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Individual perceptions of complex projects: A window into project team and stakeholder mental models

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ABSTRACT

Understanding the current state of a complex project is challenging but essential for project teams to make effective management decisions. This research explores whether the indirect elicitation and comparison of mental models measured through individual level perceptions can encourage project team double loop learning about a complex project to inform management decisions. The best-worst scaling object case method was applied at the individual level to measure system-wide perceptions of two case study projects, demonstrating its efficacy in capturing team and stakeholder perceptions, and measuring how these change over time. Analysis of the case studies showed that highlighting the differences in mental models uncovered using the best-worst scaling object case method at the individual level can facilitate double loop learning and prompt management decisions about complex projects.

1. Introduction

A key challenge to the successful management of projects is their increasing complexity (Marle & Vidal, 2016; PMI, 2013; San Cristóbal et al., 2018) due to the limited effectiveness of traditional plan and control based methods for managing complex projects (Böhle et al., 2016; Elia et al., 2021; Findlay & Straus, 2015). Drawing on complex adaptive systems theory, complex projects are defined as complex adaptive systems characterised by unclear cause and effect relationships due to emergent properties, adaption and non-linear effects from agent interactions and feedback loops influenced by sources of complexity (Bakhshi et al., 2016; Remington et al., 2009; Vidal et al., 2011). These sources of complexity may include interrelated task structures, uncertainty in goals, methods or requirements, dynamic change in the project or environment, accelerated project pace or tempo, and/or a challenging socio-political environment (Geraldi et al., 2011; Remington & Pollack, 2007). The limited effectiveness of traditional project management methods comes from the project team's difficulty understanding the current state of a complex project as a complex adaptive system and difficulty predicting its future states (Cooke-Davies et al., 2007; Daniel & Daniel, 2018; Nachbagauer, 2021; Vidal & Marle, 2008).

Daniel and Daniel (2018) argue that emergence is the defining characteristic of managing complex projects due to their unstable dynamic over time as complex adaptive systems. Drawing on the theory of mental models, Daniel and Daniel (2018) propose that it is the inability of the project team's individual and shared mental models to accurately reflect a complex project's current state that leads to this emergence. Mental models are "the mechanisms whereby humans generate descriptions of system purpose and form, explanations of system functioning and observed system states, and predictions of future system states" (Rouse & Morris, 1986, p. 360). Shared mental models in the form of longer-term stable team mental models (Cannon-Bowers & Salas, 1990; Orasanu, 1990) and dynamic team situation models (Cooke et al., 2003, 2000) are system representations that emerge at the team level from individual mental and situation models. Team mental models are shared knowledge about and expectations for a system that enable the effective coordination of team members to perform a task (Cannon-Bowers et al., 1993) while team situation models are a shared "mental representation associated with a dynamic understanding of the current situation" (Rico et al., 2008, p. 167).

The most relevant form of mental models for understanding the current state of a complex project as described by Daniel and Daniel (2018) are individual and team situation models. The inaccuracy of project team situation models is argued to impact the project team's ability to make accurate predictions about the project's future states reducing the effectiveness of project team management decisions.

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Feedback loops between the project team's situation models and the project reality are believed to improve the accuracy of the models and effectiveness of management decisions. This perspective is consistent with reflective approaches, such as double loop learning from organisational learning theory, which are recommended for effective complex project management (Crawford & Hoffman, 2011; Crawford et al., 2006).

Double loop learning questions the underlying assumptions and objectives of a situation to produce valid impersonal information on which to make decisions (Argyris, 1977; Argyris & Schön, 1996). This process of questioning assumptions and/or objectives is a way for teams managing complex projects to update their individual and shared situation models which could lead to more effective decision making (Daniel & Daniel, 2018; Reyes, 2012). Furthermore, individuals are likely to perceive the same complex project differently based on their interpretation of the information available to them about the project (Cooke-Davies, 2011; Jaafari, 2003; Stingl & Geraldi, 2017, 2021). The differences between the individual and shared project team and stakeholder perceptions provide a window into their situation models of the complex project. This means individual situation models of a complex project could be elicited indirectly by measuring the perceptions of project team members and other stakeholders to provide the system-wide information that Findlay and Straus (2015) argue is necessary to manage complex projects as complex adaptive systems. To date, the limited project research about mental models has focussed on longer-term stable team mental models (e.g., Shafique & Mollaoglu-Scott 2020; Hsu et al. 2011; Wu et al. 2023). There has been no prior empirical research into dynamic individual or team situation models in relation to the adaptive and emergent nature of complex projects as complex adaptive systems. This is a significant gap in the literature. Therefore, the aim of this research is:

> *To explore whether the elicitation and comparison of individual and shared situation models could be used to encourage project team double loop learning about a complex project to inform management decisions.*

This research addresses this gap in the literature by empirically testing an approach to encouraging double loop learning, informed by situation models from mental model theory, in the context of the management of complex projects understood as complex adaptive systems. It makes four key contributions to complex project research. First, the research explores the combined application of mental model theory with complex adaptive systems theory; something that Daniel and Daniel (2018) proposed to explain the emergent nature of complex projects. Second, the research introduces situation models to project research and extends the application of mental models in project research from team members to stakeholders. Third, the research provides empirical evidence of double loop learning in complex projects based on the elicitation and comparison of individual and shared situation models. Fourth, the research develops a practical methodology for studying individual level situation models in complex project research.

The next section reviews the literature about individual and shared mental models and double loop learning in complex projects. Then the research methodology is described including the quantitative measurement of perceptions to indirectly elicit situation models and the workshop design for project teams to compare the situation models. Two longitudinal case studies of complex projects are described. Then the evidence is analysed and the research propositions are evaluated. The findings are discussed in relation to complex adaptive systems, mental model and organisational learning theory and the theoretical, methodological and practical implications are outlined. Finally, the research strengths, limitations and proposed future research are articulated.

2. Literature review

2.1. Individual and shared mental models

Mental model theory is widely used to explain and predict human interactions with systems in literatures such as cognitive psychology and systems control (Rouse & Morris, 1986), and organisational behaviour (Mohammed & Dumville, 2001). However, to date, mental models have received relatively little attention in the project literature. The limited project research has focussed on longer-term stable team mental models (e.g., Shafique & Mollaoglu-Scott 2020; Hsu et al. 2011; Wu et al. 2023) with no empirical research about the dynamic individual and shared situation models.

Shafique and Mollaoglu-Scott (2020) in a literature review of mental models examined the implications for inter-organisation architecture engineering and construction project teams. Based on this review, Shafique and Mollaoglu-Scott (2020) outlined the potential to apply a mental model lens to leadership and project building models to address the challenges of inter-disciplinary teams and multi-level structures of these projects. Hsu et al. (2011) empirically examined the impact of team building activities on mental models and project performance in information systems project teams. Based on a Partial Least Squares (PLS) structural equation model of survey data, team building was found to improve project team mental models about teammates and interactions which in turn increased information utilisation and project performance. However, the survey focussed on the general existence and strength of longer-term shared team mental models with measures such as "I am well aware of other team member's skills and abilities" (Hsu et al., 2011, p. 7) for the teammate mental model. Wu et al. (2023) focussed on extending mental models to multi-team systems where sub-project teams with specialised skills work together towards an overall goal. Based on a PLS model of survey data, Wu et al. (2023) found evidence for a positive impact of project team shared mental models of goals and plans on cooperation, coordination and multi-team system implementation efficiency. However, the survey again focussed on general existence and strength of longer-term shared team mental models. The project research to date about longer-term shared team mental models has largely supported their representation as a support for effective coordination of team members to perform tasks. However, this research has limited relevance for the dynamic individual or team situation models which are essential to understand the adaptive and emergent nature of complex projects as complex adaptive systems. The lack of empirical research about situation models is a significant gap in the project literature.

Chang et al. (2021) outlined a highly relevant project team learning approach while developing a leadership practices framework for behaviours that promote learning within and between project teams. Drawing on the organisational learning theory socio-cognitive perspective this approach was to identify and clarify individual mental models making them explicit before comparing them to generate new insights. Potentially, the approach Chang et al. (2021) outlined could be applied to individual and shared situation models of complex projects to provide the feedback loop the Daniel and Daniel (2018) framework described as necessary to update project team's individual and team situation models. Therefore, drawing on complex adaptive systems, mental model and organisational learning theory, Proposition 1 of this research is:

> Proposition 1: Project teams will be able to reflect on the current state of their complex project based on comparisons of individual and shared situation models.

