cyclists, there may be further differences in cognitions within the sample based on these criteria. Differences in the skill level of a performer also needs to be taken in to consideration within future work, since previous research using TA in golf has established that cognitions differ based on the skill level of a performer (Whitehead et al., 2016).

Finally, the coding scheme used within this study only took into account task specific information and verbalisations deemed irrelevant were not coded. Brick, Macintyre and Campbell (2014) published a review of attentional focus in endurance activity and highlighted how ‘unimportant’ information could be interpreted as an external dissociation strategy. Future research using TA protocol should take into account all verbalisations, not just those deemed task relevant.

The findings of this study extend previous research utilising TA and have allowed for the examination of thoughts during a real-time endurance event, therefore providing support for TA as a viable method. It has evidenced that thought processes change continuously during exercise, with different thoughts becoming more prominent at different times. Such findings can be used to inform coaches, athletes and psychologists in aiding the development of appropriate interventions to optimise performance by allowing the examination of a performer’s cognition during an endurance exercise.

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Table 1. Coding framework used to analyse verbalisations during the time trial.

Primary Theme	Secondary Theme	Description	Example
Pain and discomfort	Fatigue	Any verbalisations around feeling tired or lacking energy.	"legs are starting to feel heavy", "I'm starting to feel tired"
	Pain	Any verbalisations relating to experiencing pain or discomfort as a result of the time trial performance.	"oh this hurts more than it should", "ahhhh I'm burning"
Pace and distance	Pace	Verbalisations relating to the monitoring or altering of their pace.	"Trying to pace this line well", "keeping nice and steady"
	Distance	Verbalisations relating to distance covered to distance left to complete.	"3 miles to go", "Second 5k, pretty much same as the first".
External feedback	Speed	Any verbalisations relating to speed and power output.	"need to keep watching my speed and keep my speed high", "good average speed".
	Heart rate	Any verbalisations relating to the participants own heart rate.	"heart rate 137"

	Time	Any verbalisations relating to the timing within the event.	“13.30 and half way”, “only a few minutes left”
Environment	Surroundings	Verbalisations relating to the wider environment and the visual picture of the surroundings.	“not a bad profile in the sun”
	Traffic and other cyclists	Verbalisations relating to other vehicles on the road.	“these cars are coming too close”, “I’m expecting to be passed any minute”

Table 2. Percentage and total frequency verbalisations for primary and secondary themes.

Primary Theme	(%) Total	Secondary Theme	(%) Total
Pain and discomfort	(33%) 326	Pain	(5%) 54
		Fatigue	(28%) 272
Pace and distance	(20%) 197	Pace	(16%) 153
		Distance	(4%) 44
External feedback	(9%) 86	Heart rate	(3%) 27
		Speed	(5%) 46
		Time	(1%) 13
Environment	(38%) 371	Surroundings	(7%) 65
		Traffic and other cyclists	(31%) 306

Table 3. Mean (SD) number of verbalisations by theme over distance quartile of the time trial.

Themes	Quartile 1		Quartile 2		Quartile 3		Quartile 4	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD
All Verbalisations	*17.47*	*9.06*	*15.88*	*8.91*	*17.59*	*6.63*	*10.65*	*6.83*
Pain and discomfort	**5.41**	**2.92**	**4.53**	**2.74**	**6.41**	**3.71**	**2.53**	**1.77**
Fatigue	4.59	2.72	4.18	2.67	4.82	3.50	2.18	1.70
Pain	0.82	0.88	0.35	0.49	1.59	1.62	0.35	0.60
Pace and distance	**3.06**	**2.46**	**2.76**	**1.82**	**3.35**	**2.12**	**2.41**	**2.42**
Pace	3.00	2.47	2.11	1.76	2.47	2.07	1.00	1.32
Distance	0.06	0.24	0.65	0.86	0.88	0.99	1.41	1.42
External feedback	**2.65**	**2.74**	**2.41**	**3.41**	**2.06**	**1.88**	**2.18**	**2.74**
Time	0.06	0.24	0.53	1.18	0.65	1.00	0.47	0.87
Speed	1.88	2.00	1.18	1.51	0.82	1.42	0.24	0.56
Heart rate	0.71	1.49	0.71	1.49	0.59	1.00	1.47	2.58
Environment	**6.35**	**4.17**	**6.18**	**4.39**	**5.76**	**4.39**	**3.53**	**3.39**
Surroundings	1.06	1.39	0.94	2.19	1.24	2.33	0.59	1.50
Traffic and other Cyclists	5.29	3.46	5.24	4.42	4.53	3.64	2.94	3.44