It's not all about the bike: distributed situation awareness and teamwork in elite women's cycling teams

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Abstract. This paper presents the findings from a study examining situation awareness and teamwork in elite women's cycling. This involved observing an elite racing team during two Australian National Road Series race events and conducting post-race critical decision method interviews. The data were analyzed using the Event Analysis of Systemic Teamwork framework to show the task, social and situation awareness networks underpinning team performance. The findings are discussed in relation to enhancing cycling team performance and potential applications in other sports.

Keywords. Distributed situation awareness, teamwork, cycling, elite sport

1. Introduction

Situation awareness remains one the most ubiquitous of all ergonomics concepts, with applications in an ever-expanding list of domains (Stanton et al., 2015). One area in particular that has been subject to inquiry is elite sport, with recent applications considering situation awareness in Australian Rules Football umpires (Neville et al., 2016), handball teams (De Keukelaere et al., 2013), elite hammer throwing and rowing athletes and coaches (Macquet & Stanton, 2013). Although applications have included testing of theory and methods, the primary function has been to inform the development of coaching strategies and interventions designed to optimize performance (e.g. Macquet & Stanton, 2013).

Despite exhibiting features that are characteristic of the domains in which ergonomics practitioners work, elite cycling has not yet been studied from this perspective. One interesting feature is the critical role that situation awareness apparently plays at the individual rider level, at the cycling team level, and at the overall cycling system level. To date, however, the focus of research in this area has largely been on the development of quantitative models to describe the behavior of cycling pelotons (e.g. Trenchard, 2015; Trenchard et al., 2014). What rider, team, and system situation awareness comprises, and how it can be optimized, remained unexplored.

Much has been written about the contention surrounding situation awareness and the appropriate theoretical and methodological approach to adopt in ergonomics studies (see Salmon et al., 2008). In a recent review of situation awareness models and their utility for studying and optimizing elite sport systems, Neville and Salmon (2016) identified Stanton et al's Distributed Situation Awareness (DSA) model as highly suitable for sporting applications. Prior to this, Salmon et al (2010) had noted that the Event Analysis of Systemic Teamwork framework (EAST; Stanton et al., 2013) offers a powerful framework for understanding elite sports systems.

This article brings together both of these arguments, presenting an EAST analysis of DSA and teamwork in an elite women's cycling team during two road race stages. The study was exploratory in nature, and aimed to describe and understand DSA and teamwork to assist the team in optimizing performance in future events. A secondary aim of the analysis was to further examine the utility of applying both DSA and EAST in elite sports.

1.1 Elite women's cycling

The analysis presented in this paper focuses on two elite women's road races undertaken as part of the 2016 Australian Subaru National Road Series (NRS). NRS road races typically range in length from 50 kilometers (km) to 130 km and involve teams of four to five riders. Each team has a so-called 'protected rider' (selected based on overall NRS points standing) with the remaining riders acting in a 'domestique'[1] or support capacity.

The team's goal is to ensure that their protected rider finishes each stage of the race in the best position and time possible. Accordingly, the domestiques employ various tactics to assist their protected rider, such as allowing the protected rider to ride behind them ('on their wheel') to reduce their physical workload or 'leading them out' to initiate a sprint finish.

The riders from each team form a 'peloton' of cyclists that negotiate the race route together. The peloton has been formally defined as "a group of cyclists that are coupled together through the mutual energy benefits of drafting, whereby cyclists follow others in zones of reduced air resistance" (Trenchard et al., 2014, p. 92). Throughout the race, riders may attempt to 'attack' and break away from the peloton and other teams' riders may attempt to chase them down and bring them back to the peloton or let them go until a later point in the race. Alternatively, the peloton may stay together, resulting in a 'bunch sprint' finish. Throughout the race slower riders drop out of the peloton and often work together to attempt to rejoin the peloton. An additional feature of the NRS women's road races are shorter sprint and Queen of the Mountain (QOM) sub-sections, whereby bonus points are offered for the top three cyclists within each sub-race.

A convoy of vehicles comprising the Commissaries, race officials, medical support, neutral spares, the media, and team support vehicles follows behind the peloton. The Commissaries controls the race and following convoy, communicating with the cyclists via loudspeaker and the vehicles in the convoy via UHF radio or in person by driving alongside them. A medical support vehicle follows behind the Commissaries to provide assistance in the event of a crash or injury. Each team then has a support vehicle typically containing a Director Sportif (DS), a mechanic (in some cases this may be the DS), spare parts e.g. wheels, bicycle tools, and food and drink for the riders. Each support vehicle is permitted to provide mechanical or nutritional support to team riders and can offer tactical guidance and encouragement through verbal exchanges.