Mental models as a complex latent construct are difficult to directly measure (Kraiger & Wenzel, 1997). This is why Hsu et al. (2011) and Wu et al. (2023) measured indirect indicators of longer-term team shared mental models such as awareness and agreement. Individual situation

models about a complex project represent an understanding of its current state by heterogenous agents who through their interactions have different experiences of this change over time (Mitleton-Kelly 2003; Wallis 2008; Byrne & Callaghan 2014). An aspect of this dynamic understanding that can be measured is the individual's perceptions about an aspect of the complex project such as risks, objectives or deliverables. This means individual situation models of a complex project could be indirectly measured via the individual level perceptions of project team members and other stakeholders. These individual perceptions and shared group perceptions could then be compared to establish if project teams reflect about the current state of their complex projects to test Proposition 1. This means an individual's perceptions of a complex project are treated as a measurable indicator that reflects the individual's situation model of the project and measured as a form of in-task probe (Wildman et al., 2014). In essence, measuring an individual's perceptions about an aspect of a complex project provides a window into their mental model of the project's current state.

2.2. Double loop learning in complex projects

Organisation learning theory focusses on the processes by which organisations acquire new knowledge, skills and capabilities to maintain and improve their performance at different levels from individuals to groups and the entire organisation (Crossan et al., 1999, 2011). Learning in complex projects can take the form of single loop learning. Single loop learning is where the consequences of management actions are observed and evaluated against performance criteria to take corrective action (Argyris & Schön, 1996). However, single loop learning is based on the project team's existing shared situation model of the project which may be inaccurate due to difficulty in understanding the current state of complex projects as complex adaptive systems (Cooke-Davies et al., 2007; Daniel & Daniel, 2018; Nachbagauer, 2021; Vidal & Marle, 2008). Reflective double loop learning moves beyond the optimisation process of single loop learning to question the underlying assumptions and objectives of a situation (Argyris, 1977). Therefore, the process of double loop learning has more potential than single loop learning to update the project team's individual and shared situation models to better reflect the reality of the complex project as a complex adaptive system. Lan and Ramesh (2007) even argue that a key reason for applying agile practices in complex software development projects is the facilitation of double loop learning that enables project teams to examine and experiment with their mental models. It is also at least partially why reflective learning has been described by Crawford and Hoffman (2011) as an essential meta-competency for the effective management of complex projects. In addition, it is consistent with the complex adaptive systems theory conceptualisation of agents updating their rules of interaction based on feedback (Stacey 1996; Dooley 1997; Axelrod & Cohen 2000), in a reflexive double loop learning process (Stacey 1996) that incorporates information from the environment (Dooley 1997).

Nachbagauer (2021) in extending the Snowden (2002) Cynefin framework to managing complexity in projects discussed the challenges of managing complex projects from an organisational learning perspective. Highlighting the difficulty of understanding the current state of complex projects, team members are encouraged "to track possible mis-assumptions and question their own routines" (Nachbagauer, 2021, p.7). However, Nachbagauer (2021) argues complex projects are mainly non-repetitive leading to a scarcity of naturally occurring opportunities to engage in double loop learning. This means teams need to take a proactive approach to question their knowledge and assumptions about the management of a complex project drawing on diverse views of its current state. As Findlay and Straus (2015) argue, methods of managing complex projects as complex adaptive systems need to draw on system-wide information to understand these projects. If project team members and other stakeholder's individual situation models of a complex project were indirectly measured as individual level perceptions this would provide the requisite system-wide information and enable comparisons of mental models as Chang et al. (2021) described. As Stacey (1996) states for social complex adaptive systems "when members of a group jointly reflect upon and discuss the system they constitute. This is double-loop learning" (p.162). Therefore, drawing on mental model, organisational learning and complex adaptive systems theory, Proposition 2 of this research is:

> Proposition 2: Comparing project team and stakeholder individual and shared situation models about the project will lead to reflective double loop learning about the complex project's current state by the project team.

2.3. Informing management decisions

Double loop learning from organisational learning theory has been framed as providing valuable information for management decisions in complex projects (e.g., Argyris, 1977; Daniel & Daniel, 2018; Nachbagauer, 2021). However, there are few empirical studies about whether double loop learning informs team management decisions in complex projects. In one such study, Reyes (2012) explored the impact of incorporating single and double loop organisational learning in a Columbian university complex project. The project aimed to increase the number of rural students by delivering the initial two years of degrees in student's home regions. The project incorporated single and double learning cycles at different structural levels about the effectiveness of teaching practices which were found to improve the viability of the project. Henderson et al. (2013) in a study of large complex healthcare construction projects also focused on the potential to incorporate double loop learning cycles during complex projects for improved management decisions. Based on a survey of industry professionals, Henderson et al. (2013) determined that not engaging in cross-phase double-loop learning in these projects led to "reduced quality, client dissatisfaction, safety issues and an increase in disputes" (p. 301) highlighting the need for double loop learning cycles during these projects. This suggests that if a team engaged in double loop learning about the complex project based on comparing individual and shared situation models it would inform their management decisions. Therefore, drawing on organisational learning and complex adaptive systems theory, Proposition 3 of this research is:

> Proposition 3: Comparing individual and shared situation models about a complex project in double loop learning to understand its current state will inform the project team's management decisions.

3. Research methodology

The aim of this research was to explore whether elicitation and comparison of individual and shared situation models could be used as a way of encouraging team double loop learning to inform project team management decisions. This research was conducted using an exploratory embedded multi-case research design (Yin, 2014) involving two case study projects, each of which involved multiple rounds of researcher engagement and data collection via surveys and workshops. Case studies are widely considered to be the most suitable form of inquiry for holistic and in-depth investigations of bounded cases, such as projects, where human behaviour is central to the topic of interest (Flyvbjerg, 2011; Harrison et al., 2017; Yin, 2014). A multi-case approach was selected to enhance the generalisability of findings in this study and to understand whether the contextual differences between the cases affected the research results. The external validity comes through replication logic with multiple cases to achieve analytic generalisability (Yin, 2014) which requires diversity in the case studies for robust conclusions (Firestone, 1993). To ensure the reliability of the data collected, a detailed case study research protocol was developed and followed for the case studies.

To thoroughly address the aim of this research three data collection

cycles provided longitudinal data about two case study projects. The first project was in a private sector financial service organisation and the second was in public sector organisation. Each case study involved the following three processes:

1. Measuring individual level perceptions to represent an aspect of situation models via the best-worst scaling (BWS) object case.
2. Reflecting on the differences between individual and shared situation models in a team setting via workshops; and
3. Identifying instances of double-loop learning.

3.1. Measuring individual level perceptions

There are many ways of exploring individual level perceptions. Qualitative methods such as interviews and focus groups are used extensively to elicit perceptions (e.g., Brink, 2017; Loosemore & Cheung, 2015; Mesa et al., 2016; Odusanya et al., 2021; Remington, 2011), but are time consuming (Ezzy, 2002); which was problematic given the need to move quickly between measuring individual perceptions and reflecting on those perceptions in the case study projects. For this reason, the research design focused on quantitative methods that could measure individual level perceptions and be quickly implemented system-wide.

Project team members and stakeholders will exhibit heterogeneity in their observer dependant perceptions of projects based on their individual life experiences (Cooke-Davies, 2011; Jaafari, 2003; Stingl & Geraldi, 2017, 2021). Therefore, when considering quantitative measures of individual perceptions, it was important to account for the impact of this individual heterogeneity on the measurement task. To do this, a quantitative measurement technique needed to address the impact of individual level scale effects, response biases and styles (Baumgartner & Steenkamp, 2001; Cohen & Orme, 2004; Hackman, 2021; Harzing, 2006; Lee et al., 2008). Measurement tasks that rely on absolute measurements of perceptions to be consistent between individuals fail to address individual scale effects (Hackman, 2021). Biases such as social desirability and acquiescence (Krumpal, 2013; Paulhus, 1991) along with responses styles (Cohen & Orme, 2004; Harzing, 2006; Lee et al., 2008) are known to impact responses to interval rating scales leading to the potential for unobserved effects. For example, respondents from different countries have been found to use different parts of rating scales leading to sufficiently large scalar inequivalence that responses cannot be directly compared (Baumgartner & Steenkamp, 2001; Harzing, 2006). Hence, when completing a measurement task, two individuals may mean something different despite providing the same response or alternatively mean the same thing despite providing different responses. Therefore, the key criterion in selecting an appropriate quantitative technique was that it would allow direct comparisons between heterogeneous individual perceptions.

