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Cue-utilisation typologies and pilots' pre-flight and in-flight weather decision-making

Mark W. Wiggins [a,*], Danielle Azar [a], Jake Hawken [a], Thomas Loveday [a], David Newman [b]

[a] Centre for Elite Performance, Expertise and Training, Macquarie University, NSW 2109, Australia
[b] Department of Aviation, Swinburne University, Australia

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ABSTRACT

In complex, high consequence environments such as aviation, the capacity to acquire, integrate, and respond to task-related cues is critical for accurate situation assessment and to avoid plan-continuation errors. The aim of the present study was to establish whether differences in performance on a series of aviation-related, cue-based tasks corresponded to differences in decision selection during simulated pre-flight and in-flight weather-related decision-making. In Phase 1 (pre-flight decisions), 57 participants were categorised into one of two typologies based on their performance on the cue-based tasks. These typologies reflected behaviour that was consistent with relatively greater or lesser levels of cue utilisation, and corresponded to whether the pilots elected to make an immediate decision or wait for additional information during a simulated pre-flight decision task. In Phase 2, a cohort of 20 pilots was selected on the basis that they represented one of the two cue-based typologies established in Phase 1. They undertook a simulated flight during which the weather conditions deteriorated progressively en-route. Those pilots who demonstrated a relatively greater level of cue utilisation were more likely to continue the flight as planned, while those pilots who demonstrated a relatively lesser level of cue utilisation were more likely to descend or divert from the planned track. The implications are discussed in terms of targeted training and explanations of plan-continuation errors in the context of weather-related decision-making.

1. Introduction

Inadvertent or deliberate visual flight into instrument meteorological conditions, and the resultant collision with terrain, continues to account for a disproportionate number of fatalities amongst general aviation pilots (Groff and Price, 2006; Hunter et al., 2011). This is due largely to the fact that pilots who are authorised to fly under Visual Flight Rules (VFR) lack the psychomotor and cognitive skills necessary to maintain control of the aircraft in the absence of visual reference to the horizon. Once visually-related pilots have lost visual reference to the horizon (such as occurs when flying in cloud), they can lose control of the aircraft within a few minutes (Bryan et al., 1955).

Like other decision-making tasks, weather-related decision-making involves the acquisition of information from a range of sources and a comparison between the options available, each of which carries a degree of uncertainty (Knecht, 2005). Prior to a flight, this process involves the acquisition and interpretation of actual and forecast weather-related information, often from a number of different sources, including meteorological weather reports and aeronautical charts (Wiggins et al., 2002). During a flight, weather-related decision-making involves the assessment of the weather-related information available from the cockpit of the aircraft and its integration with the existing state of the aircraft. Both prior to, and during the flight, the information available provides the foundation for an assessment of the situation, which is the precursor to the selection of a particular option.

The significance of accurate and efficient situation assessment in decision-making under uncertainty is illustrated by Kaempf et al. (1996) in their analysis of tactical decision making in military operations. They noted that the accuracy of experienced United States Navy officers' responses was dependent upon a process of feature matching in which elements were compared to a prototype in memory. This enabled the rapid assessment of the system state (e.g. type of aircraft, speed, and altitude), together with an understanding of the significance of any changes that had occurred.

* Corresponding author. Tel.: +61 2 9850 9705; fax: +61 2 9850 8062.
E-mail address: mark.wiggins@mq.edu.au (M.W. Wiggins).

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From a theoretical perspective, accurate and efficient situation assessment forms the foundation of the Recognition-Primed Model of decision-making (Klein, 1993). Incorporated within this model is the proposition that effective situation assessment involves the recognition and response to a familiar pattern of environmental features (Noble, 1993; Wiegmann et al., 2002). Indeed, Klein (1997) argues that this process is the basis of expertise, since it enables accurate and rapid responses, even in situations involving high cognitive load.

The Recognition-Primed Model also proposes that the recognition of patterns of environmental features derives from the availability of a repertoire of cues in long-term memory that can be triggered in response to specific stimuli (Klein, 1993; Salas et al., 2010; Wiggins and O'Hare, 2003). Cues are thought to represent a relationship between a feature and event or object that has been established through repeated association in the past (Shanteau, 1992; Wiggins, 2012). Following exposure to repeated pairings, the relationship between features and events/objects may become non-conscious, so that the response is both rapid and difficult for the operator to articulate (Zacks et al., 2007).

The utility of cues lies in their capacity to reduce the demand on working memory and enable a rapid and accurate interpretation of a scene. This increases the time and the cognitive resources available for subsequent decision-making (Fadde, 2009; Schriver et al., 2008). At the highest levels of performance, expert decision-makers rely on relatively fewer cues to form a diagnosis, having identified specific relationships that are optimally predictive of the changes that occur in the system state (Shanteau, 1992). For example, Schriver et al. (2008) have demonstrated that the capacity to create efficiencies in diagnosis is associated with shorter response latency amongst expert pilots in a dynamic flight simulation task, thereby enabling more appropriate and timely decisions.

