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A Behaviour-Based Approach to the Assessment of Cue Utilisation: Implications for Situation Assessment and Performance

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Abstract

Although the utilisation of cues is widely recognised as essential for skilled situation assessment, it is a construct that is difficult to evaluate due to the idiosyncratic and nonconscious nature of cues. This raises risks for high consequence organisations where there is an expectation that operators are capable of accurate and timely situation assessment. The objective of this paper was to articulate the development and evaluation of novel, behaviour-based approach to the assessment of cue utilisation. Explorations that are based on this approach have yielded consistent outcomes in differentiating higher from lower performance across a range of operational domains, including transmission power control, paediatric intensive care, audiology, and aviation. Opportunities are proposed for further research to explain the inherent cognitive mechanisms involved and better model the performance of operators under a range of environmental conditions.

Keywords: Cue Utilisation, Situation Assessment, Expert, Workplace Evaluation

Precis: Situation assessment is a critical skill in high consequence environments. Behaviour-based assessments offer a cost-effective means of providing feedback on cue utilisation as the foundation for skilled situation assessment. Empirical evaluations suggest that a behaviour-based, psychometric approach offers a valid, reliable, and cost-effective solution for the assessment of cue utilisation amongst skilled operators.

Introduction

In complex operational environments, making sense of emerging situations is critical to the generation of timely and appropriate responses (Wiltshire, Neville, Lauth, Rinkinen, & Ramirez, 2014). The failure to interpret task-related information accurately and/or rapidly has been associated with a number of system failures, from aircraft accidents (de Wit & Cruz, 2019) to meltdowns of nuclear reactors (Oppenheimer, 2003), and the loss of spacecraft (Dunbar and Garud, 2009). In each case, the information available was either overlooked or misinterpreted, suggesting a mismatch between the presentation of information and the corresponding mental representations in memory.

Sensemaking is a construct that refers to the explanation of events, where operators draw conclusions based on a series of features. Rather than a passive process, Weick, Sutcliffe, & Obstfeld (2005) suggest that it involves the active interpretation and management of information, leading to the suppression of some detail, in favour of other features. Therefore, it takes account of the constraints imposed by human information processing which limits the amount of information that can be processed at a single point in time (Marois & Ivanov, 2005).

Initiated by a perception that the state of the world differs from the circumstances that were anticipated (Weick et al., 2005), a search for explanation is triggered by drawing on pre-existing mental representations of the context. This account is similar to the process described by Klein, Moon, & Hoffman (2006) as recognition-primed decision-making, where cues embodied within the context of a situation trigger an explanation or ‘story’ from memory. This ‘story’ together with its implications, emerge through mental representations in memory, and thereby direct behaviour. Like sensemaking, recognition-primed decision-making is a cognitive strategy that minimises the demands on information processing, and this is most evident in the serial nature of the assessment of prospective responses (Gore, Flin, Stanton, & Wong, 2015)

Critical to both sensemaking and recognition-primed decision-making is situation assessment, a strategy that encapsulates the transition from the perception of features in the environment to the meaningful recognition of those features as ‘familiar’ (Blasch et al., 2006). For features, or patterns of features, to be recognised as familiar, they must be associated in memory with objects (e.g. a chair) or events (e.g. a car ahead is likely to turn). These feature-event/object relationships constitute the cues that enable the interpretation of information in the environment.

From an information processing perspective, the availability and utilisation of cues reduces the demands on cognitive resources (Sekicki & Staudte, 2018; Shah & Oppenheimer, 2008). Attention is restricted to only those features where there is an association in memory in the form of cues (Feng & Spence, 2017). Similarly, the necessity for higher-order reasoning is obviated since cues are recognition-driven and are presumed to activate once a threshold is reached (Goldstein & Gigerenzer, 2002). Finally, corresponding cue-based associations can be integrated so that the need for comparative assessments of features is minimised (Perales, Catena, & Maldonado, 2004).

Expertise and Cues

The reductions in cognitive resources that are associated with cue utilisation are most evident in comparisons between experts and non-experts where increases in the demands of a task impact the performance of non-experts, while the performance of experts remains unaffected (Runswick et al., 2018). In this case, expertise is characterised by automatic processing while non-experts are engaging controlled processing which is both conscious and cognitively demanding (Shiffrin & Schneider, 1977). Eventually, the task demands are such that they exceed the capabilities of non-experts and information is overlooked, interpreted incorrectly, and/or forgotten, leading to deteriorations in performance (Patten, Kircher, Östlund, Nilsson, & Svenson, 2006).