The BWS object case was chosen for this research as it is a survey based discrete choice method that measures the perceived relative position of a series of objects on a latent subjective scale (Louviere et al., 2015). The discrete choice questions of BWS object case avoid most response styles and biases (Cohen & Orme, 2004; Loose & Lockshin, 2013). Individual perceptions can be elicited system-wide simultaneously using an online BWS object case survey producing individual level models that are "scale-free and unaffected by issues of scalar inequivalence" (Sirieix et al., 2011, p. 503) addressing individual scale effects to enable direct comparisons between individuals and groups (e.g., Auger et al., 2007; Rankin et al., 2019). This also means there is no minimum sample size for the BWS object case when implemented at the individual level enabling project research into contexts with limited numbers of respondents. The BWS object case can also be used to understand individual changes over time by repeating the survey for an individual (e.g., Kim et al., 2018). This ability to make direct comparisons at the individual level is essential for highlighting whether meaningful differences in perceptions as an indirect measure of situation models can prompt discussions about the reality of the projects and the project team's underlying assumptions. Hackman (2021) provided an in-depth review of BWS object case data collection method at the individual level and discussion of its application in project research. This research followed the procedures outlined by Hackman (2021) for the implementation of the BWS object case at the individual level including the following steps to produce the surveys described in Sections 4.1 and 4.2:

1. Identify the topic and context of the BWS question (e.g., project manager leadership behaviours for project team performance).
2. Select the subjective scale (e.g., importance) and the end points for a BWS question (e.g., "Most Important" and "Least Important").
3. Collate the list of objects to compare on the subjective scale (e.g., "clear communication", "effective delegation")
4. Develop the BWS scaling question to compare the objects on the subjective scale using the end points for the topic (e.g., "Out of the project manager leadership behaviours below which do you think is Most and Least Important for project team performance?").
5. Identify an experimental design such as a balanced incomplete block design based on the number of objects and modify if required based on the Hackman (2021) recommendations.
6. Generate a survey based on the experimental design with a page for each set of the design that repeats the BWS question and end points with the set of objects.

In this research, the surveys were completed by respondents within a defined window of time to ensure the same project conditions influenced their perceptions. The survey question in BWS object case can relate to anything respondents perceive as distinct (e.g., implementation options or risks) and can be measured on any subjective scale (e.g., confidence or preference). The question in the first case study related to individuals' perception of the relative likelihood of different project outcomes being achieved, while in the second case study the question related to the relative confidence that the processes, services or tools delivered by the project would operate effectively. However, for the purposes of addressing the aim of this research, the exact survey questions are not the focus. The primary concern relates to consideration of whether and how team reflection on different situation models as represented by differences in survey responses contributed to double loop learning.

3.2. Reflecting on the differences in situation models

Workshops have been used in project research to present information, facilitate discussion and elicit feedback from project team members (e.g., Brink, 2017; Mesa et al., 2016). In this research, workshop participants were asked to reflect on the current state of their project based on the differences in the individual and shared situation models represented by the individual level BWS object case results. In the workshops, the individual level BWS object case results were presented with prompts for the participants to articulate reasons for the differences in perceptions which required them to reflect on the current state of the project. Double loop learning about the project was encouraged though the process of discussing differences in the individual level BWS object case results and capturing new or revised project team actions for the management of the project.

The workshops were designed to remove inhibitors to double loop learning by creating a collaborative learning environment that minimised defensive interpersonal dynamics and supported participants to reflect on and speak up about the complex project (Argyris, 1977). To minimise defensive interpersonal dynamics, results were only provided at the project team and stakeholder group levels. Furthermore, it was ensured that the project team and stakeholder groups contained at least three individuals to ensure participant anonymity for the discussion of the BWS object case results.

To support participants, consistent with Chang et al. (2021), the BWS object case results were visualised to make the situation models explicit and facilitate comparisons. The use of visuals is believed to improve the speed and accuracy of data interpretation (Geraldi & Arlt, 2015) and to facilitate interactions and/or improved decision-making in project work (Killen, 2013; Killen & Kjaer, 2012). In addition, visualisations that are well designed for an audience and a purpose can also improve the comprehension of complex and dynamic situations (Thomas & Cook, 2005).

The BWS object case results for the groups representing their shared situation model were visually represented as a stacked 100% bar graphs aiding the interpretation for the project team in the workshops. The relative percentages in these graphs focused participants on the differences between results, highlighting the differences between shared situation models for the project team workshops. The individual level results were also used to create histograms for each BWS object to visualise the dispersion or level of agreement between individual situation models in the groups about the BWS objects (e.g., Louviere et al., 2015). See the supplementary material for more information about the analysis and visualisation of the BWS object case results. Three workshops were conducted in each case study via online video conferences due to the COVID-19 work from home policies of the organisations during the data collection in late 2021 and early 2022.

Based on the (Argyris, 1977) description of a workshop to encourage double loop learning, the sequence of workshop activities were:

1. Facilitator briefly outlines the workshop principles (e.g., no individual results identified) and expectations for participants.
2. Facilitator establishes the frame of reference for workshop by asking participants:
   - What has happened in the project recently and/or since the last workshop that might influence perceptions?
3. Facilitator presents a stacked 100% bar graph of the overall, project team and stakeholder group results for the BWS survey highlighting key results.
4. Facilitator presents a stacked 100% bar graph of project team group relative percentage results and dispersion histograms of the individual project team results from the BWS survey highlighting key results.
   - Participants are prompted to reflect on reasons for perspectives in bar graph and differences in the perceptions in dispersion histogram.
5. Facilitator presents a stacked 100% bar graph of stakeholder group relative percentage results and dispersion histograms of the individual stakeholder results from the BWS survey highlighting key results.
   - Participants are prompted to reflect on reasons for perspectives in bar graph and differences in the perceptions in dispersion histogram.
6. A group discussion is facilitated to agree the new and/or revised project team actions to undertake based on current situation.

In the workshops, the researcher facilitator presented the visualisations of individual perceptions and shared group perceptions for the project team to compare verbally highlighting the differences in the perceptions. The comparisons included the differences in the perceptions between the groups (100% bar graphs) and within the groups at a point in time (histograms) along with the changes over time for the second and third workshops. Workshop participants were prompted visually on the presentation slides and verbally by the researcher facilitator to identify reasons for the differences in perceptions. The researcher facilitator did not take an active role in the team discussions after these prompts. This was approach provided the project teams the opportunity to simply discuss the differences and potentially reflect on their complex project's current state. If the project teams extended these reflections to engage in single loop or double loop learning about the complex project's current state it was entirely of their own volition.

3.3. Identifying instances of double loop learning

The workshop outputs were lists of new and/or revised project team actions. These were captured in the participants' own words, providing high descriptive validity (Maxwell, 1992). Hand-written notes were made on printouts of the presentation slides during the workshops, which were transcribed into electronic form directly after the workshop then reviewed in subsequent days to ensure completeness and accuracy. Workshops were not audio recorded due to participant concerns about confidentiality. Observations about the workshop focused on participant behaviour, directly noting participant responses to information presented to them in the workshops. Researcher notes focused on the sequencing between presented BWS data that represented an aspect of the situation models and participant comments and actions to support claims that a particular piece of presented data led to a particular response.

The identification of instances of double loop learning in the workshops was based on Maxwell (1992) concept of theoretical validity. Theoretical validity addresses "the legitimacy of the application of a given concept or theory to established facts" (Maxwell, 1992, p.292). It requires the identification of operationalised theory construct blocks with well-developed relationships in the setting. Double loop learning would be identified if the underlying assumptions or objectives of the project were questioned based on the situation models presented in the workshop, resulting in informed decisions (Argyris, 1977; Argyris & Schön, 1996). Therefore, the theory construct blocks that needed to exist in the workshop discussions to indicate double loop learning based on the situation models were:

- a specific BWS object case result or results presented in the workshop;
- reflections about the project based on the presented information;
- questioning of assumptions about the project (e.g., how it is being managed); and/or
- questioning of the project objectives (e.g., can an objective be achieved).

