Social Cue Utilisation in Ad Hoc Teams and Applied Environments

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Table of Contents

Candidate Declaration

This thesis has not been submitted for a higher degree to any other university or institution. The work is predominantly that of the Combined Doctor of Philosophy/Master of Organisational Psychology candidate. Components of the thesis that involved collaboration have been noted as such. The Macquarie University Human Research Ethics Committee approved the research presented in this thesis on the following dates: 30th April 2014 (Reference number 5201400349), 27th March 2015 (Reference number 5201500041) and 28th April 2016 (Reference number 5201600171). See Appendix A for documentation.

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"...most global trends can be viewed through a social cognitive lens."

(Salas, Stagl, & Burke, 2004, p. 47)

Thesis Summary

The capacity to identify and utilise cues to inform situation assessment and problem-solving has been established as a critical precursor to high levels of operational performance. However, most of the research in this area has focused on predictions of technical performance. There has been little regard for the role of cue utilisation in environments where performance is dependent upon a combination of technical and social cues. This thesis outlines the development of a method to examine individuals' ability to utilise social cues, includes a progressive investigation into the impact of social cue utilisation on performance in laboratory and applied settings, and examines the relative contribution of social and technical cue utilisation to expert performance.

Paper 1 summarised the development of a novel measure of social cue utilisation and established an association between social cue utilisation, closed loop communication, and ad hoc team performance on a general problem-solving task. Paper 2 extended these findings using a higher-fidelity, simulated rail control task, and revealed that social cue utilisation is associated with superior response latencies and lower perceived workload in the context of a simulated task, together with closed loop and informative communication strategies. The findings also indicated that social cue utilisation exerts an indirect effect on perceived workload through informative communication. Paper 3 was designed to evaluate the relative importance of technical and social cue utilisation within two settings where performance is characterised by both technical and non-technical capability and skills: power control and football coaching. The results revealed that self-ratings and job level were not associated with technical and social cue utilisation within the context of power control. However, the combination of technical and social cue utilisation predicted football coaching expertise as defined by level of qualification.

The outcomes of the research program highlight the importance of social cue utilisation in ad hoc team performance and expertise in applied settings. The implications extend to both research focusing on the individual-level factors that promote effectiveness in ad hoc team environments, and the assessment and training of individuals within dynamic settings that rely on the utilisation of social cues.

General Introduction

Overview of General Introduction

The General Introduction comprises three chapters. Chapter One: The Nature of Teams, reviews the literature on team effectiveness with a specific focus on the emergence, application, and nature of ad hoc teams. Research examining the factors that promote performance in ad hoc team settings is included. This chapter also explores the importance of team cognition and communication in the context of ad hoc teams and concludes by highlighting the importance of establishing an explanatory mechanism for ad hoc team effectiveness.

The second chapter, Chapter Two: Social Cue Utilisation and Communication, outlines existing cognitive models of situation assessment that explain how emergent cognitive states arise in the context of applied environments. Central to these models is the ability of individuals to identify, retain, and utilise cues to inform situation assessment and performance. While the literature concerning cue utilisation has tended to focus on domain-specific, technical cues, this chapter provides a discussion as to how the utilisation of broader, social cues represents a key cognitive strategy underpinning communication and subsequent situation assessment in ad hoc team and applied environments.

The final chapter, Chapter Three: Research Aims and General Method, integrates the theoretical and empirical propositions outlined in the preceding chapters, the overall research questions, and aims of the research program. This chapter also outlines the development of the measure of social cue utilisation employed in the research reported in each of the three empirical papers presented.

Chapter One: The Nature of Teams

The Nature of Teams

Teams are defined as groups of interdependent individuals who work together to achieve common outcomes (Cohen & Bailey, 1997). Generally, they share the following key features: (1) they perform tasks that are relevant to the organisation; (2) they have shared goals; (3) they interact socially and are interdependent; (4) they have boundaries; and (5) they are embedded in an organisational context (Kozlowski & Bell, 2003). However, not all teams, characterised by these features, are necessarily effective.

Organisational teams are also found in a variety of different forms depending on the purpose of their formation, such as production, service, management, project, action, and advisory team types (for detailed taxonomies, see Sundstrom, McIntyre, Halfhill, and Richards, 2000; Hollenbeck et al., 2012). Although the settings in which different teams operate are unique, teamwork is typically defined as the knowledge, skills, and attitudes that facilitate coordination efforts and task performance (Cannon-Bowers, Tannenbaum, Salas, & Volpe, 1995; Baker, Day, & Salas, 2006; Rico, de la Hera, & Tabernero, 2011). Since different types of teams face unique demands and require different characteristics and strategies to succeed, the classification of teams represents an important step in facilitating more specific research focused on the factors that characterise effective teams.

Effective teams provide organisations with tangible economic benefits including increased productivity (Banker, Field, Schroeder, & Sinha, 1996; Glassop, 2002), and improved safety outcomes (Baker et al., 2006). Organisations rely on teams because they bring together individuals who can provide unique and complimentary contributions, a greater capacity to solve problems, and broader input to improve complex decision making (Kichuk & Wiesner, 1998). Particularly when employed alongside organisational structures that promote the likelihood of success (e.g., decentralising leadership to increase the autonomy of teams), effective teams provide operational benefits such as improved innovation, financial benefits such as better productivity, and improvements in employee commitment (Glassop, 2002; Delarue, Van Hootegem, Procter, & Burridge, 2008; Richter, Dawson, & West, 2011).

Teams have traditionally been employed in environments where team members occupy prescribed roles and work on defined tasks in settings where the demands are consistent and stable (Tannenbaum, Mathieu, Salas, & Cohen, 2012). In these environments, such as production and manufacturing, teams are characterised more by the types of tasks they are formed to complete, rather than the unique processes and strategies that they implement (Cohen & Bailey, 1997; Sundstrom et al., 2000).

Within these types of settings, structural and compositional factors like team size, and team member characteristics such as experience, can often be associated with the likelihood of success, although findings have been inconsistent (Campion, Medsker, & Higgs, 1993; Devine, Clayton, Philips, Dunford, & Melner, 1999). While there is some evidence supporting the importance of compositional factors for team cohesion (Allen & Hecht, 2004), other researchers have found that diversity within teams with respect to structural and compositional factors, has only a weak, positive association with team cohesion and effectiveness (Devine et al., 1999).

Research into top management and board team composition has generally indicated the positive benefits of functional diversity within teams (e.g., Beckman, Burton, & O'Reilly, 2007). However, emerging research into the contingent benefit of diversity has highlighted that diversity within these teams is only associated with higher performance when such composition aligns with the objectives of the organisation and the business environment (Eesley, Hsu, & Roberts, 2014). These findings reinforce the importance of undertaking more specific research into understanding the demands faced by teams faced with complex contextual demands.

Ad Hoc Teams

The increasingly complex and dynamic environments faced by organisations has led to changes in the demands placed on contemporary teams (Tannenbaum et al., 2012). This is particularly evident where decision-making and problem solving occurs in dynamic settings like emergency incident management (e.g., Klein, Wiggins, & Dominguez, 2010; Reader, Flin, & Cuthbertson, 2007). In addition, the complex and dynamic nature of the challenges that arise in these situations tend to require skills, knowledge, and expertise from different, yet interdependent domains (e.g., Michinov, Olivier-Chiron, Rusch, & Chiron, 2008). For instance, effective teamwork and coordination between clinicians, nurses, and allied health professionals, is positively associated with patient safety outcomes in medical environments (Manser, 2009).

Hollenbeck et al. (2012) note that, in response to increasing complexity, organisations are developing and relying more on diverse teams that differ in relation to three fundamental properties: skill differentiation, authority differentiation (i.e., the extent to which decision-making authority is shared), and temporal stability (i.e., the duration of time for which a team exists). Although some researchers have attempted to understand the impact of these characteristics on the way teams operate (e.g., Bakker, 2010), there remains a need to focus on the specific factors that promote team effectiveness in dynamic contexts.

Within dynamic contexts, organisations depend upon groups of interdependent individuals that are referred to as ad hoc teams because they are formed quickly to resolve high-pressure, complex situations that evolve and change (Kozlowski & Ilgen, 2006). Ad hoc teams are defined as a group of interdependent group members who form at short-notice for limited durations, and are required to integrate and adapt quickly to specific task or situational demands (Salas, Stagl, & Burke, 2004). Ad hoc teams are often described as temporary, project, action, or transient teams, and are characterised by what Tannenbaum et al. (2012) refer to as ‘dynamic composition’.

The growing importance and utilisation of ad hoc teams had led to a greater focus on how the dynamic nature of these teams impact the processes they employ to achieve effective performance (Tannenbaum et al., 2012). For instance, the complex demands faced by ad hoc teams requires that team members share information rapidly and frequently to establish shared understanding and expectations around processes and procedures, thereby achieving the intended goals (Stanton & Ashleigh, 2000). Furthermore, the emergence of shared group-level understanding in ad hoc teams, particularly around task requirements, occurs rapidly during the early stages of formation and interaction to support the coordination of responses efficiently (Allen & O'Neill, 2015).

There is also evidence to suggest that different types of team processes and their application may differ based on situational demands. For example, Svensson and Andersson (2006) observed that fighter pilot team performance in simulator training was positively correlated with communication frequency. However, communication that was offered at sub-optimal periods (e.g., tactics and strategies offered before the task parameters were identified) was associated with performance deficits. Kolbe et al. (2012) also note that better anaesthesia team performance is dependent on the level of communication, focusing on clarifying procedures and initiating actions. Importantly, the level of proactivity associated with team processes appears to have an impact on effectiveness, whereby more proactive and goal-oriented communication tends to be associated with improved team performance (Butchibabu, Sparano-Huiban, Sonenberg, & Shah, 2016).

Effective decision-making in dynamic environments has also been shown to be associated with the ability of individuals to efficiently and effectively develop an understanding of the key elements of a situation to inform potential behaviour, decisions, and responses (Klein et al., 2010). This enables the ongoing management of situational demands as they evolve, and aids efforts to coordinate responses and achieve successful performance (Wickens, 2008).

Given the multi-dimensional nature of team effectiveness (see Pina, Martinez, & Martinez, 2008), the criteria for evaluating the success of teams should also incorporate factors that extend beyond the achievement of outcomes. This would enable the assessment of teams beyond the end-result desired, and also takes into account the processes and strategies employed by teams to formulate decisions and respond to the demands of a situation (Salas et al., 2004). However, the research into team effectiveness has tended to focus on the factors that are associated with performance across different teams, lacking a focus on ad hoc teams (Wageman, Gardner, & Mortensen, 2012).

Team Effectiveness

Team effectiveness frameworks incorporate team input factors (e.g., personality of team members), team process factors (e.g., communication), and team outcomes (e.g., a performance measure) (Mathieu, Maynard, Rapp, & Gilson, 2008). Team input factors refer to both team composition traits and individual team member characteristics such as the competence, ability, and the personality of individuals (Bell, 2007). These characteristics can impact the ability of team members to engage in specific processes that facilitate performance, such as individuals' different levels of skill and experience in communicating with others (Butchibabu et al., 2016).

Team process factors refer to the task and team-based strategies employed to facilitate the coordination and interaction necessary for performance (Antoni & Hertel, 2009; Stout, Cannon-Bowers, Salas, & Milanovich, 1999). These factors are classified into transition, action, and interpersonal processes (Marks, Mathieu, & Zaccaro, 2001). Transition processes refer to planning and those strategies that focus on establishing norms of behaviour and team organisation, and which have been shown to correlate positively with team performance (Mathieu et al., 2008). Action processes refer to specific actions taken, like communication between team members that facilitate teamwork behaviours, and the monitoring of team progress towards the accomplishment of goals (LePine, Piccolo, Jackson, Mathieu, & Saul, 2008). Interpersonal processes refer to activities focused on maximising interaction and the engagement of team members (Marks et al., 2001).

Based on a meta-analysis of team process studies, LePine et al. (2008) reported that the employment of all three types of team process factors were positively related to team cohesion and effectiveness. While LePine et al. (2008) note that this does not necessarily indicate that each process impacts team effectiveness at similar stages of team operation (e.g., team formation), the results provide evidence to suggest that team effectiveness is associated with the ability of teams to strategise and plan, take action to facilitate performance, and communicate and coordinate with team members to achieve their goals.

The positive relationship between team processes and team effectiveness has also been demonstrated for different types of processes employed by team members. In a review of team-based research, Kozlowski and Ilgen (2006) identified that behavioural and cognitive processes are consistently associated with team effectiveness outcomes such as performance. Behavioural processes refer to specific actions and behaviours on which team members rely to coordinate and communicate with each other when working together. Cognitive processes refer to emergent states that can arise during, or as a consequence of, the coordination efforts of team members (e.g., shared knowledge of task requirements; Kozlowski & Ilgen, 2006). This indicates that processes directed towards facilitating greater interaction and shared understanding are likely to improve outcomes for teams, irrespective of their composition and nature (Pina et al., 2008).

The central framework used by team-based researchers to examine team effectiveness is referred to as the Input-Mediator-Outcome-Input framework (IMOI; Ilgen, Hollenbeck, Johnson, & Jundt, 2005). The IMOI framework provides a model of team effectiveness that accounts for cognitive and behavioural processes, together with various individual and team-level inputs (Mathieu et al., 2008). The application of the IMOI as the central framework in team-based research is due to the fact that the model: (1) provides an evidence-based conceptualisation of the relevant factors that impact team effectiveness; (2) is based on the recognition that team effectiveness outcomes are highly variable depending upon the team and the scenario in which they are employed; (3) broadens the definition of effectiveness beyond performance; and (4) acknowledges the complex interplay between inputs, mediators, and outcomes, that has previously been seen as linear and unidirectional (Ilgen et al., 2005).

The Input-Mediator-Outcome-Input Framework of Team Effectiveness. The IMOI framework (see Figure 1.1) represents the most comprehensive model integrating the various factors that are related to the effectiveness of teams (Mathieu et al., 2008). First introduced by McGrath (1964), the original framework was referred to as the Input-Process-Output (IPO) model and was based on the proposition that team effectiveness was the product of a linear progression starting from inputs (e.g., team member expertise), followed by processes including communication that then impact performance outcomes (McGrath, 1964; Cohen & Bailey, 1997).

Ilgen et al. (2005) developed the IMOI framework to account for situations where interactions and feedback loops exist between inputs, processes, and outcome measures. For instance, the process of communication can facilitate, and be the product of, the coordination and planning efforts of teams (Butchibabu et al., 2016). The IPO model is based on the assumption that processes facilitating performance are explicit actions and strategies. However, this assumption has since been refuted by research establishing the emergence and importance of cognitive states that arise during team performance (Marks et al., 2001). Such emergent states differ from explicit behavioural processes as they tend to arise as a consequence of explicit processes and can involve implicit strategies (Pina et al., 2008).

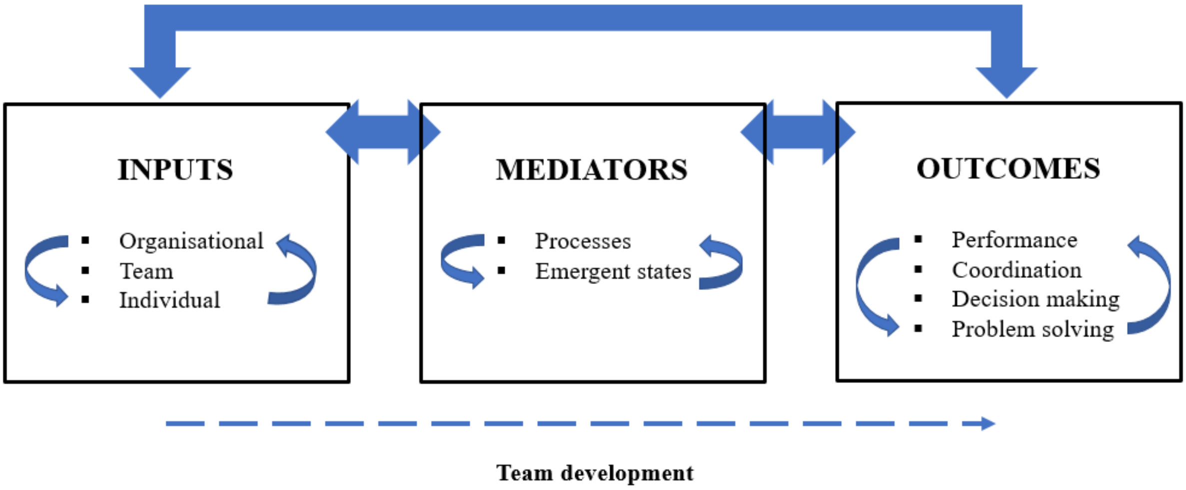

Figure 1.1. Input-Mediator-Outcome-Input Framework (Ilgen et al., 2005).

Implicit in the IMOI framework is the proposition that team outcomes are the product of inputs such as team or individual characteristics (e.g. personality), and mediators, which can involve either explicit processes (e.g. communication), or emergent states (e.g. shared understanding and situational norms) (Mathieu et al., 2008). Overall, the IMOI extends the original IPO model by distinguishing processes from emergent states, treating outputs such as team performance as inputs into future performance episodes, and removing the assumption of linearity based on the evidence that mediators can interact with and have an impact upon inputs (Antoni & Hertel, 2009).

As teams interact and function together, the development and application of mediating processes and strategies leads to the development of team outcomes. For example, the ability of teams to communicate with each other to develop a shared understanding of a situation impacts their ability to coordinate responses and solve problems (DeChurch & Mesmer-Magnus, 2010). These outcomes can be in the form of explicit performance or other relevant team-based outcomes, including team member satisfaction. As a team situation or episode concludes, the team outcomes (e.g., performance) feed back into future team episodes for ongoing teams (Ilgen et al., 2005).

The broad nature of the framework provides utility in guiding the development of research into the factors that impact the effectiveness of different team types. However, the theoretical strength of the model has not always provided sufficient direction for researchers to follow, at times leading to inconsistent empirical approaches in team research (Mathieu et al., 2008). In addition, while many researchers have identified various inputs and processes linked with team performance [for reviews, see Salas, Burke, & Cannon-Bowers (2000), Mickan & Rodger (2000), and LePine et al. (2008)], few studies have provided specific empirical examinations of team effectiveness frameworks for particular team types, including ad hoc teams.

Initial evidence points to the fact that group-level, shared constructs like team cohesion can, in fact, emerge promptly in the context of rapidly-formed ad hoc teams (Allen & O'Neill, 2015). In an investigation of coordination strategies for newly formed ad hoc teams, Butchibabu et al. (2016) noted that higher performing teams were more likely to engage in deliberative, goal-oriented communication compared to lower performing teams. Randall, Resick, and DeChurch (2011) also established that, in the context of decision-making, ad hoc teams were better able to adapt to changing demands if they engaged in greater sensegiving behaviour (i.e., communicating to build a shared understanding).

Research into ad hoc virtual teams also highlights the importance of building trust in the quality of team performance (Altschuller & Benbunan-Fich, 2010). The development of swift trust, which refers to the suspension of uncertainty that allows for presumptive trust to be built and results to be achieved quickly, has also been shown to be positively associated with the performance of ad hoc teams as well as the level of trust reported during subsequent interactions (Crisp & Jarvenpaa, 2013). Swift trust likely enables ad hoc team members who may not have had the chance to build confidence in each other's abilities, to work together to respond to dynamic and complex situational demands (Wildman et al., 2012).

For ad hoc teams, empirical research has been directed towards understanding the team-level inputs (e.g., individual skills) and processes (e.g., communication) that are associated with team performance. This has occurred in the absence of specific examinations of the underlying mechanisms that enable the emergence of these inputs and processes. This is likely due to the fact that previous research has not differentiated ad hoc team types from broader team classifications or has failed to apply an integrated approach to understanding team effectiveness (Mesmer-Magnus & DeChurch, 2009).

Especially in the context of ad hoc environments, underlying explanatory and predictive mechanisms have not been examined consistently. For example, Smith, Baber, Hunter, and Butler (2008) highlighted the importance of teamwork skills such as information gathering and sharing in ad hoc crime scene investigation teams, and yet failed to provide an examination of the circumstances and variables that facilitate the emergence of these strategies. Similarly, Roberts et al. (2014) identified an association between effective communication and teamwork with team satisfaction in ad hoc trauma care teams, yet excluded a specific definition of communication and an exploration of underlying factors promoting its utilisation.

Similar findings and limitations exist for research around ad hoc intensive care team effectiveness (Reader et al., 2007), and emergency response ad hoc teams (Crichton & Flin, 2004). This has led to a need for more research concerning the factors that promote the emergence and application of critical team processes that impact the functioning and performance of ad hoc teams.

Since ad hoc teams are often faced with dynamic and complex demands, it is unsurprising that strategies and processes that enable efficient and effective responses offer particular utility (McKinney Jr, Barker, Davis, & Smith, 2005; Randall et al., 2011). Strategies such as information sharing and coordination can occur implicitly through the anticipatory responses of team members (Butchibabu et al., 2016), as well as through explicit communication strategies that are designed to facilitate greater and more rapid adaptation to task demands (Randall et al., 2011).

The ability to anticipate the needs of team members, together with the ability to identify optimal opportunities to communicate and coordinate with others, appears to be an important component of ad hoc team effectiveness (DeChurch & Mesmer-Magnus, 2010). Strategies involving communication, however, are effective in ad hoc settings only if they are employed correctly and at the appropriate time (e.g., Svensson & Andersson, 2006). From a theoretical viewpoint, a key underlying mechanism that explains how individuals are able to identify and capitalise on these opportunities in team environments is founded in research around team cognition.

Team Cognition

Team cognition refers to cognitive processes that are essential in enabling individual team members to mentally organise, represent, and distribute knowledge within the team (DeChurch & Mesmer-Magnus, 2010). The key assumption underpinning team cognition is that the effectiveness of teams is ultimately determined by the capacity of team members to develop and share information and understanding about a given task or situation (Hinsz, Tindale, & Vollrath, 1997). This shared understanding enables team members to anticipate the needs and actions of other team members, coordinate appropriate actions, and adapt behaviours to task demands (Mohammed, Ferzandi, & Hamilton, 2010).

The importance of team cognition has been demonstrated in various settings. In simulation contexts, the convergence of team and task-related knowledge is positively associated with team performance, and communication and coordination efforts (Stout et al., 1999; Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Marks, Zaccaro, & Mathieu, 2000). Field studies have also demonstrated the positive relationship between emergent team cognitive states and team performance (Lim & Klein, 2006). Finally, Smith-Jentsch, Mathieu, and Kraiger (2005) also highlighted the importance of cognitive processes in the context of air traffic control teams' safety and efficiency.

The emergence of collective states in the context of teams depends on both the convergence of team cognition, and the accuracy of teams' shared understanding and knowledge of a situation. This is evident through research highlighting the importance of both convergence and accuracy in predicting team performance outcomes (for a review, see Mohammed et al., 2010). While there is some evidence to suggest that accuracy may constitute a stronger predictor of team performance than similarity or convergence (Edwards, Day, & Arthur Jr, & Bell, 2006), the consistency of team members' understanding represents an important characteristic of team cognition.

The assessment of team cognition has taken two different forms in prior research. The first is referred to as the shared mental models perspective. This perspective conceptualises collective emergent states as cognitive models representing the key aspects of a situation (e.g., people involved, task demands) (Ilgen et al., 2005). These cognitive models refer to the information and knowledge that is shared and congruent among individual team members, a characteristic referred to as compositional emergence (Kozlowski & Klein, 2000).

The second perspective is the transactive memory system perspective. This perspective defines team cognition as the emergent system of differentiated knowledge held by individuals, in addition to the awareness as to which team members hold certain knowledge (Ren & Argote, 2011). Transactive memory systems are compilational in nature insofar as team members do not necessarily share common knowledge, and collective states are compiled based on the incremental and unique perspectives of different team members (Rentsch, Small, & Hanges, 2008). In addition, this system-based perspective assumes that team cognitive processes exist at a system level rather than at an individual level. This allows information to be exchanged implicitly so that unique system agents (i.e., different team members) can serve different purposes (Stanton et al., 2006; Salmon et al., 2008).

While both methods of defining team cognition are positively associated with team processes and team effectiveness, meta-analytic findings indicate that the shared mental models perspective is more predictive of team behavioural processes such as communication for highly interdependent, action teams (DeChurch & Mesmer-Magnus, 2010). Transactive memory systems are also highly predictive of team processes. However, these findings have been demonstrated for moderately interdependent teams that work together for extended periods on a project basis (Wegner, 1987; DeChurch & Mesmer-Magnus, 2010). Given the focus of the current research program on teams operating in ad hoc environments, the shared mental models perspective was adopted to operationalise team cognition.

Shared Mental Models Perspective. Shared mental models are defined as the mental representations that are shared by team members and that are used to identify and understand the key elements within a working environment (Mohammed & Dumville, 2001). They represent a network of associations between individual team members' mental models, that refer to frameworks of knowledge about the concepts and structures within a particular domain that are represented in long-term memory (Langan-Fox, Code, & Langfield-Smith, 2000). These associations are updated and developed based on environmental inputs, and represent team members' shared understanding of the important aspects of a specific environment that they are experiencing.

The shared understanding provided by shared mental models enables more efficient operations by creating a common view of what is occurring, what is likely to occur in the future, when it might be likely to occur, and why (Mohammed et al., 2010). The emergence of shared understanding assists in both novel situations where team members are required to promptly assess the demands of the situation, together with ambiguous situations, where the resolution of ambiguity is essential before any action is taken. This is especially evident in team performance research in complex decision-making scenarios such as air traffic control (e.g., Smith-Jentsch et al., 2005).

Lim and Klein (2006) examined the relationship between shared mental model development and decision-making in military teams and noted that, in the context of high-pressure and time-limited decision-making scenarios, teams with greater similarities in their shared mental models performed at a higher level. Within nuclear power plant control room teams, higher-performing teams are more likely to collect and share information and develop shared mental models during non-routine situations (Waller, Gupta, & Giambatista, 2004). The importance of shared mental model development to team decision-making is also evident in air traffic control teams (Smith-Jentsch et al., 2005).

The development of shared mental models is directly associated with superior team performance. For example, in an examination of dyadic group performance on a simulated flight combat scenario, Mathieu et al. (2000) noted that shared mental models surrounding task requirements and team member characteristics related positively to both team processes (e.g., coordination) and task performance. Specifically, teams where members' ratings of the importance and relatedness of scenario features converged more strongly, tended to perform at a higher level and be rated by observers as communicating, cooperating, and coordinating more effectively.

Using the same methodology for measuring shared mental models, Lim and Klein (2006) conducted a field study of military combat teams. They had participants judge the relatedness of task-related statements, and used these ratings to determine the extent to which team members were accurate, and shared similar understandings about the task. They established that both the accuracy and similarity of shared mental models predicted team performance in a military assessment centre exercise.

Team processes that promote shared understanding underpin the emergence of shared mental models within teams (Antoni & Hertel, 2009). For instance, communication serves as a vital mechanism through which shared mental models emerge in the context of multidisciplinary teams (Bierhals, Schuster, Kohler, & Badke-Schaub, 2007). Specifically, Bierhals et al. (2007) observed that more successful teams were more likely to establish accepted knowledge through which the team could structure tasks and allocate responsibilities. This outcome is consistent with results across simulation studies (Marks et al., 2000; Mathieu et al., 2000), laboratory studies (Cooke & Shope, 2005), and field studies (Smith-Jentsch et al., 2005).

It is likely that the process by which team members communicate their shared understanding of a situation represents the single most important predictor in the formation of shared mental models and the subsequent emergence of team cognition (Cooke, 2015). Given the expected reliance of ad hoc teams on efficient and effective development of shared understanding concerning situational demands, communication should serve as an essential mechanism through which team cognition emerges.

Communication and Team Cognition

Communication-based research typically classifies communication in two different ways: functional and mediational. While the functional perspective suggests that communication directly enables team members to coordinate decision making and collective efforts, the mediational perspective is based on the proposition that communication serves as a mechanism through which team processes ultimately impact team functioning (Hirokawa & Salazar, 1999). Team-based researchers have tended to define communication as both functional and mediational, with evidence indicating that communication is both a direct, functional process in facilitating team performance outcomes, and a mediational process through which team effectiveness outcomes like team cognition emerge (Antoni & Hertel, 2009; Mathieu et al., 2008).

Effective team-based communication is defined as the capacity to ensure the reception of an intended message, acknowledgement of the reception of an intended message, and the achievement of an appropriate and efficient understanding on the part of the message recipient (Baker et al., 2006). According to Ashmos and Nathan (2002), the most important function of communication is to allow team members to make sense of, and share, a common understanding of a given situation.

Within ad hoc environments, where task demands and the risks of error are relatively high, communication must be exchanged efficiently to ensure successful performance and team functioning (Davies, 2005). For example, Kolbe et al. (2012) established that ad hoc medical teams achieve greater performance when team members speak up to clarify their understanding of situational demands, discovering that this communication led to a greater and more rapid clarification and initiation of procedural actions. Meta-analytic evidence also points to the positive relationship between the frequency of information sharing and both team cohesion and knowledge integration (Mesmer-Magnus & DeChurch, 2009).

While communication that focuses on building shared knowledge of a situation promotes the development of shared cognition in teams (e.g., information sharing), the importance of knowing when to engage in this form of communication is vital (Patrashkova-Volzdoska, McComb, & Green, 2003). In a study with fighter pilot teams, Svensson and Andersson (2006) observed that team members needed to communicate to enhance their understanding of situational and mission-related demands. However, more efficient and effective teams communicated less frequently and only at appropriate times. This is consistent with research into team adaptation, where communication centred on sensegiving (i.e., drawing meaning from a complex environment) tended to promote the development of team cognitive processing (Randall et al., 2011). These results suggest that the nature of team-based communication, both in terms of frequency and type, is an important quality of communication that determines its impact on team cognition.

The reliance of teams on effective communication is especially evident in studies examining the outcomes associated with ineffective communication, commonly defined as the failure to present content accurately and achieve the intended message with a recipient (Clark, 1994). Breakdowns in the quality of communication (e.g., inadequate or absence of responses to requests for clarification) are common factors in the occurrence of aviation incidents and medical error in ad hoc environments (Leonard, Graham, & Bonacum, 2004; Baker et al., 2006; Salas, Cooke, & Rosen, 2008a).

In the context of teams, communication can serve as both a team process and an *outcome* of effective team processes (LePine et al., 2008). However, studies positioning communication as an outcome of team interaction employ a methodology that excludes the possibility for communication to precede team cognition. While it is possible that the development of team cognition precedes the development of communication, it is perhaps more likely that communication serves as a conduit for team members to be able to share their interpretations and understanding of a given situation with one other (Marks et al., 2000). For ad hoc teams, this shared understanding would enable a more rapid adaptation to situational demands and the successful coordination of actions and responses.

One of the difficulties associated with communication as a precursor to the development of team cognition, however, is when, where, and how individuals communicate task-related information (Svensson & Andersson, 2006). Although the evidence available highlights the need for team members to identify appropriate and key opportunities to engage others to develop shared understanding, there lacks empirical research identifying and testing a specific mechanism that might enable effective ad hoc team communication.

Chapter One presented a review of the team-based literature with a focus on the emergence of ad hoc teams and team effectiveness. While empirical research has tended to lag behind the application of ad hoc teams in applied environments (Tannenbaum et al., 2012), the frameworks employed in understanding team effectiveness and explaining the emergence of shared cognitive states are likely to be transferable to ad hoc teams. A more specific focus on the mechanisms that encourage communication and emergent cognitive states of ad hoc teams will provide a more rigorous understanding of how ad hoc teams can be more effective.

Chapter Two: Social Cue Utilisation and Communication

Social Cue Utilisation and Communication

Ad hoc teams are often engaged in environments that are characterised by rapidly changing and complex scenarios. Within these environments, situational demands are typically dynamic, and require efficient and effective interaction, coordination and performance. Consequently, communication serves as an important strategy for individuals and teams operating in these settings (Mesmer-Magnus & DeChurch, 2009). This chapter examines how social cue utilisation might serve as an underlying mechanism in facilitating effective communication in the context of ad hoc teams, and presents a framework outlining how communication aids individuals and teams in navigating the demands in the settings typically faced by ad hoc teams.

Communication in Teams

Communication in teams involves ensuring that team members receive, acknowledge, and understand at the appropriate time, the messages that are being provided by individuals (Ashmos & Nathan, 2002). For ad hoc teams, communication needs to occur efficiently and effectively to support the prompt sharing of knowledge, and to establish a shared understanding in the context of situational parameters and demands (Davies, 2005).

Through the exchange of key information, different team members are more likely to build a collective understanding and distribute knowledge, and form critical, shared cognitive frameworks that facilitate performance and effectiveness (DeChurch & Mesmer-Magnus, 2010). This positive association between communication and coordination activities that is directed towards identifying necessary tasks and actions is evident in successful ad hoc teams in emergency medical care, crime scene investigation, and within experimental settings (Roberts et al., 2014; Smith, Baber, Hunter, & Butler, 2008; Yee, Wiggins, & Searle, 2017).

Approaches to the study of communication vary significantly amongst researchers. For instance, while some researchers adopt a quantitative approach by measuring the frequency of specific communicative statements (e.g., responding to a question with a clarifying statement; see Kolbe et al., 2012), others consider the quality of communication which focuses more on communicating at optimal times (e.g., task-focused or team-focused; see Randall, Resick, and DeChurch, 2011). Linguistic approaches to communication also focus on understanding how the features of team-based communication such as the positive affect and inclusiveness of the language used, are associated with team functioning (e.g., Fischer, McDonnell, & Orasanu, 2007; Sheehan, Robertson, & Ormond, 2007). However, regardless of the approach, the effectiveness of communication in the context of teams is largely determined by its capacity to facilitate the development of shared understanding (Mesmer-Magnus & DeChurch, 2009).

This functional role of communication enables teams to make sense of, and share their understanding of, a specific situation (Hirokawa & Salazar, 1999). Nevertheless, it remains unclear precisely how, and in what form communication needs to occur to ensure an accurate assessment of the situation, and to what extent it facilitates the coordination of responses, particularly in the context of ad hoc teams.

Especially in those environments where success relies heavily on effective teamwork, communication is associated with greater situational awareness, problem identification, coordination of tasks and actions, and quality of resolution (Davies, 2005). Communication is especially important during the initial stages of problem definition and situational assessment, since individuals need to establish critical parameters and demands as efficiently as possible (Wickens, 2008). For ad hoc teams, communication likely provides the primary means by which team members facilitate the process of forming and developing a shared understanding and situational assessment (McKinney Jr, Barker, Davis, & Smith, 2005).