At the initial stages of skill acquisition, information processing tends to be characterised by the acquisition of information from a range of sources, usually directed by their perceived salience (McCormack, Wiggins, Loveday, & Festa, 2014). For operators in high-technology environments, attention is likely to be captured by the inherent characteristics of features, including the presence of an associated auditory or visual alarm, or its proximity or visibility (Anderson, Fincham, & Douglass, 1997; Schriver, Morrow, Wickens, & Talleur, 2008). This bottom-up activation reflects little organisation or prioritisation in the acquisition of task-related information. The consequence is the acquisition of potentially unnecessary information that exhausts the capacity of working memory.

Anderson et al., (1997) suggest that, during the early stages of skill acquisition, the information acquired during information acquisition is largely declarative, with meaning derived only through a corresponding process of reasoning. The process is evident in a child facing an unfamiliar mathematics problem and having to draw from memory any information that remotely relates to the problem under consideration. This information might be previously learned laws or principles, each of which is drawn together in working memory in an attempt to resolve a solution. The process tends to be time-consuming, demanding, and prone to error (Tenison, Fincham, & Anderson, 2016).

Through repeated exposure, the co-existence of features and events/objects becomes evident and can be drawn upon to reduce the demands on short-term memory. For example, during summer months in warm climates, there is an increase in electricity loads following the end of the school day as families return home and activate devices such as air conditioners. Therefore, the association might be drawn between the type of day (school day or non-school day), the time of day, and the changes in demands for electricity. This enables any changes in the demand for electricity to be interpreted quickly and accurately as a normal part of the demand cycle.

Where some associations between features and events/objects might be drawn through explicit learning, with operators attending consciously to the coexistence of features and event/objects (e.g. releasing the clutch to coincide with depressing the accelerator in a manual motor vehicle), other associations are acquired nonconsciously through implicit or incidental learning (e.g. the level of pressure applied to the brake pedal and the associated rate of deceleration) (Monaghan, Schoetensack, & Rebuschat, 2019; Reber, 1989; Seger, 1994). Nevertheless, once established in memory, these associations constitute rules-of-thumb or heuristics that can be employed to direct behaviour with minimal processing (Anderson et al., 1997).

While there is little doubt that heuristics can, at times, lead to erroneous performance (Itri & Patel, 2018; Walmsley & Gilbey, 2016), they remain a cognitive strategy necessary for skilled performance, particularly in time-constrained, complex domains (Gigerenzer & Gaissmaier, 2011). With repeated exposure, associations that are developed between features and events/objects are adapted, refined, reviewed, and potentially discarded in favour of associations that embody greater reliability and accuracy (Youmans & Ohlsson, 2008). Inevitably, this process of refinement is likely to involve errors as the initial associations between features and objects/events are typically the product of a limited number of interactions that are unlikely to encapsulate the breadth of experiences necessary for more nuanced cues (Brouwers, Wiggins, & Griffin 2018).

Although errors are problematic in high consequence environments such as transportation and medicine, it remains the case that these errors are likely to prompt the process of review that initiates the more accurate cue-based associations that ultimately provide the foundation for expertise. However, since experts have presumably progressed through stages where errors are more likely, it might be reasoned that simply identifying the cues that experts engage and then informing less experienced practitioners will be sufficient to improve cue utilisation. Unfortunately, as logical as this approach might appear, there remain a number of difficulties, the most significant of which is the assumption that different experts engage the same cues during situation assessment.

The idiosyncrasy of cue utilisation has been one of the challenges faced in testing the validity of theoretical perspectives of cue utilisation (Johnson et al., 1981; Pachur & Marinello, 2013; Schraagen, 1993; Reinerman, Mercado, Szalma, & Hancock, 2020). While the conceptual basis of cue utilisation is largely undisputed, developing an understanding of the relative contributions of different cues and how these are integrated to yield a specific decision within a particular context appears to be impacted significantly by the experience and inherent capability of decision-makers. Even when cue-based associations are taught to participants, thereby controlling for experience, individual differences are evident that influence the process of integration and thresholds for action (Johnson et al., 1981).