There are a number of key elements that form the foundation of situation assessments, including the capacity to accurately identify task-related features from an array, the capability to differentiate relevant from less relevant feature-event/object associations, and the capacity to implement a structured process of information acquisition in response to a task-related problem (Wiggins, 2006, 2012).

In the context of a particular domain, the effective acquisition and utilisation of cues differs depending on the nature of individual and the domain-related experiences that have been acquired. Therefore, it is not necessarily possible to identify a single set of cues that are optimal for a particular context since different operators may use different cues to equal effect when resolving a problem (Patrick et al., 1999). What can be established is the extent to which an operator acquires and responds to information in a form that is characteristic of the effective use of cues.

The formation of feature-event/object relationships in the form of cues involves an iterative process whereby cues are modified or discarded as it becomes clear that there are more predictive and/or more efficient associations that might be available (Shah and Oppenheimer, 2008). This process of cue formation is a risky period during the process of skill acquisition, since it is during this period where mistakes are most likely to occur (O'Hare et al., 1994). Indeed, analyses of both automotive and aircraft accident statistics indicate that severe accidents are most likely to occur during the period immediately post-training, when operators begin honing their skills (Duncan et al., 1991; O'Hare et al., 1994).

Weather-related decision-making amongst pilots is an unusual context in which to examine the role of cue utilisation since the features associated with deteriorating weather conditions are dynamic, may present in different forms and, in the case of in-flight decisions, the speed of the aircraft often requires assessments within very short periods of time. There is also a strong motivational component associated with weather-related decision-making, and this is most evident during in-flight decision-making where pilots can be subject to plan-continuation errors (Bearman et al., 2009).

Plan-continuation errors occur where operators continue to execute a planned behaviour, despite the presentation of information suggesting that an alternative response is warranted (Orasanu et al., 2001). The incidence of plan-continuation errors has been demonstrated experimentally amongst pilots who were confronted with deteriorating weather conditions during a simulated flight (Wiegmann et al., 2002). Where pilots had already completed a significant proportion of the flight, there was a tendency amongst some participants to continue the planned flight to the destination despite a deterioration in the weather conditions that rendered this option inadvisable (Wiegmann et al., 2002).

During the early stages of skill acquisition, learners tend to develop relatively imprecise associations between features and events or objects (Ellis, 1996; Klayman and Ha, 1989) (see Fig. 1). For learner pilots, the association between deteriorating weather and the safety and security of the aircraft is particularly salient so that even the mere presence of cloud may dissuade a visual pilot from undertaking a flight. However, through experience, a greater level of precision is acquired so that different types of weather conditions may be associated with different levels of risk to the aircraft and the likelihood of reaching the destination safely.

For visual pilots who are in the more advanced stages of cue development, the availability of a range of cues may result in a conflict. One of the most significant of these conflicts concerns the situation where the aircraft is in relatively close proximity to the destination but the weather conditions warrant a diversion to either an alternate destination or, in some cases, the original point of departure. It is in this type of situation that the plan-continuation error is most likely to occur since the proximity to the destination appears to be a particularly salient cue that may over-ride the cues associated with the deteriorating weather conditions.

To test this proposition in the present study, pilots were initially evaluated and classified into one of two typologies using the Expert Intensive Skills Evaluation (EXPERTise) Situational Judgement Test (SJT). The EXPERTise SJT classifies participants based on their composite scores across three tasks that are associated with cue utilisation:

1. The *Feature Identification Task*, whereby the participants must identify a key features from an array. The speed and accuracy with which participants are able to acquire that feature is indicative of the strength of their cue associations in memory (Ratcliff and McKoon, 1995).
2. The *Feature Association Task*, whereby participants must rate the association between feature-event/object pairs. The speed and variance of the participant's ratings is indicative of their capacity to distinguish related from unrelated features and events/objects (Morrison et al., 2013).

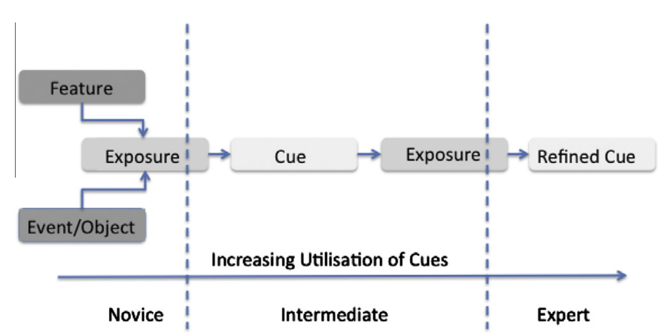

Fig. 1. A conceptual illustration of the formation, progression and refinement of cues and the correspondence with levels of expertise.