Models of Situation Assessment

Situation assessment involves interpreting and building an understanding of the critical information in a specific context that supports the development of judgements, decision making, and behavioural responses (Wellens, 1993). It is an essential strategy that enables the drawing together of otherwise disparate pieces of information to make sense of a condition and provide the basis for a response (Endsley, 1995). The capability of individuals to accurately assess, comprehend, and utilise key information in a situation is associated with their effectiveness in identifying and implementing specific courses of action (Lipshitz, Klein, Orasanu, & Salas, 2001).

The capacity for situation assessment is driven by the ability to identify, retain, and utilise cues in the surrounding environment (Klein, 1993). Cues refer to signals in an environment that represent associations between features and events that are stored in long-term memory (Ericsson & Kintsch, 1995; Chi, Feltovich, & Glaser, 1981). Cue utilisation refers to the process of identifying and applying cues in an environment to form situational judgements, that enables the anticipation of, and responses to, changing situational demands (Wiggins, 2014, 2015). In effect, cue utilisation promotes the extraction of critical information to inform situation assessment which is essential in dealing with uncertain and complex situations (Weiss & Shanteau, 2003).

Although there are a number of different theoretical models that are purported to explain the cognitive mechanisms that underpin situation assessment, only three models integrate the process of cue utilisation with situation assessment. The three models are referred to as the Lens Model (Brunswik, 1955), the Perceptual Cycle Model (Smith & Hancock, 1995), and the Recognition-Primed Decision Model (Klein, 1993).

The Lens Model. The Lens Model (see Figure 2.1) was developed by Brunswik (1955) to explain how judgements are formed, with a central focus on the role of environmental cues and their utilisation in aiding the accuracy and utility of judgements that inform perception, diagnosis, and behaviour.

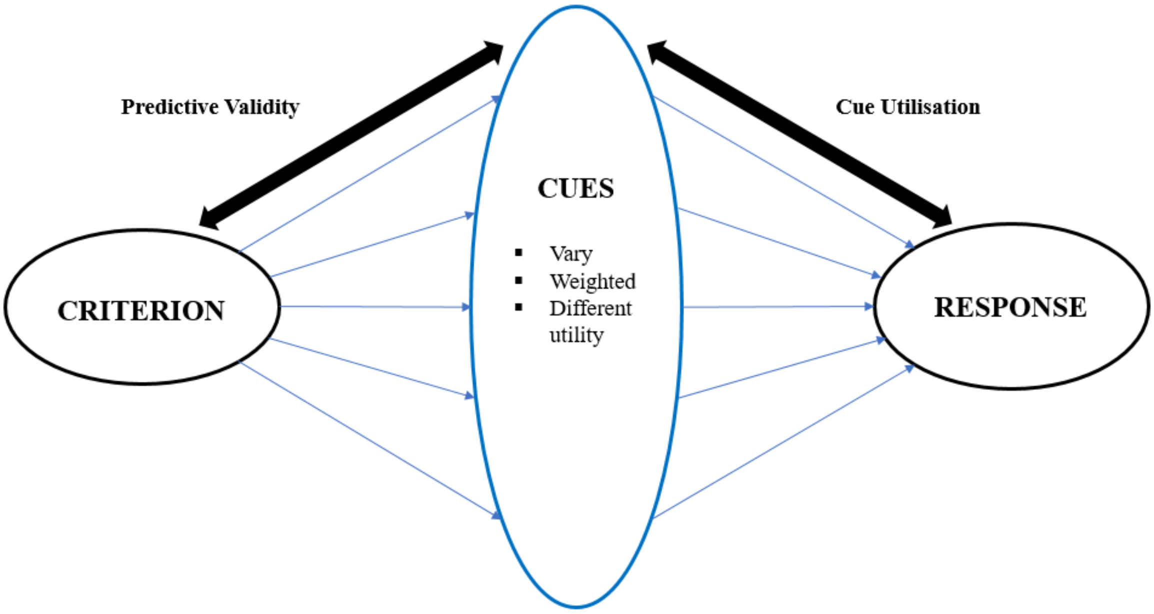

Figure 2.1. The Lens Model (Brunswik, 1955).

The Lens Model describes two related processes that underpin cognitive assessments and judgements: Cue identification and cue utilisation. Cue identification describes the process whereby individuals develop associative links in the environment that offer important information and that are subsequently retained in memory (Ericcson & Kintsch, 1995). These associative links form cues that can be utilised to quickly and accurately assist the interpretation of a visual or auditory scene.

Cues provide an efficient means of activating memory-based, feature-event associations that enable individuals to process environmental information without impeding working memory (Van Gog, Kester, & Paas, 2010). By reducing the impact on working memory, cues can facilitate more rapid judgements and problem resolution (Wiggins, 2014; Ericcson & Kintsch, 1995). Without the explicit need to recall specific cases from long-term memory, cues are thought to reduce the cognitive demands placed on individuals when making decisions and responding to environmental stimuli (Ericsson & Kintsch, 1995; Loveday, Wiggins, & Searle, 2014).

Expert and novice differences with respect to cue utilisation and performance provide support for the proposition underpinning the Lens Model that variability in cognitive judgements and assessments is associated with different levels of effectiveness in identifying and utilising cues. Specifically, it is the individual's capacity to learn, retain, and utilise relevant cues, and not the presence of features in the environment, that appears to determine how effectively operators are able to form situation assessments and coordinate responses. These differences are evident across multiple settings including elite sport (Williams & Ford, 2008), medicine (Schubert, Denmark, Crandall, Grome, & Pappas, 2013), aviation (Schriver, Morrow, Wickens, & Talleur, 2008), and the military (Randel, Pugh, & Reed, 1996).

Cues vary in the degree of predictive validity that they embody which can, in turn, impact the likelihood that they will be utilised to inform future responses (Goldstein, 2004). According to Brunswik (1955), cues that provide strong predictive validity are those that are associated with effective judgements, while cues with low predictive validity either lack utility, or are irrelevant for specific situations.

Brunswik (1955) also suggests that effective situation assessment depends upon the ability to accurately weight the various cues available in an environment and utilise them to form judgements and responses. The extent to which individuals are able to weight cues in the context of situation assessment varies and is typically based on the associative links that have been retained in memory (Karalaia & Hogarth, 2008; Doherty & Kruz, 1996; Mosier & Kirlik, 2004).

In the context of ad hoc teams, individual differences in cue utilisation raise the possibility that, given the same situation, different team members will perceive the situation differently. Unless there is a mechanism to recognise, share, and resolve these differences to establish and maintain collective understanding, it is possible that errors may emerge, or performance may be negatively impacted (Klein, Wiggins, & Dominguez, 2010; see Mohammed, Ferzandi, & Hamilton, 2010). Although the Lens Model provides an explanation for how cue utilisation is integrated with the process of situation assessment, it fails to outline a mechanism that promotes the alignment of different perspectives within a team that might promote situation assessment.

The Perceptual Cycle Model. The Perceptual Cycle Model (PCM) (see Figure 2.2) was developed by Smith and Hancock (1995) and proposes that situation assessment occurs through an adaptive cycle of information gathering, the activation of knowledge schemas, and goal-directed actions.

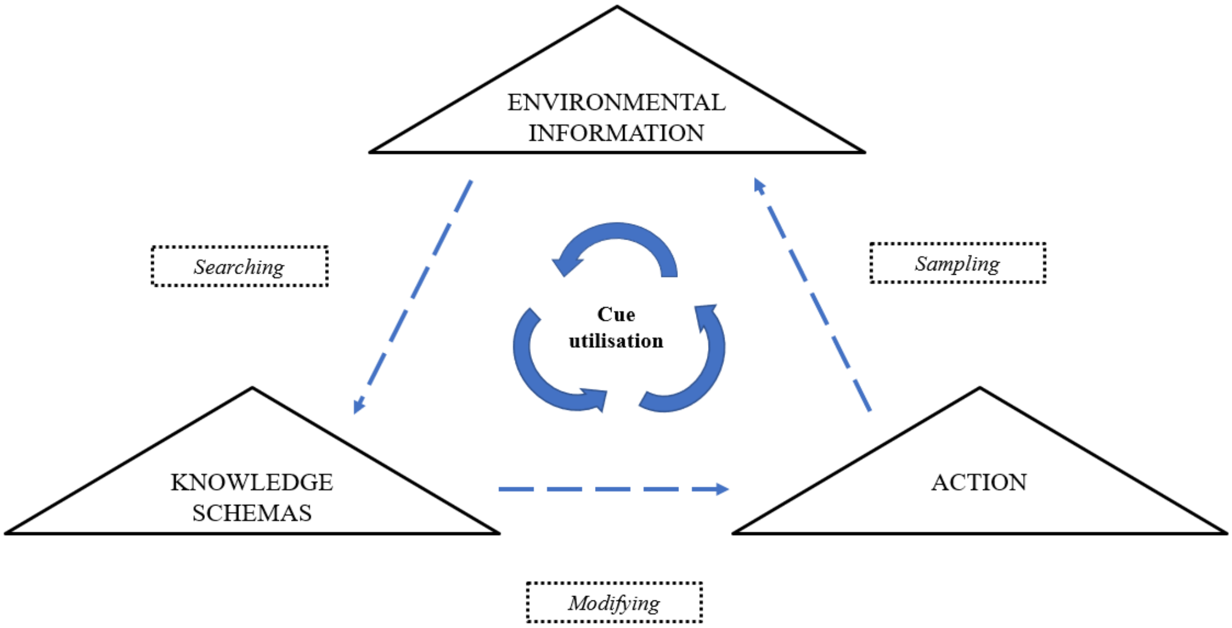

Figure 2.2. The Perceptual Cycle Model (Smith & Hancock, 1995).

The PCM highlights the importance of three key processes that enable adaptive situation assessment. First, Smith and Hancock (1995) argue that individuals' interactions with the external environment are inherently goal-driven in a top-down fashion, which serves to guide their *searching* behaviour in a way that focuses their attention on specific cues that provide goal-relevant information. These cues serve to trigger knowledge schemas which represent mental models held by individuals that have been retained in memory by individuals due to their utility in supporting successful goal achievement (Endsley, 1995; Salmon et al., 2008).

These mental models consist of knowledge about the environment and the impact of specific actions they have taken previously, allowing individuals to *modify* and direct their actions in order to maximise the likelihood of achieving their goals (Smith & Hancock, 1995). According to the PCM, actions are an essential component of situation assessment because they enable the *sampling* of environmental information that serves as feedback for how instrumental the directed course of actions have been. This serves to modify existing knowledge schemas and future *searching* behaviour in an adaptive cycle (Adams, Tenney, & Pew, 1995).

Central to the PCM is the ability of individuals to identify cues in the environment based on the knowledge schemas that they possess in long-term memory (Smith & Hancock, 1995). While the process of situation assessment advanced is referred to as adaptive, the model does not provide a clear explanation for how more non-conscious or bottom-up directed behaviour could drive situation assessment in the absence of explicit goals that the individual holds.

The Recognition-Primed Decision Model. The Recognition-Primed Decision Model (RPDM) (see Figure 2.3) centres around the role of pattern recognition in situation assessment and is based on the proposition that individuals can recognise patterns of cues in the environment through the priming of memory-based associations (Klein, 1993, 2003). A dual-process model, the RPDM outlines two systems of cognitive processing underpinning situation assessment: (1) a more rapid, unconscious, and automatic system that enables individuals to overcome limitations around working memory and cognitive capacity; and (2) a more conscious, deliberate, and resource-intense system that enables individuals to deal with novel and complex situations (for a more detailed explanation of the two-system model of decision-making, see Kahneman & Frederick, 2002, 2005, Croskerry, 2009; Evans, 2008; for a discussion on the development of dual-process models of reasoning, see Stanovich, West, & Toplak, 2011).

According to the RPDM, when individuals encounter situations that require rapid and accurate decisions and actions, they rely on patterns of cues to inform their response. For instance, an experienced nurse who is a member of a medical surgery team is likely to 'know' how to respond to patient symptoms during a routine procedure. The recognition of patterns enables individuals to form assessments of the relevant antecedents, actions, and outcomes that are likely to occur to support their judgements, decisions, and responses (Klein, 2003; Klein, 2008).

On recognising familiar patterns in the environment, action scripts are activated from memory (Klein, 2008). For example, in the context of weather-related decision-making, pilots with a superior ability to identify cues that signal unsafe conditions are more likely to take evasive manoeuvres having been primed to take action to ameliorate the situation (Wiggins, Azar, Hawken, Loveday, & Newman, 2014a).

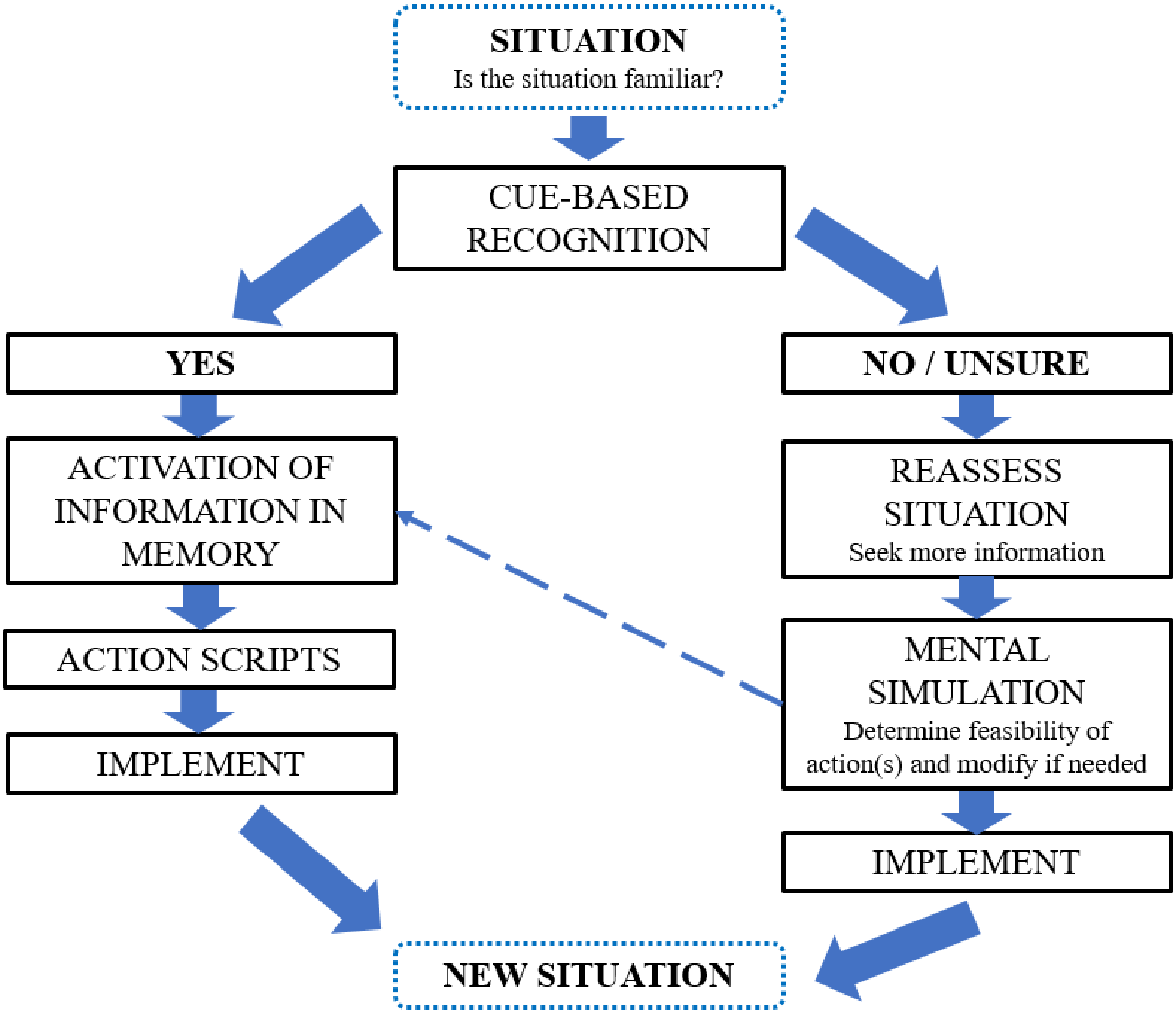

Figure 2.3. The Recognition-Primed Decision Model (Klein, 1993, 2003).

Like the Perceptual Cycle model, the RPD model also accounts for situations where individuals are unable to activate scripts retained in memory, though a more deliberate explanation is given for these scenarios. In these situations, individuals are likely to find the most workable solution, rather than any ideal option they might have experienced in the past, a process known as satisficing (Simon, 1978; Klein, 1999; Klein, 2008). During these situations, individuals are predicted to mentally simulate different response options based on the information available to identify the optimal solution (Lipshitz et al., 2001).

The rapid, nonconscious system of information processing, together with the more conscious, deliberate system of processing are likely to be fluid in their application, particularly where individuals encounter complex scenarios that do not permit clear pattern recognition (Klein, 2008). Further, the activation of either system is heavily dependent upon individuals' capacity to identify and utilise cues in their environment (Farrington-Darby & Wilson, 2006; Evans, 2008).

Cue Utilisation and Situation Assessment

Cue utilisation provides a relatively efficient process for individuals to discriminate relevant from non-relevant features in an environment to extract the key information needed for situation assessment and cognitive judgements (Chi et al., 1981; Weiss & Shanteau, 2003). It reduces the cognitive resources required to form situation assessments and potentially allows for more cognitive resources to be dedicated towards more complex situational demands, sustaining attention, and task performance (Wiggins, 2006; Small, Wiggins, & Loveday, 2014; Brouwers, Wiggins, Helton, O'Hare, & Griffin, 2016).

Both the Lens Model (Bruswik, 1955) and the RPD model (Klein, 1993) posit that the utilisation of environmental cues represents a key mechanism for situation assessment. However, the recognition of visual patterns of cues also forms the basis of reasoning and diagnostic strategies. For example, Coderre, Mandin, Harasym, and Fick (2003) demonstrated that expert gastroenterologists were more likely to rely on visual pattern recognition to extract cues and demonstrate greater success in diagnosing clinical presentations in comparison to non-experts. The application of cue-based reasoning is also evident across different domains including sport (Williams & Ford, 2008), aviation (Schriver et al., 2008), and medicine (Schubert et al., 2013; Hoffman, Aitken, & Duffield, 2009).

Although there may be similarities in the process of information acquisition, different individuals are likely to identify and apply different cues, and utilise cues differently, when forming situation assessment and resolving problems or making decisions to equal effect (Wiggins, Brouwers, Davies, & Loveday, 2014b). The reliance on multiple cues to form judgements and build an understanding is evident in both undergraduate (e.g., Enkvist, Newell, Juslin, & Olsson, 2006; Rolison, Evans, Walsh, & Dennis, 2011) and industry (e.g., operators, Patrick et al., 1999; sporting referees, Plessner, Schweizer, Brand, & O'Hare, 2009) samples.

Assessments of Cue Utilisation. There are two key approaches to the assessment of cue utilisation, the first of which targets the specific cues to which decision-makers attend during decision-making. For instance, Hoffman et al. (2009) used concurrent verbal protocol analysis to identify the cues employed by skilled clinicians during clinical decision-making. Cues have also been identified using recall strategies post-decision, where decision-makers are asked to review systematically the processes that were engaged during decision-making (e.g., Reischman & Yarandi, 2002; Naumann, Vazire, Rentfrow, & Gosling, 2009). Given the evidence that individuals use multiple, often unique, cues to inform their decision-making and judgements, recall-based methods enable unique cue-based strategies to be identified (Enkvist et al., 2006; Rolison et al., 2011).

While the identification of cues employed by individual decision-makers is useful, it has been difficult to establish a universal set of cues to which all skilled operators attend. These differences in the cues to which operators attend probably reflects the idiosyncrasy associated with the accumulation of experience and the progression to expertise. In fact, there is considerable evidence to suggest that different individuals, particularly experts, adopt and apply unique patterns of cues and strategies, even though they achieve remarkably similar outcomes in response to a problem (e.g., Belisle & Bodur, 2010; North, Williams, Hodges, Ward, & Ericcson, 2009; Jarodzka, Scheiter, Gerjets, & van Gog, 2010).

The second approach to the assessment of cue utilisation involves characterising behaviour that is indicative of the utilisation of cues, rather than focusing explicitly on the utilisation of specific cues and related strategies. For instance, the Cochrain-Weiss-Shanteau (CWS) index focuses on individuals' ability to discriminate between similar cases in a consistent manner (Shanteau, Weiss, Thomas, & Pounds, 2003). The assessment of behaviour that is indicative of cue utilisation overcomes the limitation that individuals must be able to recall and articulate the cues they relied on to form judgements, and enables the aggregation of performance, thereby facilitating comparative analyses at a cohort-level. (Weiss & Shanteau, 2014).

Behaviours that are indicative of the utilisation of cues include the capacity to: (1) identify and recognise key features rapidly and accurately, (2) discriminate relevant from non-relevant features, (3) identify the strength of association between features and events, and (4) prioritise the acquisition of information to resolve a problem (Wiggins, Harris, Loveday, & O'Hare, 2010; Wiggins, Loveday, & Auton, 2015). These behaviours can be assessed using situation judgement tools that incorporate the features germane to the operational context.

In measuring behaviour in response to operational features, comparative analyses are possible. For example, Loveday et al. (2014) demonstrated that, in software engineering, individuals with a greater capacity to demonstrate behaviour consistent with the utilisation of cues were more likely to be perceived as an expert, self-reported behaviours associated with expertise, and exhibited more effective decision-making and problem-solving. Similarly, Loveday, Wiggins, Searle, Festa, and Schell (2013b) showed that paediatricians' characteristic behaviour indicative of cue utilisation was positively associated with their diagnostic accuracy. Finally, in aviation, Schriver et al. (2008) noted that pilots with greater expertise as defined by flight hours, knowledge, and qualification, displayed more attention (i.e., visual dwell time) to features that were necessary to diagnose failures during a series of simulated flights requiring diagnosis and response.

Both the Lens (Brunswik, 1995) and RPD (Klein, 1993) models suggest that cue utilisation represents a key mechanism through which situation assessment occurs at the individual level. Yet, in the context of ad hoc teams, the idiosyncrasy in cue utilisation represents a significant impediment to group-level performance, unless the basis of situation assessment is expounded, and a joint position is established. Therefore, the success of situation assessment in team-based environments is likely to depend upon the ability of team members to communicate effectively and at the appropriate time during a problem-oriented activity (i.e., both in terms of quantity and quality).

Social Cue Utilisation and Communication

At present, the role of cue utilisation in aiding operators to formulate assessments of a technical problem is relatively well-established (e.g., Wiggins et al., 2014b). However, team performance is often dependent upon a combination of both the technical and non-technical skills of team members (e.g., Roberts et al., 2014; Smith et al., 2008; Hull et al., 2012, McCulloch et al. 2009). Non-technical cues, such as those that occur in response to social and emotional features, are likely to contribute to team performance by enabling team members to attend to, and build, a shared assessment of a technical problem.

Individuals differ in the extent to which they can utilise social cues. Social cues constitute feature-event relationships that are associated with an interpersonal exchange and that provide information about the behaviour, emotion, or cognitions of others (Pickett, Gardner, & Knowles, 2004). Given the importance of perception in the interpretation of social cues, visual social cue utilisation involves the monitoring of emotional expressions by individuals, such as observing the smile of another person as indicative of happiness (Prati, Douglas, Ferris, Ammeter, & Buckley, 2003). Auditory social cue utilisation involves the interpretation of prosodic and semantic features inherent in auditory communication (Auton, Wiggins, Searle, Loveday, & Rattanasone, 2013).

The utilisation of non-technical, or social cues, is likely to represent a key underlying mechanism of team performance, particularly in the context of ad hoc teams, and over and above the technical cue utilisation of individual practitioners. What will be referred to as social cue utilisation, describes the capacity of individuals to identify and respond to social and emotional cues that pertain to communication, coordination, and/or interpersonal interactions and actions.

The utilisation of social cues may involve the identification of emotional expressions through visual features, non-verbal behaviour such as a lack of eye contact that may signal disinterest, or verbal behaviour like hesitation that may signal uncertainty (see Krahmer & Swerts, 2005). The relationship between facial expressions and the identification of specific emotions such as anger and happiness is well established (Kanade, Cohn, & Tian, 2000). Other emotions, such as confusion, worry, and concentration are also conveyed through changes in the facial features of individuals (Rozin & Cohen, 2003). Physical cues like posture and facial expressions are also associated with judgements around trust and cooperation in the context of team problem solving (Boone, Declerck, & Suetens, 2008), together with judgements about the personality characteristics of others (Naumann et al., 2009).

In addition to facial expressions, people convey information through verbal communication such as uncertainty and disagreement (Krahmer & Swerts, 2005; Roberts, Francis, & Morgan, 2006). Both prosodic and semantic features of communication can be employed and can convey a broad array of responses. In the context of ad hoc teams, where decision-making and cognitive judgements take place in dynamic and complex settings, verbal responses are critically important to convey uncertainty or disagreement which should in turn, prompt the retransmission or clarification of an exchange. Investigating the role of social cue utilisation in verbal exchanges, Auton et al. (2013) noted that prosodic cues, including delays, fillers (e.g., ‘um’), and rising intonation all contributed to perceptions of nonunderstanding on behalf of the listener.

Social cue utilisation may provide a key mechanism that enables situation assessment, since it facilitates communication in response to environment features. The utilisation of social cues appears to be an important component in assisting individuals to form judgements and respond to situations involving interaction and coordination with others (e.g., Boone et al., 2008). At an applied level, social cues are also an important factor in aiding clinical decision making for intensive care (Hoffman et al., 2009) and in playmaking amongst rugby league athletes (Johnston & Morrison, 2016).

Chapter Two examined key models of situation assessment to explore how the process of assessing situational demands and characteristics provides individuals and teams with a greater capacity to form judgements and formulate decisions rapidly and efficiently. Within the context of ad hoc teams, where team members must work together to quickly develop an accurate and shared understanding of situational parameters, communication represents an essential strategy that enables this process to occur. Given the utility of social cues in providing individuals with key information about the behaviour, emotion, or cognitions of others, it is likely that social cue utilisation promotes effective communication that forms the foundation for the effectiveness of ad hoc teams.

Chapter Three: Research Aims and General Method

Research Aims and General Method

Ad hoc teams can face highly complex and time-pressured scenarios that necessitate rapid and effective decision-making and task performance. To meet these needs, both individuals and teams are required to carry out rapid and efficient situation assessment to identify the key situational factors and operational demands. At present, there lacks a comprehensive and empirically-tested model as to how emergent cognitive states arise in the context of ad hoc teams. In addition, despite the importance of communication in these environments, inconsistent approaches to defining communication, together with insufficient exploration of the factors that facilitate effective communication in the context of ad hoc teams, has led to a need to identify and examine a framework linking these constructs.

There is evidence to suggest that team performance is associated with emergent cognitive states in the form of shared mental models that represent the level of understanding shared by team members about a given situation (DeChurch & Mesmer-Magnus, 2010). These shared mental models are associated with the ability of teams to coordinate efforts and perform tasks efficiently (Mohammed, Ferzandi, & Hamilton, 2010). Although a number of factors have been identified as potential antecedents for the development of shared mental models, communication has been selected in the present program of research based on evidence highlighting its importance in facilitating team coordination and performance.

The present program of research explores whether communication enables the emergence of shared mental models. Testing this proposition will provide a better understanding of the temporal and functional role of communication in the development of team cognitive processes that are linked with the performance of teams. The underlying mechanism through which communication arises will also be examined by exploring the association between communication and social cue utilisation, a cognitive process that allows individuals to understand and respond to the behaviour, emotions, and the cognitions of others.

Prior research has tended to focus on the impact of domain-specific, technical cue utilisation, and the identification, retention, and utilisation of task-based cues that increase the likelihood of successful task performance. There has also tended to be a focus mainly on individual performance, rather than on the performance of the team. What has yet to be examined is whether the utilisation of social cues might impact task performance by facilitating interpersonal interaction, coordination efforts, and more efficient and effective collaboration, particularly in the context of ad hoc teams.

The relative importance of social and technical cue utilisation will also be examined in the context of two applied environments: power control and football coaching. These environments rely upon the combination of technical and social expertise to achieve desired outcomes. The program of research represents the first attempt to examine the relative importance of social and technical cue utilisation in applied environments. In addition, the exploration of whether cue utilisation may be associated with markers of expertise should advance the line of research focusing on accelerating and developing the progression to expertise (Campitelli, Connors, Balalic, & Hambrick, 2015).

The program of research outlined in this dissertation seeks to draw together concepts from across various research disciplines to examine the role of social cue utilisation, communication, and team cognition in the performance of ad hoc teams. It is also intended to provide one of the first experimental investigations into the role of social cue utilisation, communication, and shared mental models in determining ad hoc team performance. The overall aim of this research was to:

Determine whether the utilisation of social cues represents a key cognitive strategy that impacts the effectiveness of individuals operating in ad hoc team and applied environments, and whether social cue utilisation facilitates effective communication and the emergence of shared cognitive states within ad hoc teams.

Research Program Questions

This program of research consists of three unique papers that address the overall aim of determining the impact of social cue utilisation in ad hoc team and applied environments. Together, the body of research addresses the research questions summarised in Figure 3.1.

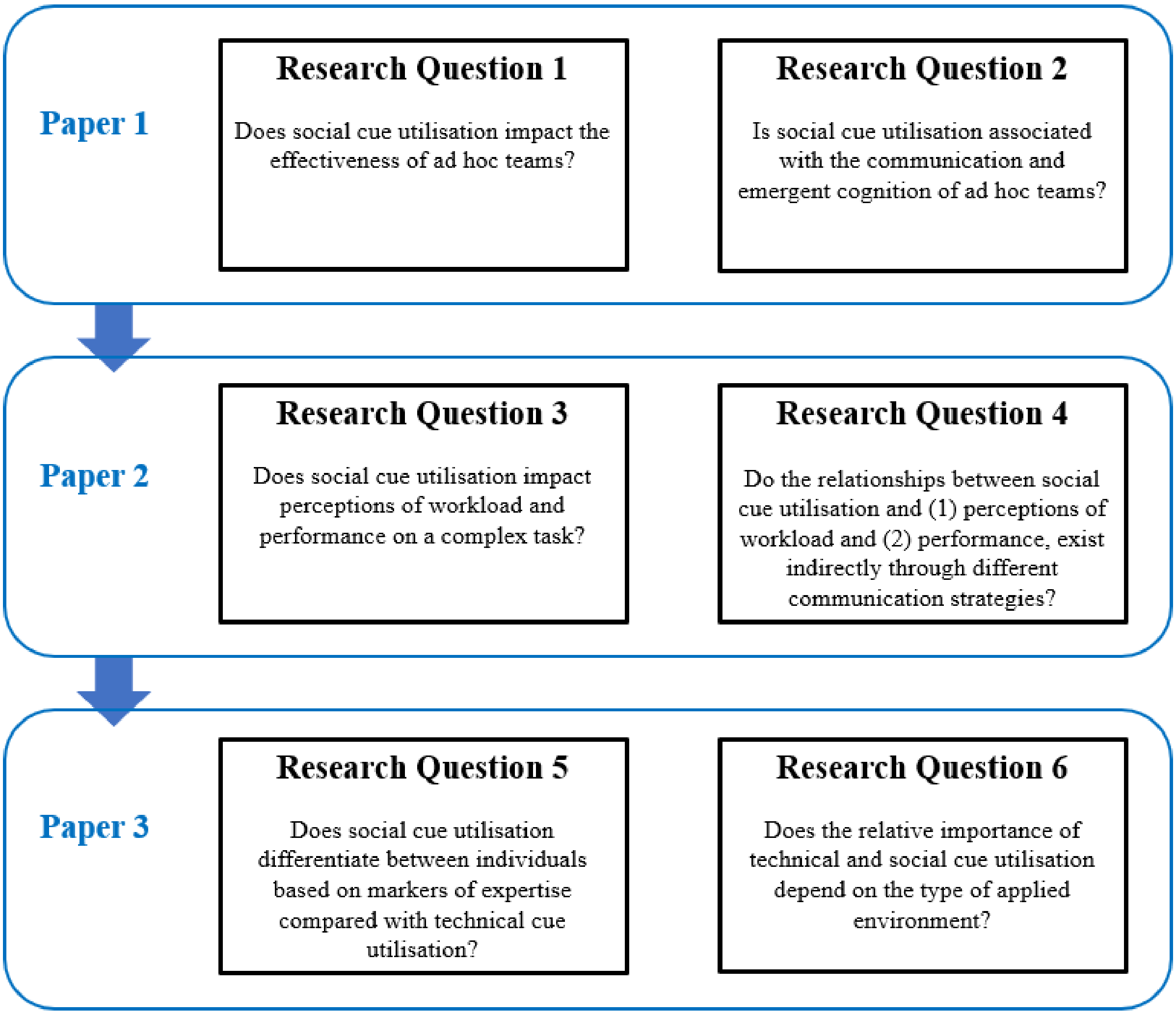

Figure 3.1. Research program questions with associated papers.

Paper 1 describes a novel investigation of the impact of social cue utilisation on ad hoc team performance, while examining the association between social cue utilisation and the communication and cognitive processes of ad hoc teams. Paper 2 extends the findings from Paper 1 by examining ad hoc team performance using a higher fidelity and more complex simulation task, while exploring whether perceptions of workload are also impacted by social cue utilisation. Paper 2 was also designed to examine whether different communication strategies may impact differently, the relationship between social cue utilisation and the outcomes of ad hoc teams. Paper 3 examines the relative importance of social and technical forms of cue utilisation in two different environments: power control and football coaching, where previous research has highlighted the role of cognitive expertise and strategies in successful performance.

Development of a Social Cue Utilisation Measure

To reflect the different components involved in the process of cue utilisation, and to provide a more systematic method of assessing cue utilisation that is not dependent upon explicit declaration or observation of cue identification, Wiggins, Harris, Loveday, and O'Hare (2010) developed the EXPERT intensive skills evaluation program (EXPERTise 1.0; updated to EXPERTise 2.0 by Wiggins, Loveday, & Auton, 2015). EXPERTise 2.0 is an online shell program that enables stimuli from specific domains to be inserted to evaluate behaviour associated with the utilisation of cues, and comprises tasks that assess performance around key aspects of cue utilisation (Wiggins, 2006, 2014), including the: (1) Identification and recognition of critical features in an environment; (2) Assessing the strength of associations between features and events; (3) Discriminating relevant from non-relevant feature-event associations; and (4) Using cue-based associations to inform the order in which cues are prioritised and acquired to inform judgements and decision making.