To discount the rival explanation (Yin, 2014) that the project team could have achieved the same understanding of the current state of the project through discussion without the presented results, all instances of double-loop learning needed to involve a clear link to the situation models presented in the workshops. The qualitative coding of the workshop discussions is outlined in Appendix 1.

3.4. Summary

The research methodology, incorporating BWS object case surveys to measure perceptions and workshops to compare visualisations of the situation models in case studies, is summarised in Fig. 1.

4. Case studies

Two case studies about complex projects in organisations based in Australia were conducted from August 2021 to April 2022. Descriptions of the key documents for each case study (e.g., Annual Review - 1.1) are provided in Appendix 2. The case study data included several public documents about the organisations. An additional twenty-one documents for Case Study 1 and twenty-five documents for Case Study 2 were created as part of the research. These included communications, workshop materials and notes that were captured at a point in time along with meeting and case notes documents created at the start then updated throughout the case studies. Generic wording has replaced any potentially identifying information in the case descriptions.

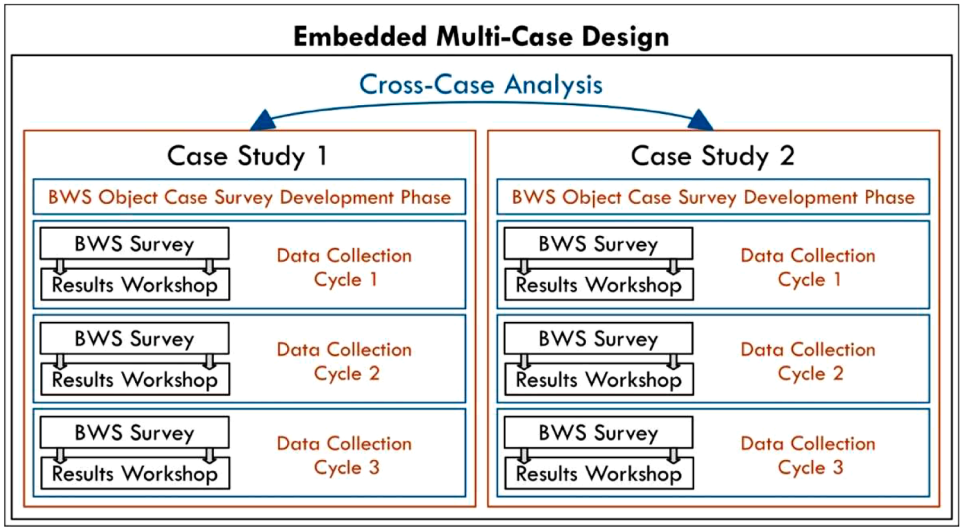

Fig. 1. Research methodology.

4.1. Case study 1 – private sector organisation context

Case Study 1 involved a complex project in a large Australian private sector financial services organisation. Employing approximately 12,000 people across Australasia (ESG Summary - 1.2), the organisation had offices in several Australian state capital cities (Annual Review - 1.1). The project's objective was to source and test the capacity of natural language processing Artificial Intelligence (AI) software to analyse customer call centre recordings for quality assurance purposes. The project was important to the organisation because call centres were a key point of customer contact and had a significant influence on customer satisfaction. It was essential to conduct quality assurance on these calls to ensure both positive customer experiences and compliance with regulatory requirements. The ability of AI software to analyse large volumes call recordings and identify calls for review by quality assurance staff was the basis for this project.

Case Study 1 covered Phase 1 of the stage gate project which was the pilot stage with a budget of approximately $4 million (AUD). The objectives of Phase 1 were to identify business requirements and select an AI software solution before testing the solution's capabilities and evaluating the usefulness of outputs. There were three data collection cycles for this case study from September to November 2021 at monthly intervals each comprised of a survey and workshop. The project team included a full-time project manager, change manager and business analyst dedicated to the project along with a test manager who worked on multiple projects. All project team members agreed to participate in the research completing BWS surveys and attending workshops. The project had a range of stakeholders within the organisation. The project owner from the quality assurance unit and two business transformation division staff agreed to participate in the research by completing BWS surveys as key project stakeholders.

The BWS object case surveys were developed following the steps in Section 3.1 and measured the relative confidence that the Phase 1 project outcomes would be fully achieved. This topic was chosen by the project manager to directly address the uncertainty in project requirements in the context of the accelerated timeline and disrupted environment. The BWS question developed was "Out of the Voice AI phase 1 project outcomes below which are you Most and Least confident will be fully achieved?". This question was displayed in the survey ten times with sets of three phase 1 project outcomes from the list below. The sets were constructed based on the balanced incomplete block design for six objects provided in the supplementary materials.

- Determine the business value of key Voice AI solution use cases
- Identify regulatory implications in key business use cases
- Validate that Voice AI solution can assess 100% of in-scope call recordings
- Assess value of Voice AI solution outputs for staff coaching and training
- Evaluate accuracy of Voice AI solution in identifying calls for review
- Assess Voice AI solution as an end-to-end operationalised solution

The individual project team members' and key stakeholders' relative confidence in fully achieving the project outcomes reflected their individual situation models of the project at that point in time. The measure drew on their understanding of the project as complex system including its observed states and predictions about future states. The individual and group BWS object case results over time were therefore an indirect measure of an aspect of their individual and shared situation models of the project.

4.2. Case study 2 – public sector organisation context

Case Study 2 involved a complex project in an Australian public sector organisation. The organisation employed approximately 230 people in a single Australian city and had state-wide responsibilities (Annual Report - 2.1). The project's first objective was to implement a vendor solution for outsourced live captioning of audiovisual streams. The outsourced process required the vendor to provide text captions to be broadcast as part of live audiovisual streams that would also be available in text form for initial transcripts. The second objective was to integrate the initial transcripts produced by live captioning into the media unit business as usual (BAU) processes that produced official records (Annual Report - 2.1). The project formed part of a $14.2 million (AUD) multi-year audiovisual technology upgrade program which supported a key strategic priority of modernising the organisation (Strategic Plan - 2.2). Historically, IT projects within the organisation had struggled to deliver effective solutions to end users so the media unit stakeholders were sceptical about the project.

The case study was focussed on the change management required to establish the new media unit processes, services and tools. The project shared the staff assigned to the audiovisual technology upgrade program with other projects, some of whom were employed part-time by the organisation. This included a project manager, change manager, change analyst and graduate trainee at the start of the case study, all of whom agreed to participate in the research completing BWS surveys and attending workshops. The media unit staff were the key project stakeholders for the change management and all six members of the media

unit staff working group agreed to participate in the research completing BWS surveys. The case study data collection cycles covered the period from December 2021 when the test version of the vendor solution implementation went live through to just before the new BAU processes went live in April 2022 with eight-week intervals.

The BWS object case surveys were developed following the steps in Section 3.1 and measured the relative confidence that the new processes, services and tools would operate effectively. This topic was chosen collectively by the project team to directly address the interrelated task structures and challenging socio-political environment of the project. The BWS question developed was "Out of the Media project new processes, services or tools below which are you currently Most and Least Confident will operate effectively?". This question was displayed in the online survey ten times with sets of three Media project new processes, services or tools from the list below constructed based on the same design for six objects utilised in Case Study 1.

- Live captioning portal
- Quality audit and vendor feedback process
- Transcript download process
- Official record publication process
- Internal support model process
- Vendor support model process

The individual project team members' and key stakeholders' relative confidence that the project's new processes, services and tools would operate effectively reflected their individual situation models of the project. The measure drew on their understanding of the projects' current state and predicted future states in terms of the effectiveness of the delivered new processes, services and tools. The individual and group BWS object case results over time were therefore an indirect measure of an aspect of their individual and shared situation models of the project.

4.3. Complexity and representativeness of the case study projects

Each case study project was influenced by multiple interacting sources of complexity that led to unclear cause and effect relationships. The private sector Voice AI project sources of complexity included uncertainty in the project requirements, interrelated task structures with the AI vendor selection and definition of the AI solution, dynamic change in the project and environment due to COVID-19, and an accelerated tempo due to delays from an organisation restructure. The interactions of these sources of complexity made it difficult for the project team to utilise the organisation's traditional plan and control project management methods. In particular, the project requirements were unclear at the start of the case study data collection with the project teams' understanding of the project outcomes evolving multiple times during the data collection. In addition, during the case study data collection as the project's visibility increased within the organisation a new source of complexity emerged, a challenging socio-political environment due to senior management interest in the project.

