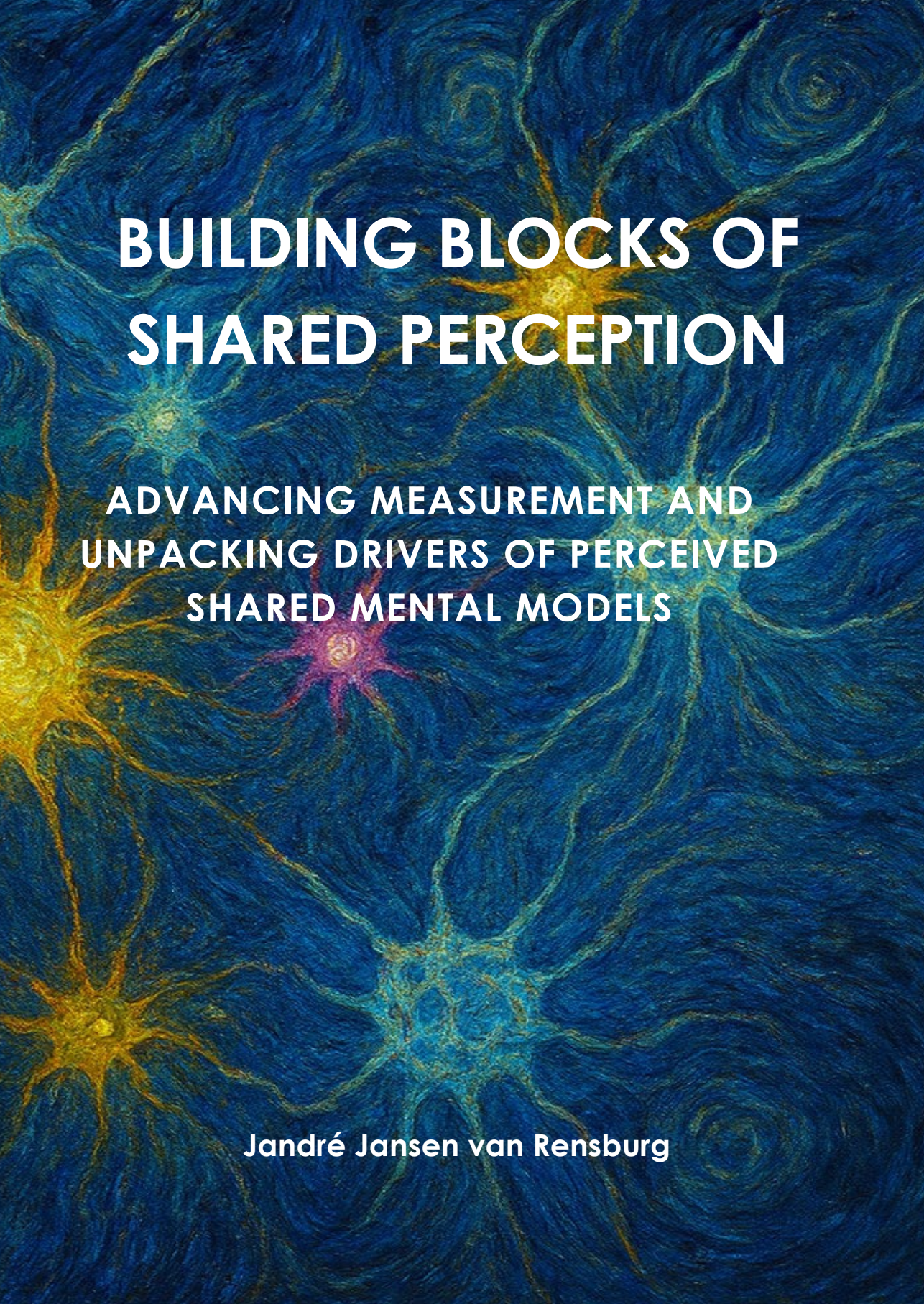


BUILDING BLOCKS OF SHARED PERCEPTION

ADVANCING MEASUREMENT AND UNPACKING DRIVERS OF PERCEIVED SHARED MENTAL MODELS

Jandré Jansen van Rensburg

PROPOSITIONS

Accompanying the doctoral dissertation:

Building Blocks of Shared Perception

Advancing Measurement And Unpacking Drivers Of Perceived Shared Mental Models

1. Time transcends tasks – every aspect of the work environment can be tied to some temporal component and we should not become fixated on deadlines alone – Chapter 2

2. Construct proliferation is not the problem – improper development of measurements may be – Chapter 2

3. Team cognition need not always be shared – we need to understand differences in cognition between team members if we are to fully understand similarities – Chapter 2

4. Even if it seems obvious, assuming things are the way they are, and that working together leads to particular outcomes, remains an assumption until tested – Chapter 3

5. Depending on one another to complete tasks is insufficient – the assessment and recognition of success also needs to be shared among team members – Chapter 3

6. Self-efficacy is a strong motivational tool in learning and thinking as a team, but overconfidence can risk ignorance and there is benefit in carefully appraising your (team's) capabilities – Chapter 4

7. Even in newly formed teams, members are likely to think that they generally think alike – Chapter 4

8. An expiration date does not represent an expiration intention – Chapter 4

9. A day is only wasted if you didn't learn something new – childhood lesson

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ISBN: 9789465345093

Cover and chapter overleaf designed by Jandré Jansen van Rensburg with ChatGPT

Printed in the Netherlands by Proefschriftmaken

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DISSERTATION

To obtain the degree of Doctor at Maastricht University, on the authority of the Rector Magnificus, Prof. Dr. Jan Smits, in accordance with the decision of the Board of Deans, to be defended in public on

Tuesday, 7 July 2026, at 16:00 hours

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CHAPTER
1

GENERAL INTRODUCTION

1.1. General introduction

Throughout history a fundamental component of human progress and development has been the collective efforts that groups of individuals put in towards the achievement of common goals (i.e., teamwork). For instance, the role of teams (defined as two or more interdependent individuals that interact with one another via different communication media, who share common goals aligned within an organisational system to perform tasks relevant to the organisation, within the boundaries of their task environment; Kozlowski & Ilgen, 2006; Mathieu et al., 2019) can be drawn back to the earliest examples of hunter-gatherer tribes who would organise into groups to track animals or forage for food (Andras & Lazarus, 2005; Lee, 1979). By pooling collective resources and coordinating with one another, these early humans were able to sustain and develop progressively more advanced tactics and techniques to supply their tribes. Teamwork today is no less a part of how we organise ourselves and complete challenging tasks than it was thousands of years ago. In keeping with societal development, humans have developed more complex industries and processes to supply various emerging social, economic, and psychological needs where teams are ever relevant (Van Vugt et al., 2024). One of the core differences is that the focus has shifted from collaborating to ensure a tribe's survival, to realising different, often more psychologically oriented, needs in different contexts (including teams and organisations; Maslow & Lewis, 1987). Consequently, teams are vital functional

units in virtually every organisation and we witness increasing complexity in their composition and operation as we advance our understanding of how teams work (Fyhn et al., 2023). This is exemplified in how organisations draw on various compositions of individuals, ranging from solitary workers, to dyads and teams to achieve their outcomes (Park et al., 2020), often with different compositional features that shape team members' cognition (Hollenbeck et al., 2012).

In this chapter, I advance the literature on (perceived) shared mental models (SMMs) by integrating emerging insights in the field into a more coherent understanding of how perceived SMMs are measured and develop over time. Firstly, in order to understand shared cognition, I will argue that one must acknowledge its roots in individual cognition (e.g., Marks et al., 2001). Secondly, in my view, an understanding of the content of SMMs (i.e., what are the main dimensions of the construct, as per contemporary literature; e.g., Cannon-Bowers et al., 1993; Mohammed et al., 2010; 2015) is required before one can discuss the lenses (e.g., structure vs. perception; Rentsch et al., 2008) through which it is viewed. I argue that this in turn enables the appropriate conceptualisation, study and measurement of *perceived* SMMs as a relevant, up-and-coming topic while accounting for its development over time. Finally, I conclude this chapter with an overview of the dissertation and show how the different studies I conducted with my co-authors fit together.

1.2. Team cognition

Teams are called on to make effective decisions when performing their work, especially when this entails complicated processes or performing complex functions that would not be feasible for individuals (Hollenbeck et al., 2012). This requires their members to utilise their work-related knowledge and capability for reasoning in making effective decisions that meet their team's requirements (Cooke et al., 2013). Within the team context, individuals need to collaborate and work towards mutual success. To enable this collaboration to go as smoothly as possible, teams can strive to understand their cognition and how individual thought and reasoning influence collective action (DeChurch & Mesmer-Magnus, 2010b; Mesmer-Magnus et al., 2017; Mohammed et al., 2021). In collective contexts such as dyads (i.e., pairs of individuals who may be a fully functional team or form part of a larger team; Kenny et al., 2006) and teams (a group of two or more individuals working towards a shared goal, interdependently yet with different roles and responsibilities; Kozlowski & Ilgen, 2006), individuals have the opportunity to develop shared cognition, where they acquire, integrate, and structure knowledge derived from their work environment into their individual and shared understanding (Cannon-Bowers et al., 1993). Mohammed et al. (2021, p. 460) describe such shared cognition as *team cognition* which they define as "knowledge building activities (processes) or sharedness of knowledge content or structure (representations)".

The development of team cognition depends on its form and content (Mesmer-Magnus et al., 2017; Niler et al., 2019). Rentsch et al. (2008) argue that team cognition is best understood over three distinct forms: 1) *perception* (reflecting beliefs, attitudes, or expectations about either individual or shared cognition in the team); 2) *structure* (organised knowledge structures, representations, and schemas); and 3) *interpretation* (social construction of meaning via team processes, such as sensemaking and collective learning). While dividing the concept of team cognition into these three forms is useful in understanding how different cognitive processes work and contribute to shared cognition, I argue that this underrepresents the connections between the three forms of cognition and thus constrains the way we can understand how such processes influence them. In addition, I propose that perceptions can influence teams' structural representation and interpretation of information and that different types of team cognition (see DeChurch & Mesmer-Magnus, 2010b; Rapp et al., 2021 for overviews) may draw on *all three* forms of team cognition in their development, depending on the demands teams face or goals they need to achieve.

The nature of work is often dynamic and requires teams to adapt their understanding of how they need to work together and can best achieve their various goals (Cronin, 2015; Uitdewilligen et al., 2013, 2018). Teams' interaction with this environment stems from how they interpret and understand various defining

features of their collective work (e.g., their tasks and their fellow team members). Over time, this leads to the development of a shared understanding about key aspects of the team's working environment – i.e., a shared mental model (SMM; Klimoski & Mohammed, 1994).

1.3. Mental models – from sharing to shared perceptions

Mental models are not inherently a *shared* element within teams, but rather start out as individual understandings of the team's work, that can become shared as they work together. As individuals navigate different challenges and situations while working in their teams, they gather and integrate knowledge relating to key elements of their work environment via various team processes (i.e., "members' interdependent acts that convert inputs to outcomes through cognitive, verbal, and behavioural activities directed toward organizing taskwork to achieve collective goals"; Marks et al., 2001, p. 357). This knowledge equips individuals to develop their own mental model by prioritising and organising this knowledge into a structured representation of their work relative to the broader context of their team. Mental models become an important component of our work-related cognition as they enable people to understand and act on (familiar) challenges more swiftly since it offers a roadmap of how we need to perform our tasks, with whom, and according to what temporal demands (Mohammed et al., 2010, 2021).

