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# Measuring Decision Accuracy and Confidence of Mock Air Defence Operators

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This study aimed to understand more fully some of the factors that influence decisions as related to air defence in a naval vessel's operation room. The study considered the impact of decision criticality (DC) and task load (TL) on measures of accuracy, confidence, and within-subjects confidence-accuracy (W-S C-A; a measure of metacognition). Personality constructs, workload, and situational awareness were also assessed. Participants were allocated to either a high, moderate, or low TL condition. Each took part in a computer-generated simulated air defence scenario where they were required to make a range of decisions and provide a corresponding confidence rating for each decision taken. Results showed that low DC increased confidence in decisions and high DC increased decision accuracy. Thus, DC significantly impacts decision confidence and decision accuracy. In addition, those less tolerant of ambiguity were less accurate in their decision-making. Future studies should take account of these factors.

*Keywords:* Decision-making, Command and control, Military, Metacognition

**_General Audience Summary_**

Air defence decision-making is often conducted in a complex and uncertain environment. It is therefore important that the individuals faced with this task are able to make accurate and confident decisions under varying degrees of stress and criticality (i.e., the consequence associated with a decision). The purpose of this study was to examine external factors (e.g., task duration/stress) and internal factors (e.g., personality constructs) that may impact air defence operator's decision-making abilities. In this study a measure of within-subjects confidence-accuracy was used. This measure considers the relationship between decision confidence and decision accuracy by assessing individual awareness of the accuracy of decisions made. For the task, a realistic set of scenarios, which varied in task difficulty, were designed with subject matter experts. Participants were required to make a range of decisions which varied in criticality and then rate how confident they were that they had made the best decision given the situation. The results demonstrated that the criticality of the decision impacted both decision accuracy and confidence. Low decision criticality increased confidence in decisions and high decision criticality increased decision accuracy. The implications of this research include an increased understanding of the understanding of decision criticality on decision-making in critical environments. The introduction of a novel method which has potential application in terms of informing the selection and in the training of personnel who are required to make accurate and confident decisions under conditions of uncertainty and stress is also highlighted. It is important to note that these inferences are based on findings from a novice sample and that non-trained staff are unlikely to make decisions in critical environments.

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A ship's operations room (OR) is the focal point for air defence decision-making. Large amounts of information must be attended to and managed to make tactical war-fighting decisions. Trained operators must detect, locate, and identify potential air threats to make complex and cognitively demanding decisions in the uncertain environment of naval warfare. This often involves information overload and ambiguous information.

Lipshitz and Strauss (1997, p. 150) define uncertainty as a "sense of doubt that blocks or delays action." Previous fatal air defence incidents emphasised the need to better understand how decisions are made under uncertain conditions. For instance, human error, including poor decision-making, was one of the main factors that led to the USS Vincennes shooting down an airliner after mistaking it for a hostile aircraft (Fogarty, 1988). To help militate against the impact of stress on decision-making, research was needed to gain an understanding of decision-making in critical and uncertain environments (Cannon-Bowers & Salas, 1998).

One paradigm which aims to understand decision-making in such environments is naturalistic decision making (NDM). NDM aims to understand the way people use their experience to make decisions in field settings (Zsambok & Klein, 1997). It is domain specific and strives for high ecological validity. NDM investigates how experts make decisions in environments that have been defined as ill-structured, uncertain, ill-defined, high stakes, and which include feedback loops, organisational goals and norms, and time-stress (Orasanu & Connolly, 1993). NDM attempts to understand human capabilities and the decision-making processes, not just outcomes. NDM models are therefore descriptive. A range of methods have been used to help obtain a better understanding of decision-making processes in these environments, including knowledge-elicitation techniques (Kaempf, Klein, Thordsen, & Wolf, 1996) and *microworlds* (Brehmer & Dörner, 1993).