The public sector Media project was also characterised by multiple interacting sources of complexity. The primary source was a challenging socio-political environment created by the media unit staff who were concerned about the potential for future job losses from the outsourcing of work. The tension from this perceived industrial relations issue increased the difficulty for the project team to engage with the media unit staff stakeholders which was essential to the project deliverables. Other sources of complexity included interrelated task structures from implementing new tools and BAU processes, dynamic change in the project and its environment from COVID-19, and an accelerated tempo due to delays in starting the project.

The project teams worked with the researchers to select the survey topic and question they believed would provide the most useful information for their management decisions over time based on their understanding of these challenges. In Case Study 1, the BWS survey directly addressed the uncertainty in and the potential for different interpretations of project requirements. In Case Study 2, the BWS survey addressed the scepticism of the media unit staff about the project delivering an effective end user solution. Both project teams focussed on a form of project success for their the BWS surveys, project outcomes for the Voice AI project and project deliverables for the Media project. Stakeholders are known to hold diverse views of project success (Davis, 2017) that change over time (Turner & Zolin, 2012) which potentially increased the value of real-time stakeholder inputs about these topics for team project management decisions.

The case studies also needed to represent diverse conditions to be an effective replication test for analytic generalisability (Firestone, 1993). The key details of the case study organisations, projects and BWS surveys are summarised in Table 1. The two cases have different organisation scale and sector, project objectives, resourcing levels and focus for their BWS surveys. It is not possible for two cases to represent the full potential diversity of complex projects; however, the two cases represent sufficiently different conditions to provide an effective replication test for analytic generalisability.

5. Results

Three workshops in each case study provided the data to evaluate the evidence for the propositions. The workshop data was comprised of the researcher notes about the behaviours exhibited by participants and some direct quotes along with the workshop outputs captured in the participants' own words. The individuals who participated in each project team workshop are outlined in Appendix 3.

Table 1
Case study organisations, projects and BWS surveys.

		Case Study 1 "Voice AI project"	Case Study 2 "Media project"
Organisation	Sector	Private sector financial services	Public sector
	Employees	12,000	230
	Locations	All Australian state and territory capital cities, New Zealand and several Southeast Asian countries	An Australian state capital city
Project	Objective	Source and trial AI software to evaluate analytical capabilities and utility of outputs	Implement outsourced audiovisual streaming live captioning vendor solution
	Business Impact	Implement a limited rollout of parallel business processes to test the AI software in some call centres	Replace media unit BAU processes for producing official records of videos utilising the transcripts from the live captioning service
	Project Team	Multiple full-time project staff and supporting staff	Sharing staff assigned to program some of whom were part-time
BWS Survey	Focus of Surveys	Strategic focus on project outcomes	Tactical focus on operation of new processes, services and tools
	Psychological Scale	Relative confidence	Relative confidence
	Survey Topic	Relative confidence that the Phase 1 project outcomes would be fully achieved	Relative confidence that the new processes, services and tools would operate effectively

5.1. Proposition 1 – reflection on the current state of the complex project

> Proposition 1: Project teams will be able to reflect on the current state of their complex project based on comparisons of individual and shared situation models.

The project teams were observed reflecting on the current state of their complex projects based on the BWS object case results fifty-one times during the Case Study 1 (24) and Case Study 2 (27) workshops. Illustrative examples are provided from each case study. In Case Study 1 Workshop 2, presentation of the project team dispersion histograms (Fig. 2) led to a discussion about areas of agreement within the project team. The tight grouping of project team responses in the top left histogram in Fig. 2 indicated agreement that the project would "Validate that Voice AI solution can assess 100% of in-scope call recordings". In discussion, the project team identified that receipt of the preferred AI software vendor's statement of work in October 2021 as the likely reason for agreement across the team. The statement of work described accuracy testing as standard for all deployments, giving the team confidence this outcome would be achieved (Workshop 2 notes - 1.9).

In Case Study 2 Workshop 1, the presentation of the project team dispersion histograms also led to discussion. The histograms (Workshop 1 slides - 2.6, p. 8) indicated high levels of agreement and disagreement across the new processes, services and tools for the project team. For example, the wide dispersion in the "Internal support model process" and "Official record publication process" histograms indicated high levels of disagreement. The project team discussed reasons for the indicated disagreement, reflecting on the project. The lack of definition for the two processes was identified as the likely reason for differences between individual project team member perceptions.

In Case Study 2 Workshop 2, another clear example occurred when the prompt "Reasons for change in stakeholder results over time" (Workshop 2 slides - 2.8, p. 11) was displayed with the stakeholder longitudinal December and February results (see Fig. 3). The researcher facilitator highlighted changes including the increased confidence in the effective operation of the "Live captioning portal", shown in the second bar from the left in Fig. 3 moving from 21.7% in December to 23.9% in February, and "Vendor support model process", shown in the third bar from right moving from 10.8% in December to 12.8% in February. The project team reflected on the current state of the project in February 2022, noting the stakeholder group's recent opportunity to trial a test version of the live captioning portal and vendor support process. The project team identified that seeing the vendor implementing change requests to the live captioning portal may have influenced stakeholder perceptions (Workshop 2 notes - 2.9).

These examples are three of the fifty-one instances of reflection observed in the six workshops. Therefore, Proposition 1 is supported because both project teams were able to reflect on the current state of their complex project based on comparisons of individual and shared situation models represented by the perceptions in the individual level BWS object case results.

5.2. Proposition 2 – double loop learning

> Proposition 2: Comparing project team and stakeholder individual and shared situation models about the project will lead to reflective double loop learning about the complex project's current state by the project team.

There were fourteen examples of double loop learning observed in the workshops, twelve of which directly related to the BWS object case results. Illustrative examples are provided from each case study. In Case Study 1 Workshop 1, the project team engaged in a double loop learning cycle based on the difference between the stakeholder group's and project team's perceptions of the "Determine the business value of key Voice AI solution use cases" Phase 1 project outcome. The project team's relative percentage confidence for this project outcome was 7.5%, less than half the 18.9% for the stakeholder group (Workshop 1 slides – 1.6, p. 9, 11). This difference in responses prompted a discussion about the business value the project would deliver to different stakeholders. As part of this discussion the project manager questioned whether they understood the stakeholders' and specifically the quality assurance manager's conceptualisation of the business value the project would deliver. In addition, the project manager and business analyst questioned what metrics would be used to evaluate the project (Workshop notes 1 - 1.7). In this example, the reflections about the business value of the project and questioning assumptions about how the project would be evaluated occurred immediately after presentation of and explicitly

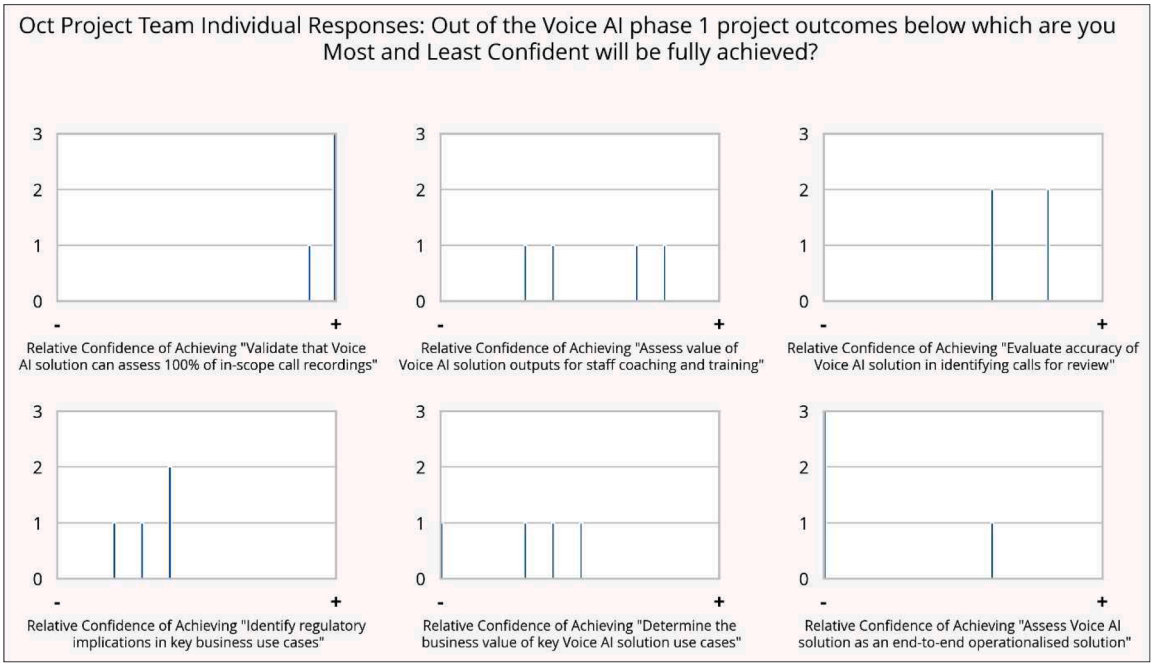

Fig. 2. Case Study 1 Workshop 2 dispersion histograms visualising project team individual situation models for each Phase 1 project outcome.