While these mental models are formed through individual cognition, they can also be shared among groups of individuals who work towards the achievement of shared goals, i.e., mental model can be shared within work teams. Within the field of organisational research, numerous studies have shown that SMMs develop over time as teams engage in various team processes (e.g., Fyhn et al., 2023; Marks et al., 2001; Santos et al., 2021; Van den Bossche et al., 2011). As team members collaborate, interact, learn, and share information, they are able to develop better SMMs. The increased understanding of their shared work environment that stems from their engagement with these processes, enables them to adapt and improve existing mental models by supporting or disputing their work-related cognition. This further enables team members to better coordinate their actions as team members' behaviour becomes more predictable as behaviour is informed by a shared understanding of how tasks are performed (Mohammed et al., 2010; Müller & Antoni, 2020a; Santos et al., 2015b) and enables them to adapt their SMMs as per situational demands (Uitdewilligen et al., 2013).

This means that both individual and SMMs are dynamic and change over time, based on the behaviour of team members within their shared context, and therefore are considered as an emergent state (i.e., "constructs that characterize properties of the team that are typically dynamic in nature and vary as a function of team context, inputs, processes, and outcomes"; Marks et al., 2001, p. 357) that has

unique and important ties to various team processes. This notion has been supported in past research, which demonstrate the dynamic nature of SMMs (cf., Mathieu et al., 2000; Santos & Passos, 2013; Santos et al., 2021). These past works have often described SMMs purely in terms of a structural form of team cognition, a notion we dispute in this dissertation. For example, Rentsch et al. (2008) argue that SMMs are an example of *structured* shared cognition, and not categorised under other forms of shared cognition (i.e., perception or interpretation). In this dissertation, I argue that SMMs are not only a structural representation of teams' knowledge, but that these SMMs can also draw on the other two forms of team cognition in their development. I argue that SMMs are unlikely to be based on objective data alone, given the involvement of individual thought and cognition in their development, and will most likely contain information that is relevant to the team (i.e., in terms of content), collected via observations and distilled by beliefs and expectations (and thus contain *perception*) and be meaningfully applied to their work (and thus contain *interpretation* as well). While teams dynamically develop SMMs, this may not be a conscious process that unfolds along clear, structured lines and teams may therefore (not) always be aware of their shared understanding of their work.

1.4. The dimensionality of shared mental models – key content domains

SMMs incorporate knowledge about key elements relating to the individual's work environment. Cannon-Bowers et al. (1993) distinguished between four

dimensions of SMMs: two under the *task* mental models (equipment and task) and two under the *team* mental models (team interaction and team). Equipment SMMs incorporate knowledge relating to the specific equipment, tools, and technologies used to complete tasks (e.g., two team members may work with the same computer system, but have access to different modules that could influence their shared understanding of the system's function). Task SMMs refer to the specific task related processes, contingencies and strategies (e.g., a construction team may need to follow a particular sequence of steps in building a wall, involving several members at different points). Team interaction mental models refer to the way people interact and communicate, relative to their individual roles (e.g., a human resources team may need to exchange information inside and outside the team that determines how a job offer is compiled when appointing a new employee). The team mental model refers to the composition of the team in terms of various individual attributes relevant to their work, such as their knowledge, abilities, skills (e.g., a research team needs to know which researcher is capable of performing what kind of data analyses).

Later work on SMMs simplified the conceptualisation of SMMs over two categories, since equipment and tasks, and interaction and team were closely related, resulting in SMMs being predominantly categorised under ‘new’ labels of task SMMs and team SMMs (Mathieu et al., 2000, 2009). While research on task

and team SMMs has emerged as the norm, these two dimensions have been described as being overly broad and generic (Klimoski & Mohammed, 1994; DeChurch & Mesmer-Magnus, 2010a). Mohammed et al. (2010) note the multidimensional nature of SMMs (teams can have mental models about any aspect of their work) as an issue that warrants attention in research. Adopting a narrow focus in the study of SMMs may neglect to take into account the impact of a vast number of contextual, functional, and individual factors – e.g., harvest teams working in agriculture will have very different tasks, demands, and working processes, compared to audit teams working on assignment at a client's urban offices.

The framework of content included in the study of SMMs has been dynamic as scholars seek to understand what kinds of SMMs are important for teams. This is demonstrated in the expansion of the focus of SMM research to include the temporal cognition in relation to SMMs (Mohammed et al., 2015). Temporal mental models, highlighting the shared understanding of time (such as schedules, timing, and deadlines), have emerged as a fifth commonly studied dimension to consider in this broader framework, given the importance of time in coordinating and collaborating within teams. An increasing number of scholars are taking up the call by Mohammed et al. (2015) to explore temporal SMM. These studies have shown the relevance of time and temporal cognition in SMMs, with results indicating that

temporal SMMs have implications for team learning (Santos et al., 2015a; 2016), and performance (Li & Zhang, 2021; Marhefka et al., 2018). As such, a shared understanding of time and its implications for the team has emerged as an important, widely applicable dimension of SMMs.

We build on the development of the dimensionality of SMMs that are likely to be relevant to most teams. In doing so, we revert to the original four dimensions suggested by Cannon-Bowers et al. (1993), with the inclusion of temporal SMMs. This allows for more precise and clearly defined underlying dimensions that could be generalisable to teams in their respective settings. This dissertation therefore notes five SMM dimensions, namely: task execution, task equipment, team interaction, team composition, and temporal SMMs.

Any framework of SMM dimensions has to summarise and focus on over-arching concepts, since team members can develop structured and organised understandings about any conceivable topic they encounter or can imagine in their work. Dimensions such as those noted above can be near infinitely divided and expanded, raising the question: Why these five dimensions in particular? When considering the body of literature on the topic, there is little deviation from the dimensions noted above, barring some more specialised papers that took into account highly specific mental models (e.g., SMMs of expertise location, Ellwart et al., 2014; perceived internet and communication technology (ICT) SMMs,

Müller & Antoni, 2020b, 2022; strategy mental models, Resick et al., 2010). These more specific forms of SMMs can usually be drawn back to one of the five dimensions used in this dissertation. To illustrate, SMMs of expertise location form part of the team composition content domain, since this refers back to the understanding of which team members possess what knowledge (Ellwart et al., 2014); ICT SMMs form part of the task equipment content domain, since these SMMs refer to technologies and tools team members use to collaborate at work (Müller & Antoni, 2020b, 2022); and strategy mental models can be categorised under task execution SMMs, since it relates to making suitable decisions about the best course of action for teams to achieve their goals (Resick et al., 2010). Therefore, the five dimensions identified in this dissertation serve as a reasonable baseline for SMM content which, while certainly not exhaustive, may well apply to most (if not all) teams. One illustration of this broad application could be: the technology (equipment) a team uses and the way that team members apply this (task) while communicating with their fellow team members (interaction) who possess unique and important skills (composition) enables them to meet their goals within specified timelines (temporal). This is only one illustration and it is important to note, as Cannon-Bowers et al (1993) stated, there will be numerous situational factors that determine the precise nature and constitution of SMMs in teams. However, scholars have largely stuck to the dimensions and content domains

described above, indicating strong support for these dimensions as the general baseline for the study of SMMs in teams.

1.5. SMM structure and perceptions

Team members can develop mental models regarding any aspect of the team's work. The knowledge associated therewith defines the content of the team's SMM (i.e., what the team's work is about). This knowledge can be organised and structurally represented in a manner that reflects how different components of a SMM fit together (i.e., how is the content of a mental model organised and represented to form an understandable, shared structure).

The different dimensions of SMMs explained in the previous sub-section represent generic content domains that are most likely present in, but unique across, different teams (for example, the differences in equipment used by a team of architects will differ strongly from the equipment used by a surgical team, yet both teams are likely to have SMMs about their respective equipment). How SMM content is represented in structure depends on the team members and how they interpret, organise and integrate information in the representations of their mental models – SMM structure is therefore a representation of structural relationships between information or data related to the team's work environment (DeChurch & Mesmer-Magnus, 2010a). Past work has shown that teams can, when prompted, create organised representations about important information relevant to their work,

which can be illustrated via different means (e.g., verbally via discussion in the team, or graphically as a drawing of the team's workflow over time). Doing so enables the direct comparison of individuals' representations of their own mental models relative to one another when prompted to do so.

For example, Santos et al. (2021) found that concept mapping (a common measurement of SMMs, where team members organise and represent knowledge in a structure represented by boxes and indicators such as arrows for relationships between them), when applied as an experimental intervention, prompted more similar and accurate structures in task SMMs over time. Past studies have been particularly interested in the *similarity* (i.e., how closely team members' structural SMMs resemble that of their peers) and *accuracy* (i.e., how closely their structural SMMs resemble their work environment) of the structure of SMMs (cf., DeChurch & Mesmer-Magnus, 2010a). Measures of SMM structure have prevailed over perceived measures, since the latter have been critiqued as being restricted to eliciting information about the *content* of SMMs (DeChurch & Mesmer-Magnus, 2010b; Mesmer-Magnus et al., 2017; Mohammed et al., 2021). I argue that this focus on structure, however, has often been burdened by the implicit assumption that if a structural SMM can be elicited, teams are also conscious and aware of its existence and therefore able to draw on it in their work (e.g., while two or more team members may independently have a mental model that is similar to that of

their fellow team members, they may not be aware of this or believe this to be the case). By prioritising structure over perception in the study of SMMs, scholars risk underestimating the role perceptions play in emerging shared cognition. In this dissertation, we do not dispute the arguments above, however we contend that perception as a form of shared cognition is vital for team members to be able to draw on their structured SMMs.

Whether team members are aware of their SMMs and whether they believe these SMMs to exist (i.e., *perceptions* of SMMs), has only recently started gaining traction as an explicit topic of research (cf., Gevers et al., 2020; Marhefka et al., 2018; Müller & Antoni, 2020a, 2020b, 2022). Some early publications in the SMM field have, in effect, studied perceived SMMs (cf., Levesque et al., 2001), but at this juncture literature did not yet clearly distinguish between the different forms of shared cognition (Rentsch et al., 2008). This resulted in works being published under the SMM banner, without suitably specifying the perceptual nature of measurement and how this differs from structural representations of SMMs. DeChurch and Mesmer-Magnus (2010a, 2010b) shed light on the way that studies in the field operationalise variables and made a case for more clearly defining the form of cognition under study. Through their meta-analysis, DeChurch and Mesmer-Magnus (2010a) showed that SMMs measured by means of questionnaires (i.e., perceptions of SMMs) were positively related to team outcomes, hinting at the

relevance of perceived SMMs for teams. Studies that have since been published on this topic have adopted a clearer stance on what they measure and perception is progressively being noted and explained more explicitly. For example, Müller and Antoni (2020a, 2022) explicitly study *perceived* ICT SMMs and Marhefka et al. (2018) does the same with *perceived* temporal SMMs.

Cognition is inherently linked to perception, since individuals gather vital information that can support or challenge their existing knowledge via perceptual means (i.e., when team they see, hear or otherwise observe the consequences of a particular course of action in doing their work, they are able to update or reinforce their interpretations about this particular action; Goldstone et al., 2015). Perceptual information is essential to teams' ability to capitalise on their shared cognition for a number of reasons. First, our individual cognition is to a large degree informed by our perceptions: the information we gather via different sensory means need to be integrated into our cognitive representations of a particular subject via cognition (Goldstone et al., 2015; Kastanakis & Voyer, 2014). It is therefore essential that individuals make effective use of their perception in informing the content and structure of their own mental models since learning from perception can enhance their integration of perceptual information in their cognition and therefore their SMMs.