Performance on EXPERTise 2.0 has differentiated individuals on the basis of their ability to utilise cues in a range of contexts including aviation (Wiggins, Azar, Hawken, Loveday, & Newman, 2014a; Wiggins, Brouwers, Davies, & Loveday, 2014b), power control (Small, Wiggins, & Loveday, 2014; Loveday, Wiggins, Harris, O'Hare, & Smith, 2013a), firefighting (Perry & Wiggins, 2008), software engineering (Loveday, Wiggins, & Searle, 2014), and medical diagnosis (Loveday, Wiggins, Searle, Festa, & Schell, 2013b). However, research examining cue utilisation has tended to focus on the utilisation of domain-specific, technical cues. These environmental cues are critical for task performance and situation assessment in circumstances where successful performance does not necessarily depend on the social cues exhibited by others. Indeed, most of the research has been conducted in settings where individual operators are instrumental in ensuring successful performance outcomes are achieved.

To test the capacity to utilise social cues, a version of EXPERTise 2.0 was developed for the present program of research that targeted cue utilisation in a social context. This version was based on the evidence that individuals differed in their ability to identify and respond to social cues (Pickett, Gardner, & Knowles, 2004; Prati, Douglas, Ferris, Ammeter, & Buckley, 2003). Examples of social cues include facial expressions and emotional content in various communication forms (e.g., written). The social cue utilisation version of EXPERTise 2.0 was developed by creating stimuli for the four tasks designed to assess the components of cue utilisation: the Feature Identification Task (FIT), the Feature Association Task (FAT), the Feature Discrimination Task (FDT), and the Feature Prioritisation Task (FPT).

The FIT assesses individuals' ability to identify and extract features from the environment. In the case of social cues, facial stimuli were selected from a validated database of emotional expressions (Kanade, Cohn, & Tian, 2000; Lucey et al., 2010). Two versions of the task were developed. One required the recognition of emotions expressed by individual faces. A second version required individuals to view a group of faces whereby a single face was conveying a unique emotion to the other two faces in the group. This was designed to establish whether individuals are able to identify key features efficiently in a more realistic scenario. Higher social cue utilisation is characterised by a greater accuracy when identifying relevant features (Yee, Wiggins, & Searle, 2017).

The FAT is designed to assess the strength of associations between features and events in memory. For this task, both related and unrelated stimuli were paired together. For instance, ‘smile’ and ‘happy’ (related) and ‘shrug’ and ‘fear’ (unrelated). Higher social cue utilisation is characterised by a greater variance in the ratings of relatedness of feature-event pairings, suggesting a superior capacity to recognise associative strength (Morrison, Wiggins, Bond, & Tyler, 2013; Yee et al., 2017).

The FDT is intended to evaluate the capacity to discriminate relevant from non-relevant feature-event associations in the environment. The task involves reading a scenario where individuals are asked initially to respond to a social dilemma. Having initiated a response, respondents then indicate the extent to which different features that were presented in the scenario, impacted their judgement process. Higher social cue utilisation is characterised by a greater variance in the degree of utility offered by different features, suggesting a stronger capacity to distinguish between relevant and less relevant information in the context of situation assessment (Weiss & Shanteau, 2003; Yee et al., 2017).

The FPT assesses how individuals prioritise the acquisition of informative features in the context of decision making. Individuals read a social-oriented scenario and are given a limited time to access features with differing degrees of utility for decision making. The time limit forces individuals to prioritise the more important features that they perceive will assist in resolving the situation as efficiently as possible. Higher social cue utilisation is characterised by a more non-linear, preferential pattern of feature access, rather than the linear pattern that is often evident amongst non-experts (Wiggins & O'Hare, 1995; Randel, Pugh, & Reed, 1996).

The development of a measure of social cue utilisation represents a necessary, albeit supplementary, contribution of this program of research. Previously, the utilisation of social cues has lacked the rigorous and comprehensive approach required to enable an adequate assessment of cue utilisation. The measurement of social cue utilisation will advance the methodology employed by Wiggins et al. (2015) in using a situational judgement tool in EXPERTise 2.0. This measure was used as part of the examination of research questions for each of the empirical papers outlined in this research program.

Empirical Papers

Chapter Four: Social Cue Utilisation and Ad Hoc Team Effectiveness

Paper 1 Outline

The aim of Paper 1 was to establish whether social cue utilisation was a construct of importance in the context of ad hoc teams. The development of the social cue utilisation measure is outlined. In addition, Paper 1 was designed to examine whether the ability to utilise social cues represents a key factor in the development of communication and emergent cognition in ad hoc teams. This paper provided a novel examination of the role of social cue utilisation in ad hoc team effectiveness and represented a unique exploration of the association between social cue utilisation and team communication and cognition in the form of shared mental models. Paper 1 also represents the first research to link the aforementioned constructs together in an effort to provide an explanatory mechanism for the effectiveness of ad hoc teams. The study was conducted in an experimental laboratory setting.

Paper 1 Publication History

A modified version of Paper 1 was accepted for publication in Human Factors: The Journal of the Human Factors and Ergonomics Society on 14th February, 2017. At present, this journal has an impact factor of 2.219 and a ranking of 3rd out of 16 in the Ergonomics category of the 2016 Journal Citation Reports (Clarivate Analytics). The author of the present dissertation was responsible for the write-up of Paper 1 and the modified version that was accepted for publication. Professor Mark Wiggins and Dr. Ben Searle supervised and reviewed the research and write-up. The modified version accepted for publication is presented in Appendix B.

The role of social cue utilisation, closing the loop communication, and shared mental model development in the performance of ad hoc dyads

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Abstract

Objective: Examine whether social cue utilisation impacts on the performance of ad hoc dyads through its relationship with closing the loop and shared mental model development.

Background: There lacks equivocal experimental evidence for any single factor that might predict shared mental model development and the performance of ad hoc team systems.

Method: Using a quasi-experimental design, 80 participants were classified into 40 dyads based on their levels of social cue utilisation, and attempted a team problem solving task. A serial multiple mediation model was utilised to examine the indirect effect of social cue utilisation on ad hoc dyad performance through closing the loop communication and shared mental model development.

Results: Analyses showed social cue utilisation exerts an effect on ad hoc dyad performance independently of non-verbal reasoning ability and emotional intelligence. Additionally, the level of social cue utilisation within dyads exhibits a positive indirect effect on ad hoc dyad performance through closing the loop communication.

Conclusion: Ad hoc dyads with higher levels of social cue utilisation engaged in a greater incidence of closing the loop communication, and showed better subsequent performance on a problem solving task than dyads with lower levels of social cue utilisation.

Application: This research provides an important theoretical contribution to the literature through providing quasi-experimental evidence for the importance of social cue utilisation, as well as practical contributions for organisations employing ad hoc teams seeking to optimise their effectiveness.

Keywords: Expert-novice differences, team communication, team mental models

Precis: The study was designed to examine whether ad hoc team performance could be predicted by team-level differences in social cue utilisation, closing the loop communication, and shared mental model development.

The Role of Social Cue Utilisation, Closing the Loop Communication, and Shared Mental Model Development in the Performance of Ad Hoc Dyads

Traditionally, teams have been employed in work environments where team members share common goals, occupy established roles, work on defined tasks, and are employed within the same location (Tannenbaum, Mathieu, Salas, & Cohen, 2012). The types of demands and the range of situations faced by these teams are usually relatively stable. However, due to the dynamic nature of certain work environments (e.g., engineering, the military, medical practice), there is an increasing need to employ teams where the composition and duration of which is more dynamic (Hollenbeck, Beersma, & Schouten, 2012).

These types of teams are referred to as ad hoc teams, although they are often referred to in the literature as temporary, project, action, or ad hoc teams. Ad hoc teams are characterised by what Tannenbaum et al. (2012) refer to as ‘dynamic composition’. This term reflects teams which typically form at short-notice for a limited duration, with team members needing to integrate and adapt quickly to the demands of any given situation. Examples of ad hoc teams include crew members meeting for the first time to fly an aircraft, or a medical emergency team forming and responding to an incident. Ad hoc teams represent the strategy of choice in highly technical environments such as aviation and emergency medical surgery, where the consequences of errors can be severe (e.g., mortality), and decision-making occurs in dynamic and complex settings (Salas, Cooke, & Rosen, 2008a). Within these complex environments, the outcomes depend on the capacity of these teams to solve problems, make decisions, and coordinate appropriate responses at short notice.

Teams embody a greater capacity to solve complex problems, generate and implement informed decisions, and coordinate responses and actions (for a review, see Salas et al., 2008a; Kichuk & Wiesner, 1998). The emergence of ad hoc teams (and, in fact, numerous other different team structures; Kozlowski & Bell, 2003) has led to a greater focus on those environments within which they might be implemented, and the utility of more specific research around the unique properties of ad hoc teams. Investigations into ad hoc teams have generally occurred in the context of project teams in knowledge-based industries such as product development (Bakker, Boros, Kenis, & Oerlemans, 2013), health care institutions (Baker et al., 2006), medical surgery (McCulloch et al., 2009), and emergency incident response teams (Crichton & Flin, 2004). In these accounts, more effective ad hoc teams are generally characterised by a greater compliance with safety-related requirements, reduced error rates in medical surgery, or better incident management during emergency responses.

The utilisation of teams does not always guarantee successful performance (Allen & Hecht, 2004). The potential risk of complications or mistakes inevitably increases due to the additional complexity brought about by team member interactions (Baker et al., 2006). For instance, breakdowns in team coordination efforts in domains such as aviation and medical care have been shown to contribute to the occurrence of accidents and errors resulting in negative consequences such as harm to individuals (e.g., Greenberg et al., 2007).

Teamwork has also been identified as a key characteristic that determines whether critical incidents are dealt with effectively or ineffectively in hospital settings (Manser, 2009). While the challenges associated with working in teams will always be an artefact of bringing together groups of individuals, meta-analytic evidence supports the capacity of teams to improve in performance and cohesion after training interventions (Salas et al., 2008b). This suggests that even though there are risks inherent in the utilisation of teams, it is possible for teams to not only improve, but also provide positive outcomes for organisations (e.g., Manser, 2009). Despite the complexity involved in teamwork, teams are able to deal with scenarios that would otherwise be too difficult for individuals operating independently (Mathieu, Maynard, Rapp, & Gilson, 2008).

The reliance on teams for organisational success has also led to a growing interest in the factors that facilitate effective team performance. A meta-analysis undertaken by DeChurch and Mesmer-Magnus (2010) explored the relationship between team cognition (the shared cognitive processes presumed to be essential in allowing individual team members to mentally organise, represent, and distribute knowledge within the team) and team performance, and established that team cognitive states are uniquely critical to team performance, separate from both motivational (e.g., collective efficacy) and behavioural (e.g., specific collective acts) team processes (DeChurch & Mesmer-Magnus, 2010). Given that, in comparison to established teams, newly-formed teams tend to engage in a greater incidence of information-sharing to establish expectations of processes and procedures (Stanton & Ashleigh, 2000), and are required to do so more quickly and accurately, the establishment of shared cognition and understanding may explain how effective ad hoc teams are able to respond and adapt promptly to the dynamic environments that they experience. Moreover, the emergence of such shared cognition is likely to allow team members to anticipate the needs and actions of other team members, coordinate appropriate actions, and adapt behaviours to task demands (Mohammed, Ferzandi, & Hamilton, 2010).

Although the link between these shared cognitive states and team performance has received increasing attention, there is currently little experimental research that focuses on the specific psychological mechanisms which determine the development of such shared cognitive states within teams of an ad hoc nature. Inconsistent approaches to the measurement and explanation of team cognition has driven this growing need to identify the precise precursors to the development of team cognition. In response, the present study utilises serial multiple mediation analysis within an experimental design, to test whether a specific explanatory mechanism of team cognition (shared mental models) is conducive to the performance of ad hoc dyads.

Teams and Shared Mental Models

The shared mental models perspective suggests that emergent cognitive processes are enabled by the development of shared mental models (Mohammed & Dumville, 2001). Shared mental models refer to the collective understanding of a given situation that is shared by team members and used to identify and understand the key elements within a working environment (Mohammed et al., 2010). They represent a network of associations that exist between concepts and structures within a particular domain, and they originate from the long-term memory of team members (Langan-Fox, Code, & Langfield-Smith, 2000). These associations are updated and developed, based on environmental input.

This shared understanding provided by shared mental models enables more efficient operations by creating a common view of what is occurring, what is likely to occur in the future, when it might be likely to occur, and why (Mohammed et al., 2010). This type of information can assist in both novel situations where team members are required to promptly assess the demands of the situation, and ambiguous situations where the resolution of ambiguity is essential before any action is taken. In an examination of dyadic group performance on a simulated flight combat scenario, Mathieu, Heffner, Goodwin, Salas, and Cannon-Bowers (2000) reported that teams of individuals which exhibited stronger convergence in ratings of task understanding demonstrated superior performance on a flight combat simulation task, and were rated as communicating, cooperating, and coordinating their efforts better by observers.

Building on this outcome, Lim and Klein (2006) conducted a field study examining the role of shared mental models in field combat teams, and established that both the accuracy and similarity of shared mental models predicted team performance in a military assessment centre exercise. The authors had participants judge the relatedness of task statements, and used these ratings to determine the extent to which team members were accurate, and shared similar understandings about the task.

Although the link between shared mental models and team performance has been established, there has yet to be conclusive experimental evidence as to what specific factors might facilitate the development of shared mental models (DeChurch & Mesmer-Magnus, 2010). Studies have examined various factors like team member personality (Fisher, Bell, Dierdorff, & Belohlav, 2012), propensity for sensegiving (Randall, Resick, & DeChurch, 2011), participative leadership (Dionne, Sayama, Hao, & Bush, 2010) as well as training and planning in facilitating shared mental models (Mohammed et al., 2010). An opportunity exists, however, for experimental research that examines antecedents of shared mental models in the context of ad hoc teams. Specifically, it might be argued that that the process by which ad hoc team members communicate their understandings to each other represents the single most important predictor in the formation of shared mental models and subsequent emergent team cognition.

Communication and Shared Mental Models

Existing research has tended to treat communication as an outcome of shared mental model consistency among team members (Mohammed et al., 2010). That is, team members who share similar ratings about a particular task or situation tend to be able to communicate better as a result of having a shared understanding. Communication has been implicated as an important outcome of shared mental models, suggesting that the emergence of shared mental models precedes the act of explicit communication (Stout, Cannon-Bowers, Salas, & Milanovich, 1999; Marks, Zaccaro, & Mathieu, 2000). However, this may be a product of the methodology employed by the researchers, who did not assess communication levels concurrently with shared mental models, but only as a post-task outcome measure. Such a methodology excludes the possibility that communication might precede the development of shared mental models.

While it is possible that the development of shared mental models precedes the development of communicative processes in teams, without explicit communication that enables team members to share their interpretations and understanding of a given situation with each other, it is unlikely that accurate and functional shared mental models would emerge (Marks et al., 2000). Furthermore, the sharing of information about important events and situations faced by teams is related positively to shared mental model convergence (Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Mathieu et al., 2008). The lack of clear empirical evidence concerning the temporal and functional role of communication in the development of team cognitive processes, like shared mental models, has contributed to a research gap as to how team cognition develops, especially in the context of ad hoc teams, where there are increased demands on team members to develop, as efficiently as possible, a shared understanding of the task.

One of the difficulties associated with communication as a precursor to the development of team cognition is when, where, and how individuals communicate task-related information. Within high-risk environments such as medical surgery, breakdowns in interpersonal interactions (communication and teamwork) remain key factors in the occurrence of surgical errors worldwide (Hull et al., 2011). According to Leonard, Graham, and Bonacum (2004), communication failure represents over 70% of all primary root causes of inadvertent patient harm in hospitals. Effective communication likely relies on the capacity of team members to identify appropriate opportunities to initiate communication, clarify or amplify existing information, and/or restate information.

Even though meta-analytic evidence suggests that moderately positive relationships exist between team training and team-based processes (e.g., communication) and outcomes (i.e., performance) (Salas et al., 2008b), the specific skills targeted by communication-based training are not often specified. If communicating effectively within ad hoc teams depends upon the ability for team members to recognise appropriate opportunities to engage others and create a shared understanding of the key aspects of a situation, then successful performance is dependent upon the timely and accurate recognition and response to cues that prompt this form of interaction.

Social Cue Utilisation and Closing the Loop

Cues represent associations, retained in memory, between features and objects or events (e.g., being able to identify the emotion expressed by an individual by looking at the visual cues on their face). At a theoretical level, the utilisation of cues is thought to reduce the cognitive demands in responding to environmental stimuli (Ericsson & Kintsch, 1995; Loveday, Wiggins, & Searle, 2014; Wiggins, 2014). However, cue utilisation also aids the efficient coordination of a response, the discrimination between relevant and irrelevant information (Chi, Feltovich, & Glaser, 1981), and is associated with improvements in accuracy and response latency during diagnosis (Wiggins & O'Hare, 2003; Hill & Schneider, 2006; Loveday et al., 2014).

The utilisation of cues is evident in both technical and non-technical domains, and signature features range from changes in visual displays to changes in vocal intonation and facial expression (Prati, Douglas, Ferris, Ammeter, & Buckley, 2003). Different individuals develop distinctive cue associations depending upon their experiences and the level of feedback available. What might represent a cue for one practitioner might be overlooked by others, either on the basis that they have yet to experience situations in which the feature-event relationship is evident, or that they are simply unable to develop, retain, or apply the associations from memory (Wiggins, 2015).

Pickett, Gardner, and Knowles (2005) have demonstrated that individuals differ in the extent to which they are able to attend to, and interpret, socially-related cues (e.g., facial cues, vocal intonation, non-verbal gestures). This is characterised by a capacity to monitor the auditory, non-verbal, and facial expressions of others and remain sensitive to the feedback that are provided by other team members (Prati et al., 2003; Riggio, 2006; Auton, Wiggins, Searle, Loveday, & Rattanasone, 2013; Rozin & Cogen, 2003).

Emotional responses arising from facial expressions suggest that confusion, worry, and concentration may also be signalled by changes in facial cues (Rozin & Cohen, 2003). The literature on verbal cues is also well established, with empirical evidence highlighting the capacity for individuals to identify uncertainty, non-understanding, and levels of disagreement in others' verbal communication (Auton et al., 2013; Krahmer & Swerts, 2005; Roberts, Francis, & Morgan, 2006). In the context of ad hoc teams, the utilisation of these social cues is critical in work environments characterised by strict time limits and high pressure to perform, and where prompt and informative communication is not only essential, but can be facilitated by the effective utilisation of social cues.

Although some researchers have examined the utility of effective communication in the operation of ad hoc teams (see Schillinger et al., 2003; Brindley & Reynolds, 2011), they do not focus on the specific mechanism that enables communication to occur successfully. A key characteristic of successful communication in these environments is the capacity to 'close the loop', or provide a response to an enquiry or statement given by another individual. This process essentially confirms the accuracy of a statement or serves as a way of clarifying the understanding between team members. This study will be the first to utilise a quasi-experimental design to examine whether closing the loop is facilitated by team members' capacity to utilise social cues, and how this impacts the performance of ad hoc dyads.

The Present Study

The aim of the present research was to examine whether, in the context of ad hoc dyads, closing the loop represents a key mechanism for the development of shared mental models, and whether social cue utilisation facilitates greater frequency of closing the loop communication. Specifically, it was hypothesised that (see Figure 1 for the hypothesised model):

Hypothesis 1. Ad hoc dyads with relatively higher levels of social cue utilisation would solve problems more rapidly compared to ad hoc dyads with relatively lower levels of social cue utilisation.

Hypothesis 2. Higher levels of social cue utilisation would be associated with a higher frequency of closing the loop communication, and greater shared mental model development.

Hypothesis 3. Higher frequencies of closing the loop communication would be associated with greater shared mental model development.

Hypothesis 4. Social cue utilisation would have a positive, direct relationship with ad hoc dyad performance, together with a positive, indirect relationship with ad hoc dyad performance through closing the loop communication and shared mental model development.

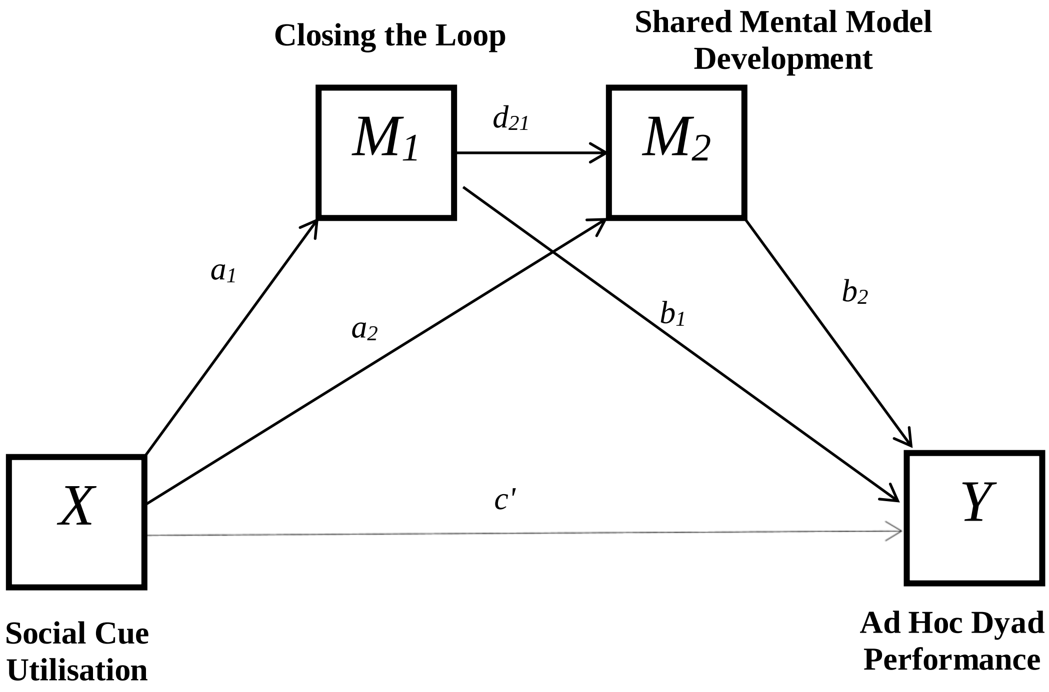

Figure 1. Serial multiple mediation model describing the hypothesised relationship between social cue utilisation and ad hoc dyad performance through closing the loop and shared mental model development.

Method

Participants

The initial sample of participants comprised 170 university students ranging in age from 18 to 55 years (*M* = 21.28, *SD* = 7.42). The sample was entirely female to avoid variation in responses that could be attributed to gender, and all participants were enrolled in a first year psychology course. English was the first language for 97% of participants, and they all received course credit for participation in the screening phase of the study. A total of 80 students participated in the second phase of the study and either received additional course credit for participation, or were reimbursed with money. Independent sample t-tests showed no significant differences in terms of age, or English as first language, between those participants in the first phase only, and those who also participated in the second phase. This research complied with the American Psychological

Association Code of Ethics and was approved by the Macquarie University Human Research Ethics Committee. Informed consent was obtained from each participant.

Measures

Cue utilisation assessment: EXPERTise. The Expert Intensive Skills Evaluation program (EXPERTise 1.0; Wiggins, Harris, Loveday, & O'Hare, 2010) was used to assess participants' levels of social cue utilisation. EXPERTise measures the capacity to recognise and respond to naturalistic visual cues and patterns, as well as the ability to distinguish important from less-important features within the environment. To draw inferences about individuals' cue utilisation within a particular domain, EXPERTise enables users to tailor the stimuli to align with a particular context. Therefore, social contextual stimuli were developed for four tasks: the Feature Identification Task (FID), the Feature Discrimination Task (FDT), the Paired Association Task (PAT), and the Transition Task (TT).

The FID is designed to measure the participant's ability to extract features from the environment. The task was divided into two parts. In the first part (Static version), respondents were asked to identify the emotional states presented in a range of facial stimuli, taken from the Cohn-Kanade AU-Coded Facial Expression Database (Kanade, Cohn, & Tian, 2000; Lucey et al., 2010). In total, a single image for each of the following seven expressions were included: anger, disgust, fear, happiness, sadness, surprise, and neutral. In each trial, a single face was presented for 250 milliseconds, determined based on pilot results that indicated the discriminative capacity of the duration.

In the second part of the FID task (Array version), respondents were asked to respond to a sequence of three faces, whereby one of the three faces conveyed an emotion that was distinct from the other two faces in the sequence. They were asked to identify the emotion that was being conveyed by the face that was inconsistent with the other faces in the sequence. Since cue utilisation requires accurate and rapid extraction of cues from the environment, individuals with higher levels of cue utilisation tend to show greater accuracy and shorter response times (Loveday, Wiggins, Harris, O'Hare, & Smith, 2013a).

The Feature Discrimination Task (FDT) uses scenarios to assess respondents' ability to distinguish task-relevant features from irrelevant features. Having read a detailed description and proposed a resolution to the event, participants rate each feature within the scenario in terms of the extent to which it assisted in their proposed resolution of the situation. Individuals with relatively higher levels of cue utilisation demonstrate greater variance in their ratings on a seven-point Likert Scale, which suggests that they are able to discriminate between more and less informative features (Shanteau, 1992; Pauley, O'Hare, & Wiggins, 2009).

The Transition Task (TT) involves the presentation of a limited amount of information pertaining to an event that requires participants to acquire additional information from a set of related and unrelated features to develop a resolution. The task assesses the extent to which individuals access and acquire information in the order that it is presented. The feature-related information is presented in a list of tabs that expand with information when opened. A score is provided by calculating the ratio of pairs of items accessed in a sequential order against the total number of pairs of items accessed (Wiggins & O'Hare, 1995; Loveday et al., 2014; Wiggins, Stevens, Howard, Henley, & O'Hare, 2002). Individuals with relatively higher levels of cue utilisation record smaller ratio scores, indicating that their method of information acquisition is guided by degree of prioritisation that is independent of the sequence in which the information is actually presented.

The Paired Associations Task (PAT) uses feature pairings and requires participants to rate, using a six point Likert Scale (ranging from 0 = extremely unrelated, to 6 =

extremely related), the extent to which the terms are related (e.g., *smile* and *happy*) or unrelated (e.g., *shrug* and *fear*). Since cue utilisation is a process that relies on the discrimination of relevant from less-relevant features and events, individuals with relatively higher levels of cue utilisation demonstrate greater variance in their ratings (Morrison, Wiggins, Bond, & Tyler, 2009; Loveday et al., 2014). Examples of the stimuli used in all four EXPERTise tasks are presented in the Appendix.

Team performance task: Tower of Hanoi. The Tower of Hanoi is a problem-solving exercise that involves three vertical pegs and a number of disks of varying sizes that can be placed on these pegs. Initially, the disks are arranged by size and placed on a single peg, with the largest disk on the bottom. The goal is to move all of the disks from one peg to the other, while making sure that only one disk is moved at a time, and that only smaller disks are placed on top of other disks. While initially used as a measure of individual problem-solving ability (Kotovsky, Hayes, & Simon, 1985), the Tower of Hanoi has been used to assess team problem solving effectiveness (Barker, 1996; Bird, 1997; Prichard, Stratford, & Bizo, 2006).

Measures of team performance included the solution time and the number of moves taken to complete the task. To establish the role of closing the loop in facilitating shared mental model development, additional rules were created to encourage interaction and simulate real-world teams. This included rules stating that team members must alternate between moves, and that team members must describe their intended move to one another before making it. While numerous variations of the Tower of Hanoi exist that incorporate a different number of disks or rules, this study utilised a five-disk version with a ten minute time-limit. This was determined based on previous findings that individuals took around 8-9 minutes to solve a four-disk version, and most comfortably finished a five-disk version within a 20 minute time limit (Bird, 1997; Ronnlund, Lovden, & Nilsson, 2001). The task was designed to be sufficiently challenging to discriminate lower from higher performing ad hoc dyads.

Shared mental model development. Shared mental models are usually assessed by examining the similarity and accuracy of ratings of understanding provided by team members (Mohammed et al., 2010). Since participants' ratings about the task would be inherently subjective, it was not possible to infer accuracy, so the degree of consistency of the mental models was assessed. The extent to which shared mental models developed was established using a purpose-developed four-item scale that measured team members' understanding of the team performance task. This scale was adapted from earlier research assessing the similarity of mental models in team members by comparing ratings of task-related features (Edwards, Day, Arthur, & Bell, 2006). Team members were asked to provide ratings (on a scale from 1 to 7, where 1 equates to Strongly Disagree and 7 equates to Strongly Agree) in response to the scale items (e.g., *"As a team, we have/had a clear strategy for how to complete this task"*). The scale exhibited adequate reliability in the present study (α = .81).

To capture the development of the shared mental models, the scale was administered at two time points. The first occurred after participants were given two minutes to discuss with each other, the task itself, while the second time point occurred at the end of the task. The similarity between the ratings from each team member was used as an index of the consistency of the mental models within teams, and was calculated using a similarity index (Saetrevik & Eid, 2014) that determined the degree to which team members had shared understandings of the situation. The similarity index itself is calculated by comparing the ratings provided by each team member in relation to each scale item:

$$\textbf{Team similarity index} = 1 - \frac{(\text{Team member 1 answer} - \text{Team member 2 answer})}{\text{highest answer}}$$

A similarity index was calculated for each item, and an average index score was generated for time 1 and time 2. A change score was then generated that represented the extent to which shared mental model consistency changed from time 1 to time 2. This provided an index of the degree to which shared mental models developed during task performance.

Closing the loop measure. The frequency with which team members closed the loop was assessing using a measure previously used in studies examining communication in the operation of ad hoc teams across medical and aviation environments (Schillinger et al., 2003; Brindley & Reynolds, 2011). Following Prinzo (1998), communication sequences (or elements as referred to in prior research) were defined as a verbal exchange involving an initiating statement from one individual, and a responding statement from another individual.

Based on a speech act coding framework developed by Kanki, Folk, and Irwin (1991) and adapted in communication research (Hutchins, Hocevar, & Kemple, 1999; Siassakos, Draycott, Montague, & Harris, 2009), questions, observations, and commands were categorised as initiating speech acts. Acknowledgements and replies were categorised as responding speech acts. This measure was intended to differentiate ad hoc dyads based on the frequency with which they closed the loop.

Control measures. The Raven's Standard Progressive Matrices (SPM; Raven, Raven, & Court, 1993) is a nonverbal test that is used to measure non-verbal reasoning (the capacity of individuals to solve problems). The SPM is a widely-validated measure that exhibits a no-disadvantage means of testing individuals from a variety of backgrounds and circumstances and can be administered in different ways to assess specific research questions. As demonstrated in previous research (Austin, 2005; Jaeggi, Buschkuehl, Jonides, & Shah, 2011; Moutafi, Furnham, & Tsaousis, 2006), individuals completed the SPM under timed conditions and were given ten minutes to complete as many of the 60 items as possible. This was designed to control for non-verbal reasoning. Due to the cognitive nature of cue utilisation, controlling for non-verbal reasoning ability ensured the unique effect of cue utilisation could be isolated.

The Mayer-Salovey-Caruso Emotional Intelligence Test (MSCEIT) is a psychometric assessment used to assess individuals' ability to solve emotion-based problems, and is based on a four-branch ability model of emotional intelligence (Mayer, Salovey, Caruso, & Sitarenios, 2001; Mayer, Salovey, Caruso, & Sitarenios, 2003). The first branch, Perceiving Emotion, measures the ability to identify emotions in people and environments. The second branch, Facilitating Thought with Emotion, measures the ability to harness emotional information to enhance thinking processes. The third branch, Understanding Emotion, measures the ability to comprehend emotional information in the context of relating to others. The final branch, Managing Emotion, measures the ability to manage emotions and emotional relationships. Participants were asked to complete the MSCEIT under un-timed conditions. A measure of emotional intelligence was included to identify whether the utilisation of social cues is distinct from emotional intelligence, and to test whether, as expected, emotional intelligence would contribute to the variance in ad hoc dyad performance.

Experimental Procedure

The study was conducted in two main phases. In the first phase, participants were invited to complete the EXPERTise program online. Once the data were collected for all participants, they were assigned to either the *relatively lower* cue utilisation group, or the *relatively higher* cue utilisation group based on a *k*-means cluster analysis of the standardised scores for each of the tasks comprising EXPERTise 1.0.

In the second phase of the study, participants were allocated to dyads based on their level of social cue utilisation. A single experimenter conducted each session where a single dyad would participate. Dyad attempts for the Tower of Hanoi task were video-recorded so that closing the loop could be measured accurately. The shared mental model measure was administered both before and after the task. After completing the team task, participants completed the SPM individually under timed (10 minutes) conditions and the MSCEIT.

Results

Team Creation Based on Cue Utilisation

Participants were classified as either having *relatively lower* or *relatively higher* levels of social cue utilisation based on their responses to the four tasks in EXPERTise. The standard procedure for classifying individuals involves standardising each of the measures for the tasks, and running a *k*-means cluster analysis with two groups (Wiggins et al., 2010). Participants who recorded a standardised z-score of more than three standard deviations from the average for their cluster were removed as outliers (n = 9). Table 1 summarises the results from this analysis and includes the mean scores for each of the tasks and their relevant outcome measures.

Table 1

Participant Social Cue Utilisation Classification Based on Non-Standardised EXPERTise Data

Task	Cluster 1: *Relatively Lower* (*n* = 66)	Cluster 2: *Relatively Higher* (*n* = 95)
	Mean (*SD)*	*Mean* (*SD)*
FID Static: Accuracy (%)	77.79 (9.36)	87.10 (8.04)
FID Array: Accuracy (%)	30.08 (22.11)	72.84 (14.43)
PAT: Variance	2.40 (.88)	2.91 (.90)
FDT: Variance	3.40 (2.54)	4.63 (2.88)
TT: Ratio	.80 (.33)	.58 (.42)

Subsequent multivariate analyses of variance revealed several differences between the two groups. Individuals with relatively higher levels of social cue utilisation had significantly higher accuracy scores on the FID Static task, F (1,155) = 44.38, $p < .001$, and the FID Array task, F (1,152) = 210.91, $p < .001$. In addition, they exhibited significantly greater levels of variance in their ratings on the PAT task, F (1,151) = 12.23, $p = .001$, as well as the FDT task, F (1,147) = 7.25, $p < .05$, and also demonstrated significantly lower ratios on the TT task, F (1,151) = 11.82, $p = .001$. Based on the cluster analysis, individuals with relatively higher levels of social cue utilisation exhibited statistically significant, superior performance on all four EXPERTise tasks. This classification was used to create dyads with team members who exhibited the same approximate level of social cue utilisation.