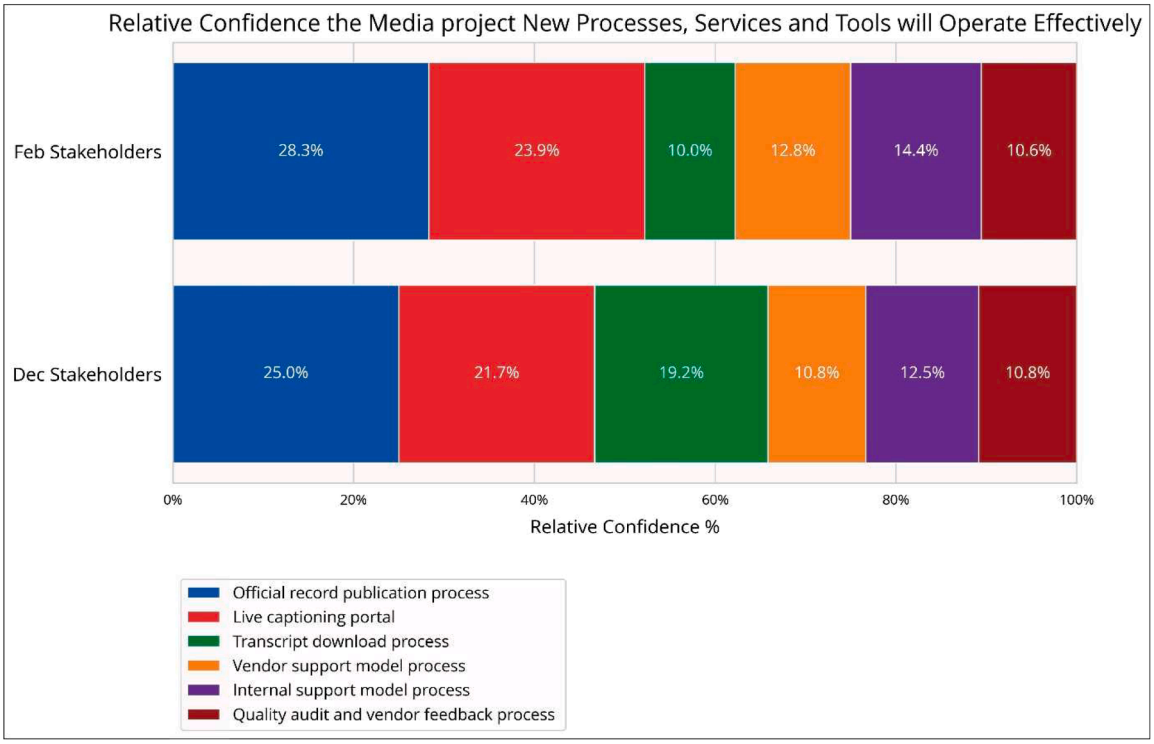

Fig. 3. Case Study 2 Workshop 2 longitudinal stacked bar graph visualising stakeholder situation models.

cited the visualised differences in the project team and stakeholder BWS object case results (Workshop 1 notes - 1.7), suggesting the results prompted the discussion.

In Case Study 1 Workshop 2, another clear example of the project team engaging in double loop learning occurred directly after the presentation of the project team dispersion histograms. The project team discussed the indicated disagreement between project team member perceptions of the "Assess value of Voice AI solution outputs for staff coaching and training" outcome. The discussion uncovered different ideas within the project team about how much staff coaching and training was included in Phase 1 of the project. This led to a broader discussion about whether there was an expectation that the project would provide BAU process training in addition to the training required to embed the AI software for end users. The change manger then questioned their assumption that the new BAU processes were outside of the scope of the Phase 1 project. These reflections about the expectations for the project occurred directly after the project team BWS object case result histograms (Workshop 2 slides - 1.8, p. 11) were presented. Participant discussion explicitly cited the differences in individual perceptions, suggesting the results prompted the discussion.

In Case Study 2 Workshop 1, the project team engaged in a double loop learning cycle in relation to the stakeholder dispersion histograms. The wide dispersion of individual stakeholder perceptions of whether the "Transcript download process" outcome would be achieved indicated disagreement. The project manager had initially stated that the disagreement within the stakeholder group was about technical details related to transcript timestamps. However, a later reflective discussion started when the graduate trainee on the project team questioned this assumption, suggesting that the disagreements in the stakeholder group might also relate to the media unit staff perceived control over their work. The graduate trainee highlighted that the effective operation of transcript download process was outside the control of the media unit staff, yet it would be essential to the future delivery of value in their jobs (Workshop 1 notes - 2.7). The project team discussed how this issue would be particularly important to media unit stakeholders in the context of the perceived industrial relations issues around the outsourced work. The reflections about the media unit staff control over the delivery of value in their jobs and questioning of the assumption about the stakeholder perceptions explicitly cited the differences in the stakeholder group BWS object case results (Workshop 1 slides - 2.6, p. 10).

In total, seven of the eight double loop learning cycles identified in Case Study 1, and five of the six double loop learning cycles identified in Case Study 2, were prompted by specific BWS object case results, giving a total of twelve relevant instances. Therefore, the rival explanation that the project team could have achieved the same understanding of the current state of the project through discussion without the results is highly unlikely and Proposition 2 is supported.

5.3. *Proposition 3 – project team decision making*

> Proposition 3: Comparing individual and shared situation models about a complex project in double loop learning to understand its current state will inform the project team's management decisions.

Ten of the twelve double loop learning cycles that were prompted by specific BWS object case results led to the project team deciding to commit to specific management actions. In Case Study 1 Workshop 2, a double loop learning cycle was observed based on the continuing high level of disagreement indicated by the stakeholder dispersion histograms. The project team questioned the assumption that project stakeholders had a shared view of Phase 1 of the project. The project team discussed how due to the ongoing change in the Phase 1 project requirements, some stakeholder's expectations for Phase 1 deliverables were increasing. In contrast, other stakeholders and the project steering committee's expectations for the deliverables had not changed from three months ago. This discussion directly led to the project team committing to three actions:

- *Address expectation creep around phase 1*
- *Communicate status of project to all stakeholders at end of current phase specifically "what is and out of scope for phase 1"*

- *Distil high level communications for steering committee*
  (Workshop 2 slides – 1.8, p.20)

In Case Study 1 Workshop 3, another a double loop learning cycle occurred in response to the project team's low relative confidence in the "Assess Voice AI solution as an end-to-end operationalised solution" Phase 1 project outcome. In the discussion about this result the project manager questioned whether it was possible to achieve this project outcome (Workshop 3 notes – 1.11). The current level of detail about the business use case requirements was described as insufficient for the project team to understand the business process implications and articulate the end-to-end solution. Due to the continuing changes in the requirements during the project the business use cases were currently only specified at a high or mid-level of detail. This led directly to the project team agreeing to the two actions:

- *Need to move beyond mid-level requirements to both detailed requirements and the business process implications before clearly articulating end-to-end solution.*
- *Clarify in team what is the operationalised end-to-end solution – need to run some workshops.*
  (Workshop 3 slides - 1.10, p.15)

Another example comes from Workshop 3 in Case Study 2 where the project team engaged in a double loop learning cycle about the stakeholder group's relative level of confidence in the "Live captioning portal" tool operating effectively (Workshop 3 slides – 2.10, p. 11). The project team discussed how the stakeholder confidence in the effective operation of the "Live captioning portal" was lower than expected in April 2022 compared to February 2022. The change manager highlighted that multiple stakeholder respondents had the minimum possible confidence in the effective operation of the "Live captioning portal". This led the project team to question whether they had fully understood the reasons for the lower confidence in the live captioning portal. The change manager posed the question: "Is there more to the stakeholders concerns than stability issues with the production version after code updates?" (Workshop 3 notes - 2.11, p. 4). The project team discussed whether the history of other past projects might be impacting the perceptions of stakeholders and if current events were feeding into existing narratives about IT projects struggling to deliver effective solutions (Workshop 3 notes - 2.11). This directly led to the project team to commit to the following two actions:

- *Sessions with stakeholders to unpack concerns around the reduced confidence in live captioning portal operating effectively*
  - *Is there more to it than recent stability issues after code updates?*
- *Unpack why stakeholder confidence in transcript download process is reduced compared February but not to the same extent as live captioning portal*
  (Workshop 3 slides – 2.10, p. 15)

Ten of the twelve project teams' workshop double loop learning cycles were based on BWS object case results were directly linked to specific management decisions. Therefore, Proposition 3 is supported.