Together the peloton and convoy forms a complex, highly dynamic system comprising multiple human (riders, DS, mechanic) and non-human agents (bicycles, vehicles, bicycle computers), which exhibits emergent properties, non-linear interactions, multiple control and feedback loops, loose and tight coupling, and rapid decision making. As such, it is amenable to ergonomics inquiry whilst offering relevant examples of sociotechnical system behavior that could inform theoretical, methodological, and practical contributions in other safety critical domains.

1.2 The Event Analysis of Systemic Teamwork

The EAST framework provides an integrated suite of ergonomics methods for analyzing the behavior of complex sociotechnical systems. Heavily underpinned by network theory and analysis, EAST takes the premise that system performance can be meaningfully described via a 'network of networks' approach and uses three interlinked network-based representations to describe and analyze behavior. Task networks are used to describe the goals and subsequent tasks being performed within a system (i.e. which agents, both human and non-human, do what). Social networks are used to analyze the structure of the system and the communications taking place between agents (i.e. who/what interacts and communicates with who/what). Situation awareness networks show how information and knowledge is distributed across different agents within the system (i.e. who/what knows what at different points in time). By illustrating the relationships between task, social and

[1] In French, *domestique* translates as 'servant'

situation awareness networks, and then by interrogating these networks, an in-depth understanding of system behavior is achieved.

Salmon et al. (2010) first discussed the potential utility of using EAST to analyze sports performance, presenting an EAST analysis of a fell running race that examined runner goals, situation awareness, decision making and workload. Whilst others have since used components of EAST to examine elite sports performance (e.g. Neville et al., 2016), the three forms of EAST network are yet to be used in conjunction with one another to analyze elite sports performance.

1.3 EAST analysis of elite women's cycling

The study was a naturalistic study whereby the research team collected data from an elite women's road racing team during two Australian NRS events from the 2016 NRS season. Both events were elite cycling road race events incorporating a series of stages including a time trial, road races, and a criterium race. The analysis presented in this paper focuses on one of the races from the first NRS event: stage 1 of the Battle on the Border, which took place in the Tweed Coast region, New South Wales. The full analysis will be included in the conference presentation.

2. Methods

2.1 Participants

The participants were members of an elite women's Australian NRS cycling team. For the present analysis the sample included five riders, one Director Sportif (DS) and one mechanic. Due to the naturalistic nature of the study it was not possible to gather complete participant demographic data; however all were experienced in elite cycling and had raced throughout the 2016 NRS season. The study was granted ethics approval by the University of the Sunshine Coast's Human Ethics Committee.

2.2 Materials

The research team observed the race from within the cycling team's support vehicle. Go Pro™ cameras were used to record the races and a Dictaphone was used to record the verbal communications occurring within the team support car. Dictaphones were also used to record team race planning meetings, the post-race Critical Decision Method (CDM; Klein et al., 1989) interviews and post-race team debriefs. A pro-forma containing the CDM interview probes was used by the interviewers. The interview transcripts were transcribed using Microsoft Word™. For data representation, the task and social networks were created using Microsoft Visio™.

2.3 Procedure

The research team provided the cycling team with an overview of the study, its aims, and the data collection methodology prior to the first race of each event. The research team travelled to each race with the cycling team and observed the warm up and pre-race discussions. The Go Pro cameras and Dictaphone were placed within the support vehicle and set to record shortly before the start of each race. Once the races began, the research team observed the peloton from the support vehicle and made hand written notes regarding the team's performance, tactics and the interactions between the DS, the Commissaries, and riders. During low workload periods of the race the researchers were also able to discuss the team's performance with the DS.

Following the race, the research team attended the riders' post-race debrief and planning session for the next race, recording both using a Dictaphone.

At the conclusion of the planning and debrief sessions, the research team conducted one-on-one CDM interviews with each rider regarding the earlier race. The interviewers used a set of CDM probes adapted for the cycling race context and recorded each interview using a Dictaphone. Following the interview each rider was also asked to complete a social network analysis diagram to show who and what they interacted with during the race. This involved presenting them with a diagram showing all agents (riders, other riders, DS, Commissaries, cycling computer) and asking them to rate their level of communication with each during the race on a scale of low (<10 communications), medium (between 10 and 20 communications) and high (>20 communications).