In this dissertation, I argue that as team members develop perceptual awareness of their SMMs, they become better equipped to realise their benefits. The existence of a similar SMM in teams, whether accurate or not, will be unlikely to yield benefit if they are not known to their members – a team of cooks in a kitchen may all have a similar understanding of the process required to cook a particular dish and, whether their understanding is accurate or not, if they do not perceive this understanding to be similar between one another, they will be unlikely to fully benefit from the ease with which they can coordinate their actions in the kitchen. This means that team members need to develop representations of their mental models with one another through verbal or perceptual processes (cf., Johnson-Laird, 1980) that enable the mental model to become shared between members – i.e., they need to discuss and reflect on their own understanding of their work and observe how the team performs its various functions. They can then develop structured and perceived SMMs that enable positive outcomes for teams through an enhanced ability to anticipate each other's actions given certain situational cues (Mathieu et al., 2000). Observing the effects of coordinated action under a SMM and becoming aware of its existence can therefore offer substantial benefit to teams' ability to foresee the course of their shared actions relative to their work.

1.6. The need for more research into perceived SMMs

In this dissertation, I respond to the call for a better understanding of perceived SMMs that has been made in the literature by several scholars (cf., Mesmer-Magnus et al., 2017; Mohammed et al., 2010; 2021; Niler et al., 2021). Essentially, the reason for this is that much past research has not sufficiently operationalised *perceived* SMMs as such. Prior studies often relied on measures of SMM perceptions (i.e., questionnaires using agreement ratings) in measuring what was subsequently argued to represent SMM similarity or SMMs in general (cf., Fransen et al., 2011; Santos et al., 2015b). In these prior studies, the *concept* of perceived SMMs is not addressed, however, and it is only after nearly *three decades* of SMM research (Mohammed et al., 2010, 2021) that perceived SMMs are being operationalised and described in a specific and accurate manner. I argue that this indicates that there is a critical area of research under the SMM banner that needs to be better understood, if we are to understand and appreciate what SMMs are, how they develop, and how teams are able to use them to their advantage.

This is perhaps best illustrated in the findings from studies that centred on perceptions of SMMs over the last decade, as there are relatively few publications that specifically included or mentioned perceived SMMs prior to the papers that constitute this dissertation. Examples include: Müller and Antoni (2020a), who found that perceptions of *ICT* SMMs positively influenced team coordination and

performance; Marhefka et al. (2018), on the other hand found that perceived temporal SMMs negatively moderated the relationship between actual temporal SMMs and timeliness; whereas Ellwart et al. (2014) found that their index of team mental models of *expertise location* (a perception measure), predicted performance and team coordination, at the team level. These papers clearly indicate perception as focus of their measurement and these studies all drew on narrow bands of SMM content which give detailed insight into specific types of perceived SMMs, but could be limited to the specific environments in which they were studied. In turn, this complicates comparison between these studies and the broader literature.

Questionnaires have been used as a method of eliciting SMM *content* in past studies. Questionnaires are an example of perceptual measures, since they rely on individuals' subjective evaluation of the topic under study. These questionnaires have nevertheless been used with great success in the management and psychology literature, since they enable researchers to systematically collect and compare large volumes of data, across functionally diverse teams and organisations. Data collected using questionnaires are easily comparable between samples, and provide a structured assessment of participants' inner perceptions in a way that is translatable between different contexts (Babbie, 2020; DeVellis, 2021). In the past, four scales have been developed and validated for the measurement of perceived SMMs. However, all face some critical limitations. Ellwart et al. (2014) developed

a single-factor index scale for shared mental models of expertise location, a highly specific type of mental model, much like Müller and Antoni (2020b), who developed a single-factor scale to measure perceptions of ICT SMMs. These two questionnaires adopt a narrow focus and are suitable only in the measurement of their very specific focal dimensions of perceived SMMs. Johnson et al. (2007) developed a five-factor scale, drawing on relevant literature, but not following the dimensions as presented in literature. Their dimensions included: 1) general task and team knowledge, 2) general task and communication skills, 3) attitude toward teammates and task, 4) team dynamics and interactions and 5) team resources and working environment, convoluting team- and task-related dimensions of SMMs. Millward and Jeffries (2001), on the other hand, included SMM as a component of a larger team measurement instrument with two broad SMM sub-dimensions: 1) team interaction models and 2) team models. These two factors were divided into five further sub-dimensions: 1a) roles/responsibilities, 1b) interdependencies/support, 1c) information sources, 2a) knowledge of team members – KSAs, and 2b) utilization of team members' KSAs (knowledge, skills, abilities). Before this dissertation, a validated, reliable measure of perceived SMMs that is reflective of its contemporary theoretical dimensionality, was absent from the literature, which may offer some clue as to why the study of perceived SMMs has been limited and somewhat fractured in the past.

1.7. Perceived SMMs' development over time

Past research has yielded a wealth of insight into the development and relevance of SMMs in theory and practice. As emergent states, SMMs develop as team members engage in team processes (Marks et al., 2001; Mohammed et al., 2010) by obtaining and integrating new information in their shared understanding of their work environment over time. While past studies are predominantly oriented towards structured SMMs, I argue that the same team processes that shape SMMs are likely to contribute to perceived SMMs. The knowledge conveyed via team processes entails the use of various senses to integrate information into team members' cognition and therefore contribute to their perceived and structured SMMs. Cognitive structures (such as SMMs) are a product of perception and action within a particular context as part of team members' participation in team processes (Marks et al., 2001; Pecher & Zwaan, 2005). For example, observing the behaviour of a team member and its consequences can draw on various senses (sight, hearing, etc.) to prompt interpretation and cognition around the subject (Kozlowski & Chao, 2012). By *perceiving* the cause and effect of a particular team process in action, team members can gain knowledge from their exposure to, and observations of, the process in question. This suggests that perceptions may be a unique and important starting point for both individual and shared cognition.

I therefore argue that the processes described above, and emergent states such as perceived SMMs, are dynamic and liable to change over time in their development. More specifically, I argue that the passage of time contributes to the emergence of perceived SMMs in a number of ways: first, the direct interpersonal exposure that team members have to one another takes place cumulatively over time – their shared tenure leads to more opportunities for social interaction and exchanges of knowledge, which can lead to increasingly shared knowledge and understanding (cf. Cannon-Bowers et al., 1993; Cooke et al., 2013); second, team processes unfold and operate over time, meaning that team members will most likely be able to observe these processes in action and develop mental models about their work environment via perceptual means (Rentsch et al., 2008; Santos et al., 2016). By observing the behaviour and outcomes of their fellow team members, and by interacting with them as described above, they can develop better shared perceptions and knowledge about their work environment (Cannon-Bowers et al., 1993; Kozlowski & Chao, 2012). Since most work environments are prone to change over time, team members' (perceived) SMMs will likely reflect this, and be updated over time as new observations are made, new knowledge is acquired, or contradictions between the work environment and their mental models are exposed via social interactions (Uitdewilligen et al., 2013, 2018).

1.8. Overview of the dissertation

There are a number of concerns within the literature with perceived SMMs and their place in theory and practice. More specifically, there have been calls for perception to be more explicitly included and evaluated in SMM research, as well as criticism against the way that perceptions of SMMs have been measured and operationalised in past studies (cf., DeChurch & Mesmer-Magnus, 2010a, 2010b; Mohammed et al., 2021; 2017). In this dissertation, I expand on these calls and argue that literature on SMMs needs to expand beyond the study of single dimensions of perceived SMMs (cf., Marhefka et al., 2018, 2020; Müller & Antoni, 2020a, 2022) to include a broader perspective and eventually compare dimensions of perceived SMMs. As such, this dissertation makes a start of clearly representing perceived SMMs as a theoretical and empirical construct that encompasses multiple dimensions. Together with my co-authors, I respond to the existing calls relating to perceived SMMs by developing a measurement instrument and showing that, perceived SMMs can yield positive team outcomes. In doing so, we lay the groundwork for future research to build forth on this theme and to incorporate not only a comparative, but also an integrated, view of SMMs. This dissertation aims to spur this topic by clarifying what perceived SMMs generally entail and specifically addresses the following foundational questions: 1) How can perceived SMMs best be measured?; 2) How is shared tenure between team members associated with perceived SMMs and does interdependence influence this

relationship?; and 3) Do perceived SMMs evolve over time, and if so, what is the role of team learning and team member self-efficacy in their development? Figure 1.1 shows a graphical representation of how these chapters fit together within this dissertation.

Chapter 2[1] of this dissertation aims to address the measurement of perceived SMMs. Several studies have made use of questionnaires that are intended to measure SMM perceptions (e.g., Marhefka et al., 2018; Müller & Antoni, 2020a). Before this chapter, no study had developed and validated a perceived measure

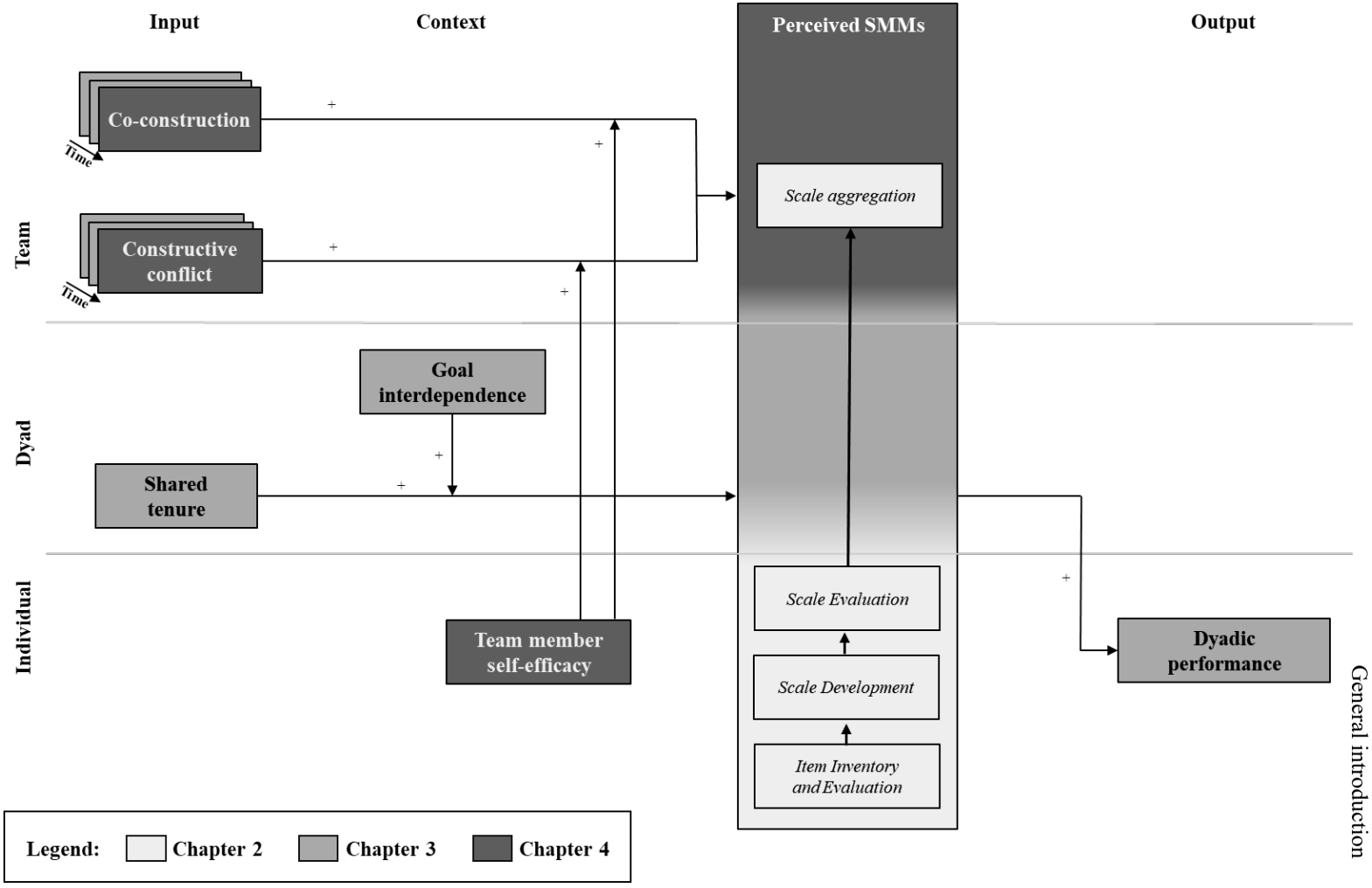
Table 1.1
Overview of empirical chapters' key topics, research questions, and research design

Chapter	Key topic	Research question	Design
2	Development of the five-factor perceived SMM scale	What are the core theoretical dimensions of SMMs, as currently represented in literature, and how can teams' perceived SMMs be measured in a manner reflecting these dimensions?	Multi-study deductive scale development
3	Shared tenure and perceived SMMs	How do shared tenure and goal interdependence interact to influence perceived SMMs, and how does this influence performance, in turn?	Dyadic survey study
4	Team learning and perceived SMMs over time	How do perceived SMMs develop over time as a result of the interaction between co-construction and constructive conflict, respectively, with team member self-efficacy?	Three-wave longitudinal team-level survey study

[1]The chapters of this dissertation, in particular Chapter 2, Chapter 3, and Chapter 4, are written to be stand-alone publications. As a result, some repetition is unavoidable.

