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Cross-task cue utilisation and situational awareness in simulated air traffic control

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ABSTRACT

Objective: To examine the role of cross-task cue utilisation in the acquisition of situational awareness during the initial stages of learning to operate an air traffic control simulation.

Background: Cue-based associations are an important component of situational awareness, a construct that is necessary for skilled process control, where the location, movement, and direction of multiple targets needs to be managed. However, the potential for high levels of situational awareness is difficult to assess in the absence of exposure. Previous research suggests that cross-task cue utilisation predicts the acquisition of feature-event associations that form the basis of situational awareness

Method: Sixty university students undertook an assessment of cue utilisation in the context of motor vehicle driving and subsequently engaged in an air traffic control simulation task. During the air traffic control simulation task, situational awareness queries were introduced based on the Situation Awareness Global Assessment Test (SAGAT).

Results: The analyses revealed that participants who demonstrated relatively higher levels of cross-task cue utilisation also demonstrated greater performance on the SAGAT and achieved greater performance during the simulated air traffic control task.

Conclusion: The outcomes suggest a relationship between cross-task cue utilisation and situational awareness, particularly at the initial stages of skill acquisition.

Application: Assessments of cross-task cue utilisation may be used to distinguish the propensity for prospective trainees to acquire the situational awareness necessary for complex, process control tasks such as air traffic control.

1. Introduction

Air traffic controllers play a critical role in managing the safe and orderly flow of air traffic (Durso and Manning, 2008). This role involves monitoring the position, speed, and altitude of each aircraft flying within the airspace (Endsley, 1995). For instance, controllers must ensure the minimum separation between aircraft to ensure safe arrivals and departures (Endsley, 1995).

Air traffic controllers draw data from many different sources, including radar displays and radio communication (Hauland, 2008). Using these data, controllers describe forming a mental model of the location and movement of air traffic (Mogford, 1997). This mental model is presumed to assist with the timely, efficient, and safe movement of air traffic in response to changes in the system state through a process referred to as situational awareness (Endsley and Garland, 2000).

Endsley (1995) argues that the development of situational awareness within a given situation occurs in a hierarchical, three-stage model (Patrick and Morgan, 2010; Rasmussen, 1983). Level 1 pertains to the perception of elements in the environment. This is the lowest level of situational awareness and involves components such as the operator's perception of information from system instrumentation (Stanton et al., 2001). In the context of air traffic control, the information available includes the location of aircraft, together with their track, airspeed, and altitude (Harrison et al., 2014). In many cases, weather information will also be available.

Level 2 situational awareness is associated with the comprehension of a situation. This process is essential in enabling operators to understand the significance of features within the environment and to discern the nature of the situation (Endsley, 1995; Hauland, 2008). Successful Level 2 situational awareness is dependent upon the accurate and timely perception of system instrumentation identified at Level 1

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(Mogford, 1997).

Level 3 situational awareness refers to the prediction of the future state of the system and is associated with the capability to project the impact of changes on the system state (Stanton et al., 2001). The accuracy with which this prediction occurs is dependent upon the degree of situational awareness acquired during the preceding levels (Hauland, 2008; Patrick and Morgan, 2010).

While there are a number of different approaches to the assessment of situational awareness, the most common strategies include the Situational Awareness Rating Technique (SART) and the Situational Awareness Global Assessment Technique (SAGAT). The SART involves subjective perceptions of situational awareness and correlates with confidence (Endsley et al., 1998). Therefore, it may not necessarily reflect levels of situational awareness in practice. The SAGAT overcomes the limitations imposed by the subjective perceptions by adopting a freeze query technique in which an activity (normally a simulation) is paused and the display occluded before participants are queried as to the information displayed by the system instrumentation (Level 1), the implications of the information displayed the system instrumentation (Level 2), and the future state of the system (Level 3; Endsley, 1995; Stanton et al., 2013).

Although situational awareness has been the subject of considerable research, there remains some debate to as to whether it constitutes a singular psychological construct or a psychological process (Dekker, 2015; Flach, 2015; Stanton et al., 2010). The main differences between these approaches is whether situational awareness is indicative of a product developed from interacting with the system, or a process involving continuous interaction between the individual and the system (Endsley, 2015; Flach, 2015). Consequently, there are differences in the approaches to the measurement of situational awareness, whereby product-orientated measures assess a situational awareness outcome (e.g., SAGAT), while process-orientated measures assess the underlying mechanisms required to achieve situational awareness (Stanton et al., 2010).