The video and audio footage was transcribed verbatim using Microsoft Word^{TM}. The three EAST network representations were constructed as follows:

1. *Task network*. The task network was built based on the research team's observations, a review of the video data and the interview transcripts. A draft version of the task network was reviewed and refined by the cycling team during the Battle on the Border event.
2. *Social networks*. Construction of the social network involved transforming the social network diagrams obtained following the races into a social network diagram detailing the number of interactions between the cyclists and other agents.
3. *Situation awareness networks*. 'Situation awareness' networks were constructed through content analysis of the riders' interview transcripts. Specifically, the riders' responses to the CDM questions 'What were your specific goals for the race?', 'What information were you using throughout the race?'; and 'What was the most important piece of information' and riders' initial description of the race content were analyzed by one analyst. Keywords and the relationships between them were extracted and used to construct a situation awareness network comprising concepts and the relationships between them. For example, from the sentence, "I was checking my position in the peloton", the related concepts 'Checking', 'Position' and 'Peloton' were extracted. Once the situation awareness network was constructed, concepts were shaded based on their presence in each of the rider's interview transcripts.

3. Results

3.1 Task network

The task network is presented in Figure 1. Within Figure 1 the circular nodes represent distinct tasks undertaken immediately prior to and during the road races. The linkages between the nodes represent relationships between tasks e.g. the 'attack' and 'support protected rider' tasks are closely linked since the attacks are made by domestique riders to either help the protected rider break away from the peloton or to tire out opposing team riders. The colored rings around each node represent the agents in the cycling system who undertake each task e.g. the 'attack' task is undertaken by the riders only, whereby the 'monitor other riders' task is undertaken by the riders, the Commissaries, and the DS.

For the present paper, two features of the task network should be noted. First, there are a range of tasks involved, including both individual and shared tasks. For example, the task of communicating with other riders is undertaken by team riders within the peloton e.g. asking for assistance to initiate a break, by the DS in the support vehicle e.g. communicating tactics with team riders, and by the Commissaries e.g. informing other riders in the peloton and the DS's in the support vehicles of the time gap between a breakaway rider and the peloton. Second, the relationships between each task can be used to identify those tasks which are integral to team success. In this case, the task network indicates that the tasks of 'race planning and tactics', 'establish and maintain appropriate position in the peloton', 'monitor other riders', 'communicate with other riders', and 'monitor speed, cadence, power and distance' are integral to team success. It is notable that these tasks are highly interrelated with one another.