Figure 1.1

Overview of empirical chapters



of SMMs that was reflective of their broad/general dimensions as captured in current literature. In this chapter we adopt a deductive scale development approach (Hinkin, 1998) in identifying perception-based measures of SMMs and items that can be used in measuring SMM perceptions (see Table 1.1 for an overview of the three empirical chapters, their research questions, and research design). Based on the scale development process mentioned above, we identified 314 items from an initial pool of 61 published sources, which we reduce to a scale of 20 items (four items representing each SMM dimension) via a rigorous scale development process encompassing four stages of data collection and analysis. In conducting this research, we also ascertain that the theoretical representation of temporal SMMs has been unwittingly framed as a sub-component to task SMMs. We rectify this by adopting a broader view of temporality that does not favour one of the existing four dimensions.

Chapter 3 is focused on two fundamental aspects of interpersonal relationships at work relative to perceived SMMs, namely shared tenure (Gonzalez-Mulé et al., 2020) and goal interdependence (Van der Vegt & Janssen, 2003). The body of research on SMMs has historically been more concerned with the outcomes and impact of SMMs, rather than their antecedents. In this chapter, we therefore set out to understand the relationship between shared tenure – the time individuals have worked together – and perceived SMMs, moderated by a key interpersonal

characteristic (i.e., goal interdependence), at the most basic level at which perceived SMMs could be observed (i.e., in leader-member dyads).

The time dyads spend working together is intrinsically linked to how much opportunity they have to exchange information and SMM research has long held the assumption that the longer team members work together, the more they will share mental models. Some past longitudinal studies have shown a positive influence of time on SMMs (e.g., Santos et al., 2021), however none directly studied the role of time dyads spent *working together* in the team (i.e., shared tenure). This chapter is the first to test this relationship directly, on the expectation that the longer individuals work together, the more opportunities they have to share information that contributes to their (shared) mental models (Grand et al., 2016; Van den Bossche et al., 2011). We determined that this is, indeed, the case for perceived SMMs and found that dyadic tenure positively influenced perceived SMMs. Of course, not all dyads can be expected to be equally inclined to work towards greater perceived SMMs in the time they spend together, prompting the question whether this could somehow be encouraged. We therefore argue – and demonstrate – that the degree to which dyad partners are dependent on one another to reach their goals (i.e., their goal interdependence) moderates the effect of dyadic tenure on perceived SMMs. More specifically, a shorter shared tenure was required to reach higher perceived SMMs for dyads who reported higher goal interdependence. This is of

particular relevance in contexts where (new) team members need to rapidly develop their perceived SMMs, especially since this chapter also shows that perceived SMMs further positively influenced leader-rated dyadic performance. The moderated mediation model was also supported, indicating that dyads can reach higher perceived SMMs, earlier in their tenure if goal interdependence is high, and consequently perform better.

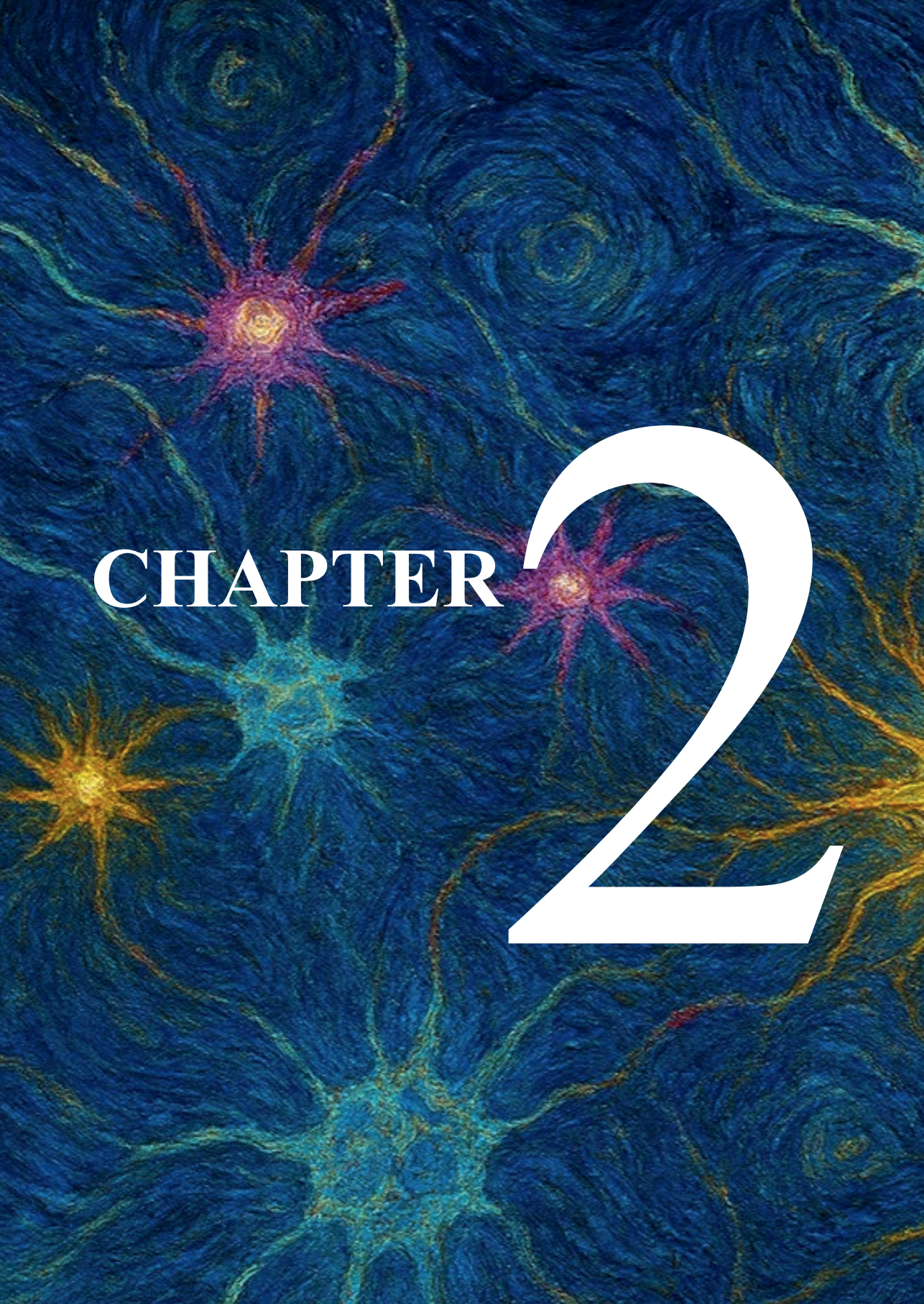
Chapter 4 looks at the temporal nature of perceived SMMs in greater detail. SMMs are emergent states, yet it is only recently that scholars have started viewing them with a longitudinal lens (cf., Gevers et al., 2020; Santos et al., 2015b, 2021), following calls for greater attention to their development over time (Mohammed et al., 2021; Fyhn et al., 2023). The same is not true for perceived SMMs: these emergent states have not yet been studied longitudinally, and their likely developmental trajectories therefore unknown. In this chapter my coauthors and I argue that perceived SMMs are likely to increase over time, but, due to the emergent nature of perceived SMMs, this may not follow a linear trend. To test this, we take a longitudinal look at the perceived SMMs of 165 student project teams of three to four members over three time points.

A key finding is that perceived SMMs tend to grow over time, and follow a linear trajectory (even though we also tested for possible curvilinear ones). Given their important role in team and individual cognition, in this chapter we study the

effect of one such process, team learning behaviour (specifically co-construction and constructive conflict; Van den Bossche et al., 2011) on perceived SMMs over time, accounting for team members' general self-efficacy (Bandura, 1986; Cook & Artino, 2016). We find that co-construction and constructive conflict both contribute to perceived SMMs' growth over time. We expected that team member self-efficacy would positively moderate this effect across conditions. This was the case in general, yet, surprisingly, the moderating effect of team member self-efficacy was stronger for teams with lower team member self-efficacy. This apparent contradiction of conventional wisdom (i.e., that greater self-efficacy will foster better learning), highlights the risk of overconfidence early in team lifespans and suggests that a more (self) critical attitude is beneficial to the process of learning in a team. These findings highlight the relevance of team learning behaviour and team member self-efficacy in the development of perceived SMMs, while, on the other hand, demonstrating that these dynamic variables could interact in unforeseen ways that warrants further investigation in future.

Chapter 5 concludes the dissertation and provides theoretical and practical implications and a broader discussion of the studies involved in this dissertation. In this chapter I integrate the implications from across the three chapters and provide suggestions for future research, based on the outcomes from the dissertation and the lessons learned along the way.

Chapter 6 presents my impact statement which offers insights into the relevance of the research in this dissertation and what it offers academia, practice, and society as a whole. More specifically, I illustrate the scientific and societal impact that flows from this research, drawing on the practical implications sections of the three empirical chapters and the efforts that have gone into creating awareness of their content via publication and conference presentations.


CHAPTER
2

THE FIVE-FACTOR PERCEIVED SHARED MENTAL MODEL SCALE: A CONSOLIDATION OF ITEMS ACROSS THE CONTEMPORARY LITERATURE

Chapter based on: Van Rensburg, J. J., Santos, C. M., de Jong, S. B., & Uitdewilligen, S. (2022). The five-factor perceived shared mental model scale: A consolidation of items across the contemporary literature. *Frontiers in Psychology*, *12*, 784200.

An early version of this manuscript was presented at The 81st Annual Meeting of the Academy of Management in 2021.

Abstract

Literature on Shared Mental Models (SMMs) has been burgeoning in recent years and this has provided increasingly detailed insight and evidence into the importance of SMMs within specific contexts. However, because past research predominantly focused on SMM structure as measured by diverse, context dependent measures, a consolidated multi-dimensional measure of perceived SMMs that can be used across diverse team contexts is currently lacking. Furthermore, different conceptualizations of the dimensionality of SMMs exist, which further impedes the comparison between studies. These key limitations might hinder future development in the SMM literature. We argue that the field of SMMs has now matured enough that it is possible to take a deductive approach and evaluate the prior studies in order to refine the key SMMs dimensions, operationalizations, and measurement. Hence, we take a three-stage approach to consolidate existing literature scale-based measures of SMMs, using four samples. Ultimately, this leads to a 20-item five-dimensional scale (i.e., equipment, execution, interaction, composition, and temporal SMMs) – the Five Factor Perceived Shared Mental Model Scale (5-PSMMS). Our scale provides scholars with a tool which enables the measurement, and comparison, of SMMs across diverse team contexts. It offers practitioners the option to more straightforwardly assess perceived SMMs in their teams, allowing the identification of challenges in their teams and facilitating the design of appropriate interventions.