The other major challenge associated with cue utilisation is that they are nonconscious or ‘automatic’. Therefore, the foundations of cues tend to be to very difficult to verbalise, with experts reportedly ‘knowing’ that something wasn’t quite right, but not being able to articulate quite how or why (Patterson, Pierce, Bell, & Klein, 2010). To overcome the difficulty in verbalising what would otherwise be described as automatic actions, a number of tools have been developed, the most popular of which is arguably the cognitive interview (Militello & Hutton, 1998; Schaafstal, Schraagen, & Van Berl, 2000). While there are a number of different approaches to cognitive interviews, they are generally qualitative and time-consuming. As a result, it can be difficult to establish whether individual differences simply reflect idiosyncrasies or whether they reflect systematic issues associated with the acquisition and utilisation of cues (Wheeler & Gabbert, 2017).

Individual differences in the acquisition and subsequent utilisation of cues is unsurprising, and explains differences in capability, even when accounting for exposure. Exposure in the absence of cue acquisition is unlikely to result in skilled performance. Further, it is possible that, while cue-based associations are acquired during the initial stages of skill acquisition, they are neither adapted nor discarded in favour of more accurate and reliable cues. The consequence is potentially a ‘performance plateau’ where no further improvements occur despite additional exposure (Gray & Lindstedt, 2017).

Where plateaus in performance occur at an organisational level, the impact may only become evident in the context of a high-consequence emergency. This presents a major risk for high-reliability organisations, such as energy transmission and transportation where there is an expectation that operators possess the skills necessary for accurate and timely situation assessment during the relatively few occasions when these skills are necessary and critical. In the absence of skilled situation assessment, operators may delay responses or may respond inappropriately to changes in the system state.

While many organisations now have access to highly realistic, simulated environments that might be employed to evaluate the situation assessment skills of their employees, the regular use of simulation can incur significant direct and indirect costs (Nousiainen, McQueen, Ferguson, Alman, Kraemer, Safir, Reznick, & Sonnadara, 2016). Further, in evoking a level of realism, the complexity of scenarios that are employed during simulations can mask situation assessment. For example, in the case of check and training simulations in airline environments, scenarios generally require the application of a range of skills in addition to situation assessment, including leadership, team building, communication, the management of distractions, anxiety management, and/or vigilance (Arora et al., 2011). Discerning the role of situation assessment in this case, requires a detailed and time-consuming analysis of behaviour either during or following the completion of the exercise.

While post-exercise debriefings can be helpful in exploring the role of situation assessment, it can be difficult for operators to accurately recall the critical features to which they were attending during a particular phase of a dynamic scenario. Inevitably, the process becomes more an opportunity for introspection than it is an opportunity for objective and reliable feedback as to the appropriateness of the features to which the operator was attending (Sawyer, Eppich, Brett-Fleeger, Grant, & Cheng, 2016).

Observations of behaviour presents an alternative approach to the evaluation of situation assessment whereby patterns and sources of task-related information are derived through video recordings and/or eye tracking during the conduct of an exercise. However, the interpretation of this information is subject to inference, since there is evidence to suggest that experienced operators can acquire task-related information in the absence of direct engagement or interaction (Evans, Georgian-Smith, Tambouret, Birdwell, & Wolfe, 2013; Krupinski, Graham, & Weinstein, 2013). It also risks comparisons against what might be considered an ‘optimal’ or ‘ideal’ strategy espoused by observer but which fails to take account of the experience and capabilities of the operator.

The solution involves establishing the capacity for situation assessment by assessing the cognitive structures that support situation assessment. Since the availability and utilisation of cue-based associations in memory constitutes a critical structural component of skilled situation assessment, and is implicated in the progression towards expertise more generally, it potentially offers a useful correlate to situation assessment in practice.