Preliminary Data Analysis

From the 170 participants who completed the first phase of the study, data from nine participants were excluded as outliers as a result of having standardised z-scores greater than 3.0. There were no missing data. The 80 participants who returned for the second phase of the study were divided into 40 dyads consisting of two team members within the same level of social cue utilisation. Twenty dyads displayed relatively lower levels of cue utilisation, and twenty dyads displayed relatively higher levels of cue utilisation. Individual data relating to SPM and MSCEIT results were averaged at the team level to produce an indication of non-verbal reasoning ability and emotional intelligence. Closing the loop communication, shared mental model development, and task performance were measured at the team level. The means, standard deviations, and correlations between the variables in the study are presented in Table 2.

Table 2

Summary of Means, Standard Deviations, and Correlations for Study Variables

Variables	*M*	*SD*	1	2	3	4	5
1. Social cue utilisation	-	-	-	-	-	-	-
2. Dyad task performance (600 seconds – Task time)	302.60	158.12	.35*	-	-	-	-
3. SPM	39.04	4.09	-.01	.12	-	-	-
4. MSCEIT	53.84	15.14	.19	.09	.08	-	-
5. Closing the loop	73.76	9.12	.62***	.47**	.10	.12	-
6. Shared mental model development	7.44	12.85	.28	.14	.21	.10	.49**

Note. ****p<.001, **p* < .01, **p* < .05.

Assumptions and Statistical Analysis Procedures. The assumptions of independence, normality, and homogeneity were met for the ANCOVA analysis used to test Hypothesis 1, and the regression analyses used to test Hypotheses 2 and 3. In addition, a serial multiple mediation analysis was used to test Hypothesis 4, utilising Hayes' (2009) ordinary least squares regression method. A serial multiple mediation analysis was selected because it allows for an examination of the hypothesised temporal role of communication and shared mental model development in the relationship between social cue utilisation and ad hoc team performance. This approach enables greater power and control of Type 1 error with bias-corrected bootstrap confidence intervals for indirect effects, and also removes the assumption proposed by Baron and Kenny (1986) that a main effect must exist between an independent and dependent variable for indirect effects to be shown to occur. The analysis was conducted using the SPSS script PROCESS (Hayes, 2009).

Social Cue Utilisation and Ad hoc Dyad Performance

An ANCOVA was conducted to determine whether ad hoc dyads with a higher level of social cue utilisation exhibited stronger performance on the team task, the Tower of Hanoi, when compared to those with a lower level of social cue utilisation. The analysis was run including SPM and MSCEIT as control variables. Consistent with the hypothesis, a statistically significant main effect was evident for social cue utilisation, F (1, 38) = 5.02, $p < .05$, $\eta_p^2 = .12$. As evident in Figure 2, these results show that ad hoc dyads with higher levels of social cue utilisation solved the Tower of Hanoi problem at a faster rate than those with lower levels of social cue utilisation. In this case, the level of social cue utilisation within dyads accounts for approximately 12% of the variance in team task performance.

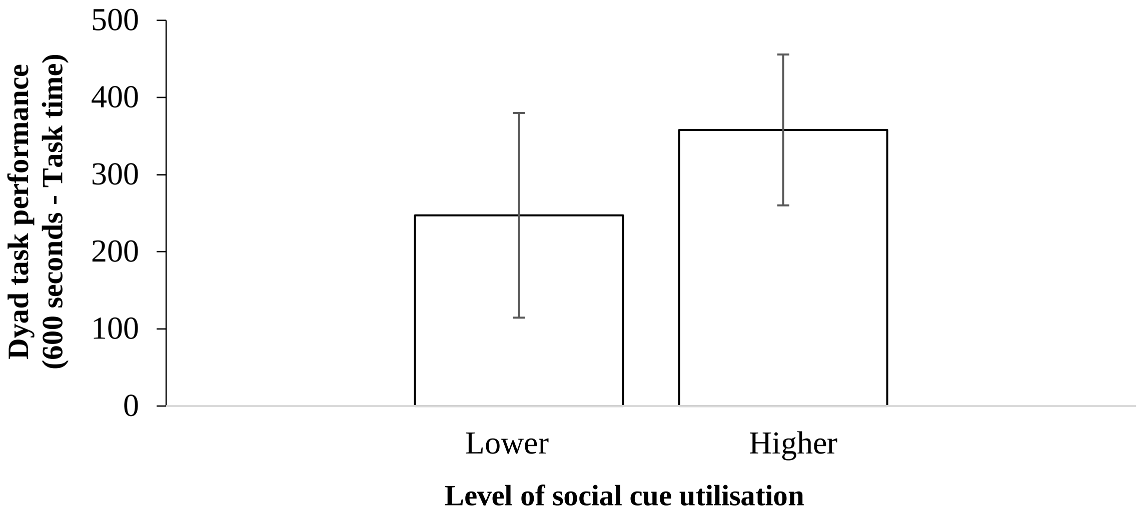

Figure 2. Mean task performance for lower social cue utilisation groups (n = 20), and higher social cue utilisation groups (n = 20).

Social Cue Utilisation, Closing the Loop, and Shared Mental Model Development

To test the associations between social cue utilisation and closing the loop, and social cue utilisation and shared mental model development, two simple linear regression analyses were conducted. The first analysis regressed closing the loop on social cue utilisation, and the second regressed shared mental model development on social cue utilisation. SPM and MSCEIT scores were included in both models as covariates.

In the first regression model, a model containing social cue utilisation as an independent variable, and SPM and MSCEIT scores as covariates, predicted the frequency of closing the loop in ad hoc dyads, F (3, 36) = 7.77, p < .001, explaining 39.3% of the variance in closing the loop communication. There was a statistically significant effect of social cue utilisation on closing the loop, t (36) = 4.68, p < .001. This result is consistent with Hypothesis 2, that higher levels of social cue utilisation are positively associated with closing the loop communication in ad hoc dyads, controlling for non-verbal reasoning and emotional intelligence (B = 11.16, 95% CI [6.32, 15.99]).

In the second regression model, a model containing social cue utilisation as an independent variable and SPM and MSCEIT scores as covariates did not significantly predict shared mental model development in ad hoc dyads, F (3, 36) = 1.68, p = .188, explaining 12.3% of the variance in shared mental model development. There were no significant effects between the independent variable and covariates with shared mental model development. This result failed to support Hypothesis 2, namely the prediction that higher levels of social cue utilisation are positively associated with the development of shared mental models in ad hoc dyads, controlling for non-verbal reasoning ability and emotional intelligence.

Closing the Loop and Shared Mental Model Development

To test the association between closing the loop communication and shared mental model development, a simple linear regression analysis was carried out. The analysis involved regressing shared mental model development on closing the loop with SPM and MSCEIT included as covariates.

A model containing closing the loop as an independent variable, and SPM and MSCEIT scores as covariates, predicted the shared mental model development of ad hoc dyads, F (3, 36) = 4.38, p < .05, explaining 26.7% of the variance in shared mental model development. There was a statistically significant effect of closing the loop on shared mental model development, t (36) = 3.26, p < .01. This result is consistent with Hypothesis 3, that higher frequencies of closing the loop are positively associated with the development of shared mental models in ad hoc dyads, controlling for non-verbal reasoning and emotional intelligence (B = .66, 95% CI [.25, 1.08]). The results of the regression analyses conducted are presented in Table 3.

Table 3

Summary of Simple Linear Regression Analyses (n=40)

Variable	*B*	*SE B*	*β*	*t*	*p*
Regressing Closing the Loop on Social Cue Utilisation					
Social Cue Utilisation	11.16	2.38	.62	4.68	.000
SPM	.24	.29	.11	.81	.423
MSCEIT	-.00	.08	-.00	-.03	.973
Regressing Shared Mental Model Development on Social Cue Utilisation					
Social Cue Utilisation	6.94	4.04	.27	1.72	.094
SPM	.66	.49	.21	1.35	.186
MSCEIT	.02	.13	.03	.16	.870
Regressing Shared Mental Model Development on Closing the Loop					
Closing the Loop	.66	.20	.47	3.26	.002
SPM	.51	.45	.16	1.13	.267
MSCEIT	.02	.12	.02	.17	.863

Note. SPM = Standard Progressive Matrices, MSCEIT = Mayer-Salovey-Caruso Emotional Intelligence Test.

Testing Direct and Indirect Effect of Social Cue Utilisation on Ad hoc Dyad Performance through Closing the Loop and Shared Mental Model Development

The direct effect of social cue utilisation on ad hoc dyad performance, together with the indirect effect of social cue utilisation on ad hoc dyad performance through closing the loop and shared mental model development, were tested using a serial multiple mediator model analysis with Hayes' (2009) ordinary least squares regression method. To obtain standardised coefficients for the indirect effects (since each variable was assessed on a unique scale), the independent variables, mediators, and dependent variable were standardised with the exception of social cue utilisation which only consisted of two levels. Indirect effects were generated using a bias-corrected bootstrap 95% confidence interval with 1,000 replications, and statistical inference was inferred based on whether the confidence intervals for the indirect effects contained zero (Hayes, 2009). The results of this analysis are summarised in Figure 3.

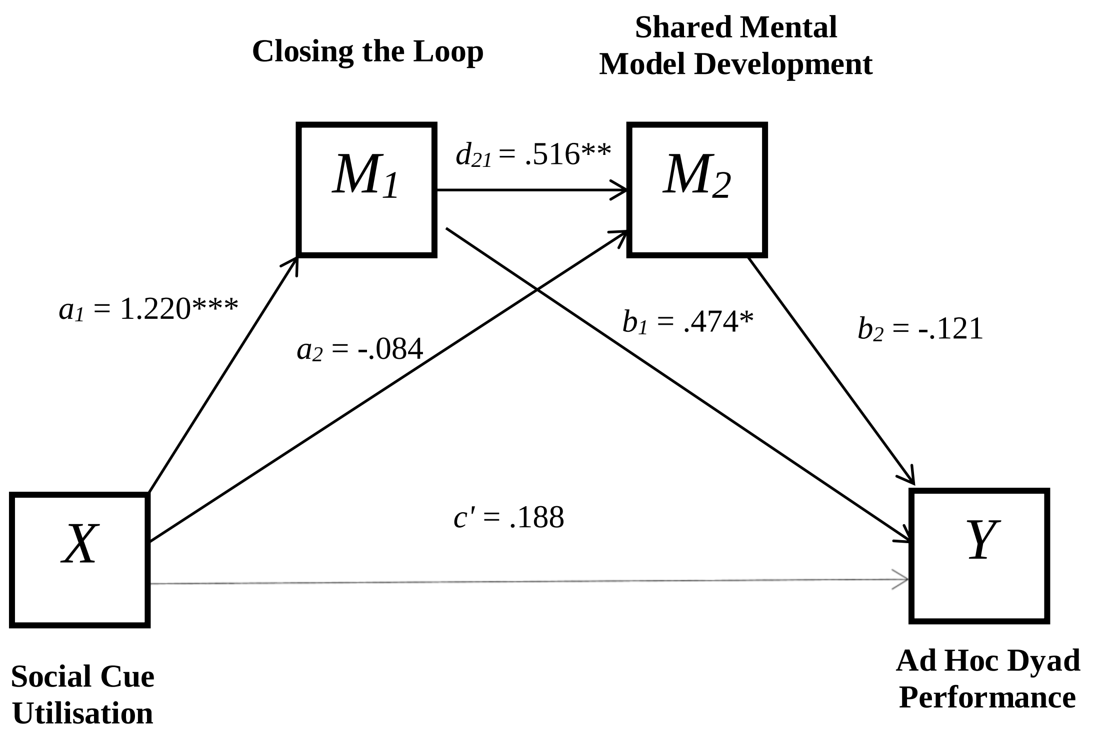

Figure 3. Serial multiple mediation model results (Note. *p < .05, **p < .01, ***p < .001).

Overall, social cue utilisation had a positive total effect on ad hoc dyad performance, $effect_{total}$ = .70, $p < .05$, 95% CI (.094, 1.307), suggesting that the sum of all direct and indirect effect pathways from social cue utilisation to ad hoc dyad performance is statistically significant. However, the direct effect of social cue utilisation on ad hoc dyad performance (*c'*) was non-significant, c' = .188, p = .609, 95% CI (-.552, .928). This result indicates that the relationship between social cue utilisation and ad hoc dyad performance may in fact be indirect, rather than direct, as suggested by the ANCOVA results. Three indirect effects were also tested using the same multiple mediation analysis.

Indirect effect of social cue utilisation on ad hoc dyad performance through closing the loop. As evident in Figure 3, the pathway between social cue utilisation and closing the loop reached statistical significance, a_1 = 1.220, $p < .001$, 95% CI (.710, 1.730). The pathway between closing the loop and ad hoc dyad performance was also statistically significant, b_1 = .474, $p < .05$, 95% CI (.060, .887). The indirect effect of social cue utilisation on ad hoc dyad performance through closing the loop was statistically significant, a_1b_1 = .578, 95% CI (.057, 1.111), indicating that social cue utilisation exerts an indirect effect on ad hoc dyad performance through closing the loop alone.

Indirect effect of social cue utilisation on ad hoc dyad performance through shared mental model development. The pathway between social cue utilisation and shared mental model development was not statistically significant, a_2 = -.084, p = .817, 95% CI (-.812, .645). The pathway between shared mental model development and ad hoc dyad performance was also non-significant, b_2 = -.121, p = .474, 95% CI (-.459, .217). The indirect effect did not reach statistical significance, a_2b_2 = .010, 95% CI (-.074, .188), suggesting that social cue utilisation may not exhibit an indirect effect on ad hoc dyad performance through shared mental model development alone.

Indirect effect of social cue utilisation on ad hoc dyad performance through closing the loop followed by shared mental model development. In addition to the pathways a_1 and b_2, this indirect effect contained the pathway between closing the loop and shared mental model development which was significant, d_{21} = .516, p = .007, 95% CI (.147, .885). The indirect effect did not reach statistical significance, $a_1d_{21}b_2$ = -.076, 95% CI (-.335, .107).

Discussion

The aim of this study was to examine whether ad hoc dyad performance is associated with social cue utilisation, closing the loop communication, and shared mental model development. Specifically, it was designed to examine whether social cue utilisation has an indirect effect on the performance of ad hoc dyads through closing the loop and the development of a shared mental model. The present research is based on the proposition that the capacity to utilise social cues facilitates greater frequency of closing the loop, which in turn enables the development of shared mental models. This mechanism should optimise the conditions needed for ad hoc teams to function effectively in successfully.

The initial creation of dyads based on EXPERTise indicated that individuals may differ in the extent to which they are able to identify, access, and utilise social cues. Across four tasks assessing different components of cue utilisation, individuals in the sample were classified into one of two groups, either the relatively higher social cue utilisation group, or the relatively lower social cue utilisation group. The utility of this version of EXPERTise in discriminating between higher and lower levels of cue utilisation replicates the broad application of EXPERTise as a *shell* program across different types of cue-based stimuli (Loveday et al., 2013a; Wiggins, Azar, & Loveday, 2012; Loveday et al., 2014; Loveday, Wiggins, Searle, Festa, & Schell, 2013b).

As predicted in Hypothesis 1, ad hoc dyads composed of individuals with higher levels of social cue utilisation exhibited superior performance when compared to ad hoc dyads composed of individuals with lower levels of social cue utilisation, taking significantly less time to solve the Tower of Hanoi puzzle. Since the team task involved in this study incorporated additional rules requiring individuals to interact with one another, this suggests that, in the context of ad hoc team performance, the capacity of team members to identify and utilise social cues to communicate and coordinate with each other plays an important role in determining the effectiveness of teams.

The results also provided initial support for Hypothesis 2, with regression analyses indicating that higher levels of social cue utilisation were positively associated with both closing the loop and the development of shared mental models. This suggests that ad hoc teams, composed of individuals with higher levels of social cue utilisation, may be more likely to close the loop in the context of communication sequences. This is likely due to the fact that social cue utilisation may allow team members to identify optimal opportunities to respond, provide feedback, or make observations that assist in the decision-making and problem-solving process (Schillinger et al., 2003; Brindley & Reynolds, 2011).

The positive association evident between social cue utilisation and shared mental model development suggests that teams with higher levels of social cue utilisation may be more effective in developing a shared understanding of a given task. A possible explanation for this outcome is that team members with higher levels of social cue utilisation are able to identify and respond to cues associated with uncertainty or agreement for the purposes of clarification or confirmation. This capacity is likely to assist in the development of teams' understanding of the parameters of a given situation. Further, the regression analyses controlled for non-verbal reasoning ability and emotional intelligence, suggesting that the capacity to utilise social cues to facilitate communication and a shared mental model is a capacity that occurs independently of these variables.

The third hypothesis predicted that the frequency of closing the loop would be positively associated with the development of shared mental models. The results provide support for Hypothesis 3, suggesting that the capacity of teams to close the loop may enable the development of a shared understanding of an ad hoc situation, and does so independent of emotional intelligence and non-verbal reasoning ability. This result suggests that social cue utilisation warrants additional research into its utility in aiding team-based decision-making and task performance. This is likely due to the fact that, while social cue utilisation involves the interpretation and utilisation of visual cues associated with emotion, it requires greater cognitive complexity in synthesising these cues from memory and using them in the context of decision-making.

The fourth hypothesis predicted that social cue utilisation would have a positive direct and indirect effect on ad hoc dyad performance through closing the loop and shared mental model development. A statistically significant total effect of social cue utilisation on ad hoc dyad performance was evident, suggesting that the sum of the direct effect and indirect effects on ad hoc dyad performance provide a viable model of the effect of social cue utilisation on ad hoc team performance. Hypothesis 4 also predicted that social cue utilisation would have an indirect effect on ad hoc dyad performance, firstly through closing the loop, and then through shared mental model development. A significant positive, indirect effect of social cue utilisation was evident on ad hoc dyad performance through closing the loop, indicating that social cue utilisation impacts ad hoc team performance through its positive association with closing the loop. Therefore, it is likely that individuals with higher levels of social cue utilisation close the loop more frequently in ad hoc teams in order to facilitate decision-making and problem-solving capacity necessary within the dynamic environments they face.

While the indirect effects mentioned may remain viable pathways for social cue utilisation to exert an effect on ad hoc dyad performance, we also examined whether these variables operate in a serial fashion. Although previous research has explored the role of shared mental models (DeChurch & Mesmer-Magnus, 2010) and communication in team performance (Salas et al., 2008b), as well as the relationship between communication and shared mental models (Marks et al., 2000), a model has yet to be tested that comprises both closing the loop and shared mental model development on ad hoc team performance.

Implications of the Findings

This study is the first to use a serial multiple mediation model to examine the impact of social cue utilisation, closing the loop, and shared mental model development on ad hoc team performance. The research provides a novel, quasi-experimental contribution to the team performance literature by identifying the indirect effect of social cue utilisation on ad hoc team performance through the mechanism of closing the loop communication. Theoretically, this study extends existing research into the factors that predict the emergence of shared mental models (DeChurch & Mesmer-Magnus, 2010), providing preliminary evidence that closing the loop does precede the development of shared mental models in ad hoc teams. Further, this study adds to the cue utilisation research that has tended to focus on the impact of domain-specific technical cues on performance in areas such as aviation and power control.

The findings also have practical implications for organisations. These results add to the call for organisations to focus on the development of non-technical skills of teams, including communication (Hull et al., 2011, Crichton & Flin, 2004), as they have practical benefits for the effectiveness of ad hoc teams. In highly technical and high reliability environments, the assessment of social cue utilisation may also enable the selection and optimisation of teams with higher levels of social cue utilisation that are beneficial in situations where efficient and effective communication is critical to success. Further research is required to understand the utility of social cue utilisation in predicting important ad hoc team outcomes like closing the loop which can determine the likelihood of team success.

Limitations and Future Research

Given the dynamic nature of ad hoc teams, this paper should be used as a basis for ongoing exploration into the cognitive bases of successful ad hoc team performance. While the utilisation of a purpose-built measure of shared mental models enabled an exploration of the dynamic processes exhibited by ad hoc teams in the study, it is possible that doing so may limit the generalisability of outcomes. Given the highly diverse methods employed to measure shared mental models, further research is needed to understand whether different methods of measurement lead to any differences in findings, and whether the employment of the method used in this study produces similar findings outside of experimental settings. It is also recommended that this model be tested with a more specific focus on the trajectory of shared mental model development. For instance, probe measures could be used during the task to capture more specific information about how shared mental models may be changing.

In addition, the impact of task complexity and task-based requirement to elicit the need to utilise social cues should be further examined. The generalisability of these findings should also be examined in the context of larger ad hoc teams, where the opportunity to close the loop and develop shared mental models may be different. This further emphasises the need to continue the research question identified in this study using ad hoc teams of different structures and using different team tasks.

Although the task selected to operationalise ad hoc team performance is widely used in team-based research, and additional rules were introduced to encourage greater teamwork, only one indicator of team performance was included in this study. The operationalisation of a mediating variable in closing the loop was also singular with respect to communication, though sufficient evidence highlighted the importance of closing the loop in teams of an ad hoc nature (Siassakos et al., 2009). In addition, the aggregation of individual emotional intelligence and non-verbal reasoning ability scores into a team-level score was conducted to ensure analyses were run at the team-level only. Future studies could include multi-level analyses of the effects shown in this research.

Conclusion

This study identified a relationship between social cue utilisation and the performance of ad hoc dyads, and demonstrated that the utilisation of social cues exerts an effect on ad hoc team performance independently of non-verbal reasoning ability and emotional intelligence. This study is the first to show, using a serial multiple mediation model, the indirect effect of social cue utilisation on ad hoc dyad performance through closing the loop. This research provides an important theoretical contribution to the literature as well as practical contributions for organisations employing ad hoc teams and seeking to optimise their effectiveness.

Key Points

- Social cue utilisation exerts an effect on the performance of ad hoc dyads, independent of non-verbal reasoning ability and emotional intelligence
- Social cue utilisation has a positive indirect effect on ad hoc dyad performance through its association with closing the loop
- Further research into the utility and generalisability of social cue utilisation as a construct of theoretical and practical significance is needed

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Paper 1 Appendix

Feature Identification Task (FID) stimuli

Part 1: Static task

Part 2: Array task

Feature Discrimination Task

Scenario:

You are travelling to a birthday party with a friend called Alex whose father has offered to drive in their car. They are late in picking you up, and when getting into the car, you notice that both seem rather flustered.

Alex’s father starts driving and reassures you that since he knows the best route, you will not be late to the party. For a while there is very little conversation and you become aware that the mood is quite tense in the car.

After driving for some time, you start to realise that you may not be travelling in the right direction. You pass some road signs that you do not recognise and a traffic intersection you have never seen before.

Alex starts to look around and asks whether her father knows where he is going. The father reassures Alex that he knows exactly where he is going in an agitated manner. An argument over the correct route starts to break out between Alex and her father. Alex believes her father is going the wrong way. Alex turns around in her seat, gives you a pleading look, and asks for your opinion on the matter.

Response Options:

- Tell Alex’s father that you think you are going the wrong way

- Tell Alex that you think you are going the wrong way
- Remain quiet while Alex argues with her father
- Ask Alex's father to describe the route that he is taking

Feature Ratings:

Please rate the importance of the different aspects of this scenario in arriving at your response.

- Potential to arrive late to the party
- Mood upon entering the car initially
- Alex's father reassuring you that he knows the best route
- Failure to recognise passing road signs and intersections
- Argument between Alex and her father
- Alex's behaviour when asking for your opinion

Paired Association Task (PAT) stimuli

Related Pairings		**Unrelated Pairings**	
Feature	Event	Feature	Event
Smile	Happy	Smile	Anger
Shrug	Uncertain	Shrug	Fear
Nod	Confident	Nod	Confused
Silence	Uncertain	Silence	Confident
Sweat	Stress	Sweat	Relaxed
Ignore	Disagree	Ignore	Confused
Shout	Anger	Shout	Discussion
Hesitation	Nervous	Hesitation	Distraction
Tension	Conflict	Tension	Disgust
Upset	Sad	Upset	Disinterest
Frown	Unsure	Frown	Sad

Transition Task (TT) stimuli

Scenario:

You are on your way back to work after sharing lunch with your supervisor. As you walk down the street together, you notice a pedestrian fall over in front of the both of you. One bystander rushes over to help.

How do you respond?

Information Tabs:

- Time of day: It is the middle of the day, 12:00pm
- Presence of onlookers: It is a busy street with lots of people around
- Profile of pedestrian: The pedestrian appears to be a middle-aged female
- Response of pedestrian: The pedestrian has sat up after falling over, and has a painful look on their face
- Profile of bystander helping: The bystander helping is an elderly female
- Response of bystander helping: The bystander helping seems unsure and is shaking her head
- Response of onlookers: Most people continue walking, but a small crowd has started to gather around the pedestrian
- Response of supervisor: Your supervisor seems un-phased by the incident and starts to walk away
- Topic of conversation over lunch: You received feedback that you have not been finishing your work on time each day

Response Options:

- Stop and help the pedestrian yourself
- Ask the supervisor what you should do
- Ignore the incident and continue walking
- Ask an onlooker to help the pedestrian

Chapter Five: Social Cue Utilisation, Communication Strategies and Ad Hoc Team Outcomes in a Simulated Task

Paper 2 Outline

The research findings from Paper 1 indicated that social cue utilisation is associated with the ad hoc team performance on a general problem-solving task, and that this association operates indirectly through the use of closing the loop communication. Surprisingly, team cognition in the form of shared mental models demonstrated no significant associations with key study variables. Based on these outcomes, Paper 2 excluded the examination of team cognition on the basis that the focus on social cue utilisation, communication, and ad hoc team outcomes would permit a more specific and efficient experimental design.

The aim of Paper 2 was to extend the findings from Paper 1 by incorporating a higher fidelity team task in the form of a rail control simulation. This task was selected to ensure that the impact of social cue utilisation on ad hoc team performance would still be present with more complex tasks and situations. In addition, a measure of workload perception was included to explore whether cue utilisation offered additional benefits to ad hoc teams beyond performance. In increasing the complexity of the design and the task, it was also anticipated that the complexity of communication would also increase to match the demands of the situation. Accordingly, an additional type of communication strategy, 'informative responding', was used to test this proposition.

Paper 2 Publication History

Paper 2 was submitted for publication in Ergonomics on 6th August, 2017. At present, this journal has an impact factor of 1.818. The author of the present dissertation was responsible for the write-up of Paper 2. Professor Mark Wiggins and Dr. Ben Searle supervised and reviewed the research and write-up.

The role of social cue utilisation and communication in the performance and workload perceptions of ad hoc dyads in a simulated task

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Abstract

The objective of this study was to examine whether ad hoc dyads with different levels of social cue utilisation would exhibit different levels of performance and workload perceptions in relation to a simulated rail control task. The extent to which team members engaged in closing the loop and informative responding communication strategies were examined to determine their role in performance. A quasi-experimental design using 40 dyadic teams was employed. The results indicated that levels of social cue utilisation are associated with lower response latencies and lower perceived workload, and positively associated with both closing the loop and informative responding communication strategies. Analyses also showed that social cue utilisation exerts an indirect effect on perceived workload through informative responding. The findings have implications for both theoretical advancements into the factors that determine ad hoc team performance, as well as the selection and training of teams that operate in ad hoc environments.

Keywords: Individual differences, decision making, operator workload, team working

Practitioner Summary (50 words): This study provides a novel examination of ad hoc team dynamics and highlights the importance of social cue utilisation in the communication strategies and performance of ad hoc teams.

The Role of Social Cue Utilisation and Communication in the Performance and Workload Perceptions of Ad Hoc Dyads in a Simulated Task

The growing complexity and dynamic nature of everyday work has led to an increasing reliance on teams that offer greater flexibility and responsiveness. Compared with more traditional team structures defined by familiarity and stability, ad hoc teams are relied upon to form quickly in response to rapidly changing environments and complex decision making (Kozlowski & Ilgen, 2006). Such ad hoc teams typically form quickly to solve problems and make decisions under high-pressure and often ambiguous circumstances, representing an essential part of high reliability environments seen in aviation, emergency health care, and emergency incident management (Baker, Day, & Salas, 2006; McCulloch et al., 2009). In these settings, organisations rely on ad hoc teams to integrate quickly and deliver results successfully, since failure is likely to lead to often severe consequences (e.g., patient mortality).

While team structures are constantly evolving, empirical research has often lagged behind and lacked concrete evidence exploring the specific mechanisms that explain why teams succeed or fail (Hackman, 1998). Also, according to Tannenbaum, Mathieu, Salas, and Cohen (2012), much of team-based research has tended to focus on teams with established member roles, well-defined tasks and settings, and stable practices over time. As a consequence, Tannenbaum et al. (2012) call for better alignment between research and practice that more accurately represents the reality of contemporary teams. Part of the shift in team research involves the progression towards understanding more about team processes such as communication and coordination, over an examination of team characteristics such as size and work history (Ilgen, Hollenbeck, Johnson, & Jundt, 2005; Mathieu, Maynard, Rapp, & Gilson, 2008).

Although established models of team effectiveness and performance (see Mathieu et al., 2008) incorporate increasingly dynamic frameworks for understanding how teams achieve success, the lack of consistency and number of empirical studies using experimental or rigorous methods has, at times, led to disagreement over the role that different processes, such as communication, play in the context of team performance. Consequently, research that empirically tests the utility of different explanatory variables using more contemporary and relevant team systems (i.e., ad hoc teams) should assist in improving the effectiveness of research-based team interventions (Hollenbeck, Beersma, & Schouten, 2012).

For ad hoc teams, successful performance may only form part of the definition of effectiveness alongside behaviour and processes like communication (Cohen & Bailey, 1997). Considering the critical need for ad hoc teams to adapt and respond quickly to situational demands, it is essential to prioritise both outcomes and processes in understanding performance (Mathieu et al., 2008). Performance within ad hoc teams is likely to depend upon the capacity of team members to coordinate efficiently and effectively, highlighting the importance of communication.

Communication and Ad Hoc Team Performance

An essential component of team success hinges on the capability of team members to cooperate and develop a shared understanding of situational context, parameters, and demands (DeChurch & Mesmer-Magnus, 2010). Strategies that facilitate this process should enable teams to function and perform effectively. Indeed, new-forming, high functioning teams tend to engage in high rates of information-sharing to establish key situational demands, likely enabling them to coordinate with each other and identify appropriate solutions and responses (Stanton & Ashleigh, 2000; Mohammed, Ferzandi, & Hamilton, 2010).

In the context of ad hoc teams, where decision making typically occurs in fast-paced and high-risk settings, the capacity of team members to effectively and efficiently communicate is critically important. For example, the effectiveness of communication impacts the technical performance of surgical operating teams (Hull et al., 2011; McCulloch et al., 2009), intensive care unit teams (Reader, Flin, Lauche, & Cuthbertson, 2006), and emergency response teams in nuclear incidents (Crichton & Flin, 2004). Importantly, breakdowns in effective communication (e.g., a failure to clarify or confirm instructions) play a significant role in the occurrence of error and preventable incidents (Leonard, Graham, & Bonacum, 2004; Manser, 2009).

Within ad hoc environments, effective team communication tends to be characterised by more frequent statements focused on sharing information, initiated at the appropriate time during the performance of a task, and which trigger responses from other team members (Mesmer-Magnus & DeChurch, 2009). More frequent statements are thought to better establish roles and situational requirements, and communication at the appropriate time ensures more effective coordination during task performance, and better opportunities for the clarification of strategies and the prevention of errors. Evidence also indicates that effective ad hoc teams engage in closed loop communication to ensure that messages sent and received are clarified to inform decision making (Hunt, Shilkofski, Stavroudis, & Nelson, 2007), and that team members who 'speak up' more frequently to clarify procedures and give instructions also contribute positively to ad hoc team performance (Kolbe et al., 2012).

Despite evidence to suggest that specific communication strategies facilitate performance in ad hoc teams, their application is not always necessarily associated with improvements in team performance. This may be due to inconsistent or unstandardised strategies around what constitutes effective communication (Hargestam, Lindkvist, Brulin, Jacobsson, & Hultin, 2013). For instance, Patrashkova, McComb, Green, and Compton (2003) suggest that simply promoting the frequency of communication may, in some situations, overload team members, thereby degrading performance. Similarly, Svensson and Andersson (2006) noted that ad hoc teams experienced difficulties coordinating activities where the frequency of communication increased but lacked coordination and appropriate timing. Consistent with Svensson and Andersson (2006), the two most frequent communication errors amongst operating theatre teams comprised errors of timing and content (Lingard et al., 2004).

Since the timing of communicative statements represents a critical component of ad hoc team performance in discrete tasks, team performance, in this case, should depend upon members' capacity to recognise opportunities to initiate or respond to communicative statements (Salas, Cooke, & Rosen, 2008a). These opportunities are likely to relate to features of the task, including the initiation or conclusion of a sub-task, changes to the progress of a task, and/or periods of activity or inactivity.

Social Cue Utilisation and Communication

Individuals display different levels of capability in recognising quickly and responding appropriately to features in the environment (Pickett, Gardner, & Knowles, 2005). Where these features are recognised as familiar, they exist in memory in the form of cues. Cues represent feature-event associations, the utilisation of which obviates the need for the application of cognitive resources in making sense of a situation (Ericsson & Kintsch, 1995; Wiggins, 2014). Social cue utilisation refers to the capacity of individuals to identify, respond to and draw on cues of a social nature (e.g., emotional expressions) to inform their understanding, decision-making and behaviour within social settings (Yee, Wiggins, & Searle, 2017). In the context of ad hoc teams, this likely aids in interpreting, understanding, and responding to communication from others (Prati, Douglas, Ferris, Ammeter, & Buckley, 2003; Riggio, 2006).

Outside of social settings, numerous studies have demonstrated that cue utilisation plays a key role in aiding decision making and diagnostic judgements (Loveday, Wiggins, & Searle, 2014). A greater capacity to identify and extract critical cues from the environment has been associated with improved clinical (Hoffman, Aitken, & Duffield, 2009) and weather-related decision making (Wiggins, Azar, & Loveday, 2012), a reduction in the cognitive resources required to maintain vigilance during sustained attention tasks (Small, Wiggins, & Loveday, 2014; Brouwers, Wiggins, Helton, O'Hare, & Griffin, 2016), and diagnostic performance (Loveday, Wiggins, Harris, O'Hare, & Smith, 2013a; Loveday, Wiggins, Searle, Festa, & Schell, 2013b). Fundamentally, individuals with greater levels of cue utilisation within a specific context reduce the cognitive resources needed to respond accurately and quickly to changes in a system state because they are better able to draw on pre-existing feature-event associations in memory (Brouwers et al., 2016).