2.1. Introduction

Effective teamwork is critically important to address the challenges teams face in the course of their work across a wide variety of settings, especially in today's competitive, demanding, and/or changing work environments (e.g., Kozlowski & Bell, 2013; Mathieu et al., 2019). To effectively face those challenges and perform their tasks, team members have to develop shared mental models (SMMs) – a shared understanding of knowledge among team members relating to important aspects in a team environment (Klimoski & Mohammed, 1994; Mohammed et al., 2010). SMMs are valuable to team members as they reduce uncertainty, lower misunderstandings and conflict, improve coordination and adaptation, and by such means increase effective team functioning (e.g., Cannon-Bowers et al., 1993; Santos et al., 2016; Uitdewilligen et al., 2018). Consequently, SMMs have been shown to be important in the past in many diverse settings and, given the expected challenging (business) world in the years ahead, are likely to remain so in the future (e.g., Kniffin et al., 2021; Mesmer-Magnus et al., 2017; Mohammed et al., 2017).

A thorough scientific understanding of SMMs is thus essential and SMM research has advanced over the years, however we argue that there are two challenges that need to be resolved in order to drive the SMM field forward. First, a perceived SMM scale to assess and study SMM perceptions in a systematic,

consistent, and methodical way across a wide range of contexts is needed. Second, to achieve such a scale and work towards a more coherent body of knowledge, the varied conceptualization and underlying dimensions of SMMs need to be consolidated.

To elaborate on the first challenge, SMMs are conceptualized as having both a structural and perceptual component (e.g., Marhefka et al., 2018, 2020; Mohammed et al., 2010). While structure refers to the actual SMM, i.e., existing representations of knowledge held by and shared among team members, perception refers to the awareness of a shared understanding among team members (Marhefka et al., 2020; Mohammed et al., 2010). Researchers have argued that the perception that team members are on the same page is one of the components of a SMM (Klimoski & Mohammed, 1994; Marhefka et al., 2020) and that when team members perceive they have a similar understanding, there is not only a possession of knowledge across individuals but the collective awareness thereof (Burtscher & Oostlander, 2019). Ignorance to the existence of SMMs may imply that teams are unable to leverage their SMMs in working towards collective goals (Rentsch et al., 2009). Despite the importance of analyzing the perception of SMM, research has mainly focused on SMM structure. Much of the literature on SMM structure has been informed by a variety of, often idiosyncratic, measurement approaches that are laborious, time-consuming, and often difficult to apply, as SMMs can be

context-specific (DeChurch & Mesmer-Magnus, 2010; Mohammed et al., 2000, 2010). In 2000, Mohammed et al. already observed that the measurement of SMM structure was often inconsistent. Although measurement of SMM structure has become more standardized over the last years, it remains divergent and context dependent results are difficult to compare across diverse teams (DeChurch & Mesmer-Magnus, 2010), leading scholars to suggest that more research is needed on the nature and relevance of general and perceived SMMs (e.g., Marhefka et al., 2018, 2020; Mohammed et al., 2010).

A key factor for such research is the existence of a valid and reliable measure that assesses the perceptions of SMMs in such a way that they fit to a wide range of tasks, teams, and organizational contexts. A general SMM scale would provide a solid anchor to study SMMs in a systematic, consistent, and methodical way across a wide range of contexts and across a much larger spectrum than is feasible with more time consuming methods. This would furthermore enable SMM' structure to be compared to perceived SMM as these different representations of SMMs can have different outcomes in teams (Marhefka et al., 2020). The importance of a perceived SMM scale can also be seen in the fact that there have been a few prior attempts to create or use such a scale (e.g., Levesque et al., 2001; Marhefka et al., 2018; Santos et al., 2015a), but only two such measures were developed and validated following scale development criteria (i.e., Johnson et al.,

2007; Millward & Jeffries, 2001). Previous perceived SMM scales faced their own limitations: some combined different dimensions under one factor (e.g., Ellwart et al., 2014; Santos et al., 2015a), did not focus on team members' cognitive representation of knowledge (e.g., Johnson et al., 2007), or focused only on a few SMMs dimensions (e.g., Hsu et al., 2011; Marhefka et al., 2018; Millward & Jeffries, 2001). Subsequently, a large number of measurement items that are often divergent in content factor structure exist across numerous scales, further convoluting the study of perceived SMMs. To overcome this, a general SMM scale capturing the key theoretical SMM dimensions occurring in the literature is needed.

This brings us to the second issue in the literature, namely the varying perspectives on the dimensional structure of SMMs (Mohammed et al., 2000, 2010, 2021). Mohammed et al. (2021) indicate definitional ambiguity as a limitation in the study of team cognition, including SMMs. Existing theoretical and empirical work offers conflicting ideas regarding the key content dimensions of SMMs. For example, different scholars focus on one or more of the following domains: equipment, task, team interaction, and team (Cannon-Bowers et al., 1993). Others have summarized these in two overarching dimensions of task (merging equipment and task) and team (merging team interaction and team) mental models (e.g., Mathieu et al., 2000). More recently, the conceptualization of SMMs has been expanded to include the temporal domain — a shared understanding of time and

other temporal factors which are relevant to the team's environment (e.g., Mohammed et al., 2015; Santos et al., 2015b). Scholars have observed that it is currently not clear how this dimension relates to the other content domains (Mohammed et al., 2012, 2015). Synthesizing the dimensional structure of SMMs is critical because differences may exist in team members' representations of each mental model dimension, separate dimensions may be differentially relevant in different contexts, and different dimensions may differently influence various outcomes. Hence, the way in which prior research has theorized and subsequently measured SMMs has differed substantially, and to move forward the dimensionality should be clarified so that future scholars can make more informed theoretical decisions and allow their research to become more comparable.

Addressing these two issues in the contemporary SMM literature are the key goals of the current research. First, we will explicitly discuss and theoretically ground the five SMM dimensions. Second, if needed, we will refine these conceptualizations of SMMs in order to build a strong overarching theoretical and conceptual framework. Based on that, we then, thirdly, inventory, consolidate, and validate the existing items in the literature into the new Five-Factor Perceived Shared Mental Model Scale (5-PSMMS). This creates a new measure of perceptions of SMMs, which can be applied to teams independent of context. We follow a deductive scale development approach (DeVellis, 2016; Hinkin, 1998), as

the current SMM literature is rich in the number and variety of items used, yet lacks an overview and consolidation of these efforts. Based on Hinkin (1998), our approach comprises six steps, namely (1) item inventory, (2) content validity assessment, (3) item reduction, (4) factor structure evaluation, (5) construct validity assessment, and – ultimately – (6) data aggregation assessment to assess the team level properties of our scale with the goal of creating a validated, reliable measure of perceived SMMs.

2.2. Background and theory of SMMs

Shared mental models refer to an emergent state – a cognitive construct which is "dynamic in nature and varies as a function of team context, inputs, processes, and outcomes" (Marks et al., 2001, p. 357). As an emergent state, SMMs reciprocally influence not only team outcomes, but also team processes (i.e., team members' actions that involve interaction with one other and their task environment to translate inputs into outcomes; Marks et al., 2001). Research has shown that when teams develop SMMs, team members organize information and establish response patterns that help them to adapt their behaviors to changes in their environment, and effectively coordinate and perform their work (e.g., Santos et al., 2021; Uitdewilligen et al., 2013, 2018, 2021). Thus, to effectively accomplish their tasks, we argue that it is critical that team members are "on the same page" on *which* tools or equipment to use, *what* tasks to perform, *with whom* they need to interact and

coordinate and *how* to do so, and *when* the work has to be accomplished (e.g., Cannon-Bowers et al., 1993; Mohammed et al., 2010, 2017).

2.2.1. Overview of the current measurement of SMMs

As highlighted above, SMMs are assessed through a wide range of different methodological approaches, yet they are similar in their aim to reveal "the degree of convergence among team members with regard to the content of known elements and the relationships between elements" (Mohammed et al., 2000, p. 129). Researchers study SMMs using different techniques, such as paired comparison ratings (or similarity ratings), rating scales, card sorting, concept mapping, cognitive mapping and content analysis (DeChurch & Mesmer-Magnus, 2010a; Mohammed et al., 2000, 2010). According to Mohammed et al. (2021, p. 480), the measurement of team cognition, and therefore of SMMs, "has been marked by fragmentation", as can be seen in the numerous measurement approaches and adaptations made to them. In the following sections we elaborate on the most widely used measures of structure and perceptions of SMMs, including their advantages and disadvantages.

2.2.1.1. Measures of SMM structure

Paired comparison ratings (or similarity ratings): In paired comparison ratings, participants are presented with a matrix in which concepts related with their tasks are listed along one side and the top, or with a list of pairs of brief statements

related with their tasks. These concepts or statements are derived from a detailed task analysis (Mohammed et al., 2010). Participants are asked to evaluate the relationship between each pair of concepts or statements on a numerical (scale format) rating (e.g., "-4 (*negatively related, a high degree of one requires a low degree of the other*) to 4 (*positively related, a high degree of one requires a high degree of the other*)" (Mathieu et al., 2000, p. 277). Examples can be found in Mathieu et al. (2000) and Lim and Klein (2006).

Card sorting: In card sorting, the researchers provide participants with cards that contain critical incidents. Participants are typically asked to sort these cards into categories (piles) that they find meaningful. Categorizations in this format are subsequently scored and aggregated to form mean team scores for comparison and rating (Mohammed et al., 2010). Examples can be found in Smith-Jentsch et al. (2001, 2008).

Concept mapping: In concept mapping, participants are presented with concepts or statements that they need to arrange in a hierarchical order (Mohammed et al., 2010), or that they need to select and use to build a concept map (e.g., Uitdewilligen et al., 2021). The concepts are typically predetermined and developed based on a detailed task analysis. Examples can be found in Marks et al. (2000) and Uitdewilligen et al. (2021).

Cognitive mapping: In cognitive mapping, participants present their mental model content without using pre-established concepts, statements, or categories (Mohammed et al., 2010). Instead, written or verbal statements from interactions between team members are coded and organized in a manner which illustrates concepts and the relationships between them (e.g., Waller et al., 2004). The concepts are therefore derived from unstructured participant data and compared between team members to develop a picture of the SMM. Examples can be found in Carley (1997) and Van den Bossche et al. (2021).

2.2.1.2. Measures of SMM perception

Rating scales: In rating scales, participants are provided with a series of statements and asked to respond to them using a fixed response format – e.g., from 1 = *strongly disagree* to 7 = *strongly agree*. Items can be worded according to task related concepts (e.g., Marhefka et al., 2020) but are not necessarily informed by task analyses and can be predetermined based on the theoretical content of SMMs (e.g., Santos et al., 2015a). These measures are aggregated from individual perceptions of mental models to the team level. Examples can be found in Johnson et al. (2007) and Santos et al. (2015a).

2.2.2. Comparing measures of structure and measures of perception

A variety of measures of SMMs exist, each with its own unique strengths, but also its problems and limitations. As such, we discuss the advantages and

disadvantages related to measures of structure and measures of perceptions of SMMs in the sections below.