A Behaviour-Based Model of Cue Utilisation

Since cue-based associations are both idiosyncratic and domain-dependent, their existence in memory needs to be inferred based on the behaviour of operators in response to domain-relevant stimuli (Wiggins, 2006). For example, the utilisation of cues within a specific context might be evident based on a combination of the capacity to recognise or categorise key features accurately (Wiggins & O'Hare, 2003), the precision and speed with which the strength of association between features and events/objects are differentiated (Morrison, Wiggins, Bond, & Tyler, 2013), the capacity to prioritise the acquisition of key features during the initial orientation to a problem (Wiggins & Henley, 1997; Wiggins & O'Hare, 1995; Wiggins, Stevens, & Howard, Henley, & O'Hare, 2002), the capacity to identify key features in an array (Wiggins, 2014), and the capacity to discriminate relevant from less relevant features during initial actions in response to a task-related problem (Pauley, O'Hare, & Wiggins, 2009). In combination, this process of Recognition, Association, Prioritisation, Identification, and Discrimination (RAPID) in response to task-related features reflects behavioural characteristics that corresponds to the utilisation of cues.

While inferences of underlying cognition are often fraught with difficulty, greater precision is afforded through multiple avenues of inquiry (Wiggins, 2015a). Therefore, RAPID is not an explanatory model but constitutes different methods of inquiry, each of which is intended to capitalise on a specific attribute that reflects the utilisation of cues. In combination, the outcomes offer a comprehensive profile of behaviour that reflects the utilisation of cues in response to task-related stimuli.

The advantage associated with the application of a range of assessment strategies is that it potentially captures the differences in the representations of cue-based associations in memory. For example, some practitioners may have acquired rudimentary associations in memory that are sufficient to enable the identification of key features in an array, but these associations lack the sophistication necessary to enable the prioritisation of key features during the initial orientation to a problem. Similarly, differentiating the strength of association between features and events/objects requires the accumulation of a repertoire of cue-based associations from which draw comparative evaluations.

A disadvantage associated with a reliance on a range of assessment strategies is that, while the measures independently embody linear scales, collectively, the progression towards superior performance tends to be nonlinear as performance on some measures may advance while performance on others will remain stable or even decline. Therefore, evaluations of the validity of the RAPID approach to the assessment of cue utilisation tend to involve dividing samples into dichotomous groups that collectively embody relative levels of performance. For example, Loveday, Wiggins, & Searle (2014) used the RAPID approach to the assessment of cue utilisation in the context of software engineering and divided the cohort into two groups on the basis of their collective performance across each of the assessment tasks. The relatively lower performing cohort were considered operators whose performance reflected relatively lower cue utilisation while the higher performing cohort were considered operators whose performance reflected relatively higher cue utilisation. This distinction on the basis of behaviour that reflected cue utilisation differentiated performance in both the frequency of software programming errors and in subjective assessments of peer-rated expertise. Specifically, lower cue utilisation was associated with a greater frequency of software programming errors and fewer peer ratings of expertise (Loveday et al., 2014).

In the context of evaluations that are more directly aligned with the application of situation assessment skills, higher task-related cue utilisation has been associated with more consistent and more accurate responses in diagnostic evaluations involving electrical transmission network power controllers (Loveday, Wiggins, Harris, O'Hare, & Smith, 2012), paediatric intensivists (Loveday, Wiggins, Searle, Festa, & Schell, 2013), software engineers (Loveday, Wiggins, & Searle, 2014), pilots (Wiggins, Azar, Hawken, Loveday, & Newman, 2014), and motor vehicle drivers (Yuris, Wiggins, Auton, Gaicon, & Sturman, 2019). Differences in performance based on task-related cue utilisation have also been demonstrated in the context of the recognition of water safety cues and these differences broadly correspond to differences in exposure (Wiggins, Griffin, & Brouwers, 2019).

While exposure to, or experience in, a domain is a necessary requirement for the acquisition of cues, individual differences in the rate at which cues are acquired are evident in the weak, rather than strong relationships between self-reported experience and performance on the RAPID tasks (Loveday et al., 2012; Wiggins, Azar, Hawken, Loveday, & Newman, 2014). Importantly, in comparison to domain-related experience, task-related cue utilisation tends to constitute a better differentiator of performance (Loveday, Wiggins, Schell, Festa, & Twigg, 2013).

The sensitivity of task-related cue utilisation has been evaluated in the context of audiology where students in a postgraduate audiology degree completed the RAPID tasks at the initial stages of their two-year degree and again, at the final stages (Watkinson, Bristow, Auton, McMahon, & Wiggins, 2018). Comparative groups were also evaluated to exclude familiarity with the assessment of cue utilisation as an explanatory factor. Overall, the results revealed strong reliability for the *Association*, *Prioritisation*, and *Discrimination* components of RAPID, each of which reflected improvements in performance from the initial to the final administration. While the correlation coefficients for *Identification* and *Recognition* were not statistically significant, this was explained through methodological issues associated with the administration of the tasks.