A key characteristic of the acquisition of cues is a level of precision that improves sense making by differentiating relevant from less relevant features (Chi, Feltovich, & Glaser, 1981). In the context of ad hoc teams, this precision in cue-based processing enables subtle behaviours on the part of team members to signal optimal opportunities for communication (Prati et al., 2003; Riggio, 2006). Ad hoc teams that comprise members with relatively greater levels of cue utilisation in a social context tend to perform at a higher level during novel, complex problem-solving tasks (Yee et al., 2017). This effect is associated especially with communication statements that occur in response to a statement initiated by another team member, so called 'closing the loop' statements.

The benefit associated with closing the loop statements lies in their capacity to confirm an action and thereby coordinate activity. 'Closing the loop' is a foundational tenet of telephonic communication, especially in high risk environments such as aviation and rail (Hunt et al., 2007). However, it is not clear precisely whether the benefit of 'closing the loop' lies in the confirmation of an action, the coordination of activities to reduce workload, and/or as a source of additional information for the team. Further, it is not clear whether the benefit of social cue utilisation is reflected in a greater frequency of 'closing the loop' statements.

The Present Study

The present study was designed to replicate and extend the outcomes of Yee et al. (2017) in a context beyond a generic problem-solving task. Using rail control as a context, teams of participants with higher or lower levels of social cue utilisation monitored a series of railway lines for trains that were routed on the wrong track. The rail control task simulates vigilance and monitoring scenarios, whereby variations in response latency rather than accuracy are common (Small et al., 2014). We therefore expected differences in response latency based on social cue utilisation.

In addition to examining the performance of ad hoc teams on a rail control simulation task, the extent to which ad hoc teams engaged in informative responding was included as an alternative mediator in the relationship between social cue utilisation and ad hoc team performance. This tested the importance of communication centred around information sharing (i.e., quality over quantity), rather than simply acknowledgements (i.e., responding with a “yes” or “no”) (Bowers, Jentsch, Salas, & Braun, 1998; Mesmer-Magnus & DeChurch, 2009). The present study also incorporated an additional outcome measure, team workload, to test whether improvements in performance were associated with a reduction in team workload for participants with greater levels of social cue utilisation (Cohen & Bailey, 1997). Specifically, it was hypothesised that (see Figures 1 and 2):

Hypothesis 1: Ad hoc teams with relatively higher levels of social cue utilisation would record lower mean response latency on the rail control simulation task than teams with relatively lower levels of social cue utilisation.

Hypothesis 2: Ad hoc teams with relatively higher levels of social cue utilisation would experience lower levels of perceived workload during task performance than teams with relatively lower levels of social cue utilisation.

Hypothesis 3: Levels of social cue utilisation would be associated with a greater frequency of closing the loop communication, together with a greater frequency of informative responding.

Hypothesis 4: A positive, indirect effect of social cue utilisation with ad hoc team performance would be evident through the frequency of closing the loop communication.

Hypothesis 5: A positive, indirect effect of social cue utilisation with ad hoc teams' perceptions of workload would be evident through the frequency of closing the loop communication.

Hypothesis 6: A positive, indirect effect of social cue utilisation with ad hoc team performance would be evident through the frequency of informative responding.

Hypothesis 7: A positive, indirect effect of social cue utilisation with ad hoc teams' perceptions of workload would be evident through the frequency of informative responding.

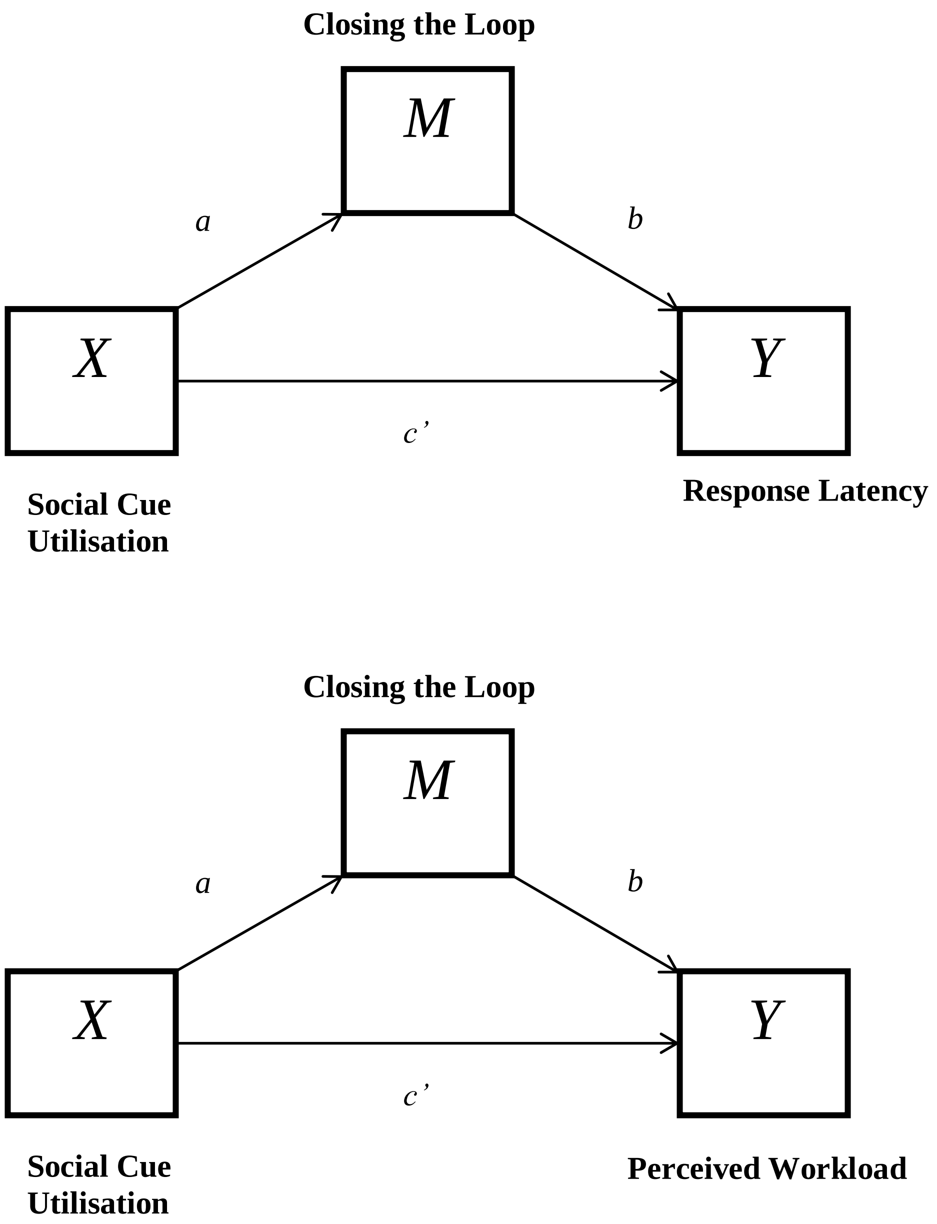
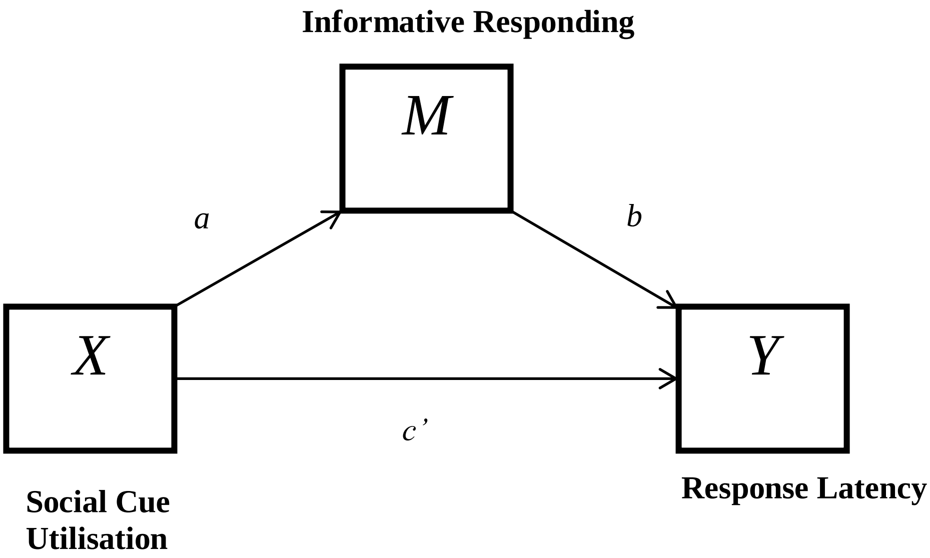


Figure 1. Simple mediation models describing predicted indirect effects through closing the loop.



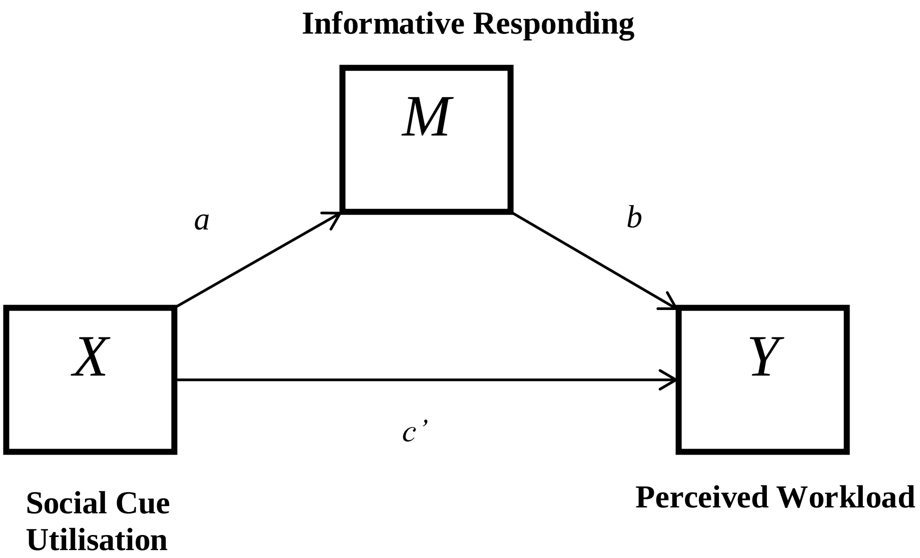


Figure 2. Simple mediation models describing predicted indirect effects through informative responding.

Method

Participants

A total of 113 first and third year female university students participated in the research, aged between 17 to 52 years (*M* = 21.09, *SD* = 5.66) and with 79% of the sample having English as their first language. Consistent with Yee et al. (2017), an entirely female sample was used to avoid variation in responses being attributed to gender. All participants received course credit related to their level of participation (80 students received additional course credit for participating in the second phase of the study). There were no significant differences in relation to age or English as first language for participants who participated in the first phase only, and those who participated in both.

Measures

Expert Intensive Skills Evaluation (EXPERTise 1.0): Assessment of social cue utilisation. EXPERTise 1.0 is a situational judgement assessment platform that is designed to assess aspects of cue utilisation related to a specific context (Wiggins, Harris, Loveday, & O'Hare, 2010). Comprising four tasks, the assessment in the present study was designed to assess unique, yet related, components of social cue utilisation. The social cue utilisation version of EXPERTise 1.0 was identical to that employed by Yee et al. (2017) which discriminated transient dyads based on task performance. It comprises four distinct tasks: the Feature Identification Task (FIT), the Feature Discrimination Task (FDT), the Feature Association Task (FAT), and the Feature Prioritisation Task (FPT).

The FIT is designed to assess the capacity to identify task-related features and extract information from scenes. Individuals with higher levels of cue utilisation demonstrate greater accuracy and lower response latency on the FIT (Loveday et al., 2014). The present research included two versions of the FIT. A static version of the task required respondents to view a series of images depicting people expressing specific emotions with their faces, and identify the emotion correctly. A single image was presented for each of the seven expressions included: anger, disgust, fear, happiness, sadness, surprise, and neutral (i.e., absence of emotion). Facial stimuli were chosen to reflect commonly encountered emotions, and were taken from a validated facial expression database (Kanade, Cohn, & Tian, 2000). An array-based version of the task was also presented which required respondents to view an array of three faces expressing specific emotions. Within each array, while two faces conveyed identical emotions, a single face expressed a distinct emotion. For each array, respondents were asked to identify the inconsistent emotion being expressed.

The FDT assesses respondents' ability to distinguish task-relevant features from less relevant features in the context of decision making. Respondents are provided with a scenario requiring them to decide on a resolution for the situation, and are then asked to rate the extent to which key features within the scenario aided in their proposed decision. Individuals with higher levels of cue utilisation exhibit greater variance in their ratings, suggesting a greater capability in differentiating between features offering utility in aiding sense making, and those that are less informative or important (Shanteau, 1992; Weiss & Shanteau, 2003; Loveday et al., 2014).

The FAT is designed to assess the ability to discriminate between related feature-event pairings (e.g., *smile* and *happy*) from those that are unrelated (e.g., *shrug* and *fear*). Consistent with the FDT, individuals with higher levels of cue utilisation demonstrate greater variance in their ratings, suggesting a greater capacity to form and draw on relevant feature-event associations (Morrison, Wiggins, Bond, & Tyler, 2013; Loveday et al., 2014).

The FPT assesses respondents' ability to prioritise and acquire information to guide their sense making. The task provides respondents with a scenario containing a limited amount of information and asks them to develop a resolution by accessing a set of features with varying degrees of utility. Features are presented in a list of tabs that expand with the relevant information when accessed, with performance on the FPT measured by calculating the ratio of feature-pairs accessed sequentially against the total number of feature-pairs accessed. Individuals with higher levels of cue utilisation record lower ratios (i.e., they access features non-sequentially rather than in the order they are presented), suggesting that the method with which they acquire information is characterised by a prioritisation of features that are important in assisting resolution (Wiggins & O'Hare, 1995; Randel, Pugh, & Reed, 1996; Loveday et al., 2014).

Rail Control Simulation Task: Assessment of dyad performance. The use of a simulation task was necessary for the present research to test the capacity of social cue utilisation to distinguish ad hoc team performance in higher fidelity situations. A rail control simulation task was selected because, like ad hoc team types such as emergency response teams, rail control teams often face high-pressure situations, are required to deal with ambiguous and complex information at times, and are characterised by heterogenous and ad hoc team compositions which require rapid communication and coordination of responses (Salas, Burke, & Samman, 2001; Reddy et al., 2009).

The rail control simulation task (see Figure 3) is a computer-based task requiring respondents to monitor the progression of trains (denoted by red bars) travelling on a series of train lines (denoted by green lines). Each train is designated as either odd or even numbered (e.g., 888 or 555), travelling on train lines that are designated odd or even. Each train line comprises an intersection point (denoted by white bars) which enables trains to be re-routed onto an alternative train line through the selection of a change button on the interface. The purpose of the task is to ensure that trains complete their route on the correct train lines (i.e., even trains end on even tracks, and odd trains end on odd tracks).

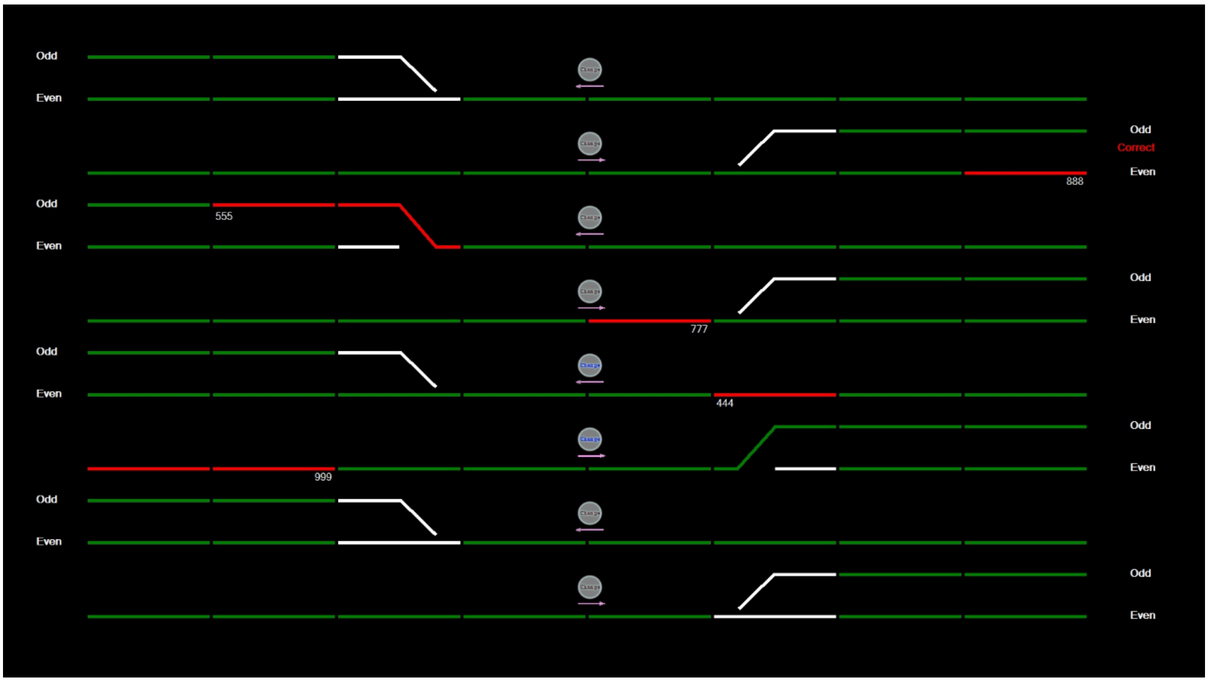


Figure 3. Rail control simulation task.

The rail control task has been employed in previous research as a low workload scenario, mirroring the use of simulation tasks in studies examining vigilance and monitoring performance (Brouwers et al., 2016; Small et al., 2014). Variation in response latency rather than accuracy is common, and is likely the result of operators being given sufficient time to respond. The appearance of trains was automated, ensuring that participants were only required to direct their attention to trains requiring re-routing. Given that sustained attention contributes to cognitive demand and vigilance decrement over an extended duration of time, tasks such as the rail control simulation are characterised by participant motivation to reduce cognitive demand by adopting strategies to monitor and respond (Helton et al., 2005). The absence of effective strategies is likely to lead to poorer performance on the task, operationalised as the accuracy of responses (i.e., correct re-routing of trains when needed) and the response latency of accurate responses (i.e., efficient and prompt selection of the change button).

A total of 119 trains appeared randomly every five seconds over eight train lines. The task continued for 10 minutes, during which half of the trains were required to be re-routed.

To increase the fidelity of the simulation, a single member of the dyad was seated in front of a smaller operator screen with access to a keyboard and mouse to respond to the task. The second member was seated in front of a separate, larger operator screen as a spotter. Both dyad members were instructed not to look at each other's screens, and to only communicate verbally to each other.

Closing the loop. Consistent with Yee et al. (2017), closing the loop statements were defined as the action taken by team members to complete a communication sequence, a verbal exchange containing both an initiating statement from one team member and a responding statement from another (Prinzo, 1998; Schillinger et al., 2003; Brindley & Reynolds, 2011). A communication loop is considered closed if a question, observation or command (initiating speech) is met by an acknowledgement or reply (responding speech) (Kanki, Folk, & Irwin, 1991), for instance a question is met with a yes/no reply. A ratio was calculated of the frequency of closed communication sequences against the total number of exchanges. Previous research has shown that closing the loop can be a critical strategy to improve team-based communication and coordination in ad hoc team environments (Bowers et al., 1998; Eppich, Branne, & Hunt, 2008).

Informative responding. By examining the utility of social cue utilisation in a higher fidelity, ad hoc context, it is likely that the incidence and impact of communication will be more complex than in Yee et al. (2017). Indeed, research concerning ad hoc team communication and performance in applied settings indicates that simply acknowledging other team members and closing the loop, or increasing the frequency of communication, may not be sufficient in increasing team performance (Patrashkova-Volzdoska et al., 2003; Svensson & Andersson, 2006; Kolbe et al., 2012). In these situations, team performance is enhanced by communication which clarifies, informs, and offers appropriate and timely information in an efficient manner. To match the increased complexity of the team task in the present study, a ratio was calculated for each dyad that compared the frequency of acknowledgements (e.g., *"Yes"* and *"No"*) with the frequency of responses (e.g., *"I think you are right about the way the trains appear on the tracks"*).

NASA Task Load Index (NASA-TLX): Perceptions of workload. The NASA-TLX is a multi-dimensional measure of subjective workload that has been used and validated in different applied settings (Hart & Staveland, 1988; Braarud, 2001). Respondents provide a rating of workload from 0-100 on each of the six subscale components: mental demand, physical demand, temporal demand, effort, performance satisfaction, and frustration, and receive an overall workload score. In the present study, the NASA-TLX was given to dyad members to complete collaboratively, to ensure that a singular measure of workload was collected for each ad hoc team.

Experimental Procedure

The present study was divided into two phases. Following approval from the Macquarie University Human Research Ethics Committee, participants were invited to complete a brief demographic questionnaire together with the EXPERTise program online as part of the first phase. This was designed as a pre-screening process to collect the data needed to establish participants' level of social cue utilisation. Once data collection was complete, participants were assigned to either a relatively *lower* or relatively *higher* social cue utilisation group based on their performance on the EXPERTise battery of tasks.

In the second phase of the study, participants were invited back to attempt the rail control simulation task in dyads. Forty dyads were formed based on levels of social cue utilisation, 20 with relatively higher levels of social cue utilisation and 20 with relatively lower levels of social cue utilisation. Participants were provided with verbal instructions for the task, including the requirement to only communicate verbally. Following a 10 minute practice period, dyads completed the 10-minute rail simulation task, and were then administered the NASA-TLX. The session was video-recorded so that the experimenters could code communication sequences and variables post-session.

Results

Ad Hoc Team Creation Based on Levels of Social Cue Utilisation

Participants' data from EXPERTise were used to initially determine their levels of social cue utilisation. Following the standard procedure for classifying individuals, participant responses to the four tasks were standardised and a *k*-means cluster analyses with two groups was conducted, leading to participants being classified as having relatively *lower* or *higher* levels of social cue utilisation (Wiggins et al., 2010). Those with a standardised *z*-score of more than three and a half standard deviations from their cluster average were removed as outliers ($n = 2$). The results from the cluster analyses are presented in Table 1. Non-standardised scores for each of the tasks have been included for ease of interpretation.

Table 1

Participant Social Cue Utilisation Classification Based on Non-Standardised Scores

Task	Cluster 1: *Relatively Lower* (*n* = 47)	Cluster 2: *Relatively Higher* (*n* = 64)
	Mean (*SD*)	*Mean* (*SD*)
FIT Static: Accuracy (%)	74.92 (10.09)	87.28 (7.89)
FIT Array: Accuracy (%)	28.36 (21.73)	71.39 (15.78)
FAT: Variance	2.31 (.94)	2.82 (.82)
FDT: Variance	2.08 (1.73)	4.38 (2.73)
FPT: Ratio (%)	97.47 (7.56)	73.51 (24.62)

Note. FIT = Feature Identification Task, FAT = Feature Association Task, FDT = Feature Discrimination Task, FPT = Feature Prioritisation Task.

Individuals from Cluster 2 demonstrated superior performance across all four tasks. Multivariate analyses of variance indicated that compared to Cluster 1, individuals in Cluster 2 exhibited significantly greater accuracy on both the static, $F[1,109] = 52.372$, $p < .001$, and array, $F[1,108] = 144.852$, $p < .001$, versions of the FIT, greater variance on both the FAT, $F[1,108] = 9.223$, $p < .01$, and FDT, $F[1,105] = 35.737$, $p < .001$, tasks, and a less sequential method of prioritising features on the FPT, $F[1,109] = 41.539$, $p < .001$. Consistent with previous studies (e.g., Loveday et al., 2014), individuals from Cluster 2 were classified as possessing relatively *higher* levels of social cue utilisation due to their superior performance compared to those from Cluster 1, who were classified as possessing relatively *lower* levels of social cue utilisation.

Preliminary Analysis

One hundred and thirteen participants completed EXPERTise in the first phase of the study. Two participants' data were removed as outliers. Eighty participants returned for the second phase of the study, whereby ad hoc teams were created by pairing individuals within the same level of social cue utilisation. Twenty ad hoc teams were classified as comprising relatively *higher* levels of social cue utilisation, with 20 being classified as relatively *lower*.

Statistical Analysis Procedures. Assumptions for the ANOVA analyses used to test Hypotheses 1 and 2 were met, together with those for the regression analysis used to test Hypothesis 3. Simple mediation analyses were carried out using ordinary least squares regression in SPSS PROCESS (Hayes, 2009) to test Hypotheses 4 to 7. This method enabled greater power and control of Type 1 error with bias-corrected bootstrap confidence intervals for indirect effects. The method also eliminates the requirement that a main effect must exist between an independent and dependent variable to examine indirect effects. The means, standard deviations, and correlations between study variables are presented in Table 2.

Table 2

Summary of Means, Standard Deviations, and Correlations for Study Variables

Variables	*M*	*SD*	1	2	3	4	5
1. Social cue utilisation	-	-	-	-	-	-	-
2. Rail control task accuracy (%)	99.24	.87	.28	-	-	-	-
3. Rail control task response latency (ms)	1472.58	442.50	-.44**	-.53**	-	-	-
4. Total workload	32.18	4.00	-.65**	-.18	.28	-	-
5. Closing the loop	62.93	15.20	.51**	.14	-.19	-.29	-
6. Informative responding	44.77	14.58	.62**	.12	-.31*	-.61*	.50**

Note. ***p* < .01, **p* < .05.

Social Cue Utilisation and Ad Hoc Team Performance

Two one-way ANOVAs were carried out to determine whether ad hoc teams, defined based on their social cue utilisation, performed differently on the rail control simulation task. Consistent with Hypothesis 1, a statistically significant main effect was evident for response latency, F (1,38) = 9.06, p <.01, η_p^2 = .17, whereby teams with higher levels of social cue utilisation recorded lower mean response latencies (ms) (*M* = 1280.89, *SD* = 372.18) compared to those with lower levels of social cue utilisation (*M* = 1664.26, *SD* = 431.34). There was no main effect for accuracy, F (1,38) = 3.34, p = .08, η_p^2 = .08. While the level of social cue utilisation accounted for eight percent of the variance in accuracy, it accounted for 17% of the variance in response latency.

Social Cue Utilisation and Ad Hoc Team Perceived Workload

A one-way ANOVA was used to determine whether ad hoc teams with relatively *higher* levels of social cue utilisation would report lower levels of workload in relation to task performance. The results provided support for Hypothesis 2 with a statistically significant main effect for social cue utilisation, F (1,38) = 27.63, p < .001, η_p^2 = .42). This result suggests that ad hoc teams with relatively *higher* levels of social cue utilisation reported significantly lower workload in response to task performance, with social cue utilisation level accounting for 42% of the variance in workload. Given the subscale structure inherent in the NASA-TLX, a series of one-way ANOVAs were conducted to examine whether ad hoc teams differed with respect to different aspects of workload. Of the six subscales reported, statistically significant differences were evident for mental demand, F [1,38] = 10.15, p < .01, temporal demand, F [1,38] = 10.24, p <.01, and frustration, F [1,38] = 5.36, p < .05. These results are illustrated in Figure 4.

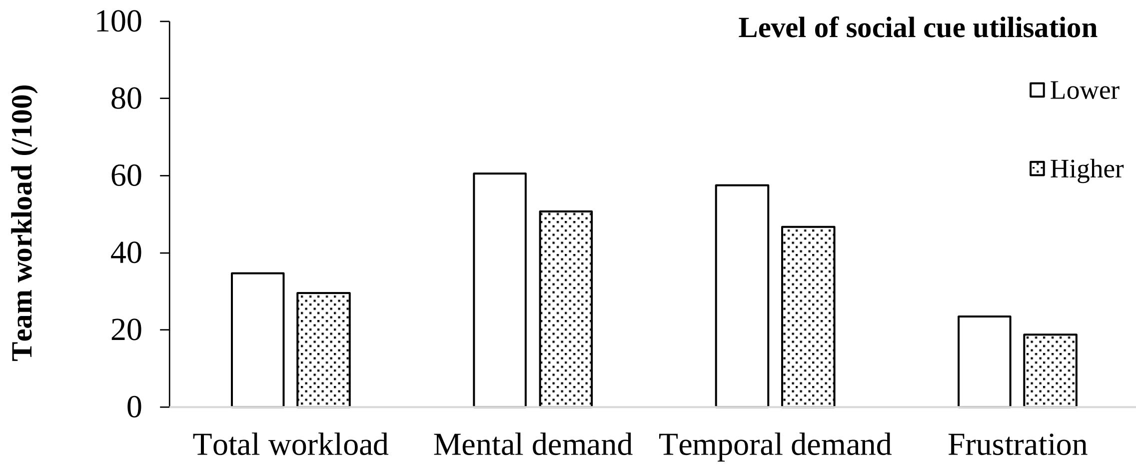


Figure 4. Ad hoc team workload.

Social Cue Utilisation and Communication

Two simple linear regression analyses were conducted to test the association between levels of social cue utilisation and (1) the frequency of closing the loop statements, and (2) informative responding within ad hoc teams. In the first regression model, closing the loop was regressed on social cue utilisation, with a statistically significant effect of social cue utilisation on closing the loop, F (1,38) = 13.21, p = .001, explaining 26% of the variance in closing the loop. In the second regression model, informative responding was regressed on social cue utilisation, with a statistically significant effect of social cue utilisation on informative responding, F (1,38) = 24.17, p < .001, explaining 39% of the variance in informative responding. The results provide support for Hypothesis 3.

Testing Direct and Indirect Effect of Social Cue Utilisation on Ad Hoc Team Performance through Closing the Loop

Given the non-significant findings exploring the relationship between levels of social cue utilisation and accuracy achieved on the rail control simulation task, performance was subsequently operationalised as response latency in isolation for remaining analyses. The direct effect of social cue utilisation on ad hoc team performance, and the indirect effect of social cue utilisation on ad hoc team performance through closing the loop, were tested using simple mediation via ordinary least squares regression. Variables were standardised prior to entering them into the model to ensure standardised coefficients for all indirect and direct effects. Indirect effects were generated using a bias-corrected bootstrap 95% confidence interval with 1,000 replications, and statistical inference was inferred based on whether the confidence intervals for the indirect effects contained zero (Hayes, 2009).

Levels of social cue utilisation exhibited a negative total effect on response latency, $\text{effect}_{\text{total}}$ = -.866, p < .01, 95% CI (-1.449, -.284), suggesting that the sum of all direct and indirect effect pathways from social cue utilisation to response latency is statistically significant. Social cue utilisation also exhibited a direct effect on response latency, c' = -.914, p < .05, 95% CI (-1.600, -.229). While the pathway between social cue utilisation and closing the loop was significant, $a_1 = 1.003$, $p < .001$, 95% CI (.444, 1.562), the pathway between closing the loop and response latency was not statistically significant, $b_1 = .047$, $p = .78$, 95% CI (-.299, .395).

The indirect effect of social cue utilisation on response latency through closing the loop was non-significant, $a_1b_1 = .048$, 95% CI (-.391, .593). These results suggest that social cue utilisation is unlikely to exert an indirect effect on response latency through closing the loop alone, suggesting that the relationship between social cue utilisation and response latency may be direct. The results are not consistent with Hypothesis 4 and are summarised in Figure 5.

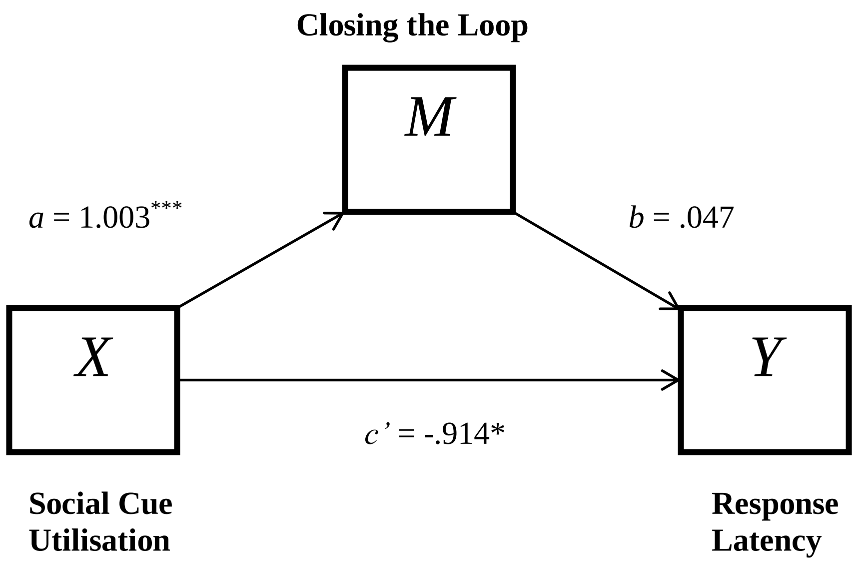


Figure 5. Simple mediation model testing indirect effect of social cue utilisation on ad hoc team response latency through closing the loop (Note. *p < .05, ***p < .001).

Testing Direct and Indirect Effect of Social Cue Utilisation on Ad Hoc Team Performance through Informative Responding

Levels of social cue utilisation displayed a negative total effect on response latency, $\text{effect}_{\text{total}} = -.866$, $p < .01$, 95% CI (-1.449, -.284), suggesting that the sum of all direct and indirect effect pathways from social cue utilisation to response latency was statistically significant. Social cue utilisation also exhibited a direct effect on response latency, *c'* = -.783, $p < .05$, 95% CI (-1.538, -.029). While the pathway between social cue utilisation and informative responding was statistically significant, $a_1 = 1.231$, $p < .001$, 95% CI (.724, 1.738), the pathway between informative responding and response latency was not significant, $b_1 = -.067$, $p = .72$, 95% CI (-.450, .315).

The indirect effect of social cue utilisation on response latency through informative responding was non-significant, $a_1b_1 = -.083$, 95% CI (-.626, .298). These results suggest that social cue utilisation is unlikely to exert an indirect effect on response latency through informative responding alone, reinforcing the direct relationship between social cue utilisation and response latency. The results are not consistent with Hypothesis 5 and are summarised in Figure 6.