2.2.2.1. Measures of SMM structure

Advantages: Measures of SMM structure are typically related to a specific task and based on rigorous task analyses, and hence contain specific, in-depth, task related information. As they are based on task analyses, these measures enable the assessment of SMM similarity (i.e., the degree to which mental models are compatible among team members) and SMM accuracy (i.e., the degree to which mental models correctly represent the team task when compared with a subject matter expert; Edwards et al., 2006). Concept mapping and cognitive mapping have advantages over, for instance, paired comparison ratings. Concept mapping allows participants to create and visualize a concept map and assess the relationship between the main concepts, and hence SMMs reflect procedural or sequential task elements. Cognitive mapping allows participants to determine the content for inclusion in the SMM and researcher influence is therefore limited (DeChurch & Mesmer Magnus, 2010a; Mohammed et al., 2010).

Disadvantages: These measures often differ in the manner and extent to which they assess the structure of SMMs. Representations of mental models across similar teams can therefore differ due to the measure being applied, rather than actual structural differences. This problem is further exacerbated when studying

diverse teams that do not share tasks or outcomes, or are dissimilar in terms of team context, such as task interdependence, task complexity, or structure (Kozlowski & Bell, 2013). These techniques are often context dependent, as they have to be informed by a rigorous and detailed task analysis to identify the concepts or statements that are relevant to a particular team in a particular organization (Mohammed et al., 2010). While this enables the measurement of task-specific content inherent to the team's SMM, it presents practical difficulties in studying teams in the field as it is a difficult, complex, time- and resource-consuming task (Mohammed & Hamilton, 2012). There are critical limitations of such custom-made measures, namely that data collection "is time consuming, is labor intensive, takes longer to analyze (and thus do not render ready feedback for constituencies in the field)" (DeChurch & Mesmer-Magnus, 2010a, p. 10) and results are difficult to compare and integrate across a range of settings.

2.2.2.2. Measures of SMM perception

Advantages: Measures of SMM perception provide researchers and practitioners with insight on the awareness of team members of the existence of SMMs, without which they would arguably be unable to capitalize on these models in working towards team goals (Marhefka et al., 2020). Measures of SMM perception require less time and effort from researchers to use in their questionnaires and are easier for participants to assess and can therefore be used

with relative ease (DeChurch & Mesmer Magnus, 2010a; Mohammed et al., 2010). Analyses of perception measures are also simpler to execute and compare within and across samples than conducting content analyses on team interactions or participant-driven representations of SMMs (as is the case in cognitive maps, for example). Participants can complete measures of perceived SMMs within a few minutes, given the relative simplicity of completing questionnaires. These measures are not dependent on tasks and task analyses and the generic item content can be applied in any team context where people work together towards a shared goal. The influence of researchers is limited because the SMM content and dimensions are defined in a manner that can be applied to teams in general and they are therefore free from qualitative interpretations by the researcher (Mohammed et al., 2010). In addition, measures of perception enable replication across a broad spectrum of teams and over time. The comparison between different teams is not reliant on task analyses and therefore simple to code and analyze while completing a series of questionnaires spread over a specific time is easy to coordinate.

Disadvantages: The main disadvantage of measures of SMM perceptions is that the nature of rating scales is such that items are not directly compared to one another by the participant and hence offers no indication of the structure of the individual's mental model. Measures of SMM perceptions may yield false indications of sharedness among team members in cases where these perceptions

are inaccurate (Marhefka et al., 2020). As such, it is important to select and prepare respondents well and check the data for outliers and inconsistencies.

2.2.3. The need for a measure of SMM perceptions

Thus, the context dependency typically inherent in measures of SMM structure implies that different teams are likely to develop divergent SMM representations, which are difficult to compare. Currently, no measure offers the potential of comparing actual or perceived SMMs across different teams in a manner that reflects its full factor structure. The lack of a validated and generalizable scale complicates the study and comparison of SMMs across different functions as well as the comparison between the structure and perceptions of SMMs. To overcome this difficulty, it is crucial to have a measure that assesses the perceptions of SMMs that can be completed by team members from various teams and organizational contexts.

Although several scales with many measurement items exist, none of these reflect all the contemporary dimensions of SMMs. The perceptions of SMMs warrant their own measurement as was already acknowledged by Klimoski and Mohammed in 1994, when they suggested that SMMs are in part a reflection of team members' perceptions of their knowledge structures. The awareness of the existence of SMMs is important in capitalizing on shared resources in the team as members may possess consensus regarding their organized understanding and

representations of knowledge but be ignorant to this fact (Rentsch et al., 2009). Marhefka et al. (2020) support the notion that perceptions of SMMs are an important aspect of their manifestation in teams and found that perceived SMMs and actual SMMs (i.e., structured representations of the SMM and its content) had different, but complementary team outcomes: perceived SMM were associated with greater team viability and actual SMMs with greater performance. The benefits of a perceived SMM scale are twofold. First, it relates to an important issue in the SMM literature, namely the relevance of perceptions of SMMs given their implications for team outcomes and the ability of teams to take action based on their actual mental models. Second, such a scale would be simple to implement, analyze, and compare, hence offering insights into perceptions of SMMs not only within specific teams, but also across different teams. It can be distributed to multiple teams, completed without direct observation, and its results are readily interpretable through simple statistical analyses. Naturally, the perceived scale can also be used in comparison, or conjunction, with assessments of actual SMMs. Such a perceived scale would also ease the burden of studying SMMs over time and in dynamic and changing circumstances, given the ease with which it can be distributed and findings can be generalized. Yet, in order to build such a perceived scale, it is vital to adequately capture the dimensionality of SMMs.

2.3. Hypotheses

2.3.1. Dimensionality

Our scale represents five main dimensions of SMMs used in the literature that capture team members' understanding about the equipment, execution, interaction, composition, and temporal aspects of work. Therefore, it is important to confirm the factor structure of our measure, in particular because previous measures have not been developed to represent all these dimensions of SMMs. Thus, we argue that:

> *Hypothesis 1: The 5-PSMMS is multidimensional, reflecting a five-factor model representing equipment, execution, interaction, composition and temporal mental model similarity and providing good fit to the data across samples.*

2.3.2. Convergent validity

It is important to distinguish our scale from similar and dissimilar related constructs within its nomological network, providing evidence for its construct validity (Hinkin, 1998). We test convergent, discriminant, nomological, and criterion validity (Hair et al., 2018). To test for convergent validity, we assess if there is a positive correlation between our 5-PSMMS with an existing SMM scale which covers four SMM dimensions with a single item per dimension, serving as a fair, albeit limited, measure for assessing general SMMs (Santos et al., 2015a).

Hypothesis 2a: The 5-PSMMS is positively correlated with the SMM scale of Santos et al. (2015a).

Hypothesis 2b: The 5-PSMMS is more strongly correlated with the SMM scale of Santos et al. (2015a) than with other variables in the nomological network.

2.3.3. Discriminant validity

To test for discriminant validity, we compare the 5-PSMMS with transactive memory systems (TMS), as both TMS and SMMs are shared cognitive constructs categorized as emergent states (DeChurch & Mesmer-Magnus, 2010b). TMS refer to a cognitive structure regarding team members' expertise as well as the shared perception of who knows what (Lewis, 2003; Mesmer-Magnus et al., 2017). By developing TMS, team members can locate and access specific knowledge relevant to team functioning (Lewis, 2003). SMMs are related to TMS and both promote team performance as team members can draw on SMMs and TMS to inform their decisions and adapt their behaviors (e.g., Bachrach et al., 2019; Mesmer-Magnus et al., 2017; Uitdewilligen et al., 2018). SMMs and TMS are distinct, as SMMs refer to the knowledge that is shared among team members, TMS refer to the location of and access to specialized knowledge that members possess (Lewis, 2003; Mesmer-Magnus et al., 2017).

Hypothesis 3: The 5-PSMMS and its dimensions correlate positively with TMS.

2.3.4. Nomological validity with positively associated constructs

To further assess our scale's validity, we will assess the nomological network and also compare our scale to five other constructs, three positively associated with SMMs and, in the next section, two negatively associated constructs (cf. Paulin & Griffin, 2015; Thomas & Lucas, 2019). We start with team learning, which refers to an "ongoing process of reflection and action, characterized by asking questions, seeking feedback, experimenting, reflecting on results, and discussing errors or unexpected outcomes of actions" (Edmondson, 1999, p. 353). It leads to increased knowledge, skills, and abilities within the team which facilitates performance. The construction of meaning and shared understanding that can result from team learning behaviors have been shown to enable the development of SMMs (Van den Bossche et al., 2011). Team learning is related to, but conceptually and empirically different from, SMMs in that it represents the development process of mental representations and structures relating to the team environment rather than those structures themselves.

Next, we assess team reflexivity, a process of overt reflection, analysis and discussion of teams' performance and strategies for improvement in terms of accomplishments and goals (Tesler et al., 2018; West, 1996). Research has shown

that team reflexivity leads to positive team outcomes such as improved team innovation, performance, and learning (Schippers et al., 2015). Team members engaging in team reflexivity actively share information and integrate the product of these discussions their shared conceptualization of the structure and content of their environment, leading to greater similarity in SMMs (Gurtner et al., 2007; Tesler et al., 2018). Team reflexivity therefore enables the development of SMMs, but is conceptually and empirically different from SMMs as it refers to the processing and interpretation of information within the team, rather than the shared understanding thereof.

Teams often possess a degree of intrateam interdependence, where members are reliant on one another to perform their tasks and achieve their goals, to a greater or lesser extent (Van der Vegt & Janssen, 2003). Interdependence in teams has also been shown to impact on knowledge sharing and learning (e.g., Van der Vegt et al., 2010), which is central to the development and emergence of SMMs (Staples & Webster, 2008; Van den Bossche et al., 2011). Maynard and Gilson (2014) propose that interdependence is related to SMMs, and interact in yielding team outcomes. Van der Vegt and Van de Vliert (2005) also show that interdependence is relevant to perceptions of skill dissimilarity and can therefore be related a shared understanding of which team members possess what skills.

Hypothesis 4: The 5-PSMMS and its dimensions are positively correlated with (a) team learning, (b) team reflexivity, and (c) interdependence.

2.3.5. Nomological validity with negatively associated constructs

We also assess factors that have been theoretically and empirically negatively associated with SMMs, namely team cognitive diversity and intrateam conflict. Individual and task-related differences between team members can impact on their perception of one another, but also have the potential to affect how they develop a shared understanding about important aspects of their work (Lim & Klein, 2006; Mohammed et al., 2010). Team cognitive diversity is the extent of interpersonal differences between team members in terms of their knowledge, skills, values, assumptions and beliefs (Van der Vegt & Janssen 2003; Schilpzand, 2010). Different members may possess unique knowledge or interpretations regarding their environment (e.g., Martins et al., 2013). This heterogeneity could lead to conflicting individual representations of mental models, as was shown by Schilpzand (2010), hence team cognitive diversity can be expected to be negatively related to SMMs.

Conflict is a dysfunctional team process that can adversely impact team performance and effectiveness (e.g., de Wit et al., 2012). Three types of conflict can occur in teams (Jehn, 1995; Jehn & Mannix, 2001): relationship conflict (interpersonal incompatibilities characterized by negative affectivity between team

members), task conflict (differences in ideas and opinions regarding the team's task), and process conflict (conflict on how tasks will be executed in terms of duties and resources). De Wit et al. (2012) showed that all three conflict types are negatively associated with emergent states in teams, as they impose constraints on team interaction which is essential to their emergence. In particular, previous research has suggested a negative relationship between SMMs and intrateam conflict (Santos & Passos, 2013; Santos et al., 2015a). Previous studies have shown that one type of conflict can lead to another (e.g., Greer et al., 2008) and that the types often load on the same factor (e.g., Polzer et al., 2006), thus we consider conflict as one construct. We therefore hypothesize that:

Hypothesis 5: The 5-PSMMS and its dimensions are negatively correlated with (a) team cognitive diversity and (b) intrateam conflict.