6. Discussion

This research empirically tested the application of mental model theory and double loop learning from organisational learning theory to the management of complex projects as complex adaptive systems drawing on complex adaptive systems theory. It extended the limited prior empirical project research by focusing on indirectly measuring and utilising comparisons of individual and shared situation models of the current state of complex projects. Three propositions were developed and evaluated:

Proposition 1: Project teams will be able to reflect on the current state of their complex project based on comparisons of individual and shared situation models.
Proposition 2: Comparing project team and stakeholder individual and shared situation models about the project will lead to reflective double loop learning about the complex project's current state by the project team.
Proposition 3: Comparing individual and shared situation models about a complex project in double loop learning to understand its current state will inform the project team's management decisions.

The analysis of the longitudinal workshop data from the two case studies provides evidence to support each proposition. In the six workshops there were 52 instances of reflections about the current state of the project based on mental models. This led to 12 instances of double loop learning cycles based on the reflections which in turn led to 10 instances of management decisions directly informed by the double loop learning cycles. Forty of the reflective discussions about the current state of the project identified in Proposition 1 led to single loop learning cycles instead of the double loop learning cycles as required for Proposition 2.

6.1. Research contributions and theoretical implications

This research explored whether mental model and complex adaptive systems theory in conjunction with double loop learning from organisational learning theory could explain the process by which project team's update their situation models of a complex project. In addition, the research explored whether the project team's updated individual and shared group situation models would directly inform management decisions. The results demonstrated that differences between representations of individual and group situation models of a complex project can be used by the project team to reflect on the project reality in double loop learning to update their situation models. Furthermore, the project team's updated situation models from the double loop learning cycles can directly inform management decisions about the complex project. These results support the combined application of mental model and complex adaptive systems theory to explain the emergent nature of complex projects as proposed in the Daniel and Daniel (2018) conceptual framework. Specifically, consistent with this framework, the longitudinal measurement of individual perceptions in the case studies provided evidence of the changing individual and shared group situation models over time in relation to project events that inform decision making.

The extension of situation models to stakeholders also brings a new perspective to the application of mental model theory in projects. Previous research about mental models focussed on project teams (e.g., Shafique & Mollaoglu-Scott 2020; Hsu et al. 2011; Wu et al. 2023), yet stakeholders are a significant focus of project research due to their potential impact on project outcomes (Eskerod et al., 2015; Littau et al., 2010). This research has highlighted how situation models from mental model theory could be applied in project stakeholder research to better understand stakeholder views. This is important because understanding the differences between stakeholders allows limited project stakeholder engagement resources to be prioritised (Huemann et al., 2016).

For organisational learning theory, these results provide the first empirical evidence of double loop learning in complex projects based on the elicitation and comparison of representations of individual and shared situation models. The evidence for the efficacy of project teams' learning based on these comparisons supports the Chang et al. (2021) socio-cognitive project team learning framework based on organisation learning theory. Despite the framing of double loop learning as providing valuable information for management decisions and its widespread application in project research (e.g., Lan & Ramesh, 2007; Crawford & Hoffman, 2011; Henderson et al., 2013) there does not appear to have been prior empirical evidence of this process in complex projects. The results provide empirical evidence for project team double

loop learning about a complex project's current state directly informing management decisions. In addition, the rejection of the rival explanation for Proposition 2, that the same understanding about current state of the project could be obtained through project team discussion without the BWS object case results, supports the Nachbagauer (2021) argument for proactive approaches to project team double loop learning in complex projects.

The process of comparing situation models in the workshops may also have the potential to encourage project teams to reflect on their own learning processes, a form of deutero-learning (Argyris & Schön, 1978). In Case Study 1 at the end of Workshop 3, the project team discussed the value of the workshops with the change manager stating, "I approached the workshop thinking nothing had changed in the project but after working through the results and the resulting discussions I realised that a lot had happened" (Workshop 3 notes – 2.11, p. 4). In the same discussion the project manager described the workshops as "like a health check" that "made sure everyone was on the same page" (Workshop 3 notes – 2.11, p. 6) suggesting that the project team in Case Study 1 were reflecting on their own learning processes and outcomes. While deutero-learning was not the focus of this research, there is evidence to suggest the comparison of representations of mental models in complex projects may have benefits for project team learning that extend beyond double loop learning. This further supports the application of the socio-cognitive perspective on project team learning from organisational learning theory.

6.2. Methodological implications

This research is the first empirical application of the BWS object case at the individual level in the project literature. The method was used to produce indirect measurements of situation models that accounted for individual level scale effects, response biases and styles to enable direct comparison between and within heterogeneous individuals' perceptions at a point in time and over time. The results support the potential Hackman (2021) identified for the BWS object case to be applied to a wide range of perception focussed project research topics such as risk management, proposal bidding and negotiation. The number of individuals who completed the BWS surveys was relatively limited in the case studies, however, previous research has applied the method at the individual level with thousands of respondents (e.g., Chrysochou et al., 2022; Lockshin & Cohen, 2011) highlighting its scalability. In addition, the research demonstrates the potential of the BWS object case for longitudinal research into how individual and group perceptions change in response to the emergent nature of complex projects as complex adaptive systems.

This research is therefore also the first to utilise the individual level BWS object case to indirectly measure team individual and shared situation models of complex projects. The methodology answers the Cooke et al. (2004) call for broadly applicable measures for team situation models that have a clear method to aggregating heterogeneous individual data to derive collective knowledge. The case studies also demonstrated how the methodology can be embedded within a task context which is important for studying team cognition that emerges through interactions in the context of a changing task environment (Cooke et al., 2013). This research has demonstrated a generalisable research methodology for eliciting individual perceptions as an indirect measure of mental models in complex projects. The focus on a generalisable methodology contrasts with most project research that focuses on developing a specific measurement instrument for a topic (e.g., risk) within a context (e.g., complex projects).

6.3. Practical implications

This research also demonstrated how the mental model lens can be used to develop practical methods to improve the management of complex projects. Specifically, individual level perceptions that provide an indirect measurement of situation models and can form the basis for system-wide tools for teams managing complex projects called for by Findlay and Straus (2015). The representations of situation models can be visualised and the reasons for the differences then explored in workshops to develop an understanding of a project as demonstrated in the case studies. Furthermore, the case study workshops illustrated how to create a collaborative learning environment about a complex project based on situation models that minimises defensive interpersonal dynamics. This environment was found to support participants in their reflections about their project, encouraging double loop learning to inform project team management decisions.

6.4. Research strengths and limitations

The two cases provided a replication test for analytic generalisability with different organisation scale and sector, project objectives, resourcing levels and focus for their BWS surveys. However, a limitation was that there were only two case studies about projects in one country, Australia. Also, in both cases the project teams selected the relative confidence scale for their BWS object case surveys. In addition, this research was exploratory in nature and further confirmatory studies are needed to establish whether the findings hold true for a wider range of complex projects.

The participation of all project team members (i.e., the population) in both case studies was a strength of this research. It meant that the BWS object case results presented in the workshops were representative of the project team situation models. Relevant key stakeholders for the complex projects also agreed to participate in the research providing useful results to compare with the project teams in each workshop. However, two limitations for the generalisability of the findings were the relatively small size of the project teams and the small number of key stakeholders that were all internal to the organisations.

The longitudinal workshop data from the two case studies was another key strength of this research. The three cycles of data collection in each case study provided data from six workshops to evaluate the propositions. However, there were only three data collection cycles in each case study with the data limited to the BWS surveys and workshops. In addition, the research did not evaluate the performance of the projects or examine the specific impact of the project team workshop management decisions with no qualitative data collection outside of the workshops.