Consistency in the categorisation of relatively higher or lower cue utilisation was demonstrated in the context of transmission power control in which 80% of participants were classified consistently over repeated testing separated by a six-month interval (Loveday et al., 2013). In combination with results in the context of audiology, there is a degree of convergence to suggest that measures of performance based on the RAPID tasks, are both reliable and sensitive to changes in performance over time.

Cognitive Mechanisms of Cue Utilisation

One of the by-products of higher task-related cue utilisation is a reduction in the cognitive resources necessary to sustain higher levels of performance. In addition to subjective assessments of workload, this reduced demand for cognitive resources is evident in objective measures, including blood oxygenation in the pre-frontal cortex. As a measure of cognitive load, the ratio of blood volume to oxygen can be assessed using functional near infrared spectroscopy (McKendrick, Mehta, Ayaz, Scheldrup, & Parasuraman, 2017). Amongst qualified electricity network controllers, Sturman, Wiggins, Auton, Loft, Helton, Westbrook, and Braithwaite (2019) demonstrated that higher task-related cue utilisation was associated with a lower blood-oxygen ratio in the prefrontal context during day-to-day tasks. Sturman and Wiggins (2019) demonstrated a similar relationship amongst drivers, with higher cue utilisation associated with a lower blood-oxygen ratio during a driving simulation. In combination, these results suggest an association between task-related cue utilisation and the application of cognitive resources.

Consistent with a reduced demand for cognitive resources, higher task-related cue utilisation has also been associated with efficiencies in task-related information acquisition.

For example, Yuris et al. (2019) noted that, amongst drivers, higher task-related cue utilisation was associated with fewer visual fixations and saccades during a driving simulation. Similarly, Sturman and Wiggins (2019) noted that higher task-related cue utilisation was associated with fewer fixation dispersions during driving simulations. This suggests that one of the opportunities afforded by higher task-related cue utilisation is selective attention that targets critical features, thereby reducing the amount of information processed within a given period.

Other attempts to explore the underlying cognitive mechanisms that support cue utilisation have largely been restricted to environments involving cross-task cue utilisation, where cue utilisation in a familiar context (e.g. driving) is used to predict performance in another, allied context (e.g. operating remote piloted vehicles, simulated rail control). The intention has been to examine whether cue acquisition is an inherent capability that can be explained by other constructs, including cognitive ability, spatial reasoning, pattern recognition, and/or fluid intelligence.

Cross-task cue utilisation is a construct distinct from task-related cue utilisation. The latter is employed where the features incorporated in the RAPID tasks that form the basis of cue utilisation are directly related to the task during which cue utilisation is expected to be applied. Cross-task cue utilisation is denoted where the features incorporated into the RAPID tasks do not necessarily correspond to the test task and which would otherwise capitalise on the cues that a particular cohort are likely to embody (Brouwers, Wiggins, Helton, O’Hare, & Griffin, 2016).

In the absence of cue-based associations in memory, establishing differences in cue utilisation in one context is unlikely to predict performance in another context, unless the two share some underlying relationship. For example, cue utilisation in motor vehicle driving and rail control both involve the perception and interpretation of spatial information (Brouwers, et al., 2017). However, where the general population is unlikely to have developed cues pertaining to the control of trains, they will generally have developed cues in relation to motor vehicle driving.

Rail control is a useful test environment in the context of cue utilisation as the process can be scaled depending upon the skills and capabilities of users. The goal of the task is to ensure that trains are directed along the correct routes. Trains emerge in succession and the planned route is denoted by a green line that overlays a track. A train is labelled with an 'odd' or 'even' number with the train number denoting whether the train travels along the odd or even line. Where the planned route of the train does not correspond to the correct line, the operator selects a button that changes the planned route, akin to an *interlocking* in the operational context.