2.3.6. Clarification of the dimensions of shared mental models

In their foundational conceptualization of SMMs, Cannon-Bowers et al. (1993) identified four different dimensions, namely equipment (i.e., tools and equipment teams use in performing their work), task (i.e., the nature of the tasks teams are required to perform), team interaction (i.e., the way in which teams are structured and team members interact with each other), and team (i.e., the attributes and knowledge team members possess). Cannon-Bowers et al. (1993) illustrate four discrepant (yet related) factors underlying SMMs in teams that inform the team's

core understanding of their function and operation. Drawing on the idea that teams need to perform activities related to the task, and work well together as a team, Mathieu et al. (2000) merged these four dimensions into two: the task (reflecting the equipment and task dimensions) and the team (reflecting the team interaction and team dimensions). The task and team domains are commonly used in literature (Mesmer-Magnus et al., 2017) and, while these domains are effective at describing broad features of a team to which the underlying factors may relate, it is difficult to reconcile that the four factors of Cannon-Bowers et al. (1993) can be paired off into single factors, for instance, that the notion of how members should communicate with one another (interaction) forms part of the same construct as the location of particular expertise in the team (team). The aforementioned factors are likely related, but describe discrepant features of the team's environment. Although past research has most commonly focused on task and/or team mental models (e.g., Lim & Klein, 2006; Mathieu et al., 2005), this dimensional structure has often not been explicitly theorized, nor tested, and has largely remained an (implicit) assumption. It is therefore critical to consider the four dimensions of SMMs and their unique aspects in order to clarify the nature of the knowledge that is shared among team members.

Although this four-dimensional view captures most of the prior work on SMMs, it does not yet incorporate a key recent development, namely the increasing

theoretical and empirical insights that time is a crucial element of a team's relevant environment (e.g., Mohammed & Harrison, 2013; Roe, 2008). This realization has recently led to the conceptualization of temporal mental models (Mohammed et al., 2015, Santos et al., 2015b). Temporal mental models reflect team members' shared understanding about how tasks and task components should be sequenced, the pace at which activities in the team need to be completed, and the deadlines and time-related milestones relevant to task accomplishment (Mohammed et al., 2015; Santos et al., 2015b). The research indicates that teams that develop temporal mental models achieve high team performance (Marhefka et al., 2018; Mohammed et al., 2015; Santos et al., 2015b). However, the temporal dimension has not yet been subjected to the same degree of scrutiny as the other four dimensions of SMMs, leaving it vulnerable to (implicit) assumptions about its uniqueness as well as its interrelatedness.

Therefore, a systematic analysis of the existing literature is needed to understand how the dimensions of SMMs can be coherently operationalized and related to one another. We synthesize the full four-factor model of SMMs as originally developed (Cannon-Bowers et al., 1993) with the recently introduced temporal dimension (Mohammed et al., 2015) to conceptualize SMMs as comprising five unique dimensions (as presented in Table 2.1) representing the most complete, generally applicable factor structure as per current literature. While

it is feasible that teams may possess SMMs relating to other aspects of their environment, these five core dimensions capture team members' understanding of *which* tools or equipment to use, *what* tasks to perform, *with whom* they need to interact and coordinate, and *how* to do so, and *when* the work has to be accomplished. Due to the interactive effects in team functioning, we expect these five dimensions to be strongly correlated to one another as any one dimension can be relevant to one of the remaining four. As an example, in effectively communicating in a team it is important to understand both how (i.e., interaction) and when (temporal) to do so. For the sake of clarity, we slightly rename the dimensions of Cannon-Bowers et al. (1993) to distinguish between *equipment* (e.g., tools and technology), *execution* (e.g., procedures, strategies and contingency

Table 2.1
Conceptualization of the five SMM dimensions

Dimension	Conceptualization
Equipment	Shared understanding among team members about equipment, tools and technology they use in performing their tasks.
Execution	Shared understanding among team members about their duties, work processes and procedures relevant in performing their tasks.
Interaction	Shared understanding among team members about the most appropriate ways and means by which members interact and communicate with one another.
Composition	Shared understanding among team members about members' knowledge, skills, and abilities.
Temporal	Shared understanding among team members about time and other temporal aspects relating to their environment.

plans), *interaction* (e.g., team members' responsibilities and communication patterns) and *composition* (e.g., team members' preferences, skills, and habits) mental models, and add to that *temporal* mental models (e.g., Santos et al., 2015b).

2.4. Scale consolidation process

To consolidate the scale, we used a deductive approach aimed at balancing factor analytical structure and model fit characteristics with meaningful content. Thereby, we follow Hinkin's (1998) and DeVellis' (2016) scale development procedures. As described in the introduction, many theoretical and empirical studies in the field of SMMs have been published which comprise multiple dimensions of SMMs, hence there is sufficient knowledge to inform a deductive approach to scale development. Conforming to Hinkin's (1998) steps, we develop the scale across three main stages, namely: 1) item development, 2) scale development, and 3) scale evaluation. In these steps, we balanced theoretical and empirical considerations in selecting items, because when "items load as expected then it will require some judgment in deciding which items to retain" (Hinkin, 1998, p. 171). Following DeVellis (2016), we take a conservative approach when reducing items and thus rather retain a surplus (i.e., redundant items) than eliminating potentially useful content too early.

2.4.1. Stage 1: Item inventory and evaluation

We conducted a systematic literature search to identify published SMMs measures that could be used to derive scale items or to inform item development using EBSCOhost, targeting four specific databases: Business Source Premier, ERIC, PsychARTICLES, and Psychology and Behavioral Sciences Collection. We searched for academic papers published in peer-reviewed journals until February 2019 yielding 216 published papers.

2.4.1.1. Criteria for inclusion

We only considered papers that directly dealt with SMMs as a construct (reducing the pool to 103 results), and measured SMMs with perceived scales (36 results) or similarity ratings (27 results) as these were the only measures likely to provide usable scale items. This left us with a total of 61 papers from which to extract items.

First, we examined the selected papers and listed all items that measured SMMs using scales. The items of four papers could not be obtained, also not after contacting the authors. We also excluded two papers in sports teams, leaving us with 30 papers for consideration, including 332 items. We removed duplicate items (a consequence of researchers using each other's scales or items), leaving 19 papers and 188 items.

Next, we listed the items we could obtain from papers using similarity ratings, which we split into two categories (we could not obtain the items of seven papers for categorization). The first category referred to items that could be adapted to reflect SMMs in generic team contexts comprising 85 usable items from eight papers. The second category referred to items that could not be adapted to generic team contexts as the researchers either used concepts, and not statements, to assess SMMs, or items which were inseparable from their contextual basis. We excluded 12 papers with 146 items in this category.

In total, we retained 27 papers (19 using scales, eight using similarity ratings) which contained 273 items (188 scale items, 85 similarity rating items).

2.4.1.2. Item generation

As our aim was to develop a scale that would be applicable in a wide range of tasks, teams, and organizational contexts, we removed all contextual information from the items. Similarity rating items were adapted into a scale format where participants could indicate their level of agreement with the statement. We also split double-barreled items into items measuring only one issue. Consequently, we had a list of 314 items.

We applied the item stem "*Team members have a similar understanding about…*" to all items and deleted exact copies of items following adaptation, using the clarity and conciseness of their wording, and publication date as basis for

retaining the best alternative. We screened all items against the criteria for high-quality scale items defined by Hinkin (1998), namely: items should be short and simple, use familiar language, and be consistent in perspective (describe behavior or feelings), address only one issue, avoid bias, and reverse scored items should be carefully worded to avoid misinterpretation. This filtering process yielded 248 items.

2.4.1.3. Content validity assessment

To assess the items in terms of their content validity (i.e., the degree to which they are likely to represent the construct they are associated with; Hair et al., 2018) we drew on two stages of review by panels of subject matter experts (SMEs) in teamwork and organizational behavior. Associated statistics were calculated to determine which items to retain for use in subsequent exploratory factor analyses.

SME review: First stage. In the first stage, we asked a panel of six SMEs (cf. Colquitt et al., 2019; Hardesty & Bearden, 2004) to categorize all the items (randomized per item) according to the five SMMs dimensions. SMEs were presented with definitions of the five dimensions of SMMs and asked to categorize each item under one or more dimensions. They could also categorize the items under “Other” – to check whether another dimension was hidden in the existing item list – or “Unrelated” – to identify misaligned items. SMEs could write suggestions when selecting either option.

SME review process: Second stage. In the second stage of the expert review process, we asked a panel of 18 SMEs (10 established Organizational Behavior scholars and eight PhD students) to rate how well the items associated with each dimension rated the particular dimension they were linked to. We presented reviewers with a definition of each dimension followed by the items categorized under each of the five dimensions as defined. We provided SMEs with Colquitt et al.'s (2019) instructions to rate how well each item measured the dimension using a scale ranging from 1 (*Item does an **EXTREMELY BAD** job of measuring the **bolded** concept provided above*) to 7 (*Item does an **EXTREMELY GOOD** job of measuring the **bolded** concept provided abov*e).

Analysis and results: SME reviews. Following the guidelines of Colquitt et al. (2019) for assessing content validity, we calculated the Coefficient of Substantive Validity (C_{sv}; frequency of aligned and discrepant categorizations[2]) and Proportional Substantive Agreement (*PSA*; proportion of reviewers agreeing on item categorization) based on the first stage expert review. We calculated the

[2] Similar to Anderson and Gerbing (1991), during the initial expert review, SMEs categorized items into different factors and associated dimensions in the first stage. We allowed SMEs to categorize each item under more than one dimension. As such we needed to adapt the calculation of Csv as the number of categorizations per item was allowed to be greater than the number of reviewers. Hence, the statistic was reformulated ($C_{sv} = (n_c - n_o) / N_o$) where n_c is the number of times the item was categorized under the relevant dimension, n_o is the number of categorizations under other dimensions, and N_o is the total number of times the item was categorized under any dimension.

Hinkin-Tracey Coefficient (*HTC*; mean item rating divided by the number of anchors) based on the second stage expert review.

Colquitt et al. (2019) provide guidelines for interpreting the three statistics mentioned above (i.e., C_{sv}, *PSA, HTC*) in terms of five categories of content validity strength based on the degree of agreement between raters (i.e., *very strong, strong, moderate, weak,* and *lack of* agreement). For all three statistics we used criteria of Colquitt et al. (2019) for scales not normed to orbital scales as no such measure was included at this point in the process. Items which showed a *lack of* agreement among SMEs under one or more of the three statistics were not considered for further use (one exception was made for an item under equipment which did not meet this requirement for C_{sv} to allow content breadth). We thus retained 127 items (nine for equipment, 35 for execution, 31 for interaction, 27 for composition, and 25 for temporal) for further evaluation.

Next, we identified if any duplicate items from the first SME review were still retained in this list. We found one such item in the execution and temporal lists and thus removed it, leaving 34 for execution and 24 for temporal. We then evaluated the remaining 125 items following Hinkin's (1998) criteria for high quality scale items and potential redundancy, opting to include items which were distinct from one another but related to, and representative of, the theoretical dimension (DeVellis, 2016) with the aim to retain eight to twelve items per dimension. This

left us with 49 items (nine for equipment and 10 each for the remaining four dimensions).

Next, we evaluated the 49 retained items in terms of their wording and content breadth. Two items under the equipment and execution dimensions respectively were worded in a manner which appeared less related to the dimensions and we included an alternative format item for each. We also added a new item to the interaction dimension given that no item was directly addressing methods of communication within the team, representing a potential gap between the items and theory. This yielded 56 items (11 for equipment, 13 for execution, 11 for interaction, 10 for composition, and 11 for temporal).

