Unobtrusive Estimation of Team Situation Awareness

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Synopsis

The training of professional teams can benefit from objective, unobtrusive, and continuous estimation of team Situation Awareness (SA). We used the framework by Salmon et al. (2008) to identify components of team SA measurable using physiological and behavioural technologies: team shared mental models (SMMs) and coordination. Through a systematic literature review, we found cardiac measures and verbal communication were most often correlated with SMMs. For team coordination, functional near-infrared spectroscopy, cardiac measures, and multimodal physiological synchrony – the interdependence of teammates' physiological activity – were most used. Measures were context-dependent, warranting future work to employ task analysis before choosing measures.

Background

Situation awareness (SA) comprises perception of a stimulus, its comprehension, and projection of the future environmental state (3-Level model; Endsley, 1995). In teams, members require adequate SA to perform their individual task, and the team requires SA about how the collective performance. Measuring team SA can improve team performance. However, existing approaches rely on subjective measures or task-interrupting probes that alter team SA itself (Salmon et al., 2008). Thus, unobtrusive, continuous, and objective measurement is preferable – hereafter named *unobtrusive measurement*.

In this study, we reviewed the literature for physiological and behavioural tools for unobtrusive measurement. Potential measures include facial behaviour, stress-related physiological signals, gaze direction, frequency of verbal communication, and others. These may reflect teammate focus, knowledge content, or may facilitate/inhibit the team processes (e.g., stress reduces coordination). We further expect measures of interpersonal signal interdependence, termed physiological synchrony (PS), as an overarching approach.

Given team SA complexity, we identified underlying team processes that may be more readily measurable using Salmon et al. (2008)'s framework: namely, team shared mental models (SMMs), coordination, and communication (Figure 1). SMMs are shared knowledge about goals, expectations, and team task execution. Coordination encompasses Salmon's previous concepts of collaboration and co-operation. Communication represents team transactive information-exchanging behaviours. In our review, we examine unobtrusive measures of SMMs and coordination, treating communication as a measure in its various measurable forms.

Methods

We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) statement and conducted a systematic search using five OR-combined keyword sets. Sets 1 and 2 covered synonyms of respectively **SMMs** and **coordination**. Set 3 contained

behavioural and physiological measures (after Zhang et al., 2023). Set 4 targeted **task-relevant behavioural actions** (e.g., key presses) as measures. Set 0 targeted **non-human agent teaming** that is out of this review's scope. We then combined (AND operator) Set 1 with Sets 3 and 4 and the keyword *team*; and Set 2 with Sets 3 and 4 and keyword *team*; excluding papers with keywords from Set 0. We carried out searches on Web of Science, on May 12th and July 17th, 2025, limited to articles and conference proceeding papers in English, published 2000-2025. From each paper, we extracted: sample and team size; task environment; measures (e.g., communication content); ground-truth high/low SMMs or coordination as used in the paper; and relationship between the measure and SMMs/coordination.

Results

In total, we selected 19 papers on team SMMs and 33 on coordination. Team tasks ranged from laboratory settings (e.g., gaming) to real-life (e.g., firefighter training). For SMMs, the most frequent measures were verbal communication (47%) and cardiac measures (42%). For coordination, cardiac measures (30%) and functional near-infrared spectroscopy (fNIRS; 27%), measuring brain activity, were most common (Figure 2). Multimodal PS was frequently used for coordination (70%). No studies used task-related behavioural actions as indicators of team processes.

Patterns across modes showed that **SMMs** were broadly characterized by *predicting teammate knowledge and needs* (e.g. measured by a decrease in asking questions and increase in offered unsolicited, relevant information; PS during high workload task periods, reflecting similar ideas about the relevance of events); *greater knowledge exchange* (evident through verbally-exchanged content); *calmness* (e.g., higher HRV); and *heightened attention* (indicated through EEG). High **coordination** involved *regular, similar teammate behaviour* (e.g., prosodic accommodation); *active social processing* (e.g., PS in social brain activity)*; calmness* (higher HRV); and *heightened attention and team planning* (through verbal and brain measures). PS was particularly relevant, likely because coordination requires intentional alignment of goals and actions.