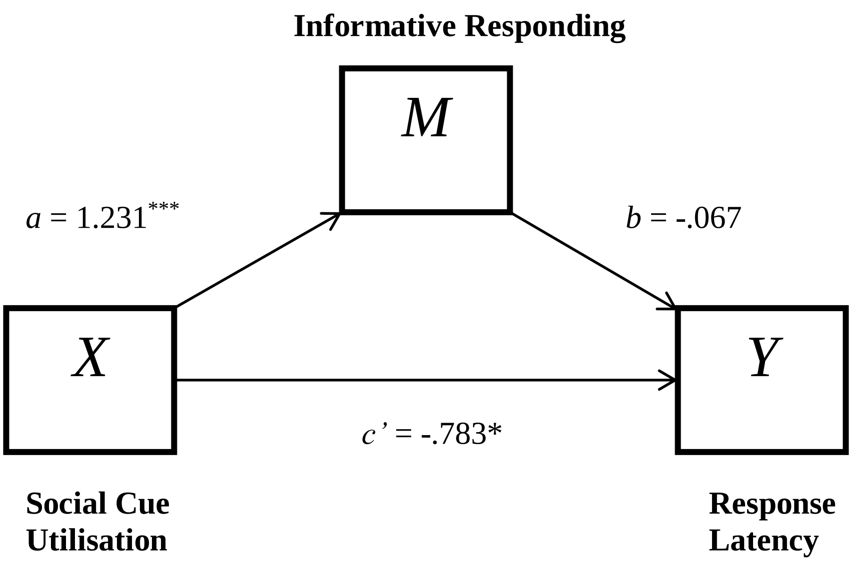


Figure 6. Simple mediation model testing indirect effect of social cue utilisation on ad hoc team response latency through informative responding (Note. *p < .05, ***p < .001).

Testing Direct and Indirect Effect of Social Cue Utilisation on Ad Hoc Team Workload through Closing the Loop

Levels of social cue utilisation exhibited a negative total effect on team workload, $\text{effect}_{total} = -1.281$, $p < .001$, 95% CI (-1.775, -.788), suggesting that the sum of all direct and indirect effect pathways from social cue utilisation to team workload is statistically significant. Social cue utilisation also exhibited a direct effect on team workload, $c' = -1.338$, $p < .001$, 95% CI (-1.918, -.758). Much like previous models, while the pathway between social cue utilisation and closing the loop was statistically significant, $a_1 = 1.003$, $p < .001$, 95% CI (.444, 1.562), the pathway between closing the loop and team workload was not significant, $b_1 = .056$, $p = .70$, 95% CI (-.237, .350).

The indirect effect of social cue utilisation on team workload through closing the loop was non-significant, $a_1b_1 = .057$, 95% CI (-.207, .307). These results suggest that social cue utilisation is unlikely to exert an indirect effect on team workload through closing the loop alone. The results failed to support Hypothesis 6 and are summarised in Figure 7.

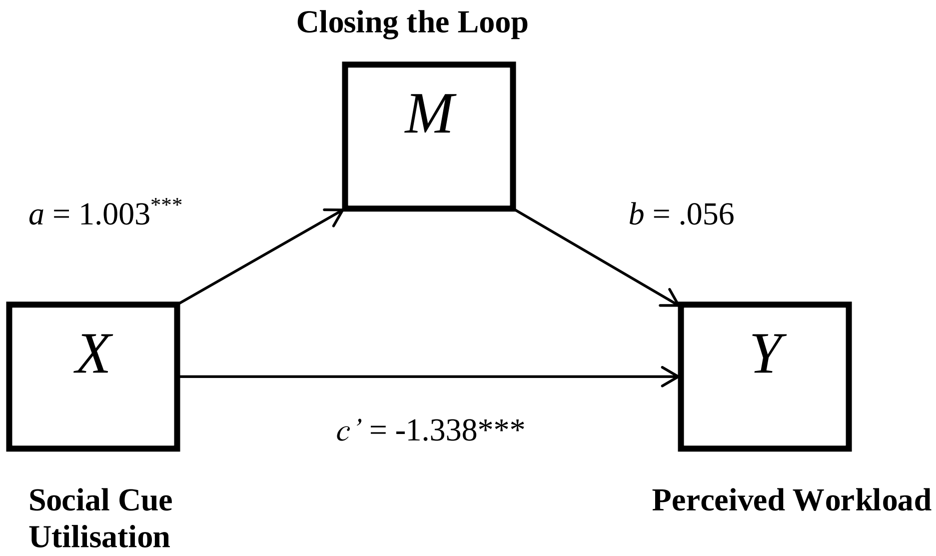


Figure 7. Simple mediation model testing indirect effect of social cue utilisation on perceived workload through closing the loop (Note. ***p < .001).

Testing Direct and Indirect Effect of Social Cue Utilisation on Ad Hoc Team Workload through Informative Responding

Levels of social cue utilisation exhibited a negative total effect on team workload, $\text{effect}_{total} = -1.281$, $p < .001$, 95% CI (-1.775, -.788), suggesting that the sum of all direct and indirect effect pathways from social cue utilisation to team workload is statistically significant. Social cue utilisation also exhibited a direct effect on team workload, $c' = -.866$, $p < .01$, 95% CI (-1.467, -.266). The pathway between social cue utilisation and informative responding was statistically significant, $a_1 = 1.231$, $p < .001$, 95% CI (.724, 1.738). In addition, the pathway between informative responding and team workload was significant, $b_1 = -.337$, $p < .05$, 95% CI (-.641, -.033).

The indirect effect of social cue utilisation on team workload through informative responding reached statistical significance, $a_1b_1 = -.415$, 95% CI (-1.029, -.087), indicating that social cue utilisation exerts an indirect effect on team workload through informative responding alone. The results provide support for Hypothesis 7 and are summarised in Figure 8.

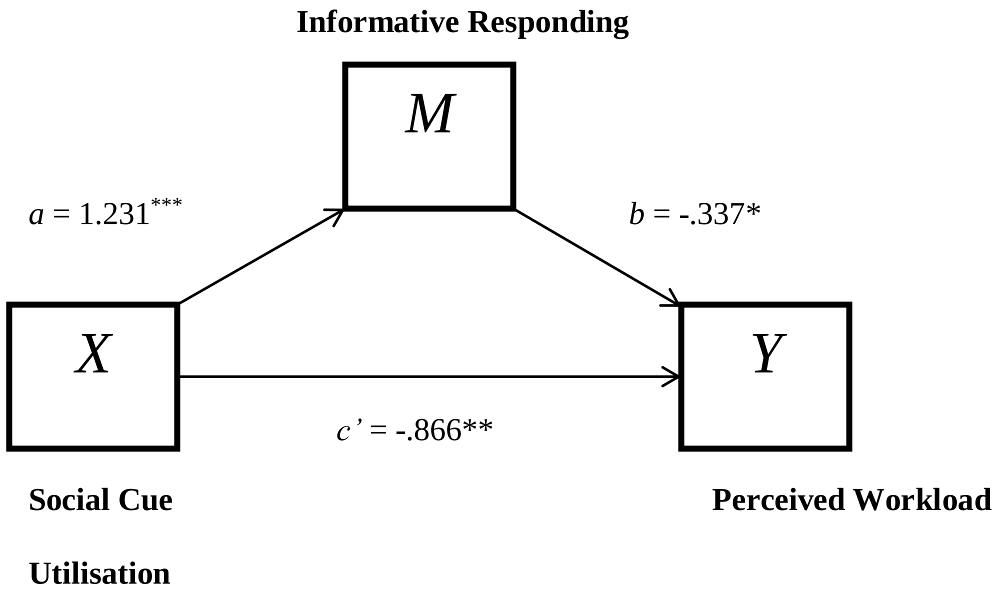


Figure 8. Simple mediation model results testing indirect effect of social cue utilisation on perceived workload through informative responding (Note. *p < .05, **p < .01, ***p < .001).

Discussion

The present study was designed to extend previous research concerning the role of social cue utilisation and communication in the context of ad hoc team performance (Yee et al., 2017). Testing teams within a rail control simulation environment enabled the examination of prior findings in a context that more closely resembled the operational context. In response to the added complexity, ad hoc team communication was operationalised as not simply closing the loop, but also as the extent to which informative responding occurred. This allowed for the exploration of social cue utilisation within ad hoc teams and whether it indirectly impacts performance and perceived workload through its association with such communication strategies. The outcomes of this study also provide further support for the utility of EXPERTise in discriminating individuals based on levels of social cue utilisation and for differentiating ad hoc team performance.

This study is the first to demonstrate that ad hoc teams comprising members with greater levels of social cue utilisation perform more effectively on a simulated rail control task, and perceive lower workload in relation to task performance, compared with ad hoc teams comprising members with lower levels of social cue utilisation. This result suggests that the capacity to identify, respond to, and differentiate between relevant and less relevant social features in the context of communication may have an important role to play in determining ad hoc team performance. In addition, the capacity to utilise social cues seemingly assists in reducing the perceptions of workload, possibly due to the fact that teams with higher levels of social cue utilisation are more efficient and effective in identifying and responding to social cues, thereby expending fewer cognitive resources in sense making and coordination (Wiggins, 2014). The benefit of greater efficiency and effectiveness in utilising social cues was particularly evident in the lower frustration, mental demand, and temporal demand ratings provided by ad hoc teams with higher levels of social cue utilisation. This may reflect the capacity of team members to identify and take advantage of optimal opportunities to communicate to support coordinative efforts and minimise workload (Schillinger et al., 2003; Brindley & Reynolds, 2011).

The present study provided further evidence that social cue utilisation is related to the communication strategies employed by ad hoc teams. Replicating previous findings concerning closing the loop and social cue utilisation (Yee et al., 2017), the extent to which teams provided informative responses was also associated with social cue utilisation and builds on studies linking information sharing with team performance (Mesmer-Magnus & DeChurch, 2009). These results indicate that ad hoc teams with higher levels of social cue utilisation use closing the loop communication sequences more frequently, ensuring that team members know when messages are received and understood (Hunt et al., 2007). They also suggest that such teams are more likely to not just confirm receipt and acknowledgement of communication, but also to engage in greater instances of informative responses that are likely to assist in cooperative decision making and building a shared understanding of the situation (DeChurch & Mesmer-Magnus, 2010; Mohammed et al., 2010).

The indirect effect of social cue utilisation on response latency through both closing the loop and informative responding were non-significant. This is despite the fact that a negative total effect was demonstrated in both simple mediation models, indicating that, for a high-fidelity rail control simulation task, ad hoc team performance may share a direct relationship with social cue utilisation. This outcome failed to replicate the mediation model identified in Yee et al. (2017) which specified an indirect effect of social cue utilisation on ad hoc team performance through closing the loop. Although this outcome could be attributed to the more complex nature of the task, it is possible that the requirements for communication in a higher fidelity and applied setting are fundamentally distinct from those found in a more generic problem-solving setting. Given previously mentioned findings from the present study, it may be the case that the capacity to utilise social cues is the primary, determining factor in ad hoc team performance within such environments.

Social cue utilisation demonstrated an indirect effect on perceived workload through informative responding, but not closing the loop. This suggests that ad hoc teams composed of individuals with higher levels of social cue utilisation are more likely to perceive lower workload during task performance due to their greater application of informative responding. Consistent with studies highlighting the importance of information sharing within teams (Mesmer-Magnus & DeChurch, 2009; Kolbe et al., 2012), it is likely that teams with higher social cue utilisation are better able to identify opportunities where the provision of information could support coordination efforts, and subsequently take advantage of these cues to communicate with purpose and reduce the perceived workload experienced by team members. This finding provides further support for the utility of cue-based processing in ad hoc environments (Brouwers et al., 2016) as well as the importance of communication in reducing workload in ad hoc teams (Khawaja, Chen, & Marcus, 2012). Based on existing research, the model identified here should provide a useful contribution to research efforts aiming to reduce the incidence of error in high reliability environments where ad hoc teams typically operate (Baker et al., 2006; Roberts et al., 2014).

Implications

The present study provides a novel, empirical contribution to the literature concerning ad hoc teams, addressing the call for more applied research that better reflects the composition of teams in contemporary environments (Tannenbaum et al., 2012), as well as the need to further disentangle the precursors and impacts of team processes like communication (Salas et al., 2008a; DeChurch & Mesmer-Magnus, 2010). From a theoretical point of view, the findings expand upon existing cue utilisation research, increasing the generalisability of the construct and identifying important mechanisms through which the utilisation of cues may operate in the context of team settings (Wiggins, 2015; Yee et al., 2017). Although the majority of studies examining the impact of cue utilisation have done so using technical, domain-specific cues (e.g., pediatric diagnosis), the present study provides further evidence for the importance of focusing on broader, non-technical cues and processes that may be equally, if not more important in environments that are defined by collaboration and teamwork (Hull et al., 2011; McCulloch et al., 2009).

In extending the findings from Yee et al. (2017), a simple mediation model proposing an indirect effect of social cue utilisation on ad hoc team performance through closing the loop was non-significant when using a more complex and higher fidelity simulation task. The present study did, however, find that social cue utilisation exerts an indirect effect on ad hoc teams' perceptions of workload through informative responding. Further research is clearly needed to explore the role of task fidelity and complexity in ad hoc team performance, as well as the communication-based mechanisms through which social cue utilisation operates within ad hoc teams.

The outcomes from the present study also highlight the importance of further exploring the capacity for cue utilisation to promote an understanding of the critical information and required responses in ad hoc team environments (i.e., situation assessment), either directly or through enabling key antecedent processes such as information sharing (Weiss & Shanteau, 2003). Furthermore, it is possible that team members relied on unique, yet compatible strategies for situation assessment to aid in initiating communication and task performance at the appropriate times, though the mechanism by which these different strategies are interpreted and shared requires further exploration (Lipshitz, Klein, Orasanu, & Salas, 2001). Further research is needed to expound the role of situation assessment in the context of ad hoc team performance and understand how situation assessment may be related to the strategies identified in the present study such as information sharing.

The present findings raise important practical implications. Team-based training around non-technical processes like communication have often resulted in mixed results given the lack of clarity around what constitutes effective communication in ad hoc settings (Salas et al., 2008b; Roberts et al., 2014; Hargestam et al., 2013). This study provides evidence not only for the utility of informative responding, but also identifies a potential precursor in social cue utilisation that could be leveraged to improve training interventions. In addition, given the importance of social cue utilisation in the functioning of ad hoc teams, the assessment of individuals' capacity to utilise cues could be a viable strategy for optimising the development and effectiveness of teams operating in applied settings where the cost of team-based breakdowns are especially high (e.g., Leonard et al., 2004).

Limitations

The present study provides a useful foundation and model for understanding ad hoc team performance that can be explored and elaborated upon by future studies. A primary focus should be to extend the generalisability of the model to more diverse ad hoc team compositions and environments. This should enable a more robust examination of the utility of the constructs examined in this study such as social cue utilisation and informative responding. While the findings provide some potential explanation for how social cue utilisation might impact ad hoc team dynamics, a more robust, multi-level experimental methodology not reliant upon cross-sectional analyses may enable greater understanding of how the utilisation of social cues interacts with various ad hoc team processes to influence performance.

Although the inclusion of more than one communication variable was intentional as part of the extension and replication of previous research, the narrow operationalisation of communication limits the conclusions that can be drawn. In addition, while the communication strategies were selected based on prior research on ad hoc team communication (e.g., Bowers et al., 1998; Eppich et al., 2008; Mesmer-Magnus & DeChurch, 2009), the present study design did not incorporate information around communication failures (Auton, Wiggins, Searle, Loveday, & Rattanasone, 2013) or more implicit measures of communication, which some studies have suggested as important determinants of team success (Patrashkova-Volzdoska et al., 2003; Lingard et al., 2004). The authors recommend further research be conducted that includes more complex measures of communication, typical ways in which communication breaks down (e.g., poor timing), as well as comparisons of explicit and implicit coordination.

Conclusion

The present study provided an extension of previous research examining the role of social cue utilisation and communication within ad hoc teams. The results suggest that ad hoc teams comprising individuals with higher levels of social cue utilisation are more likely to communicate purposefully by closing the loop and engaging in informative responding. In addition to lower response latencies on a simulated rail control task, these teams also indicated lower perceived workload, suggesting some benefit of social cue utilisation in aiding ad hoc team coordination. An indirect effect model was also found to be significant, warranting further research into the generalisability of social cue utilisation operating through informative responding in determining ad hoc team outcomes.

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Chapter Six: Social and Technical Cue Utilisation in Applied Environments

Paper 3 Outline

The research findings from Papers 1 and 2 highlighted the important role of social cue utilisation in ad hoc teams. Specifically, Paper 2 extended the findings from Paper 1 by demonstrating that, in the context of more complex and higher fidelity tasks, social cue utilisation is associated with the communication strategies, workload perceptions, and performance of ad hoc teams. However, in contrast to Paper 1, the results from Paper 2 indicated that social cue utilisation exerts an indirect effect on workload perceptions in isolation, and specifically through communication that involves informative responding. The findings suggest that when task complexity increases, it is no longer adequate to rely on ‘closing the loop’, and that informative responding communication is more likely to support the development of a shared understanding of a situation.

While the outcomes of both Paper 1 and 2 provide a strong foundation for establishing the validity of social cue utilisation, prior research has tended to focus more on domain-specific, technical cue utilisation. Given the increasing reliance on teams and teamwork in applied environments, it is likely that the utilisation of broader, social cues in such settings also promotes performance through benefits to coordination and communication. Therefore, Paper 3 was designed to provide a novel examination of the importance of technical and social cue utilisation in two different applied environments: power control and football coaching. Previously, both domains have been shown to be reliant upon the utilisation of technical cues (e.g., power control system cues, football game cues), yet little research has examined the role of social cue utilisation. This is despite the fact that performance in both domains depends on communication and to some extent, coordination.

The aim of Paper 3 was to further contribute to the outcomes of Papers 1 and 2, by examining the impact of social cue utilisation in more applied, real-world settings. In addition, Paper 3 was designed to examine the relative contribution of technical and social cue utilisation for performance in two different applied environments that rely on both technical and social expertise.

Paper 3 Publication History

A modified version of Paper 3 was submitted for publication in Sport, Exercise, and Performance Psychology on 11th February, 2018. At present, this journal has an impact factor of 1.930. The author of the present dissertation was responsible for the write-up of Paper 3. Professor Mark Wiggins supervised and reviewed the research and write-up, and Dr. Jaime Auton and Mr. Glenn Warry assisted with data collection and analysis.

Social and technical cue utilisation in expert domains

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Social and Technical Cue Utilisation in Expert Domains

Across a range of unique environments such as aviation, systems design, medicine, and sports, expertise is typically characterised by the utilisation and execution of domain-relevant strategies which lead to higher quality outcomes (Farrington-Darby & Wilson, 2006). In most cases, expert performance represents the combination of relevant perceptual, cognitive and behavioural components (Loveday, Wiggins, & Searle, 2014). The contribution of particular components and strategies is likely to be reliant upon their relevance to the nature of the demands in a given setting.

As the research examining expert-novice differences continues to grow, the psychological understanding of what constitutes expertise is becoming increasingly diverse and multidisciplinary (Campitelli, Connors, Bilalic, & Hambrick, 2015). Indeed, a growing body of research evidence highlights that deliberate practice and experience only explain some of the variance in performance in complex domains, and that other characteristics such as the unique strategies employed by certain individuals (i.e., experts) to solve problems are more important in defining expertise (Hambrick, Macnamara, Campitelli, Ullen, & Mosing, 2016).

Expertise arises from knowledge and ability-based factors that can be largely independent of the time spent within a specific domain (Hambrick et al., 2016). Therefore, the progression to expertise is likely to depend on the capacity of individuals to learn, retain and implement the most effective strategies based on situational requirements (Wiggins, Brouwers, Davies, & Loveday, 2014b; Farrington-Darby & Wilson, 2006). This builds on earlier perspectives that highlight the importance of exposure in enabling individuals to acquire critical domain knowledge through learning opportunities in the field (Ericsson & Kintsch, 1995).

The capacity to identify key situational requirements that provide the foundation for building expertise is likely to be reliant upon individuals' ability to identify and utilise essential cues within domain environments. Cues represent associations between features and objects or events that are stored in memory, and are thought to reduce the cognitive demands placed on individuals when making decisions and responding to environmental stimuli (Ericsson & Kintsch, 1995; Chi, Feltovich, & Glaser, 1981; Wiggins, 2014). Cue utilisation involves the identification and utilisation of relevant cues in the environment (e.g., visual weather cues for pilots). This process involves efficient priming of relevant information which facilitates more efficient and effective situational assessment and leads to coordination of appropriate responses (Wiggins et al., 2014b).

Cue utilisation offers an advantage to individuals by enabling the rapid and accurate extraction and application of task-relevant information in specific environments (Weiss & Shanteau, 2003). This process reduces the cognitive load required to achieve a high level of performance and increases the resources available to individuals to deal with highly complex and dynamic variables in any situation (Brouwers, Wiggins, Helton, O'Hare, & Griffin, 2016). In the context of expertise, cue utilisation serves as an adaptive and effective process whereby experts identify and prioritise the extraction of critical information to aid in cognitive processes (i.e., decision making, sense making, problem solving) and performance (e.g., diagnosis) (Shanteau, 1992; Morrison, Wiggins, Bond, & Tyler, 2013; Loveday et al., 2014).

The importance of cue utilisation is reinforced by differences between experts and novices that are evident in various domains. Within sport, expert performers demonstrate a superior ability in identifying visual cues that signify the need to adapt their behaviour and responses during performance (e.g., anticipating opposition actions; Williams & Ford, 2008; Gabbett & Abernethy, 2013). Expert navy technicians also exhibit greater ability to identify and recall radar information to inform situational assessment (Randel, Pugh, & Reed, 1996).

Within medicine, expert physicians show qualitatively different patterns of diagnosis that rely on recognising incident-related cues and patterns (Schubert, Denmark, Crandall, Grome, & Pappas, 2013). In aviation, expert pilots are more likely to attend to critical cues that impact the speed and accuracy of decisions (Schriver, Morrow, Wickens, & Talleur, 2008).

Levels of cue utilisation correlate strongly with performance in a variety of settings. Specifically, individuals with greater levels of cue utilisation are more likely to: identify task-related features and extract them from a specific scenario, distinguish relevant from less relevant features, discriminate between related and unrelated feature-event relationships, and prioritise the acquisition of task-relevant information based on importance (Loveday et al., 2014). Higher levels of cue utilisation are also associated with greater sustained attention and diagnostic performance in power control (Small, Wiggins, & Loveday, 2014; Loveday, Wiggins, Harris, O'Hare, & Smith, 2013a), more efficient skill acquisition and reduced cognitive load in response to novel tasks (Wiggins et al., 2014b; Brouwers et al., 2016), increased perceived expertise and superior error management in software engineering (Loveday et al., 2014), diagnostic accuracy in paediatrics (Loveday, Wiggins, Searle, Festa, & Schell, 2013b), and more decisive flight-related decision-making (Wiggins, Azar, Hawken, Loveday, & Newman, 2014a).

Although the impact of cue utilisation has been examined across multiple domains, much of this research is directed towards technical environments whereby the utilisation of task-specific cues (e.g., weather cues during in-flight decision making) is assumed to be the primary mechanism for facilitating expert performance. However, in many contemporary applied environments, the utilisation of broader social cues may also be an important factor in determining performance. Social cues incorporate any cues that inform social engagements, such as communication-based cues and social norms, and offer information about interpersonal interaction. The utilisation of social cues may also support performance and processes like problem solving and decision making as they differ from task-specific, technical cues that are constrained to certain environments. Therefore, ability to utilise social cues should facilitate expert performance or the progression to expertise alongside domain-specific, technical cues.

The notion that social cues offer utility in applied environments is founded on the premise that individuals differ with respect to their capacity to perceive, interpret and respond to social cues that signify emotions and thoughts held by others (Pickett, Gardner, & Knowles, 2005; Prati, Douglas, Ferris, Ammeter, & Buckley, 2003). Social cues typically take the form of verbal communication, non-verbal communication like facial and body language expression, together with auditory cues such as those signalling disagreement or uncertainty (Riggio, 2006; Auton, Wiggins, Searle, Loveday, & Rattanasone, 2013).

Within environments characterised by time-limited and high-pressure decision-making, prompt and informative communication can rely on the ability of individuals to utilise social cues to inform if, when, and how they interact and engage with others to achieve desired outcomes (Yee, Wiggins, & Searle, 2017). Such cue-based interaction allows individuals to identify optimal opportunities for communication which can often determine the success or incidence of error and failure. This is particularly evident in high reliability environments such as medical emergency and incident response teams, where communication errors, including poor timing and irrelevant content, negatively impact coordination and performance (Svenssion & Andersson, 2006; Lingard et al., 2004), while effective communication is associated with improved performance and more efficient identification of situational parameters (Leonard, Graham, & Bonacum, 2004; McCulloch et al., 2009).

Expertise can arise within different domains, depending upon contextual requirements and whether optimal strategies are targeted towards the utilisation of domain-specific, technical cues, or broader, non-technical, social cues. Yet, research examining the impact of the latter on performance in applied environments is relatively sparse (Yee et al., 2017). In addition, there is an emerging need to empirically examine the relative importance of technical and social forms of cue utilisation within workplace environments where success depends upon a combination of task-specific expertise and expertise in utilising social cues for coordination and communication.

While there is evidence to suggest that technical and non-technical skills are distinct factors contributing to performance in high reliability environments (e.g., anaesthesiology, Gjeraa, Jepsen, Rewers, Ostergaard, & Dieckmann, 2015; paramedics, Von Wyl, Zuercher, Amsler, Walter, & Ummenhofer, 2009), there is also evidence to suggest an overlap between technical and nontechnical skills (Brunckhorst et al., 2015; Riem, Boet, Bould, Tavares, & Naik, 2012). Consequently, it remains unclear how the combination of technical and nontechnical expertise influences performance in different environments. In addition, the assessment of expertise in these studies has depended mainly on subjective ratings instead of more objective, ability-based assessments (e.g., EXPERTise; Wiggins, Harris, Loveday, & O'Hare, 2010).

The present research was designed to examine the relative importance of technical and social cue utilisation within applied environments. The research comprises two separate studies focusing on the power control and football coaching domains. The different domains were selected to enable assessments in settings that were anticipated to differ in their dependence on technical and social cue utilisation. Study 1 examined the relative importance of technical and social cue utilisation in the context of power control. Power controllers completed assessments of both technical and social cue utilisation, and expertise was operationalised through self-ratings of performance as well as current power control job level. Study 2 examined the same premise within the football coaching context, while operationalising expertise through self-ratings of capability and coaching qualification level.

Study 1 Introduction

Study 1 was designed to examine the relative importance of technical and social cue utilisation in the context of power control. Previous research has demonstrated the link between greater technical cue utilisation and diagnostic performance (Loveday et al., 2013a). However, power control was selected since performance in this environment relies heavily on the ability of operators to demonstrate technical capability (e.g., system errors) and non-technical capability (e.g., communication between operators to respond to system errors). Given the incidence of error and importance of communication in mitigating the risk of incidents in high reliability settings (Leonard et al., 2004), power control provided a useful setting to test the predictions of Study 1 due to the reliance on such different capabilities.

Consistent with the methodology employed by previous researchers exploring cue utilisation in power control (Loveday et al., 2014), participants were asked to provide a self-evaluation of their current performance. Although not necessarily indicative of broader workplace performance, self-evaluations provide useful information about cognitive expertise and are associated with work outcomes and peer reviews (Johanna & Van Der Heijden, 2000). In addition, they often represent the sole means of ascertaining levels of confidence and knowledge in the absence of reliable and meaningful performance outcomes developed and employed in organisational settings (Loveday et al., 2014).

It was anticipated that the addition of a measure of social cue utilisation would provide the means to assess the relative importance of both forms of cue utilisation. Specifically, it was hypothesised that:

Hypothesis 1: Higher levels of both technical and social cue utilisation would be associated with higher self-reported performance.

Hypothesis 2: Higher levels of both technical and social cue utilisation would be associated with power controller job level.

Hypothesis 3: Technical cue utilisation would be positively associated with self-reported performance and power controller job level, controlling for the effects of social cue utilisation, and vice-versa.

Study 1 Method

Participants

The participants were recruited from three different power control organisations located in Australia and New Zealand, and were invited to participate due to their direct involvement with power control and transmission operations (e.g., network controllers). A total of 61 power control operators participated in the study, ranging in age from 25 to 60 years (*M* = 43.16, *SD* = 9.43). They comprised a predominantly male sample (96.7%). Participants indicated a range of experience in the power control domain, from 2 to 41 years (*M* = 16.92, *SD* = 11.56). There were no demographic differences based on organisation.

Measures

Technical cue utilisation: Expert Intensive Skills Evaluation (EXPERTise 2.0). EXPERTise 2.0 is a shell software platform that enables the introduction of domain-specific stimuli and content to test behaviour associated with cue utilisation (Wiggins, Loveday, & Auton, 2015). The assessment evaluates performance across four tasks centred on cue-based expertise: the Feature Identification Task, the Feature Association Task, the Feature Discrimination Task, and the Feature Prioritisation Task. To assess technical cue utilisation, a ‘power control’ version of the EXPERTise 2.0 program was used. This version was developed through subject matter expert consultation, cognitive interviews, and critical incident examination, and has been shown to be associated with diagnostic expertise in power control (Loveday et al., 2013a).

The Feature Identification Task (FIT) for the power control version assessed the capacity of respondents to identify the key features within a domain-relevant array. Since domain expertise is tied to the rapid identification of critical cues that inform sense-making and benefit diagnostic performance, the FIT incorporates two different types of stimuli (Loveday et al., 2013a). The first type centres on the need for power controllers to rapidly identify power system faults in a series of single line diagrams, while the second type requires respondents to rapidly identify open circuit breaker alarms in excerpts of alarm lists. Higher levels of technical cue utilisation are characterised by a faster response time (lower response latency).

The Feature Association Task (FAT) is based on the findings that a key characteristic of expertise is the capacity to identify critical feature-event associations, and differentiate between critically related associations and those that are less associated within a particular domain (Morrison et al., 2013; Loveday et al., 2013a). By more effectively identifying the extent to which features and events are associated, experts are more likely to be able to understand the importance of certain environmental cues. In the power control version of EXPERTise 2.0, the FAT includes both related and unrelated feature-event pairings, which respondents are asked to rate in terms of their relatedness on a scale from 1 (*Completely Unrelated*) to 7 (*Completely Related*). Higher levels of technical cue utilisation are characterised by a greater degree of variance in ratings (Morrison et al., 2013).

The Feature Discrimination Task (FDT) involves the evaluation of respondents' capacity to identify and utilise diagnostically-important cues to inform their judgements and decision-making (Weiss & Shanteau, 2003; Pauley, O'Hare, & Wiggins, 2009). Respondents are provided with scenarios describing different power control problems (e.g., weather-related disruptions to electrical infrastructure), with scenarios containing different features that vary in the extent to which they might be informative and useful to guide judgements and decisions. Individuals are asked to review the scenario information, choose a resolution from a list of options, and then rate the extent to which different features helped them to decide on a particular resolution on a scale from 1 (*Not Important at All*) to 10 (*Extremely Important*). Higher levels of technical cue utilisation are characterised by a greater degree of variance in feature ratings, indicating a higher level of feature discriminative capacity (Pauley et al., 2009).

The Feature Prioritisation Task (FPT) is based on the evidence that expertise is often defined by the strategies and approaches taken by experts in comparison to relative non-experts (Wiggins & O'Hare, 1995). Specifically, experts appear to acquire task-related information via features in a highly unique and functional manner. Rather than accessing features in a linear, sequential manner, experts tend to focus on prioritising the features that offer optimal information to assist in their decision-making and judgements (Loveday et al., 2013a). To assess feature prioritisation, the FPT provides respondents with a scenario and a time limit to nominate a resolution. They are provided with a list of feature-event labelled tabs that need to be expanded to uncover the underlying information which offer varying degrees of utility to assist decision-making. The ratio of sequential and non-sequential pairs of tabs that are access provided an assessment of the extent to which features are prioritised. Higher levels of technical cue utilisation are characterised by a less sequential pattern of accessing scenario information (less expert respondents tend to access the scenario information in a more linear fashion through the order in which it is presented in the list of labelled tabs) (Wiggins & O'Hare, 1995).

Social cue utilisation: EXPERTise 2.0. A non-technical cue utilisation version of EXPERTise 2.0 was used to examine social cue utilisation. Comprising the same task structure as the technical version, the social cue utilisation version comprises social and emotional content and scenarios to assess individuals' capability to utilise social cues to inform situational judgements. Social cue utilisation has been shown to differentiate between teams with respect to communication and problem-solving task performance (Yee et al., 2017).

The FIT is used in the social version to assess individuals' capacity to identify critical features and information from visual stimuli. The content focuses on facial expressions and the emotions conveyed through different images of faces, and is presented in two different types. Type 1 of the FIT involves the presentation of single images of faces expressing particular emotions, and requires respondents to identify the emotion being conveyed in each of the images presented to them. Stimuli were chosen from a validated facial expression database that includes seven emotional expressions: anger, disgust, fear, happiness, sadness, surprise, and neutral (Kanade, Cohn, & Tian, 2000). Type 2 of the FIT involves the presentation of an array of three faces expressing emotions, where two of the faces are expressing the same emotion, and one of the faces is expressing a different emotion. Respondents are asked to identify the distinct emotion being expressed by the single face. Higher social cue utilisation is characterised by a greater accuracy when identifying relevant features (Yee et al., 2017).

In the social cue utilisation version of EXPERTise 2.0, the FAT is used to evaluate the capacity to discriminate feature associations that are related (e.g., *smile* and *happy*) from those that are unrelated (e.g., *shrug* and *fear*). Respondents are presented with both related and unrelated feature-event pairings and asked to rate the extent to which pairings are related on a scale from 1 (*Completely Unrelated*) to 7 (*Completely Related*). Higher social cue utilisation is characterised by a higher degree of variance in ratings given by respondents (Yee et al., 2017).

The FDT is used to assess individuals' ability to identify and utilise relevant scenario features to inform their situational judgements and decision making. Specifically, the FDT examines whether individuals are able to discriminate between critical features and those that are less important or meaningful. In the social version of the program, respondents are provided with a scenario detailing social interaction and information about social and emotional cues that are present. They are then asked to select a resolution for the scenario, and rate the extent to which different features aided in their choice of resolution on a scale from 1 (*Not Important at All*) to 10 (*Extremely Important*). Greater social cue utilisation is characterised by greater variance in ratings (Yee et al., 2017).

The FPT evaluates the capacity to prioritise relevant features to inform sense-making. Respondents are provided with a scenario and a limited amount of time to access information that might aid in their choice of resolution of a social situation. The information is presented in a list of tabs that can be expanded by respondents when accessed, and provide varying degrees of utility and relevance to the scenario. Respondents who are more efficient in prioritising the relevant features are more likely to make more sense of the essential scenario features in the limited time available. Higher levels of social cue utilisation are characterised by a less sequential pattern of accessing scenario information, indicating that the method of acquiring information is based on feature prioritisation, rather than the arbitrary way in which information is presented (Yee et al., 2017).