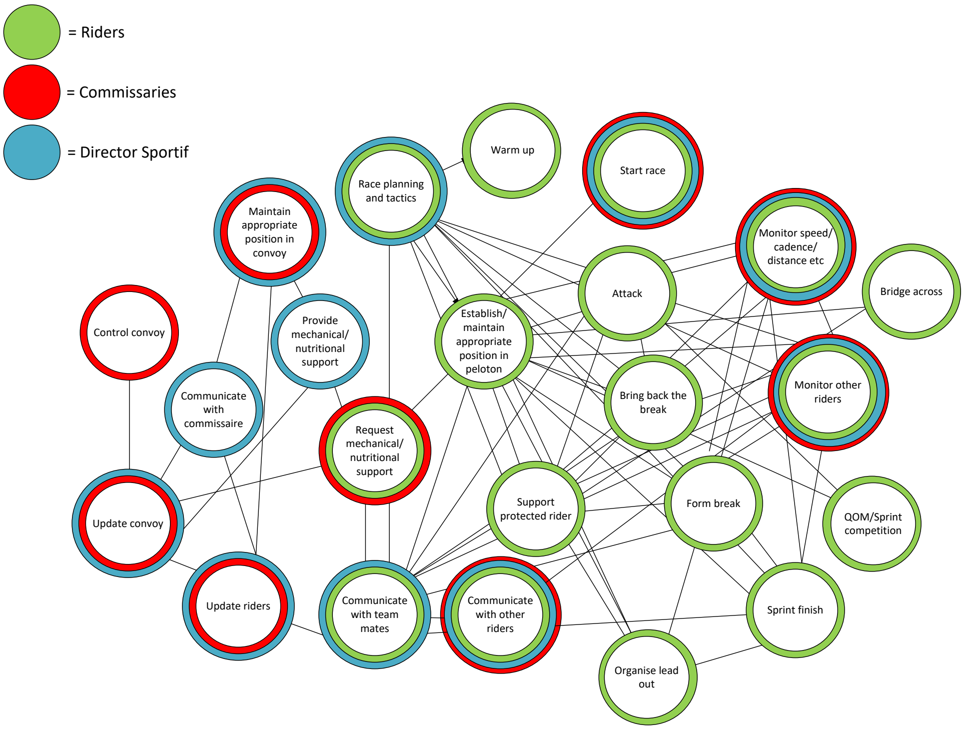

Figure 1. Generic task network for women's cycling road racing

3.2 Social network

The social network for the Battle on the Border stage 1 road race is presented in Figure 2. Within Figure 2 the circular nodes represent agents (e.g. riders, support vehicle, bicycle computers) and the arrows between them represent the extent to which the agents communicated with one another during the race.

The social network shows the structure of communications throughout the road race. In this case the protected rider and domestique rider 2 are the most connected in terms of incoming and outgoing communications. In addition, both the protected rider and domestique rider 2 have a greater frequency of communications with other agents, both of which having five connections rated as 'high' on the frequency of communications scale.

3.3 Situation awareness network

The situation awareness network for the Battle on the Border stage 1 road race is presented in Figure 3. Within the network the nodes represent pieces of information and the lines linking the nodes represent relationships between the information (e.g. 'Computer' displays 'Speed').

The network shows that certain pieces of information were critical during the road race. For example, the nodes 'Peloton', 'Position', and 'Riders' are the most connected nodes within the network, indicating that they were integral to situation awareness. This included the riders self-monitoring their position in the peloton, as well as the position of their teammates, and relating this information to tactics and energy levels. The network also shows a focus on the protected riders from other teams, what they were doing, and their position in the peloton throughout the race. The constant monitoring of own and other riders' energy levels was reported by all riders as important throughout the race and is shown through the nodes related to the 'energy' node. Nodes related to the team's race plan were also prominent. Finally, it is interesting to see safety-related nodes in the network, including the nodes 'crashes', 'weather', 'conditions' and 'pot holes'.

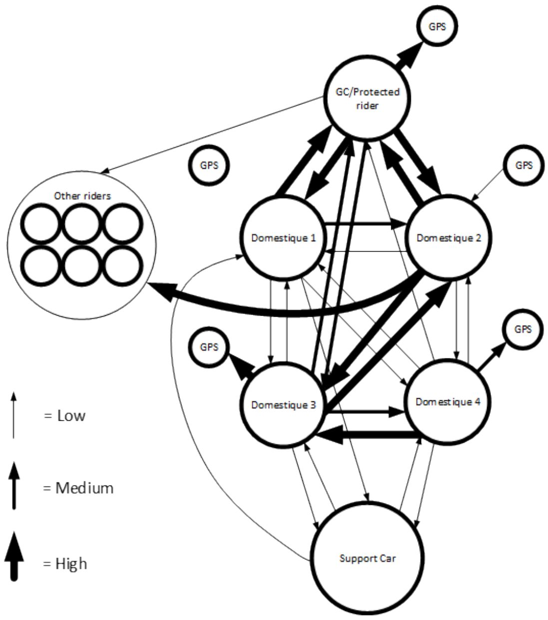

Figure 2. Social network for Battle on the Border road race stage 1.

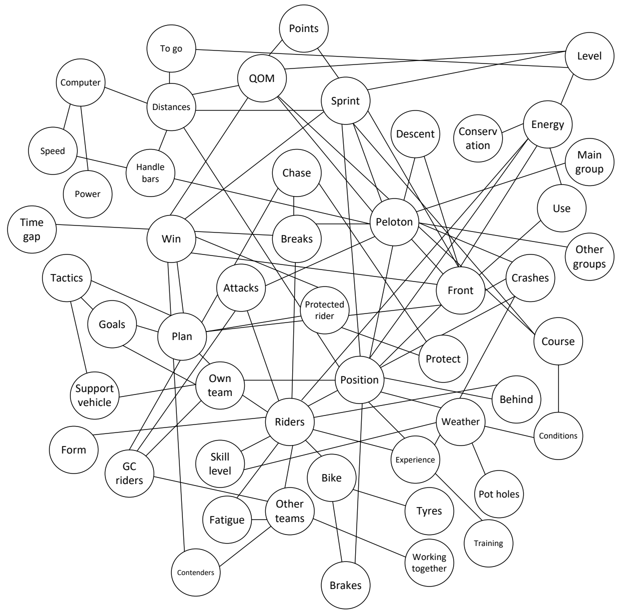

Figure 3. Situation awareness network for Battle on the Border road race stage 1.