6.5. Future research

The analytic generalisability of this research can be improved through replication with additional case studies. Case studies about projects with large project teams and those with stakeholders both internal and external to the organisation would be a valuable extension of this research. Also, case studies about projects in other industries such as healthcare or construction would increase the generalisability of the findings. In addition, replication in projects across multiple countries to test the findings about project team double loop learning in different workplace cultures would be beneficial. Such research could also be undertaken on a confirmatory basis to build on this exploratory research.

Future research could focus on the impact of management decisions on project performance. This research focussed on utilising the differences in perceptions about the complex project in feedback loops to inform decision making in workshops. Future research could examine the impact of the specific decisions made in workshops on project performance in the case studies. Alternatively, the research could focus on the impact on project performance of applying the approach to a specific process such as risk management.

Research could also examine the impact of project teams comparing their situation models in workshops on other forms of learning such as deutero-learning by collecting qualitative data about the project teams'

performance outside of the workshops. This research could also explore collaboration and team performance in the context of longer-term shared team mental models in contrast to the situation models focussed on in this research.

The novel methodology demonstrated in this research could also be applied to other complex project research topics such as the perceived complexity of projects and how these perceptions change over time in relation to project events. The ability of the BWS object case at the individual level to scale from a single respondent to thousands of respondents (e.g., Chrysochou et al., 2022; Lockshin & Cohen, 2011) would enable this research to extend to all complex projects even those with very large numbers of stakeholders such as megaprojects. In addition, future research could directly compare the BWS object case with other methods of eliciting perceptions in the same context to investigate the differences in the measured perceptions.

There is also significant potential for research that contributes to the ongoing stream of research into tools for project professionals to manage complex projects (e.g., Elia et al., 2021; Mikkelsen et al., 2021; Remington & Pollack, 2007; Williams, 2017). The individual level BWS object case could be utilised to develop practitioner tools that rapidly elicit and synthesise diverse points of view to inform team decision making in complex projects (van der Hoorn, 2020).

7. Conclusion

This research explored whether individual level perceptions as indirect measurements of situation models could be presented to teams in workshops in a way that encouraged double loop learning about the current state of complex projects to inform management decisions. The research methodology used to explore this question incorporated BWS object case surveys to measure the perceptions and workshops to compare visualisations of the perceptions. The methodology was applied in longitudinal case studies of two projects. The project teams were found to engage in double loop learning about the current state of their projects which subsequently informed their management decisions. This research has made significant contributions to complex project research theory, methodology and practice. For theory, three key contributions were made. First, the combined application of mental model theory with complex adaptive systems theory to explain the emergent nature of complex projects was explored and supported. Second, situation models were introduced as a form of mental model and extended from team members to stakeholders for project research. Third, empirical evidence was provided of double loop learning in complex projects informing decisions based on the elicitation and comparison of individual and shared situation models supporting organisational learning theory. The research demonstrated a methodology that can be used to develop a system-wide perspective of projects. Integrating quantitative individual level BWS object case perception data with qualitative data sources such as workshops in longitudinal mixed method case studies provided unique insights into change over time. For practice the research demonstrated a powerful scalable approach for project teams to incorporate subjective evaluations of a complex project and its environment into their decision making in reflective workshops. In summary, this research utilised a novel research methodology to demonstrate the utility of the mental model theory as a lens for research into the management processes of complex projects as complex adaptive systems.

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CRediT authorship contribution statement

David C. Hackman: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing, Software. **Julien Pollack:** Conceptualization, Formal analysis, Methodology, Writing – review & editing. **Marzena Baker:** Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.ijproman.2024.102603.

Appendix 1 – Qualitative Coding of Workshop Discussions

The behaviour observed in the workshop discussions needed to exhibit specific characteristics to meet the criteria for the propositions. All criteria needed to be met in a discussion for an instance of reflection, double loop learning or informed decision making to be identified. In addition, the propositions are cumulative for a specific discussion. The criteria for Proposition 1 about reflecting on the current state of the complex project being observed are a prerequisite for Proposition 2 about double loop learning being observed for a specific discussion.

Proposition 1: Project teams will be able to reflect on the current state of their complex project based on comparisons of individual and shared situation models.
1.1 - The discussion followed the presentation of one or more BWS object case results.
1.2 - One or more preceding BWS object case results were explicitly referenced in the discussion.
1.3 - The current state of the project was discussed in relation to the specific BWS object case results referenced in the discussion.

For example, the project team discussing a recent project event as the reason for a specific difference between the previous and current project team group BWS object case results.

Proposition 2: Comparing project team and stakeholder individual and shared situation models about the project will lead to reflective double loop learning about the complex project's current state by the project team.
2.1 - Reflections about the current state of the project based on one or more specific BWS object case results.
2.2a - Questioning of assumptions about the project (e.g., how it is being managed); and/or,
2.2b - Questioning of the project objectives (e.g., can an objective be achieved).

For example, the project team questioning whether they fully understand a project risk given the significant difference between the project team and stakeholder perception of its likelihood at a point in time.

Proposition 3: Comparing individual and shared situation models about a complex project in double loop learning to understand its current state will inform the project team's management decisions.
3.1 - Double loop learning about the complex project's current state by the project team based on one or more specific BWS object case results.
3.2 - One or more actions in the agreed workshop outputs that is based on the reflexive double loop learning about the project's current state by the project team.

For example, the project team committing to targeted communications with stakeholders to address the unexpected the impact of changing a supplier on their confidence a key project outcome would be fully achieved.

Appendix 2 – Key Case Study Documents

Case Study 1			
Source	Document	Description	Pages
Public Documents	1.1	Organisation Annual Review 2021	32
	1.2	Organisation Environmental, Social and Governance Data Summary 2021 Financial Year	20
Case Notes	1.3	Observations and notes about the organisation and overall case study including the survey development process	13
	1.4	A chronology of all the meetings with the project team and stakeholders for the case study	7
Workshop Materials & Notes	1.5	A Jupyter Notebook file documenting all the BWS survey data analysis steps to produce workshop result graphs	1
	1.6	Workshop 1 presentation slides including the completed outcomes	19
	1.7	Workshop 1 notes and observations	9
	1.8	Workshop 2 presentation slides including the completed outcomes	20
	1.9	Workshop 2 notes and observations	12
	1.10	Workshop 3 presentation slides including the completed outcomes	15
	1.11	Workshop 3 notes and observations	10
		Case Study 2	
Public Documents	2.1	Organisation Annual Report 2021	36
	2.2	Organisation strategic plan for 2019–2023	4
Case Notes	2.3	Observations and notes about the organisation and overall case study including the survey development process	17
	2.4	A chronology of all the meetings with the project team and stakeholders for the case study	6
Workshop Materials & Notes	2.5	Jupyter Notebook file documenting all the BWS survey data analysis steps to produce workshop result graphs	1
	2.6	Workshop 1 presentation slides including the completed outcomes	12
	2.7	Workshop 1 notes and observations	10
	2.8	Workshop 2 presentation slides including the completed outcomes	16
	2.9	Workshop 2 notes and observations	11
	2.10	Workshop 3 presentation slides including the completed outcomes	16
	2.11	Workshop 3 notes and observations	11

Appendix 3 – Workshop Participants

Case Study 1 Individuals	Case Study Workshop Participation		
	Workshop 1 Sep 2021	Workshop 2 Oct 2021	Workshop 3 Nov 2021
Project Manager	■	■	■
Business Analyst	■	■	
Test Manager	■	■	■
Change Manager	■	■	■

Case Study 2 Individuals	Data Collection Workshop Participation		
	Workshop 1 Dec 2021	Workshop 2 Feb 2022	Workshop 3 Apr 2022
Project Manager	■	■	☒
Change Manager	■	■	■
Change Analyst	■	■	
Graduate Trainee	■		
Project Coordinator			■

Key: ■ Participated; ☒ Did not participate; □ Not applicable.

In Case Study 1 the business analyst left the organisation in November 2021 and so did not participate in Workshop 3. In Case Study 2, the graduate trainee was rotated to different role so they did not participate in Workshop 2 or 3. A project coordinator was hired in March 2022 and was assigned to the project team participating in Workshop 3. The project team change analyst left the organisation in March 2022 and did not participate in Workshop 3. The project manager planned to attend Workshop 3 but was called away to an urgent meeting at the last minute and did not participate.

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