Self-Ratings of Performance. In the absence of objective and reliable indicators of performance within the power control organisations, self-ratings of performance were used to help understand how cue utilisation might be associated with expertise. Consistent with the methodology employed in previous cue utilisation research in power control (Loveday et al., 2014), respondents were asked to self-assess their performance in relation to seven areas. Four of the areas pertained to more technical aspects of their roles (e.g., *In the last week, how well have you performed without mistakes?*), and three of the areas were more relevant to non-technical components (e.g., *In the last week, how well have you handled* *disagreements by compromising and meeting other people half-way?*). The self-rating ranged from *1* (Not well at all) to *5* (Exceptionally well).

Power Controller Job Level. Participants' job level information was collected as part of their demographic data. Participants were classified into one of three job levels based on a review of their job title and the known differences in requirements at each level. Typically, the expectation for performance and expertise differs between job levels, which were assigned as follows: (1) Assistant power controller; (2) Power controller; (3) Power control manager.

Experimental Procedure

Following approval from the Macquarie University Human Research Ethics Committee, power control operators at the three different organisations were briefed separately and invited to participate in the study and given information and consent details. Participants completed a brief demographic questionnaire, a self-assessment of performance, as well as both the technical and social versions of the EXPERTise 2.0 program online in a counter-balanced fashion. Participants were then debriefed upon completion.

Study 1 Results

Statistical Analyses Approach

Participants are typically classified as possessing either *relatively higher* or *relatively lower* levels of cue utilisation based on their performance in EXPERTise 2.0. This is typically the result of a cluster analysis that determines the patterns of performance across the tasks for relative experts and non-experts (Wiggins et al., 2010). Since no previous study has tested the relative contributions of different forms of cue utilisation (i.e., technical and social), the classification of individuals as either lower or higher in cue utilisation has provided a useful means to understand the impact of cue utilisation on performance. For this research, however, it was necessary to operationalise cue utilisation as a continuous variable to enable the examination of the predictions outlined. For both technical and social forms, individuals' scores were standardised for each task, and a grand mean was calculated. Each individual received an aggregated score for both technical and social cue utilisation.

A series of linear regressions were conducted to test whether technical and social cue utilisation would be positively associated with self-reported performance, and whether these associations would remain statistically significant controlling for either form of cue utilisation. In addition, a multinomial logistic regression was carried out to test whether technical and social cue utilisation would be positively associated with power controller job level, and whether these associations would remain statistically significant controlling for either form of cue utilisation. Assumptions of independence, normality, multicollinearity and homoscedacity were examined and met. An alpha level of .05 was set for all tests.

Technical Cue Utilisation

To determine participants' levels of technical cue utilisation, performance data from the FIT, FAT, FDT, and FPT tasks from the power control version of EXPERTise 2.0 were standardised. A grand mean which represented an individual's level of technical cue utilisation was calculated by averaging the standardised scores. The scores for the FIT response time and FPT ratio variables were reversed to ensure that higher scores represented superior performance. The mean non-standardised scores (prior to reverse scoring) for each task are presented in Table 1.

Table 1

Task Performance Information – Technical Cue Utilisation (Non-Standardised Scores)

Task	Non-Standardised Scores
	Mean (*SD)*
FIT: Accuracy (%)	60.30 (16.83)
FIT: Response time (ms)	10069.75 (5152.45)
FAT: Variance	2.19 (.96)
FDT: Variance	5.16 (2.99)
FPT: Ratio (%)	66.93 (23.07)

Note. FIT = Feature Identification Task, FAT = Feature Association Task, FDT = Feature Discrimination Task, FPT = Feature Prioritisation Task.

Social Cue Utilisation

To determine participants' levels of social cue utilisation, performance data from the FIT, FAT, FDT, and FPT tasks from the social version of EXPERTise 2.0 were standardised. A grand mean which represented an individual's level of social cue utilisation was calculated by averaging the standardised scores. The scores for the FPT ratio variable were reversed to ensure that higher scores represented superior performance. The mean non-standardised scores (prior to reverse scoring) for each task are presented in Table 2.

Table 2

Task Performance Information – Social Cue Utilisation (Non-Standardised Scores)

Task	Non-Standardised Scores
	Mean (*SD)*
FIT Static: Accuracy (%)	75.76 (14.48)
FIT Array: Accuracy (%)	55.82 (25.87)
FAT: Variance	2.06 (.81)
FDT: Variance	3.73 (3.59)
FPT: Ratio (%)	80.30 (32.39)

Note. FIT = Feature Identification Task, FAT = Feature Association Task, FDT = Feature Discrimination Task, FPT = Feature Prioritisation Task.

Preliminary Data Analyses

The means, standard deviations, and correlations between the continuous variables in the study are presented in Table 3. The following significant correlations were found: (1) Technical cue utilisation was positively associated with social cue utilisation; (2) Technical self-ratings were positively associated with non-technical self-ratings; (3) Age was positively associated with years of power control experience.

Table 3

Summary of Means, Standard Deviations, and Correlations for Continuous Study Variables

Variables	*M*	*SD*	1	2	3	4	5	6
1. Technical Cue Utilisation	.00	.54	-	-	-	-	-	-
2. Social Cue Utilisation	.00	.57	.54**	-	-	-	-	-
3. SELF RATING: Overall	3.53	.63	-.12	-.22	-	-	-	-
4. SELF RATINGS: Technical	3.96	.48	.03	-.04	.20	-	-	-
5. SELF RATINGS: Non-technical	4.14	.56	.09	-.07	.10	.49**	-	-
6. Age	43.16	9.43	.01	-.25	.13	.19	.23	-
7. Years of Power Control Experience	16.92	11.56	.03	-.06	.08	.18	.11	.71**

Note. ***p* < .01.

The Relationship between Technical and Social Cue Utilisation and Self-Ratings of Performance

Three linear regression analyses were conducted to test the association between technical and social cue utilisation, and self-ratings of performance. In the first regression model, overall self-ratings of performance were regressed on technical and social cue utilisation, with a non-significant effect overall, F (2,58) = 1.49, p = .234, explaining 5.1% of the variance in overall self-ratings of performance. In the second regression model, self-ratings of technical performance were regressed on technical and social cue utilisation, F (2,58) = .19, p = .827, explaining .7% of the variance in self-ratings of technical performance. In the third regression model, self-ratings of non-technical performance were regressed on technical and social cue utilisation, F (2,58) = .76, p = .473, explaining 2.6% of the variance in self-ratings of non-technical performance.

The Relationship between Technical and Social Cue Utilisation and Role Expertise

To examine the relationship between technical and social cue utilisation and role expertise, a multinomial logistic regression was conducted. Technical and social cue utilisation were originally entered into the model in a stepwise fashion. However, neither variable contributed significant unique variance over and above the other in the model. Therefore, both variables were entered into a subsequent model as main effects instead.

In the multinomial logistic regression model containing technical and social cue utilisation as main effects predicting role expertise, the overall model was non-significant, $X^2(4) = 6.53$, p = .163, suggesting that a model with technical and social cue utilisation did not predict role expertise better than the intercept-only model. This was despite the fact the overall model provided a good fit to the data based on a non-significant Goodness-of-Fit figure, *Pearson* X^2 (116) = 119.70, p = .388. The overall model also contributed explained variance of 10.2% in role expertise, based on the *Cox and Snell* statistic.

While the overall model was non-significant, technical cue utilisation was a marginally significant predictor of power controller job level, controlling for social cue utilisation, X^2 (2) = 5.92, p = .052. Individual parameter estimates indicated that technical cue utilisation was a marginally significant predictor of whether power controllers exhibited role expertise at a power control manager or assistant power controller level, B = 2.09, Wald X^2 (1) = 3.70, p = .054. The odds ratio showed that for each unit increase in technical cue utilisation, the change in odds of a power controller exhibiting role expertise at a power control manager level (rather than at an assistant power controller level) is 8.11. In addition, technical cue utilisation was a significant predictor of whether power controllers exhibited role expertise at a power controller or assistant power controller level, B = 1.81, Wald X^2 (1) = 4.63, $p < .05$. The odds ratio showed that, for each unit increase in technical cue utilisation, the change in odds of a power controller exhibiting role expertise at a power controller level (rather than at an assistant power controller level) is 6.08.

Social cue utilisation was a non-significant main effect in the overall model predicting role expertise, controlling for technical cue utilisation, X^2 (2) = 1.95, p = .378. Individual parameter estimates were also non-significant. The overall results of the multinomial logistic regression analysis are presented in Table 4.

Table 4

Multinomial Logistic Regression Results

		95% CI for Odds Ratio		
	B (SE)	Lower	Odds Ratio	Upper
Technical Cue Utilisation				
Power control managers vs. Assistant power controllers	2.09 (1.09)^	.96	8.11	68.56
Power controllers vs. Assistant power controllers	1.81 (.84)*	1.17	6.08	31.52
Power control managers vs. Power controllers	.29 (.85)	.25	1.33	7.09
Social Cue Utilisation				
Power control managers vs. Assistant power controllers	-1.38 (1.02)	.03	.25	1.85
Power controllers vs. Assistant power controllers	-.75 (.80)	.10	.47	2.25
Power control managers vs. Power controllers	-.63 (.78)	.12	.53	2.44

Note: $R^2 = .10$ *(Cox & Snell). Model* $X^2(4) = 6.53$, $p = .163$. *^Marginal sig., *p < .05.*

Study 1 Discussion

Study 1 was designed to examine whether technical and social cue utilisation is associated with self-ratings of performance and job level in the context of power control, and whether both forms of cue utilisation would demonstrate these associations while controlling for the other variable.

The first hypothesis involved the prediction that higher levels of technical and social cue utilisation would be associated with higher self-reported performance, and the third hypothesis involved the prediction that these associations would be exhibited while controlling for the effects of the different form of cue utilisation. The findings did not provide support for these hypotheses. Despite distinguishing specific components of performance through technical and non-technical performance, technical and social cue utilisation did not correlate with self-reported performance.

The second and third hypotheses also predicted that higher levels of technical and social cue utilisation would be associated with power controller job level, while controlling for the effects of one another. While the overall model was non-significant, a marginally significant effect was found for technical cue utilisation in predicting job level. Specifically, higher levels of technical cue utilisation increase the odds of a power controller being assigned a higher job level (i.e., power control manager rather than an assistant power controller).

The results from Study 1 highlight that self-reported performance and role expertise may not be associated with technical and social cue utilisation, although this may be due to limitations in the criterion examined. While the results from Study 1 did not provide any significant findings to support the research hypotheses, it provided an examination of the importance of technical and social cue utilisation in an applied environment. The sample may have also been limited with respect to variability in underlying cue utilisation capacity.

Study 2 was designed to address the limitations of Study 1 by using an alternative domain in football coaching. A different domain was selected with specific focus on the well-documented reliance on expert-novice differences in differentiating football coaches, and the reliance of performance on both technical and social capabilities within these contexts.

Study 2 Introduction

Study 2 was designed to test the relative impact of technical and social cue utilisation in a setting where performance would be more reliant upon both technical and social capability. It was anticipated that a less technical and systems-based environment would enable further testing of the research predictions in the first study. Consistent with Study 1, participants in Study 2 completed both a technical and social version of EXPERTise 2.0. However in Study 2, participants were football coaches completing a football coaching version as a measure of technical cue utilisation. The aim of Study 2 was to examine the relative importance of technical and social cue utilisation in a domain where performance should be more dependent upon the capacity to draw on both domain-specific, technical cues, as well as broader, social cues. Study 2 builds on Study 1 by defining expertise through qualification level, which is determined through assessments of performance and capability at different levels. This provided an alternative means of examining the relationship between cue utilisation and expertise. This follows from previous research highlighting the link between perceptual-cognitive skills training in sport environments and applied environments, including the military context (Ward et al., 2008).

Given the relatively large body of research examining sport athlete expertise (e.g., rugby league: Johnston & Morrison, 2016; football: Lorains, Ball, & MacMahon, 2013), the importance of anticipatory skills and perceptual-cognitive ability is well-established (Williams, Ford, Eccles, & Ward, 2011). Indeed, meta-analytic evidence across different sports indicates a clear difference between experts and non-experts in relation to how effectively they identify perceptual cues and respond in terms of accuracy and efficiency (Mann, Williams, Ward, & Janelle, 2007). Less is known, however, about the extent to which similar expert characteristics and strategies like cue perception may play a role in the performance of officials and coaches. One example is game officials, where studies tend to focus on describing expertise without examining how such capability might impact on performance (e.g., Schweizer, Plessner, Kahlert, & Brand, 2011; Plessner, Schweizer, Brand, & O'Hare, 2009).

Coaching has been a topic of increased interest given its impact on the experience and performance of athletes (Ford, Coughlan, & Williams, 2009). Typically, coaching expertise is defined as the capacity to draw on professional, interpersonal and intrapersonal skills, and knowledge to improve athlete outcomes (Cote & Gilbert, 2009). From a measurement perspective, coaching expertise has been operationalised as effectiveness in: solving game-related problems, player motivation and management (Hagemann, Strauss, & Busch, 2008), as well as superior decision-making strategies and outcomes (Ford et al., 2009). Yet, consistent with expertise in applied settings, a comparison between the relative importance of technical and social cue utilisation in such a setting has not been examined previously. This study targeted a sample of football coaches nationally accredited within Australia at different levels of qualification. Specifically, it was hypothesised that:

Hypothesis 4: Higher levels of both technical and social cue utilisation would be associated with higher self-reported capability.

Hypothesis 5: Higher levels of both technical and social cue utilisation would be associated with superior qualification level.

Hypothesis 6: Technical cue utilisation would be positively associated with self-reported capability and qualification level, controlling for the effects of social cue utilisation, and vice-versa.

Study 2 Method

Participants

Participants were nationally accredited football coaches within Australia, and were invited to participate during qualification courses run by the national football coaching accreditation body in Australia. Courses were conducted in capital cities across Australia in five different states (Australian Capital Territory, New South Wales, Queensland, South Australia, and Victoria). A total of 70 football coaches participated, representing three different levels of qualification (Level A = 31.4%, Level B = 45.7%, Level C = 22.9%). The sample varied in age, ranging from 22 to 63 years (*M* = 39.20, *SD* = 9.34), together with the number of years of experience as a football coach, ranging from 0[1] to 40 years (*M* = 10.91, *SD* = 8.24). Participants were all male.

Measures

Technical cue utilisation: EXPERTise 2.0. The shell-based nature of EXPERTise 2.0 enabled the development of a football coaching version containing stimuli from the football coaching domain. This version was developed through subject matter expert consultation and piloted with senior national football coaches to ensure the appropriateness of content. Consistent with Study 1, the football coaching version of EXPERTise 2.0 comprised four tasks: The Feature Identification Task (FIT), Feature Association Task (FAT), Feature Discrimination Task (FDT), and Feature Prioritisation Task (FPT).

The FIT consisted of two different tasks. First, respondents viewed short clips involving a football team in ball possession, and were then asked to identify, as quickly as possible, breakdowns in team formation (e.g., a player out of position). Second, respondents were presented with short clips where a player is about to pass the ball to another player. They are asked to correctly identify the player who is about to receive the ball from three different options. Higher levels of cue utilisation were characterised by

[1] Three participants indicated less than 1 year of experience.

faster response times in the first task type, and the more accurate identification of features (pass receiver) in the second task type.

In the FAT, respondents viewed both related and unrelated pairs of football-related terms and were asked rate their relatedness on a scale from 1 (*Completely Unrelated*) to 7 (*Completely Related*). Higher levels of cue utilisation are characterised by greater variance in ratings of relatedness.

The FDT involved two scenarios describing football management problems, including choosing players to substitute into a game and changing the formation of the team in response to changing game conditions. Consistent with the power control version of EXPERTise 2.0, respondents review the scenario information, choose a resolution, and then rate how important scenario features were in helping them decide on a scale from 1 (*Not Important at All*) to 10 (*Extremely Important*). Higher levels of cue utilisation are characterised by greater variance in feature ratings.

The FPT required respondents to review a scenario involving preparations for an upcoming football game in which they are involved. Part of this scenario is the need to make a decision about the best player to bring into the team from several player options. In this task, respondents are given a short amount of time and a list of information contained in unique, feature-labelled tabs about the different players. These tabs offer different features for respondents to consider in their decision. The ratio of sequential and non-sequential pairs of tabs that are access provided an assessment of the extent to which features are prioritised. Higher levels of cue utilisation are characterised by less sequential patterns of accessing scenario information.

Social cue utilisation: EXPERTise 2.0. Consistent with Study 1, the social cue utilisation version of EXPERTise 2.0 was used to evaluate social cue utilisation in football coaches.

Self-Ratings of Capability. Participants were asked to self-assess themselves in relation to overall performance in their current coaching position, their overall knowledge, as well as their overall skills and abilities. The self-rating ranged from *1* (Well below average) to *5* (Much higher than average).

Qualification Level. As part of the demographic data collected, national football coaches provided their level of national coaching qualification. In this sample, football coaches presented at three different levels: A, B, and C license. In Australia, these qualification levels are used as a formal recognition of coaches' levels of competency and capability with respect to a nationally accredited curriculum. Each license course includes practical face-to-face workshops that run over a week, as well as theoretical and knowledge-based components (Football Federation Australia, 2017). Football coaches must pass as competent with respect to the evaluation criteria at each license, which is determined via a formal assessment process. A license is the highest level of qualification, while C license is the lowest.

Experimental Procedure

Football coaches were invited to participate and provide responses to study measures. Data collection occurred during football coach training courses carried out across Australia. For each training course, participants were briefed on the research and provided information and consent forms as part of the research. Participants then completed a brief demographic questionnaire, a self-assessment of performance, as well as both the technical and social versions of the EXPERTise 2.0 program online in a counter-balanced fashion. Participants were then debriefed upon completion.

Study 2 Results

Statistical Analyses Approach

Consistent with the approach in Study 1, individuals' scores for the technical and social cue utilisation measures were standardised for each task, and a grand mean was calculated. Each individual received a grand score for both technical and social cue utilisation. The series of linear and multinomial logistic regression analyses conducted in Study 1 were repeated for Study 2.

Technical Cue Utilisation

To determine participants' levels of technical cue utilisation, performance data from the FIT, FAT, FDT, and FPT tasks from the football coaching version of EXPERTise 2.0 were standardised. A grand mean which represented an individual's level of technical cue utilisation was calculated by averaging the standardised scores. The scores for the FIT response time and FPT ratio variables were reversed to ensure that higher scores represented superior performance. The mean non-standardised scores (prior to reverse scoring) for each task are presented in Table 5.

Table 5

Task Performance Information – Technical Cue Utilisation (Non-Standardised Scores)

Task	Non-Standardised Scores
	Mean (*SD*)
FIT2: Accuracy (%)	36.04 (12.13)
FIT: Response time (ms)	14626.52 (9112.01)
FAT: Variance	5.36 (1.71)
FDT: Variance	4.98 (3.19)
FPT: Ratio (%)	58.59 (35.96)

Note. FIT = Feature Identification Task, FAT = Feature Association Task, FDT = Feature Discrimination Task, FPT = Feature Prioritisation Task.

Social Cue Utilisation

To determine participants' levels of social cue utilisation, performance data from the FIT, FAT, FDT, and FPT tasks from the social version of EXPERTise 2.0 were standardised. A grand mean which represented an individual's level of social cue utilisation was calculated by aggregating the standardised scores. The scores for the FPT ratio variable were reversed to ensure that higher scores represented superior performance. The mean non-standardised scores (prior to reverse scoring) for each task are presented in Table 6.

Table 6

Task Performance Information – Social Cue Utilisation (Non-Standardised Scores)

Task	Non-Standardised Scores
	Mean (*SD*)
FIT Static: Accuracy (%)	75.84 (14.32)
FIT Array: Accuracy (%)	59.36 (26.97)
FAT: Variance	2.04 (2.17)
FDT: Variance	3.77 (2.91)
FPT: Ratio (%)	80.19 (36.16)

Note. FIT = Feature Identification Task, FAT = Feature Association Task, FDT = Feature Discrimination Task, FPT = Feature Prioritisation Task.

Preliminary Data Analyses

The means, standard deviations, and correlations between the continuous variables in the study are presented in Table 7. The following significant correlations were found: (1) Overall self-ratings were positively associated with technical and social cue utilisation; (2) Self-ratings of knowledge were positively associated with technical cue utilisation and overall self-ratings; (3) Self-ratings of skills and abilities were positively associated with technical and social cue utilisation, as well as overall self-ratings and self-ratings of knowledge; (4) Years of experience was positively associated with self-ratings of skills and abilities as well as age.

Table 7

Summary of Means, Standard Deviations, and Correlations for Continuous Study Variables

Variables	*M*	*SD*	1	2	3	4	5	6
1. Technical Cue Utilisation	.00	.48	-	-	-	-	-	-
2. Social Cue Utilisation	.00	.52	.18	-	-	-	-	-
3. SELF RATING: Overall	3.74	.61	.31**	.24*	-	-	-	-
4. SELF RATING: Knowledge	3.77	.59	.26*	.09	.72**	-	-	-
5. SELF RATINGS: Skills & Abilities	3.84	.55	.25*	.29*	.82**	.72**	-	-
6. Age	39.20	9.34	-.03	-.08	.05	.09	.09	-
7. Years of Football Coaching Experience	10.91	8.24	.16	.21	.17	.14	.25*	.58**

Note. ***p* < .01, **p* < .05.

The Relationship between Technical and Social Cue Utilisation and Self-Ratings of Capability

Three linear regression analyses were conducted to test the association between technical and social cue utilisation, and self-ratings of capability. In the first regression model, overall self-ratings of performance were regressed on technical and social cue utilisation, with a statistically significant result, F (2,69) = 4.92, p = .01, explaining 12.8% of the variance in overall self-ratings of performance. The relationship between technical cue utilisation and overall self-ratings of performance was statistically significant, controlling for social cue utilisation, β = .27, p = .022.

In the second regression model, self-ratings of football coaching knowledge were regressed on technical and social cue utilisation, with a non-significant result, F (2,69) = 2.47, p = .093, explaining 6.9% of the variance in self-ratings of knowledge. In the third regression model, self-ratings of skills and abilities were regressed on technical and social cue utilisation, with a statistically significant result, F (2,69) = 4.85, p = .011, explaining 12.7% of the variance in self-ratings of knowledge. The relationship between social cue utilisation and self-ratings of knowledge was statistically significant, controlling for technical cue utilisation, β = .26, p = .030.

The Relationship between Technical and Social Cue Utilisation and Qualification Level

To examine the relationship between technical and social cue utilisation and qualification level, a multinomial logistic regression was conducted. Both variables were entered into the model as main effects. In the multinomial logistic regression model containing technical and social cue utilisation as main effects predicting qualification level, the overall model was statistically significant, X^2 (4) = 27.18, p < .001, suggesting that a model with technical and social cue utilisation significantly predicts qualification level in football coaches. The model also demonstrated good fit to the data based on significant Goodness-of-Fit figure, *Pearson* X^2 (134) = 144.67, p = .250. The overall model also contributed explained variance of 32.2% in qualification level, based on the *Cox and Snell* statistic.

Technical cue utilisation was a significant predictor of qualification level, controlling for social cue utilisation, X^2 (2) = 11.46, p = .003. Individual parameter estimates indicated that technical cue utilisation was a significant predictor of whether football coaches were qualified at the A or C level, B = 2.95, Wald X^2 (1) = 8.38, p = .004. The odds ratio showed that for each unit increase in technical cue utilisation, the change in odds of a football coach being qualified at the A level (rather than at the C level) is 19.18. In addition, technical cue utilisation was a significant predictor of whether football coaches were qualified at the A or B level, B = 1.70, Wald X^2 (1) = 4.85, p = .028. The odds ratio showed that, for each unit increase in technical cue utilisation, the change in odds of a football coach being qualified at the A level (rather than at the B level) is .18.

Social cue utilisation was also a significant predictor of qualification level, controlling for technical cue utilisation, X^2 (2) = 11.83, p = .003. Individual parameter estimates indicated that social cue utilisation was a significant predictor of whether football coaches were qualified at the A or C level, B = 1.74, Wald X^2 (1) = 3.98, p = .046. The odds ratio showed that for each unit increase in social cue utilisation, the change in odds of a football coach being qualified at the A level (rather than at the C level) is 5.68. In addition, social cue utilisation was a significant predictor of whether football coaches were qualified at the A or B level, B = 2.15, Wald X^2 (1) = 8.63, p = .003. The odds ratio showed that, for each unit increase in social cue utilisation, the change in odds of a football coach being qualified at the A level (rather than at the B level) is .12. The overall results of the multinomial logistic regression analysis are presented in Table 8.

Table 8

Multinomial Logistic Regression Results

		95% CI for Odds Ratio		
	B (SE)	Lower	Odds Ratio	Upper
Technical Cue Utilisation				
A-License vs. C-License	2.95 (1.02)**	2.59	19.18	141.75
B-License vs. C-License	1.25 (.84)	.67	3.50	18.29
A-License vs. B-License	1.70 (.77)*	.03	.12	.49
Social Cue Utilisation				
A-License vs. C-License	1.74 (.87)*	1.03	5.68	31.25
B-License vs. C-License	-.41 (.73)	.16	.66	2.78
A-License vs. B-License	2.15 (.73)**	.03	.12	.49

Note: R^2 *= .32 (Cox & Snell). Model* $X^2(4) = 27.18$, $p < .001$. $^{**}p < .01$, $^{*}p < .05$.

Study 2 Discussion

Study 2 enabled the assessment of the relationship between cue utilisation and different measures of domain expertise with a sample of football coaches. It was anticipated that the football coaching domain would provide a more suitable domain than power control within which to examine the contribution of technical and social cue utilisation, given the reliance of football coach expertise on both technical and social components (e.g., player management).

In addition, and consistent with the predictions made, technical and social cue utilisation were associated with higher self-ratings of overall performance together with skills and abilities. In particular, technical cue utilisation was positively associated with overall self-ratings when controlling for social cue utilisation, suggesting that superior utilisation of technical cues may be associated with higher self-ratings of performance. Further, social cue utilisation was positively associated with self-ratings of skills and abilities when controlling for technical utilisation, suggesting that superior utilisation of social cues may be associated with higher self-ratings of skills and abilities held by football coaches.

The inclusion of both technical and social cue utilisation in a model predicting qualification level was statistically significant, indicating that both forms of cue utilisation are uniquely associated with the capability levels of football coaches. From a technical perspective, the odds of being assessed as capable at the highest level of coaching qualification (rather than the moderate and lowest levels) increased with higher levels of technical cue utilisation. This suggests that the ability to utilise technical cues is related to the assessed capability of football coaches.

From a social perspective, the odds of being assessed as capable at the highest level of coaching qualification (rather than the moderate and lowest levels) also increased with higher levels of social cue utilisation. This suggests that the ability to utilise social cues is also related to the assessed capability of football coaches and is unique from the contribution of technical cue utilisation. It is important to note, however, that the reported odds ratio for social cue utilisation was smaller than that of technical cue utilisation.

General Discussion

While definitions of expertise continue to expand due to increasingly diverse, multidisciplinary research and practice endeavours, research into the factors that promote progression to expertise are less common (Campitelli et al., 2015). Given that expertise tends to arise from knowledge and ability-based factors that can be independent of time and experience, the present research was designed to contribute to the literature by focusing on understanding the factors that might be associated with expertise in applied environments

(Hambrick et al., 2016). The present research provides a novel exploration of the relative importance of technical and social cue utilisation in two different domains: power control and football coaching.

Previous research in highly technical environments like power control has focused on the role of domain-specific, technical expertise in performance. In these contexts, individuals who are more effective at utilising task-relevant cues tend to be more effective at diagnosing problems and coordinating responses (Wiggins, 2014; Loveday et al., 2013a). Similarly, football coaching expertise is typically associated with the capacity to identify and utilise cues signifying task-critical features and events like opposition formation changes (Cote & Gilbert, 2009). However, research has yet to examine the importance of social cue utilisation in these environments where performance should be reliant on both technical and social components. It was anticipated that greater technical and social cue utilisation would be associated with expertise in two different domains.

In Study 1, there were no statistically significant results when examining the associations between technical and social cue utilisation and markers of expertise within power control. These results are surprising given that previous research has shown that levels of cue utilisation are positively associated with self-reported expertise, nominations of expertise by colleagues, and superior performance (Loveday et al., 2014). Indeed, technical cue utilisation in power control has also differentiated expert from non-expert practitioners in problem diagnosis (Loveday et al., 2013a). However, the use of self-ratings and job level in the present study as markers of expertise may have been impacted by the degree of variability inherent in self-assessments of performance and the restriction of range in the job levels reported by the sample (Donaldson & Grant-Vallone, 2002). In addition, the findings from Study 1 suggest that cue utilisation may be more effective in predicting more technically-based, objective criteria associated with expertise.

Study 2 focused on an alternative domain where capability and performance are more dependent upon a combination of technical and social skills, and also expanded the scope of self-ratings to capability, instead of performance in isolation. It was anticipated that this would enable a broader assessment of the association between cue utilisation and self-ratings. The results indicated that football coaches' levels of technical and social cue utilisation were positively associated with self-ratings of performance skills and abilities. It is possible that there may be advantages offered to football coaches who are more effective in utilising cues in technical and social contexts. It is likely that these coaches may benefit from a higher degree of confidence and mastery over their coaching capabilities, providing greater opportunity to improve the performance of those they coach (Schweizer et al., 2011). Importantly, this was a key difference between Study 1 and Study 2 results, reinforcing the unique characteristics of both domains, and highlighting the likely greater dependence of football coaching expertise on social cue utilisation.

The outcomes of Study 2 also revealed that technical and social cue utilisation both impacted the likelihood of football coaches being assessed as capable and qualified at specific levels of expertise. Importantly, these associations were evident having controlled for the effects of the other form of cue utilisation. The central finding revealed that, as levels of technical and social cue utilisation increase, the odds of football coaches being assessed as capable at higher levels of qualification also increase. This result builds on existing research focusing on the different perceptual and cognitive capabilities and strategies between experts and non-experts within sport (Mann et al., 2007) by indicating that football coaches' underlying ability to utilise cues may be an essential component of expertise. Furthermore, cue utilisation may serve as a foundation for football coaches to demonstrate the necessary levels of expertise required to achieve higher levels of qualification, for instance by reducing cognitive demands during decision-making, or by promoting a focus on critical features in a problem-solving situation (Wiggins et al., 2014a).

Study 2 provides a novel contribution to the research around expertise by highlighting that the combination of technical and social cue utilisation provides a useful prediction of football coaches' levels of expertise. This is also the first study to show that the importance of cue utilisation depends upon the specific type of cues involved, and that technical and social cue utilisation provide unique contributions to expertise. In applied environments like football coaching, the results do also suggest that technical cue utilisation may be more influential in determining expertise than social cue utilisation.

Although further research is needed to further understand the interplay of technical and social cue utilisation and its impact on performance, this is the first study to examine the relative importance of technical and social cue utilisation in applied environments. This research also provides a foundation for future research to explore how differences in technical and social cue utilisation might impact on performance, addressing the need for studies that define expertise, but also understand the factors associated with and impacted by it (Plessner et al., 2009).

Implications of Findings

The present study is the first to test the relative contributions of technical and social cue utilisation to expertise in two different applied environments. Therefore, the results have important theoretical implications for both the expertise and cue utilisation literature. In particular, the inclusion of technical and social assessments is essential when examining the factors that promote expertise in environments where performance depends upon technical and social components.

The present study also represents a novel attempt to better understand the mechanisms that might facilitate the progression to expertise. While the findings suggest that the capacity to utilise cues of a technical and social nature is associated with expertise in applied environments, further research is needed to explore whether this capacity enables processes that support the superior decision-making and problem solving exhibited by experts compared to novices (Hambrick et al., 2016). For instance, experts tend to rely on cognitive processes that promote the recognition and retention of meaningful relationships in environments the typically encounter (Campitelli et al., 2015). Previous research testing such an explanatory mechanism within ad hoc teams has identified the importance of shared frameworks of knowledge about the key parameters in a given situation or domain, known as shared mental models (see Mohammed & Dumville, 2001), for communication and performance (Yee et al., 2017). However, there remains a need to extend this research by focusing on broader domains where experts operate.

From a practitioner perspective, this research provides a useful starting point to understand expertise in applied environments, rather than simply describing it. The findings suggest that, for football coaches, expertise may be partly attributed to coaches' underlying ability to utilise technical and social cues to aid problem solving, sense-making, decision making and performance. This has important implications for the development of football coaches at various levels of expertise.

Limitations and Future Research

The current research would benefit from greater replication and extension of the methodology applied to provide more insights into the relative importance of technical and social cue utilisation. In addition, the results from both studies highlight the need to incorporate more objective indicators of expertise. This would extend the findings from the present research and provide a more generalisable assessment of the impact of technical and social cue utilisation in different expert domains. Future research using more diverse samples and expert domains would also extend the generalisability of existing findings.

Conclusion

The growing focus on the factors that underpin expertise in applied environments provides both researchers and practitioners with essential insights into how to identify, develop and extend expertise. The present study was designed to examine the relative importance of technical and social cue utilisation in expert domains. The results indicate that the ability to utilise cues of a technical and social nature may be associated with markers of expertise in applied environments. Importantly, this research is the first to test whether both forms of cue utilisation capacity exhibit unique contributions to definitions of expertise.

Paper 3 References

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General Discussion

Chapter Seven: General Discussion

Research Outcomes

Ad hoc teams and individuals operating in applied environments face highly dynamic demands that can be complex, arise rapidly, as well as evolve and change, often at short notice (Tannenbaum, Mathieu, Salas, & Cohen, 2012). Within these contexts, decision-making and coordination needs to occur rapidly and effectively to ensure that individuals and teams can overcome complex demands and achieve the desired performance outcomes.

Central to the coordination and performance of teams are the cognitive processes that enable team members to identity, organise, and share information and understanding of a given scenario (Hinsz, Tindale, & Vollrath, 1997). Referred to as team cognition (DeChurch & Mesmer-Magnus, 2010), these cognitive processes promote the development of shared mental models among team members that represent knowledge frameworks relating to a specific setting (Mohammed & Dumville, 2001).

Communication operates as an essential strategy that promotes the development of shared mental models in teams (Mohammed et al., 2010). In particular, the communication of individuals' own understanding of a situation provides the opportunity for teams to form shared knowledge frameworks that are essential to coordination, communication, and task performance (DeChurch & Mesmer-Magnus, 2010).