Regardless of the measure employed, situational awareness, as a construct, appears to be associated with differences in performance (e.g., Jipp and Ackerman, 2016; O'Brien and O'Hare, 2007). For example, greater situational awareness has been associated with superior performance amongst aviation pilots (Carretta et al., 1996), fire fighters (Li et al. (2014), surgeons (Graafland et al., 2015), and military commanders (Riley et al., 2006). This is evident in more rapid responses to changes in the system state (Reader et al., 2011), fewer errors (Sætrevik and Hystad, 2017), and greater operating efficiency (Adams et al., 1995).

Differences in situational awareness are inevitably related to exposure to the domain, since an awareness of the system state, together with the recognition of changes, demands some understanding of the nature of the system and the interactions between components. The recognition of changes to the system state is a construct with similarities to Klein's (2008) notion of *situation assessment* which forms a key component of his model of Recognition Primed Decision-Making (RPDM). As a dual-process theory of decision-making, it is the outcome of the situation assessment that determines whether the condition is 'recognised' according to RPDM. Where a condition is recognised, a rapid, routine response is initiated (Klein, 2008). Alternatively, if the condition is perceived as novel, a conscious and more deliberate compensatory process is initiated that is both highly demanding and relatively inefficient.

The capacity to recognise a situation as familiar is dependent upon a match between the features that comprise a condition and the condition-related features that lie resident in memory (Wiggins, 2015). Through exposure, features and/or patterns of features coexist with particular conditions and become associated in memory in the form of feature-event associations or cues (Wiggins, 2014). According to Klein (2008), it is the extent and specificity of cue-based associations in memory that form the foundation for accurate situation assessment which, in turn contributes to accurate and efficient situational awareness.

1.1. *Cue utilisation in process control*

The utilisation of cues in managing process control tasks is well-established at both the empirical and theoretical level. At a theoretical level, cue-based associations are presumed to provide the basis for interacting with the environment by reducing the demands on cognitive load and enabling rapid and accurate responses (Brunswik, 1955; Easterbrook, 1959). Empirical evidence suggests that behaviour that is indicative of the utilisation of cues is associated with improved diagnostic performance amongst paediatricians (Loveday et al., 2013b), power system controllers (Loveday et al., 2013a), software engineers (Loveday and Wiggins, 2014) and aircraft pilots (Wiggins et al., 2014a).

Where initial approaches to the assessment of cue utilisation were designed to assess the utilisation of specific cues that were identified a priori (e.g., Slovic, 1966), the difficulties associated with the identification of a set of universal cues, even within a given situation, have proven difficult. Typically sourced from experts, the idiosyncratic nature of their experience is such that different experts, faced with the same stimulus, may employ different features to arrive at very similar conclusions (McRobert et al., 2009). Therefore, assessments of cue utilisation that are based on interactions with specific features that are identified a priori, may misattribute levels of cue utilisation where an operator fails to acquire information from prescribed sources.

An alternative approach involves the assessment of behaviour that is presumed indicative of the utilisation of cue-based associations. For example, if an operator is capable of responding accurately and relatively rapidly to task-related stimuli, it might be assumed that cue-based associations are being applied. Consistent with this approach, Wiggins (2014) has argued that cue utilisation is also evident where operators demonstrate a strength of association between task-related features and associated events, a capacity to discriminate relevant from less relevant features in responding to a task-related problem, and demonstrate a capacity to prioritise the acquisition of feature-related information in seeking to build a mental representation of a task-related event.

Support for Wiggins' (2014) approach to the assessment of cue utilisation can be drawn from comparative analyses of operators across a range of domains, including aviation piloting (Wiggins et al., 2014a), electrical power control (Loveday et al., 2013a), and software engineering (Loveday et al., 2014), where different levels of context-related cue utilisation are associated with differences in diagnostic accuracy and self-ratings of performance, and others' ratings of expertise.

While the stimuli to which operators are normally asked to respond are generally designed for the particular domain in which they profess experience, recent research has suggested a degree of cross-task cue utilisation, whereby cue utilisation in one context is associated with the acquisition and utilisation of cue-based associations in other, related contexts (Brouwers et al., 2016; Wiggins et al., 2014b). This suggests that the propensity for cue utilisation may constitute a trait with implications for the selection and assessment of operators in environments in which they have yet to be exposed.

The cognitive process that enables cross-task cue utilisation is a capacity to recognise, and retain in memory, implicit patterns of activity. For example, Brouwers et al. (2016) demonstrated that participants who recorded greater cue utilisation in motor vehicle wayfinding and hazard detection, were also more likely to recognise implicit patterns in the movement of trains during a rail control task. Although the recognition of patterns of train movement was associated with a reduction in cognitive load, Brouwers et al. (2017) concluded that the reduction in cognitive load was a by-product of the capability to recognise and retain patterns, rather than a deliberate strategy to reduce the cognitive demands associated with the task.