From the perspective of cue utilisation, the advantage associated with the rail control task is the capability to incorporate patterns of train movements that enable the differentiation between trains that require or that do not require re-routing (Brouwers et al., 2017). Since participants are not advised of the pattern, their awareness and application of the pattern is acquired through incidental learning much like the Serial Reaction Time (SRT) task in assessments of implicit learning (Kaufman, DeYoung, Jimenez, Brown, & Mackintosh, 2010).

Implicit learning differs from explicit learning in the level of executive control that is directed towards forming associations between features and events (Reber, 1989; Seger, 1994). Where implicit learning initially involves a level of selective attention, it appears that subsequent learning occurs in the absence of conscious processing. Participants with relatively high cue utilisation in motor vehicle driving are between 12 and 16 times more likely to have identified the implicit pattern of train movements during the rail control task (Brouwers et al., 2017; Sturman, Wiggins, Auton, & Loft, 2019; Brouwers, Wiggins, & Griffin, 2018). Moreover, the identification of the pattern of train movements reduces significantly, the cognitive load experienced by participants during the task (Brouwers et al., 2017).

Through its association with the detection of implicit patterns of train movement, higher cross-task cue utilisation enables higher performance even with the additional load imposed by a secondary task, and across extended periods of sustained attention (Brouwers et al., 2017; Sturman et al., 2019). However, it is also associated with deteriorations in performance where changes to patterns of train movements occur that are unanticipated (Brouwers et al., 2018). This effect is evidence of miscueing and suggests that, although the recognition of implicit patterns comprises a critical capability that facilitates cue utilisation, the process of cue acquisition is likely to be fraught with errors as cue-based associations are acquired, tested, and revised.

Further evidence to support the role of implicit pattern recognition as a basis for cue acquisition can be drawn from Renshaw & Wiggins (2017) who noted that, during the initial stages of learning to operate a Remote Piloted Vehicle (RPV), performance was predicted by video game experience and inherent spatial abilities. However, once the initial skills had been acquired, cross-task cue utilisation emerged as the only predictive variable, accounting for 35% of the variability in piloting performance.

Like cue utilisation, pattern recognition is also implicated as a construct that underpins situational awareness (Kass, Herschler, & Companion, 1991). While the assessment of situational awareness has been the subject of considerable debate (e.g. Salmon, Stanton, Walker, Baber, Jenkins, McMaster, & Young, 2008; Sorenson, Stanton, & Banks, 2011), it is generally recognised as a characteristic of superior performance involving a perceptual stage in which task-related information is acquired, a comprehension stage, where the information available is interpreted in the context of the task, and finally, an anticipatory stage, where the implications of the information available are considered (Endsley, 2015; Stanton, Salmon, Walker, & Jenkins, 2010). In combination, the elements of the process are presumed to enable operators to identify and respond quickly and effectively to changes in the state of a system. Higher levels of situation awareness have been associated with improved performance across a range of contexts (Loft et al., 2014; Horswill & McKenna, 2004).

Theoretically, it might be argued that cue utilisation constitutes the basis on which successful situational awareness depends since the processes of perception and comprehension are likely to draw upon cue-based associations in memory (Gugerty, 1997). Therefore, they are likely to constitute complementary but distinct constructs, and this is evident in a comparative analysis of higher and lower cross-task cue utilisation and performance amongst naïve practitioners during a simulated air traffic control task (Falkland & Wiggins, 2019).

Participants initially completed an assessment of their cue utilisation in driving, after which they engage in a simulated air traffic control task, the aim of which was to direct a series of aircraft to land at an airport. Participants learnt to manage the simulation with minimal instruction, and their situational awareness was assessed at the conclusion of the simulation using a task-relevant Situational Awareness Global Assessment Technique (SAGAT). In comparing the contribution of scores on the SAGAT and cue utilisation to the final scores on the simulation task, it became evident that, as expected, both scores on the SAGAT and cross-task cue utilisation were associated with performance at the conclusion of the task (Falkland & Wiggins, 2019). However, since cross-task cue utilisation was assessed in the context of driving, it was unlikely that it constituted an outcome of interaction with the air traffic control task. By contrast, situational awareness was assessed using questions that could only have been answered correctly following engagement with the task. Therefore, it is likely that cross-task cue utilisation predicted the acquisition of cue-based associations that would emerge through implicit learning, while the SAGAT scores reflected the performance that was achieved through the utilisation of these cues.