The development of situational understanding at an individual level relies on the capacity for accurate situation assessment, which involves building a clear understanding of the critical information available in a given scenario (Wellens, 1993). Situation assessment is driven by the ability to identify and utilise cues that represent associations between features and events in the environment (Klein, 1993; Chi, Feltovich, & Glaser, 1981). Brunswik's Lens Model (1955) suggests that situation assessment depends on individuals' capacity to accurately weight the utility of cues that they observe in the environment.

The ability to utilise cues in an environment differs substantially among individuals, yet the process of cue utilisation is an essential component of formulating situation assessment. The Recognition-Primed Decision (RPD) model (Klein, 1993, 2003) suggests that, in the context of situation assessment, individuals will either: (1) engage in a rapid, nonconscious method of information processing that draws on memory-based recognition to make decisions: or (2) engage in a deliberate, conscious method that relies on mentally simulating response options based on available environmental information.

Within ad hoc teams, individuals must recognise and reconcile any differences in the assessment and identification of critical information to ensure the efficient and effective coordination and performance. While communication represents a central mechanism by which these differences can be identified and considered, there remains a lack of empirical evidence highlighting the precise mechanism that enables individuals to identify optimal opportunities to clarify and share critical information to support team interaction.

The overall aim of this research program was to investigate whether the process of social cue utilisation represents a key strategy that impacts ad hoc teams and individuals operating in dynamic group environments by facilitating communication and shared cognitive states. In addition, this research program was designed to examine the relationship between social cue utilisation and different types of communication strategies and perceptions of workload, and explore the relative importance of social and technical cue utilisation in applied environments. Three research papers were presented to examine these aims, and the specific research questions tested are summarised in Figure 3.1.

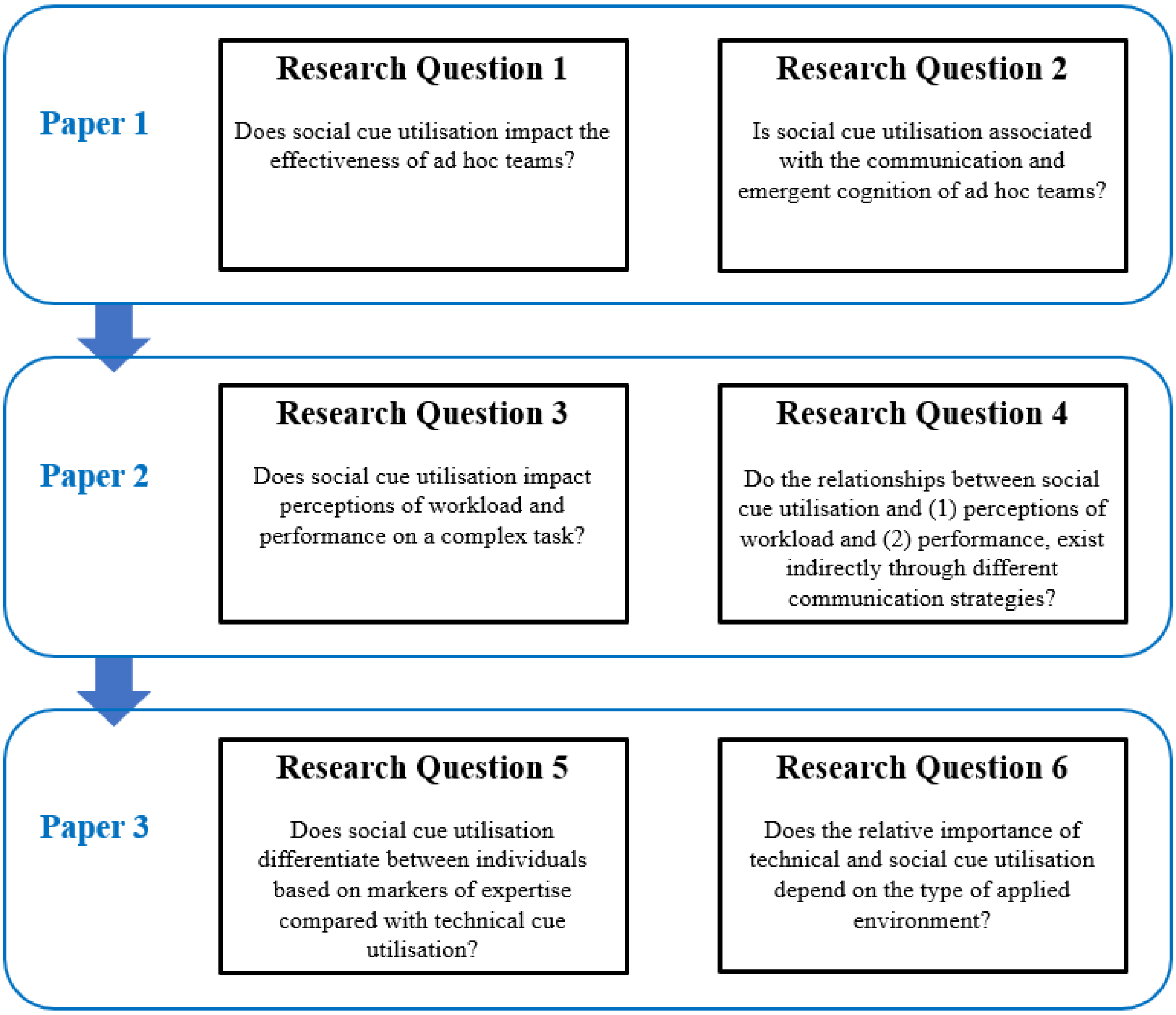

Figure 3.1. Research program questions with associated papers.

Research Question 1: *Does social cue utilisation impact the effectiveness of ad hoc teams?*

Paper 1 outlined a novel empirical investigation into the factors that promote ad hoc team effectiveness. Using a quasi-experimental design, the central aims of Paper 1 were to establish whether social cue utilisation differed amongst individuals, and whether the utilisation of social cues was associated with ad hoc team performance. Based on previous research indicating that cue utilisation performance varies in different performance domains (e.g., Loveday, Wiggins, Harris, O'Hare, & Smith, 2013a; Loveday, Wiggins, Searle, Festa, & Schell, 2013b; Wiggins, Azar, Hawken, Loveday, & Newman, 2014a), together with evidence to the effect that individuals differ in the extent to which they can interpret social cues (Picket et al., 2005), it was anticipated that teams would differ in their level of social cue utilisation. Given the importance of social cues in aiding communication and coordination efforts (Boone et al., 2008), it was also hypothesised that social cue utilisation would be positively associated with ad hoc team performance.

The participants were classified as possessing either lower or higher levels of social cue utilisation based on their responses to four different tasks assessing their ability to: (1) identify key features; (2) distinguish between related and unrelated feature-event pairings; (3) discriminate between relevant and non-relevant features in the context of problem resolution; and (4) prioritise the acquisition of key information during a decision-making scenario. Consistent with prior research involving the assessment of cue utilisation, individuals with higher social cue utilisation demonstrated significantly greater performance on all four tasks.

To test the prediction that social cue utilisation would be associated with the performance of ad hoc teams, participants were categorised into dyads, with teams comprising individuals with the same approximate level of social cue utilisation. The results from Paper 1 indicated that ad hoc dyads comprising individuals with higher levels of social cue utilisation exhibited superior performance on a team-based problem-solving task compared with ad hoc dyads comprising individuals with lower levels of social cue utilisation. The study described in Paper 1 is the first to empirically examine the impact of social cue utilisation on ad hoc team effectiveness.

Research Question 2: *Is social cue utilisation associated with the communication and emergent cognition of ad hoc teams?*

Given that the capacity to utilise social cues is expected to enable team members to identify and capitalise on optimal opportunities to communicate and share their assessment and understanding of a situation, it was hypothesised that social cue utilisation would be associated with ‘closing the loop’ communication and the development of a shared mental model. It was also hypothesised that social cue utilisation would exhibit a positive, indirect effect on ad hoc team performance through ‘closing the loop’ communication and the development of a shared mental model.

The results from Paper 1 indicated that social cue utilisation was positively associated with both closing the loop communication and the development of a shared mental model. This suggests that, in the context of ad hoc teams, a greater capacity to utilise social cues may allow team members to respond to opportunities to clarify information to support coordination and communication (Schillinger et al., 2003). The results also indicated that higher levels of social cue utilisation were associated with the development of shared mental models, suggesting that the ability to utilise social cues may enable ad hoc team members to achieve a shared understanding of situational requirements.

The relationship between social cue utilisation and both communication and shared mental development was also demonstrated while controlling for measures of emotional intelligence and non-verbal reasoning ability. In addition to establishing the independence of social cue utilisation as a construct of importance in the context of ad hoc team processes, social cue utilisation exhibited a stronger relationship with communication and the development of a shared mental model than either control measures. Specifically, neither emotional intelligence nor non-verbal reasoning ability were predictors of ad hoc team outcomes in a model including social cue utilisation. While the weaker relationships between emotional intelligence and non-verbal reasoning ability with ad hoc team outcomes may be explained by the nature of the task itself, prior research has tended to examine the utility of these two constructs in teams that have been less dynamic in their nature and the demands they face. In addition, prior research has not incorporated social cue utilisation into statistical models examining ad hoc team performance. Therefore, it is also possible that the capacity to interpret and utilise social cues may be a uniquely important factor impacting ad hoc team outcomes.

An indirect effect of social cue utilisation on ad hoc team performance through closing the loop was also evident, suggesting that ad hoc teams with higher levels of social cue utilisation were more likely to close the loop more frequently and demonstrate subsequent superior performance during a team-based problem-solving task. This outcome provided initial support for an explanatory mechanism describing how higher levels of social cue utilisation might promote greater ad hoc team performance. There was no statistically significant relationship evident between shared mental model development and ad hoc team performance. This result may indicate that, within ad hoc team settings, performance may not depend upon the capacity to develop a shared mental model, particularly in the context of time-limited, problem-solving tasks.

Research Question 3: *Does social cue utilisation impact perceptions of workload and performance on a complex task?*

Paper 2 outlined a quasi-experimental study that examined the relationship between social cue utilisation and ad hoc team outcomes associated with the completion of a complex, higher-fidelity team task. In addition, the inclusion of perceptions of workload as an outcome measure was intended to test whether the capacity to utilise cues is associated with a reduction in cognitive load (Wiggins, 2012; Ericcson & Kintsch, 1995). It was hypothesised that social cue utilisation would be positively associated with the performance of ad hoc teams. Based on prior evidence concerning the relationship between cue utilisation and cognitive load (Brouwers, Wiggins, Helton, O’Hare, & Griffin, 2016), it was also hypothesised that greater social cue utilisation would be associated with perceptions of lower workload.

The results provided evidence to indicate that ad hoc teams comprising members with higher levels of social cue utilisation demonstrated significantly greater performance on a complex, high-fidelity team task, and reported lower perceived workload in response to task demands. These results were consistent with findings from earlier research into social cue utilisation and ad hoc team performance (Paper 1; Yee, Wiggins, & Searle, 2017), together with models of cue-based situation assessment that highlight the role of cue utilisation in freeing up cognitive resources for task-based responses (Klein, 2003).

Research Question 4: *Do the relationships between social cue utilisation and (1) perceptions of workload and (2) performance, exist indirectly through different communication strategies?*

Paper 2 also incorporated the evaluation of whether social cue utilisation impacts ad hoc team performance and workload perceptions indirectly through team-based communication. Given the increased complexity of the team-based task, it was anticipated that closing the loop communication would not be sufficient to ensure that key information was shared and utilised to develop a comprehensive situation assessment. As a consequence, two different forms of communication were measured: (1) closing the loop, and (2) informative responding which focuses on the provision and clarification of information instead of simple acknowledgements (Bowers, Jentsch, Salas, & Braun, 1998; Mesmer-Magnus & DeChurch, 2009).

The results indicated that ad hoc teams comprising individuals with higher levels of social cue utilisation were more likely to engage in a greater frequency of closing the loop and informative responding communication. These results replicate the findings in Paper 1 (Yee et al., 2017) and provide further support for the proposition that information sharing in the context of team performance is likely due to the benefits that it offers team members through the communication and understanding of key information (Hunt, Shilkofski, Stavroudis, & Nelson, 2007).

There were no statistically significant, indirect effects of social cue utilisation on ad hoc team performance through either closing the loop nor informative responding communication strategies. This suggests that, in the context of a high-fidelity, applied team task, social cue utilisation may have a direct relationship with ad hoc team performance. It is also possible that due to increased task complexity, different communication strategies may have been employed by ad hoc teams.

A statistically significant, indirect effect of social cue utilisation was evident on workload perceptions through informative responding, suggesting that ad hoc teams comprising individuals with higher levels of social cue utilisation are more likely to communicate by sharing information. They also experience lower perceived workload during a complex simulation task. This finding is likely due to the fact that team members with a greater capacity to utilise social cues have a greater capacity to identify opportunities to provide information that aids coordination and minimises workload, a finding consistent with prior research (Khawaja, Chen, & Marcus, 2012; Kolbe et al., 2012; Brouwers et al., 2016).

Research Question 5: *Does social cue utilisation differentiate between individuals based on markers of expertise compared with technical cue utilisation?*

Given the evidence for the relationship between social cue utilisation and ad hoc team performance in Paper 1 and Paper 2 within experimental settings, Paper 3 outlined the examination of the impact of social cue utilisation in ad hoc applied settings. Typically, expert performance in applied settings is the product of the application of relevant, domain-specific strategies that aid essential cognitive processes like decision-making together with performance (Hambrick, Macnamara, Campitelli, Ullen, & Mosing, 2016).

Particularly in technical environments, cue utilisation is associated with superior performance across a range of different settings (e.g., Loveday et al., 2014). Yet, the majority of research in applied environments has focused on the utilisation of task-specific, technical cues, rather than those that involve social interaction. This is despite the fact that communication is a key factor in the operations of work groups and teams operating in settings where interpersonal engagements are critical to performance (Leonard, Graham, & Bonacum, 2004; McCulloch et al., 2009).

In Paper 3, power controllers and football coaches completed measures of technical and social cue utilisation. For power controllers, a version of EXPERTise 2.0 was used that incorporated stimuli from the power control domain (e.g., power system fault diagrams). For football coaches, a version incorporating stimuli from football coaching was used (e.g., player formation information). In the first study described in Paper 3, power controllers completed measures of cue utilisation and also provided self-ratings of performance and information about their level of job expertise.

While prior research has shown some evidence for the relationship between self and other-ratings of expertise with cue utilisation (e.g., Loveday et al., 2014), neither job level nor self-ratings of performance were associated with either measure of cue utilisation. These findings are likely due to the limitations of the outcome variables that were available for power controllers. Specifically, although job level may be indicative of experience-related expertise, attainment of higher job levels may not have been solely based on skill and expertise. In addition, self-ratings are reliant upon individuals possessing a degree of insight into their own levels of expertise, which may not always be associated with explicit measures of cue utilisation.

The second study in Paper 3 involved football coaches with varying levels of coaching qualification. It was anticipated that the use of a formal measure of expertise would distinguish between participants more effectively. The results from this study indicated that technical and social cue utilisation contributed unique variance in football coaches' levels of capability, suggesting that they are distinct constructs. In addition, the results also indicate that the ability to utilise both technical and social cues is associated with the expertise of football coaches, explaining approximately one-third of the variance in the level of coaching qualification. While this may be considered low, this finding represents a novel contribution to understanding the characteristics that differentiate coaches' levels of expertise.

Research Question 6: *Does the relative importance of technical and social cue utilisation depend on the type of ad hoc environment?*

The use of two different ad hoc environments enabled the assessment as to whether there are differences in the impact of technical and social cue utilisation based on the nature of the applied setting. The results discussed in Paper 3 indicate that, within the power control domain, while technical cue utilisation may be associated with expertise as defined by job level, there was no statistically significant relationship between social cue utilisation and self-ratings of performance or job level. However, within the football coaching domain, where performance is more directly associated with technical and social performance components, both technical and social cue utilisation were significant predictors of assessed expertise as defined by coaching qualification.

Summary of Key Findings

This research program comprised three experimental studies that were designed to investigate the impact of social cue utilisation in the context of ad hoc team and applied environments. Through the development of an assessment that enabled the measurement of social cue utilisation, this thesis also empirically tested the relationship between social cue utilisation and ad hoc team performance, communication, perceptions of workload, and markers of expertise. The key findings from this research program are that:

1. The capacity to utilise social cues is positively associated with the performance of ad hoc teams in the context of problem-solving and high-fidelity simulated tasks.
2. Social cue utilisation is positively associated with the frequency of two different types of communication strategies in the context of ad hoc teams: closing the loop and informative responding.
3. A positive, indirect effect of social cue utilisation exists on: (1) ad hoc team performance through closing the loop, and (2) ad hoc teams' perceptions of workload through informative responding.
4. Social cue utilisation is a construct unique from technical cue utilisation as measured in a football coaching domain.
5. Social cue utilisation is positively associated with the expertise of football coaches, controlling for the impact of technical cue utilisation.

Theoretical Implications

Contemporary ad hoc teams and individuals operating in applied environments that rely on some degree of interpersonal interaction are relied upon increasingly to deal with highly complex and dynamic demands (Tannenbaum et al., 2012). Yet, theoretical frameworks explaining team effectiveness have tended to focus on general team factors, rather than those that may be specific to contemporary ad hoc teams (Wageman, Garnder, & Mortensen, 2012).

The central team effectiveness framework is the Input-Mediator-Outcome-Input (IMOI) framework which suggests that team effectiveness is the product of team inputs such as team members' personality, team mediators like communication, and team outcomes which comprise the outputs that arise from the actions taken by team members

(Ilgen, Hollenbeck, Johnson, & Jundt, 2005). The IMOI framework conceptualises team effectiveness as a complex process whereby interactions and feedback loops exist between inputs, mediators, and outcomes. For instance, the degree to which a team communicates (mediator) is assumed to result in improved team cohesion (outcome), which encourages feedback and thereby improves communication. The IMOI framework is also based on the proposition that mediators can be both explicit behavioural processes like communication, or implicit cognitive states that emerge due to team member interaction (Ilgen et al., 2005; Pina, Martinez, & Martinez, 2008).

A key mediator that has been explored in team-based research is the shared mental models, which represent the collective understanding of a given situation about the key elements and information within a specific environment (Mohammed et al., 2010). While the positive impact of shared mental models on team performance is well established, the factors that facilitate their development (particularly in ad hoc teams) have yet to be established empirically (Mohammed et al., 2010; Mathieu, Maynard, Rapp, & Gilson, 2008). For instance, communication has been identified as an outcome of the development of a shared mental model, rather than a precursor (Mohammed et al., 2010).

The results from Paper 1 indicate that, in a team-based problem-solving task, the development of a shared mental model is associated with the frequency with which ad hoc teams utilise ‘closing the loop’ communication. While further evidence is needed to establish the precise nature and direction of the relationship, this outcome represents a novel finding due to the specific nature of how communication was defined. The results from Paper 1 also indicate that the development of a shared mental model is not necessarily associated with the performance of ad hoc teams during a team-based problem-solving task. This is a surprising finding given the body of evidence highlighting the benefits of shared mental models for team performance (e.g., Mathieu, Heffner, Goodwin, Salas, & Cannon-Bowers, 2000; Lim & Klein, 2006; Randall, Resick, & DeChurch, 2011).

However, it is possible that superior performance in the problem-solving task used did not require the development of shared mental models.

In the context of ad hoc teams, communication is generally a precursor to team performance and coordination. Yet, the specific strategy and mechanism supporting the application of communication is not commonly specified (e.g., Smith, Baber, Hunter, & Butler, 2008; Roberts et al., 2014). The result is that ad hoc team research has led to the identification of communication as a key mediator within complex and dynamic settings, but without a precise definition as to what constitutes effective communication and how it might arise in these environments (e.g., Butchibabu, Sparano-Huiban, Sonenberg, & Shah, 2016).

The results of the present program of research suggest that there may be a relationship between the application of closing the loop communication and performance in a team-based problem-solving task for ad hoc teams, and that the application of closing the loop may be facilitated by the capacity of team members to utilise social cues. While the study described in Paper 1 is the first empirical study examining the contribution of social cue utilisation to ad hoc team performance, it also extends existing research into team effectiveness factors and provides initial evidence for the temporal and functional role of communication and social cue utilisation (Mathieu et al., 2008).

The outcomes of Paper 1 also highlight the potentially unique contribution of social cue utilisation as a theoretical construct within the context of teams and environments reliant upon social interaction. The capacity to utilise social cues was more positively associated with communication and shared mental model development in ad hoc teams in comparison to either emotional intelligence or non-verbal reasoning ability, both of which have been previously identified as related to team processes and performance outcomes (e.g., Jordan & Troth, 2004; Prati et al., 2003; Feyerherm & Rice, 2002; Edwards, Day, Arthur Jr, & Bell, 2006; Devine & Philips, 2001). While this outcome warrants further investigation, particularly in field settings where other ability-based capabilities may be important, it suggests that within ad hoc teams, the capacity to utilise social cues may be more supportive of effective social interaction than either emotional intelligence or non-verbal reasoning.

In the second study outlined in Paper 2, the positive relationship between social cue utilisation and ad hoc team performance was replicated in a more complex, applied task. Social cue utilisation was also associated with lower perceived workload in relation to the task, indicating that ad hoc teams with a greater capacity to utilise social cues during a team-based task, experienced lower perceived workload. This finding is consistent with previous research highlighting the capacity for cue utilisation to reduce working memory load by priming memory-based associations to aid decision-making, thereby reducing the demands on cognitive resources (Wiggins, 2006; Small, Wiggins, & Loveday, 2014; Brouwers, Wiggins, Helton, O'Hare, & Griffin, 2016). Importantly, it also provides initial evidence for the generalisability of cue utilisation beyond technical cues.

The indirect effect of social cue utilisation on perceptions of workload through informative responding, also contributes to the theoretical understanding of the underlying mechanism through which cue utilisation might function in the context of ad hoc teams. For more complex and applied scenarios, the propensity to utilise social cues tends to be associated with the frequency with which team members are likely to provide information to assist in task performance (e.g., Mesmer-Magnus & DeChurch, 2009). This indicates that team members with a superior capacity to interpret and utilise cues of a social nature may be more effective in identifying optimal opportunities to share key information based on the emotional cues that are available in team-based settings.

Paper 3 outlined a specific examination of the impact of social cue utilisation in the context of two applied environments. Within applied environments, cue utilisation represents a key characteristic of expertise, and enables individuals to learn, retain, and implement optimal strategies based on the requirements in a given scenario (Wiggins, 2006). In the context of task performance, cue utilisation promotes the efficient extraction of domain-specific, task-critical features and information that aids cognitive processes such as decision-making that are, in turn, critical for performance (Shanteau, 1992; Morrison, Wiggins, Bond, & Tyler, 2013).

The positive association between cue utilisation and performance is evident in a range of different applied settings, including power control, software engineering, paediatric diagnosis, and aviation (Small et al., 2014; Loveday et al., 2013a; Loveday et al., 2014; Loveday et al., 2013b; Wiggins, Azar, Hawken, Loveday, & Newman, 2014a). The focus of research in these areas has been in understanding the role of technical cue utilisation, or the utilisation of task-based, domain-specific cues (e.g., weather patterns in the context of in-flight decision-making; Wiggins et al., 2014a).

The results from Paper 3 indicate that levels of social cue utilisation are associated with the assessed capability of football coaches, as represented by the level of qualification achieved. In addition to the findings from Papers 1 and 2, these results underscore the importance of social cue utilisation in environments that depend on effective social interaction for performance. Paper 3 also builds on the theoretical understanding of what constitutes expertise within sport (Mann, Williams, Ward, & Janelle, 2007). While both technical (e.g., decision making) and non-technical (e.g., player relationships) characteristics have been identified previously (e.g., Slack, Maynard, Butt, and Olusoga, 2013; Plessner, Schweizer, Brand, & O'Hare, 2009), this thesis provides initial evidence for the underlying importance of both technical and social cue utilisation in differentiating the capability of coaches.

Practical Implications

The findings arising from this program of research demonstrate that social cue utilisation is directly associated with communication strategies, perceived workload, and the performance of ad hoc teams, and indirectly associated with ad hoc team performance and perceived workload through its relationship with different communication strategies. These findings have practical implications for the training and development of ad hoc teams.

These outcomes also provide further support for the importance of developing and training team members' skills in applying team processes like communication (e.g., Pena et al., 2015; Crichton & Flin, 2004; Hull et al., 2012). Training interventions might target communication strategies like closing the loop and informative responding, since the application of these strategies is likely to result in improvements in the performance and perceived workload of ad hoc teams. While it is likely that the employment of closing the loop communication strategies will be sufficient for general problem-solving tasks, the outcomes from the present program of research suggest that communication centred around providing key information is more likely to impact performance in more complex scenarios.

A key practical implication arising from the outcomes of this research is the importance of social cue utilisation in the context of both ad hoc teams and applied environments where performance relies on interpersonal interaction. Specifically, the measurement and operationalisation of social cue utilisation indicates that teams are more likely to be effective when they comprise team members with a superior capacity to: (1) identify key social features, (2) identify the extent to which social features and events are related, (3) discriminate between related and unrelated social features, and (4) prioritise the acquisition of social information to inform problem resolution. The pattern of performance across these areas is consistent with prior findings incorporating broader cue utilisation measures (e.g., Loveday et al., 2014).

While the inclusion of team members with greater levels of social cue utilisation should lead to improved performance, training methods should also centre around improving individuals' capacity to identify, retain, and utilise social cues. Cue-based training approaches focus on maximising individuals' exposure to key features by presenting them with common scenarios associated with a particular domain (e.g., a simulated medical emergency for training novice doctors). Through multiple trials, individuals are also asked to utilise these features to form judgements, solve problems, or perform a task, after which they receive feedback on the effectiveness of their actions (e.g., Wiggins & O'Hare, 2003).

Cue-based Training. Cue-based training methods are effective in a range of different settings, including improving athletes' anticipation skills (Williams, Ward, Knowles, & Smeeton, 2002), improving radiographers' x-ray inspection skills (Litchfield, Ball, Donovan, & Manning, 2010), and improving the timeliness of weather-related decision making for pilots during simulated flights (Wiggins & O'Hare, 2003). Typically, these training methods focus on drawing individuals' attention to the features that are present before, during, and after critical events to facilitate feature-event pairings that are retained in memory (Ericcson & Kintsch, 1995; Klein, 1993). For example, Wulf, McNevin, Fuchs, Ritter, and Toole (2000) demonstrated that improvements in tennis skill were facilitated by training individuals to focus on the features that surround the technique of striking a tennis ball (e.g., the way the racquet hits the ball).

A proposed cue-based training program incorporating social cues would consist of exposure-based training that facilitates skill acquisition by increasing the likelihood that individuals identify critical features and establish relationships between these features and outcomes (Wiggins et al., 2014b). For instance, cue-based training for ad hoc teams might involve presenting team members with common scenarios they are likely to face and that require them to interact with others to coordinate and complete tasks. This approach should facilitate exposure to the types of interpersonal and social exchanges that are essential in aiding team coordination and performance.

Following exposure, individuals would be asked to form judgements around the most effective and efficient approach to aid coordination and performance, and then be provided with feedback around the appropriateness of the cues they used to inform their judgements. This process should facilitate the prioritisation of key features and events over those that may be unrelated or less important, and promote the acquisition of critical cues (Wiggins et al., 2015).

Coach Expertise. The research outcomes presented in this thesis also have implications for the selection and development of expert coaches. While the sample used consisted of national football coaches within an Australian-based performance framework, it is likely that the criteria for assessing the capability of football coaches would be generalisable. Expert football coaches are more likely to solve problems more effectively to achieve better development for athletes in both physical and psychological outcomes (Hagemann, Strauss, & Busch, 2008; Cote & Gilbert, 2009). A key characteristic that should enable progression to expertise in football coaching likely centres around the ability to utilise cues that would support decision making and problem solving (Ford, Coughlan, & Williams, 2009).

Both technical and social forms of cue utilisation are positively associated with the expertise of football coaches as defined by qualification level. While this finding was not surprising given that higher levels of qualification are dependent upon the capacity of coaches to demonstrate both technical (e.g., game analysis) and non-technical (e.g., player management) skill (Slack et al., 2013), it provides initial evidence for the importance of cue utilisation in coaching expertise. Future training interventions should target the acquisition of both technical and social cues to facilitate skill development in coaches. This could involve the presentation of scenarios involving interactions between coaches and athletes, with a focus on highlighting the key features and associated outcomes that are critical for performance (e.g., what environmental features are used by coaches to understand and develop performance deficits in an athlete).

Limitations and Future Directions

The program of research outlined in this thesis represents a novel empirical examination of the impact of social cue utilisation in ad hoc teams and applied environments. To test the research questions involved, a measure of social cue utilisation was developed and incorporated into three unique studies with increasingly realistic tasks and environments. Given the exploratory nature of the research, a general problem-solving and rail control simulation tasks were selected to establish whether social cue utilisation impacted the performance of ad hoc teams. Rail control was chosen as a domain because rail control teams are characterised by the types of situational demands that many ad hoc teams face. These include high pressure and time constraints, ambiguous and complex information, as well as the need to coordinate rapidly with team members that are brought together quickly and sometimes without prior experience working together (Salas, Burke, & Samman, 2001). A limitation of the domain and task used is that task performance may not reflect the types of demands that are typically faced by other ad hoc team types. Future research is essential in understanding how the relationships identified in this program of research emerge in the context of higher fidelity simulation or real-world settings. For example, future research could examine the relationship between social cue utilisation and team performance for ad hoc medical teams responding to actual emergencies. While this approach should increase the generalisability of the findings (e.g., Roberts et al., 2014), it may be difficult to coordinate and measure key team process variables.

Given the novel nature of the research undertaken, the use of a purpose-built and adapted measure of shared mental models was necessary to enable the measurement of ad hoc team processes during task performance. The measurement strategy captured the development and consistency of shared mental models by assessing the similarity of ratings between team members (Mohammed et al., 2010; Saetrevik & Eid, 2014). A limitation of this method is the reliance of the ratings given by team members on their level of insight into the task requirements and the performance of the team. Future research is needed to replicate the findings described in this thesis using alternative methods of measuring shared mental models (e.g., measuring team members' understanding of the level of knowledge held by other team members). However, future research using alternative methods will need to enable the efficient assessment of ad hoc team processes as demonstrated in Paper 1.

Despite the importance of the quasi-experimental design used in the laboratory studies to increase control and minimise extraneous influences, the research was experimental and cross-sectional. Although mediation analyses indicated indirect effects of social cue utilisation on ad hoc team performance through closing the loop communication, and on perceived workload through informative responding, further research is necessary to establish the precise temporal mechanism through which social cue utilisation operates. Employing a longitudinal design to investigate the temporal stability of these relationships should also enable greater causal inferences to be drawn relating to the impact of social cue utilisation.

The development of an assessment of social cue utilisation was based on general emotional and social features that are indicative of the types of cues experienced in the context of interpersonal interaction (Kanade, Cohn, & Tian, 2000; Prati, Douglas, Ferris, Ammeter, & Buckley, 2003). Broad cues and scenarios were used to ensure that the assessment of social cue utilisation could apply across different settings. Future research could examine whether the inclusion of social features and scenarios found in specific domains and environments (e.g., a medical response team dealing with an emergency) impacts the association between social cue utilisation and team-based outcomes.

The inclusion of specific communication strategies in this program of research (‘closing the loop’ and ‘informative responding’; Schillinger et al., 2003; Brindley & Reynolds, 2011; Mesmer-Magnus & DeChurch, 2009) was also informed by their association with the development of shared cognition in work groups and teams (Mesmer-Magnus & DeChurch, 2009; Svensson & Andersson, 2006). The examination of whether the utilisation of cues that relies more on domain-specific features may be associated with different communication strategies marks a potential line of future enquiry, particularly given the diverse environments in which ad hoc teams and work groups are utilised.

The research findings from this program of research suggest that closing the loop and informative responding facilitate the impact of social cue utilisation on ad hoc team performance and perceived workload respectively. Further research is needed to understand how the utilisation of social cues might impact on more objective measures of workload. In addition, further empirical examination of social cue utilisation in the context of ad hoc teams may reveal additional relationships with alternative communication strategies that could have a different impact on team performance outcomes (e.g., conflict resolution; Jordan & Troth, 2004).

The assessment of cue utilisation used in this thesis involved the development of a situational judgement-based tool (EXPERTise; Wiggins et al., 2010) that measures behaviours indicative of the utilisation of cues. This method provides a more reliable method and overcomes the subjectivity involved in recall-based methods of assessment (Plessner, Schweizer, Brand, & O'Hare, 2009). However, it remains unclear whether the complexity and idiosyncratic nature of social cues are captured comprehensively using a situational judgement-based tool. Future research could examine the utility of incorporating alternative mediums for presenting task stimuli (e.g., virtual) and investigate the relative effectiveness of a situational judgement-based tool compared with recall-based or other methods of assessment.

Increasing the external validity of cue utilisation in the context of applied environments should also represent a future priority. While the assessed capability of football coaches was an outcome measure derived from performance-based results, further examination of performance variables is necessary to support the validation of social cue utilisation. This may involve the inclusion of more objective and stable outcome measures of performance and capability that can be directly linked to levels of social cue utilisation (e.g., defining coaching performance based on tangible athlete performance).

General Conclusion

This research program was designed to determine whether social cue utilisation represents a key strategy that impacts the effectiveness of ad hoc teams and individuals operating in applied environments, and whether the mechanisms through which social cue utilisation might operate to impact effectiveness. Three empirical evaluations were conducted that were intended to investigate and test the relationship between social cue utilisation and measures of performance, perceived workload, and communication.

Overall, social cue utilisation differed between individuals and was associated with ad hoc team outcomes. Given the increasing reliance on ad hoc teams (Tannenbaum et al., 2012), the relationship between social cue utilisation and ad hoc team performance provides an important contribution to the knowledge around the factors that are associated with the effectiveness of ad hoc teams. There was also evidence to suggest that social cue utilisation has a positive impact on ad hoc team performance and perceptions of workload by facilitating communication between team members.

The results from this thesis provide the first attempt to understand the impact of social cue utilisation in ad hoc teams and applied environments. While further research is necessary to extend these outcomes, the results presented in this thesis offer initial support for the role of social cue utilisation in enabling performance in team-based settings.

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Appendix A: Ethics Committee Approvals

Appendix A of this thesis has been removed as it may contain sensitive/confidential content

Appendix B: Publication in Human Factors: The Journal of the Human Factors and Ergonomics Society

Pages 272-284 of this thesis have been removed as they contain published material.
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