4. Conclusion

4.1 What does the analysis tell us about DSA and teamwork in elite women's cycling teams?

The analysis highlights the high requirement for teamwork during elite women's racing. The Big Five model (Salas et al., 2005) identifies five key teamwork behaviors (leadership, mutual performance monitoring, back up behavior, adaptability, team orientation) along with three key supporting mechanisms (shared mental models, mutual trust, communication). Throughout the three networks it is possible to identify clear examples of key teamwork behaviors as outlined in Salas et al's (2005) 'Big Five' model of teamwork (see Table 1).

In terms of DSA, the networks demonstrate that situation awareness is indeed distributed across both the team and peloton system comprising both human and non-human agents. For example, the situation awareness network shows the importance of non-human agents, such as the bike-mounted computer and annotated handlebars. For example, the DS annotates the bicycle handlebars to provide critical race information to the riders such as when the sprint section of the race will occur. Riders then used their race computers in conjunction with the information written on the handlebars to be aware of when to attack or initiate a sprint. The importance of continual transactions within the peloton is also emphasized, as is the fact that the transactions can be both verbal e.g. talking to a team mate, and non-verbal e.g. monitoring another riders' behavior to assess their energy level. Notably, these transactions include intra-team transactions (exchanges of awareness between team mates) and inter-team transactions (exchanges of awareness between riders from different teams).

Table 1. Examples of Big Five Teamwork Behaviors.

Big Five Model Behavior	**Example**	**Source**
Leadership	The tactical direction provided by both riders within the team and the DS	Task and situation awareness network
Mutual performance monitoring	Riders need to monitor their own team mates in terms of position, fatigue etc.	Task and situation awareness network
Back up behavior	The ability of riders to respond to the needs of other riders in the team e.g. chasing down a break away for the protected rider	Task and situation awareness network
Adaptability	The need for the riders to respond to other teams' behavior e.g. breaks from the peloton, attacks	Task and situation awareness network
Team orientation	The fact that all riders in the team are working together to ensure that the protected rider wins the race (team goal overriding individual goals)	Task and situation awareness network
Shared mental models	The use of race planning to ensure that the teams have a shared understanding of the plan and of the teams goals	Task and situation awareness network
Mutual trust	The belief amongst the riders that team members will perform their roles e.g. the protected riders knowledge that her team mates will sacrifice their own overall position and protect her until the sprint finish	Task and situation awareness network
Communication	Multiple communications occurring continuously between all riders	Social and task network

4.2 What are the implications for optimizing performance in elite women's cycling teams?

The full analysis will provide specific details of where performance can be optimized; however, it is possible to identify avenues through this exploratory analysis. The importance of pre-race planning, and the implementation of the plan itself during the race was emphasized throughout the present analysis. This suggests that robust, in-depth, and detailed planning processes are likely to yield improvements in team performance. Further, the importance of devising a race plan that is agile and adaptable and contains a series of well-defined contingency plans is apparent. This will enable teams to respond appropriately and rapidly in the face of variable tactics from opposing teams. The importance of transactions in awareness was also highlighted; it may be that educating cyclists on forms of non-verbal transaction may provide ways in which teammates can communicate without giving away tactics to other teams and also ways in which to identify other teams' tactics and energy levels. A final interesting feature of the analysis is the importance of communication within the team, even when team riders may be spread throughout the peloton without the ability to communicate directly. This suggests that future work may be required to investigate strategies for rapid and effective communications during races.

4.3 What are the implications for future EAST applications in elite sport?

The analysis presented provides some evidence of the utility of applying EAST in the elite sports context. EAST provided new perspectives on elite cycling, outlining the key tasks, interactions, and information required during elite women's cycling road races. Further applications of the EAST framework are encouraged, both in cycling and in other forms of elite team sports such as Football, Rugby, Formula 1, and Baseball. In addition, formal comparisons between EAST and other analysis approaches are recommended.

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