Accounting for the role of implicit pattern recognition that emerged in experiments involving simulated rail and air traffic control, it might be argued that cross-task cue utilisation constitutes a metric of the capacity for task-related cue acquisition. A greater rate of cue acquisition differentiates performance per unit exposure, reduces cognitive load, and enables the application of residual resources necessary to facilitate task-related cue utilisation. Greater cue utilisation is associated with improvements in both situational awareness and performance. These relationships are illustrated in Figure 1.

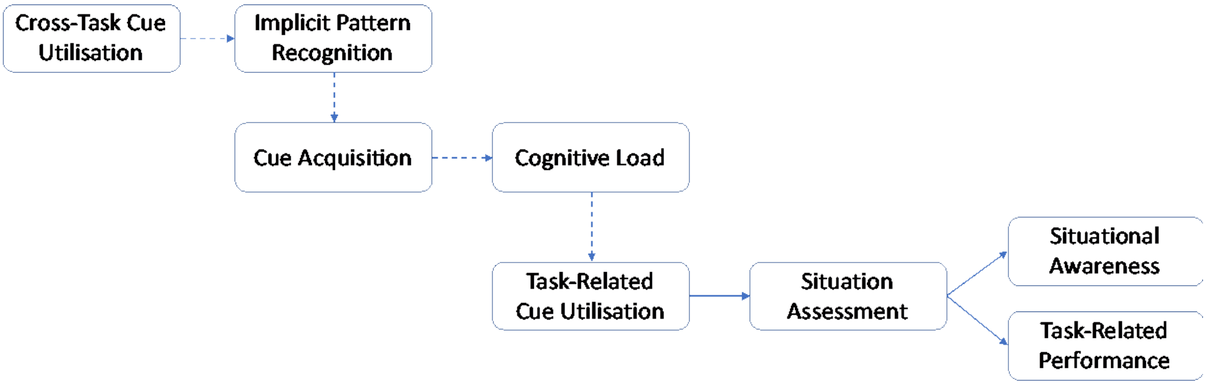

Figure 1. An illustration of the theoretical relationship between cross-task cue utilisation, task-related cue acquisition and utilisation, situation assessment, situational awareness, and task-related performance.

While other individual difference variables, including fluid intelligence, field dependence (Brouwers, Wiggins, Helton, O’Hare, & Griffin, 2016), attentional control

(Brouwers, Wiggins, Griffin, Helton, & O’Hare, 2017), mental rotation (Renshaw & Wiggins, 2017), and sensory processing sensitivity (Wiggins, Brouwers, Davies, & Loveday, 2014) have been the subject of evaluations, none account for the differences evident on the basis of cue utilisation. Nevertheless, the moderating effect of implicit pattern recognition that is evident in both cross-task and task-related cue utilisation (Brouwers et al., 2016; Loveday, Wiggins, Searle, Festa, & Schell, 2013) suggests that individual differences in the acquisition of cue-based associations are likely to exist, and are likely to explain the dissociation evident between exposure and cue utilisation in the context of task-related cue utilisation.

Further moderating effects are likely to include self-regulation and emotional regulation, both of which appear to influence the rate of skill acquisition in technical contexts (Crane et al., 2018). However, skilled performance, particularly in contemporary industrial environments involves a combination of both technical and non-technical skills, where operators must apply both their own inherent skills in the management of a system state and work with other operators to ensure that changes to the system state are managed successfully.

Social cue utilisation, like technical cue utilisation provides the basis for situation assessment (Yee, Wiggins, & Searle, 2017). However, in the context of social cue utilisation, the assessment might correspond to the visual or auditory features associated with a communicative situation. For example, visual features embodied in facial expressions might signify a lack of understanding concerning an instruction or opinion (Werkhoven, Schraagen, & Punte, 2001). Similarly, intonation or delays that constitute auditory features in communication might signify a misunderstanding or non-understanding (Auton et al., 2013).

Since social cues involve behaviours, their utilisation can be inferred using the RAPID approach, much as occurs with technical cue utilisation. Drawing on the RAPID approach, Yee et al. (2017) developed a number of scenarios that were designed to evaluate visual features associated with social cue utilisation and examined whether dyads comprising participants with higher or lower performance on the RAPID tasks were associated with differences in performance on a problem-solving task. The results revealed that dyads comprising participants with higher social cue utilisation solved the problem faster that dyads comprising participants with lower cue utilisation. This effect was explained, in part, by the frequency of ‘closing the loop’ communicative responses in which participants clarified the statements of partners, thereby ensuring a consistent approach to the interpretation and execution of problem-solving strategies.