Discussion

Our research uncovered that the team processes were separated into further, measurable sub-parts, as listed in the results (e.g., remaining calm). Thus, SMMs or coordination cannot be measured as a whole. A range of different tasks were used to study SMMs and coordination, where the specific task constrained which measuring modes and indicators can be applied, both from the perspective of the relevance of the measured sub-parts, as well as how these could be measured in that context. Thus, measuring team SA should begin by a task analysis to 1) define relevant behaviours and mental processes, and 2) select the best indicators to detect their changes. We found that task-related actions (e.g., key presses) were understudied, despite their potential to reflect coordinative actions and shared knowledge and should be considered in future work. Limitations of our work include possible exclusion of studies on adjacent factors (e.g., team performance), as we stayed focused on our target constructs; and the methodological diversity of included papers, which complicated comparisons. Nonetheless, we identified potential estimates of team SA processes, supporting further exploration in relation to established team SA measures, beginning with a task analysis.

Disclosures

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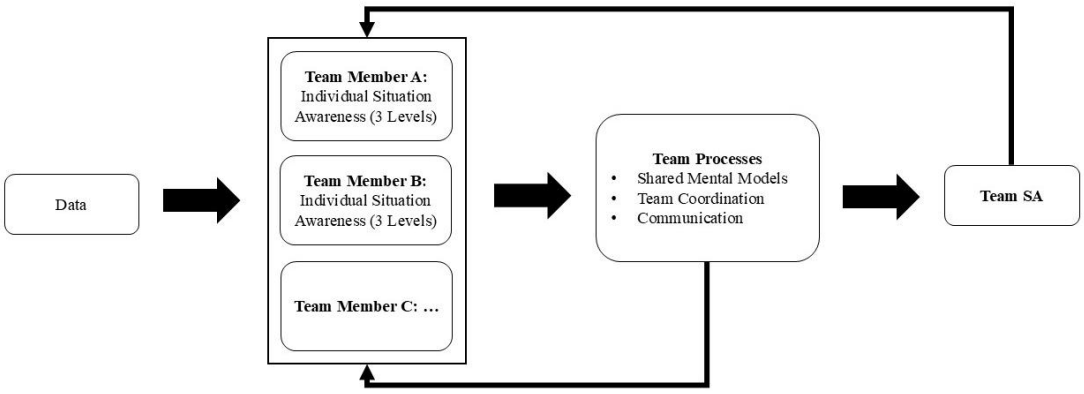

Figure 1. *Framework for Team Situation Awareness, adapted from Salmon et al. (2008).*

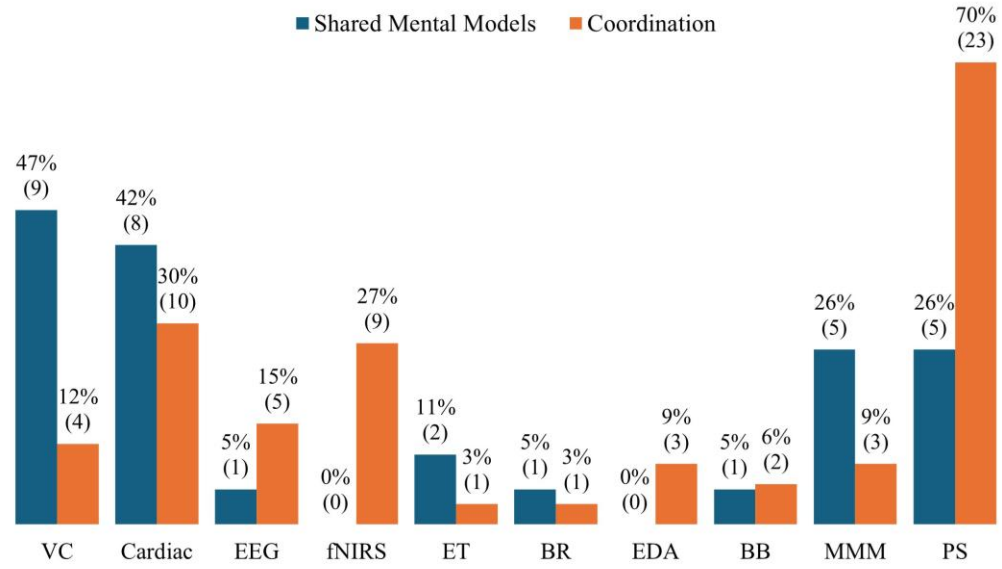

Figure 2. *Percentage and number of papers (in brackets) per main measuring mode (and PS) and team process.* VC = verbal communication, EEG = electroencephalography, fNIRS = functional near-infrared spectroscopy, ET = eye-tracking, BR = breathing, EDA = electrodermal activity, BB = bodily behaviour, MMM = multiple modes of measurement, PS = physiological synchrony. Papers using multiple modes are represented in all respective modes, and in MMM. Papers using PS are represented both in PS and in the mode(s) that PS was calculated for.

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