The term metacognition refers to an awareness of one's performance, and the ability and willingness to reflect on one's thinking processes (Parker & Stone, 2014). Previous NDM metacognition research used qualitative methods such as think-aloud protocols (Cohen, Freeman, & Wolf, 1996). However, more experimentally based methods may benefit NDM research (Lipshitz, Klein, Orasanu, & Salas, 2001). These methods allow more controlled testing to enhance understanding of variables involved in the decision-making process. Furthermore, experimental designs within the NDM paradigm may help to understand psychological constructs involved in decision-making (Elliott, Welsh, Nettelbeck, & Mills, 2007). This paper's method uses realistic decision-making scenarios and a combination of subjective measures of confidence alongside objective scores of accuracy to investigate the metacognitive abilities of mock air defence operators. It could therefore advance NDM methodologies by using NDM concepts in conditions more akin to experimental paradigms.

Arguably, metacognitive confidence should be included in studies of decision-making because it is an important indicator of real-world outcomes (Jackson & Kleitman, 2014) and is critical to performance (Rousseau, Tremblay, Banbury, Breton, & Guitouni, 2010). Ensuring confidence is correctly placed has important implications. Overconfidence has been linked to underestimation of risk which could have a direct impact on the evaluation of future events (Lovallo & Kahneman, 2003). However, it is not only how confident one is in a decision, but also the corresponding accuracy of the decision that is relevant (Wheatcroft & Woods, 2010). Strong positive relationships between confidence and accuracy are highly beneficial as they demonstrate an individual's ability to weight information and subsequent decisions appropriately (Stichman, 1967).

Given the above, metacognition can be assessed by using decision confidence. The relationship between decision confidence and accuracy can provide a quantitative measure of metacognition (Fleming & Lau, 2014). One measure which has been used to assess this relationship is the within-subjects confidence-accuracy (W-S C-A) relation. The measure of W-S C-A has been defined as a "calculation which enables expression of individual confidence in each incorrect or correct response made" (Wheatcroft & Woods, 2010; p. 195).

W-S C-A has been used successfully in domains such as forensic, investigative, and legal psychology (Wheatcroft & Woods, 2010; Wheatcroft, Wagstaff, & Kebbell, 2004), perceptual tasks (Koriat, 2011), and general knowledge tasks (Buratti, Allwood, & Kleitman, 2013). Recently, W-S C-A has been used to examine the suitability of supervisory personnel for unmanned aircraft systems (Wheatcroft, Jump, Breckell, & Adams-White, 2017).

The W-S C-A measure can add value to NDM in the assessment of individual awareness of the accuracy of decisions made. This approach is potentially similar to type 2 signal detection theory (SDT) which assesses individual confidence in correct/incorrect responses (Clarke, Birdsall, & Tanner, 1959). However, this approach remains to be consistently established empirically (Maniscalo & Lau, 2012). Whilst it is a subjective metacognitive measure, it has potential to affect the amount of resources applied to an action (Bingi, Turnipseed, & Kasper, 2001)—crucial in air defence environments.

Air defence decisions may be influenced by both environmental and individual factors. Prior research has demonstrated potentially influential environmental factors to the relationship between confidence and accuracy. For example, both difficulty of decision (Wheatcroft, Wagstaff, & Manarin, 2015) and decision danger (Wheatcroft et al., 2017) have shown to impact W-S C-A. This highlights the potential for W-S C-A to aid the understanding of external factors influencing the decision maker, such as the criticality of the decision to be made and the level of stress (task load, TL) experienced. Research has found that criticality influences performance (Hanson, Bliss, Harden, & Papelis, 2014). Decision criticality (DC) refers to the associated consequence of that decision. Hence, both DC and TL are crucial factors in an OR.

Research is required to increase understanding of individual differences that impact air defence decision-making and in highlighting internal factors that influence effective decision-making. Individual differences, such as personality, play a key role (Jackson & Kleitman, 2014). Personality traits are important to decision-making as they can influence how people think, feel, and behave (Roberts, 2009). Wheatcroft et al. (2017) found