While social cue utilisation appears similar, as a construct, to emotional intelligence, Yee et al. (2017) demonstrated that, at least in the case of scores on the Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT), the RAPID approach better differentiated the performance of dyads. Moreover, no relationship was evident between the scores on the MSCEIT and social cue utilisation. Nevertheless, there are different approaches to the assessment of emotional intelligence (e.g. Salovey & Grewal, 2005) and the relationship between social cue utilisation and these approaches to emotional intelligence has yet to be examined.

In addition to visual representations of social cue utilisation (e.g. facial expressions), auditory cues are also informative in ensuring cooperative endeavours. Although key features, including intonation, delays, and the use of fillers (e.g. Um, ah…) have been identified as key features that are associated with misunderstandings and non-understanding (Auton, Wiggins, Searle, Loveday, & Rattanasone, 2013), the extent to which individual differences in these features differentiate levels of understanding has yet to be established in an operational context.

Implications for Practice

Assessments of cue utilisation based on a normed, psychometric profile enable a number of opportunities to influence both individual and organisational performance. For example, managers and instructors alike often find it difficult to articulate precisely, the impediments to successful performance when observing an operator. A standardised profile based on the RAPID approach enables the isolation of specific areas of concern (see Figure 2). For example, it may be the case that an operator has no difficulty in recognising (R) and identifying (I) targets in an array compared to operators with similar levels of exposure. Similarly, against operators with comparable exposure, an operator may draw equivalent associations (A) between features, and prioritise (P) the acquisition of features during problem-orientation. However, it might be evident that an operator is relatively less discriminating (D) during task-related problem-solving. From an organisational perspective, the opportunity lies in targeting a specific component (in this case Discrimination) of cue utilisation using a metric against which subsequent performance can be compared.

Figure 2. An illustration of the standardised profile based on performance on the RAPID Tasks (including a communication task) and compared against a normed population.

As the capacity for cue utilisation changes over time and with exposure, performance can be compared periodically against a representative cohort and/or against previous trials with the same operator. This form of evidence-based evaluation can be used to assure a minimum standard of situation assessment or provide the basis for targeted interventions as required. These interventions might include specific training scenarios, where task-related features and associated events are highlighted and reinforced through practice, problem-solving tasks which require the discrimination between relevant from less relevant features, or problem-orienting tasks, where learners prioritise the acquisition of information during a limited period (Wiggins, 2015b).

Conclusion

While it has been widely accepted that skilled operators employ cues to assist in the recognition of, and timely and accurate response to, system changes, their usefulness from an applied perspective has been tempered by their idiosyncratic and nonconscious nature. Yet, understanding deficiencies in cue-based associations can assist in improving performance across a range of stages of the workplace life cycle. For example, identifying aspects of cue-based associations that might be contributing to plateaus in performance may facilitate the progression to expertise amongst less experienced practitioners. Operators who have experienced extended periods away from a task, or who may have been involved in an incident might benefit from understanding comparative assessments of their cue utilisation.

At an organisational level, the assessment of cue utilisation at a cohort-level might be used to identify changes in cue-based performance attributed to upgrades in human-machine interfaces or shifts in organisational culture or climate. Further comparative assessments across industries could provide the basis for benchmarking and contribute to cases for increases in investment in training and simulation.

The RAPID approach to the assessment of cue utilisation does not, in itself directly measure the cues that are acquired or utilised in a particular context. Rather, it measures behaviour that is indicative of the application of cues more generally. While this approach is intended to account for the idiosyncrasies associated with cue acquisition, it is possible that a specific cue(s) acquired by an individual operator will be inaccurate. However, since the RAPID tasks correspond to different characteristics of cue utilisation, inaccurate cues should be more evident in the performance on some tasks (e.g. Recognition) than others. In fact, it demonstrates the importance of considering a performance profile in relation to cue utilisation, rather than referring to performance on any single task. Like a personality profile, it perhaps provides a metaphorical window into the underlying, cue-based associations that are activated in response to a stimulus.

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