2.4.2. Stage 2: Scale development

In the next stage of the scale development process, shortlisted items were evaluated by administering them to a sample which is representative of the target population (i.e., adults working in teams). The purpose of this stage was two-fold: firstly, to determine whether the theorized factor structure underlying the scale is supported and, secondly, to identify which items are most suitable to measure these factors.

2.4.2.1. Initial item reduction

Participants. We recruited our first sample of 311 participants using Prolific (www.prolific.co). After screening responses for quality in terms of obvious bias

(e.g., only one response option selected throughout), failure to properly respond to attention controls (see below), and anomalous data (e.g., reported team size of 300) we retained a dataset of 287 participants. Participants reported working in teams comprising 9.12 members on average (*SD* = 6.28), ranging from three to 35 members, predominantly working in the following sectors: healthcare and social assistance (12.9%), finance and insurance (8.7%), government and public administration (8.4%), and retail (7.7%). Of these participants, 47.4% were female and 35.1% identified as leaders in their teams. The average age was 34 years (*SD* = 9.99), ranging from 19 to 65 years and the average team tenure was 3.58 years (*SD* = 3.82). Participants hailed from 32 different countries, predominantly the UK (40.8%), the USA (14.6%), Portugal (10.5%), Poland (6.6%), and Canada (4.5%).

Measures. The questionnaire contained the 56 SMMs items which were randomized per participant and measured using a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). To control for response quality, we included two attention control items instructing participants to select a particular response (e.g., "This item is an attention control item and the Disagree option needs to be selected.").

Analysis. Following Hinkin's (1998) recommendations we conducted a series of exploratory factor analyses (EFA) to determine whether the theorized factor structure was represented in the data and, if so, to reduce the number of items

in the scale based on these results. Because of the expected correlation between factors (separate, but related, facets of SMMs) and to avoid the overestimation of factors as can be encountered with principal components analysis, we used principal axis factoring and oblique rotation (Hair et al., 2018; Worthington & Whittaker, 2006).

Results. Six factors were extracted (Eigenvalues >1). The pattern matrix suggested that four of the five dimensions (equipment, interaction, composition, and temporal) possessed items which loaded sufficiently (>.40) with no problematic cross loadings (>.35) to proceed with item reduction (Hinkin, 1998). However, items linked to the execution dimension loaded on more than one factor. Three items loaded on the temporal dimension (>.40) while two loaded on a sixth factor (>.40). Upon reducing the items for four factors (excluding execution), we found that the majority of the items (N = 12) under the execution dimension now loaded on the same factor as those under the temporal dimension. This finding suggested that – based on the existing items from the literature – *Hypothesis 1* could not be supported and that a problem was incurred at the theoretical level. As such we had to undertake an additional step.

2.4.2.2. Clarification of the temporal dimension

To determine why the execution items loaded on the same factor as the temporal items, despite being described as unique in the literature, we analyzed the

definitions for both dimensions as well as the items associated with each construct. We identified a potential problem in the manner in which the temporal dimension was previously defined in the literature. This definition was focused on temporal aspects relating to "tasks", "task components" and "task accomplishments" (e.g., Gevers et al., 2006; Marhefka et al., 2018; Mohammed et al., 2015; Santos et al., 2015b).

We therefore had to challenge the current conceptualization of temporal mental models, as we discovered that it is not theoretically distinct enough from the other dimensions. More specifically, we found that existing temporal mental model items and conceptualizations overlap with the execution dimension as they state that team members have a shared representation of knowledge about how *tasks* and *task components* should be sequenced. Temporal factors such as sequencing, pace, timing, deadlines, and time-related milestones can be applied more broadly than the performance of tasks alone. For instance, the timing of sharing a new piece of information between members can affect the conditions for team functioning. Time can be considered relevant to all aspects of SMMs as team members can have greater or lesser agreement on the relevance of time in terms of their work and team functioning. The temporal dimension should therefore be considered unique and independent, warranting inclusion as a generalized construct. We therefore redefine temporal mental models as "team members' shared and organized understanding

and mental representation of knowledge about time and the temporal aspects (e.g., sequences, pace, deadlines, and timing) related to their work and the key elements of the work environment relevant to the team".

We revised temporal items to represent the revised definition of temporal mental models using the 27 temporal items originally retained from the literature as a basis. We identified all words or phrases that were linked to the execution dimension and adapted the items to reflect the revised definition for temporal mental models. Two items were duplicated after adaptation and one of each duplicate pair eliminated. The remaining 25 adapted items were subjected to a further round of content validity evaluation where we asked another panel of SMEs from the field of Organizational Behavior (N = 8) to rate the degree to which each item measured the adapted definition of the temporal dimension as well as the task dimension (with particular emphasis on the execution dimension), to determine which items would be likely to better represent a unique factor.

We calculated the *HTC* for items of both dimensions and compared these to determine which items were most convergent on the temporal dimension and most divergent from the execution dimension. We retained or eliminated items across three steps, namely we: (1) retained items with a moderate to strong *HTC* score, (2) eliminated items that were relatively similar, and (3) retained items with weak *HTC*

scores if these contributed to construct breadth. On this basis we retained 15 temporal items for further EFA.

2.4.2.3. Final item reduction

Participants. We recruited a second sample of 301 new participants using Prolific. Using the same criteria as the first dataset, our second dataset contained 275 responses. Teams had on average 7.55 members (*SD* = 4.71), predominantly worked in: information services and data processing (9.1%), health care and social assistance (8.4%), finance and insurance (7.6%), manufacturing (6.9%), and software (6.9%). Of the participants, 37.8% were female and 35.6% identified as leaders in their teams. The average age was 33.35 years (*SD* = 8.14) and average team tenure was 3.63 years (*SD* = 3.41). Participants hailed from 29 countries, but were predominantly from the UK (43.6%), the USA (18.9%), Portugal (8.7%), and Poland (6.5%).

Measures. We administered a questionnaire with 60 items (including the 15 revised temporal items and the original 11 for equipment, 13 for execution, 11 for interaction, and 10 for composition). As before, the items were randomized per participant and measured using a 7-point scale ranging from 1 (*strongly disagree*) to 7 (*strongly agree*). We also included the two attention control items.

Analysis. We again conducted EFAs following Hinkin's (1998) recommendations. We reduced items in a stepwise manner over a series of 15

exploratory factor analyses until we were left with four items per dimension. Following DeVellis' (2016) and Hinkin's (1998) guidelines, we created a set of six hierarchical rules that would be applied for every EFA in the series to identify items to eliminate. For every EFA we checked the application of the following rules, in the numerical order they are presented and subsequently eliminate items accordingly: (1) eliminate items with no factor loading above the absolute minimum of .32; (2) eliminate items that had their strongest loading under a different factor than the majority of items from the same content domain; (3) eliminate items with cross loadings greater than .32; (4) eliminate items with loadings below the ideal minimum of .40 on the expected main dimension; (5) eliminate worst loading items from alternative item pairs (as discussed in 4.1.3); (6) eliminate the worst loading item from each dimension (one per dimension per EFA).

Results. We used the rules described in the prior section to eliminate items from dimensions, and first focused on the four non-temporal dimensions as the temporal dimension was revised. This yielded a set of seven items per dimension. We then included the temporal items in the analyses and applied criteria (1) to (4) that left us with nine temporal items in addition to the seven items under each other dimension. Four temporal items had similar content (relating to deadlines) and we eliminated two of the four to ensure that the retained items reflected as much of the theoretical content as per the dimension's definition. This yielded seven items under

each of the five dimensions and we reduced this further on the basis of criteria (1) to (6) leaving the final set of 20 items (four items under each of the five dimensions). All initial Eigenvalues were around 1 and given our strong theoretical consideration we choose to specify a five-factor extraction (Hair et al, 2018).

The subsequent factor solution reflected five factors with four items each (Table 2.2), conforming to Hinkin's (1998) suggestion of 4-6 items per dimension. Reliabilities for the scales were acceptable (Hinkin, 1998), as all values were above .70 (ranging from .82 for equipment to .88 for composition, with an overall scale reliability of .94). Overall, this yielded good support for *Hypothesis* 1 and the 20 items (see Table 2.3) were]deemed adequate for entering the next stage.

Following item reduction, we evaluated the degree to which items represent the theoretical model. We conducted a third study, where we performed a confirmatory factor analysis (CFA) to test model fit and conducted evaluations of construct validity (Hair et al., 2018; Hinkin, 1998). Then we tested if the measure had distinct team-level constructs (Bliese, 2000; James et al., 1993) by conducting a fourth study using working teams. Finally, we tested whether the criterion related validity of the scale at the team level in a fifth study comprising working teams.

Table 2.2
EFA Pattern Matrix – Final Item Reduction (Sample 2)

	Factor				
Item	**1**	**2**	**3**	**4**	**5**
Equipment					
how to use other team members' equipment	*.02*	*-.01*	**.71**	*.00*	*-.08*
what equipment is important for which tasks	*-.01*	*.02*	**.72**	*.02*	*.11*
the tools needed to complete our tasks	*.06*	*.04*	**.66**	*.02*	*.11*
the technology needed to complete our tasks	*.02*	*-.07*	**.66**	*.01*	*-.02*
Execution					
specific strategies for completing various tasks	**.58**	*-.06*	*.18*	*.02*	*-.04*
how to deal with the task	**.55**	*.00*	*.17*	*.03*	*.11*
how best to perform our tasks	**.64**	*-.10*	*-.02*	*.10*	*.14*
the relationships between tasks	**.56**	*-.10*	*.02*	*.08*	*.07*
Interaction					
how to communicate with each other	*-.05*	*-.07*	*-.03*	**.86**	*-.03*
sharing information with each other	*.20*	*-.02*	*.01*	**.46**	*.12*
how we should interact with each other	*-.07*	*-.19*	*.12*	**.60**	*.04*
the best methods to communicate with each other	*.10*	*.10*	*.02*	**.81**	*.03*
Composition					
each other's knowledge	*-.03*	**-.77**	*.02*	*.01*	*.05*
each other's abilities	*.08*	**-.74**	*.06*	*.03*	*-.02*
each other's skills for doing various team tasks	*.00*	**-.73**	*-.03*	*.01*	*.21*
each other's individual strengths and weaknesses	*.10*	**-.71**	*.03*	*.08*	*-.16*
Temporal					
our deadlines	*-.08*	*-.04*	*.12*	*.11*	**.63**
how quickly we need to work	*.19*	*-.04*	*.02*	*.03*	**.54**
appropriately timing our work	*.17*	*.02*	*.00*	*.07*	**.72**
coordinating the timing of our work	*.10*	*-.22*	*.13*	*.00*	**.51**
Rotation sums of squared loadings [a]	6.72	6.16	6.32	6.59	5.40

Note. All items share the item stem "Team members have a similar understanding about…"; N = 275 individuals; Final set of items following item reduction using the second sample of participants.

[a] Principal axis factor extraction and direct oblimin rotation.

Table 2.3
5-PSMMS Items

Dimensions and items	Obtained or adapted from
Equipment	
how to use other team members' equipment	Lim and Klein (2006)
what equipment is important for which tasks	Kang et al. (2006)
the tools needed to complete our tasks [a]	Santos et al. (2015a)
the technology needed to complete our tasks [a]	Santos et al. (2015a)
Execution	
specific strategies for completing various tasks	Johnson et al. (2007)
how to deal with the task	Van den Bossche et al. (2006)
how best to perform our tasks	Guchait et al. (2014)
the relationships between tasks	Kang et al. (2006)
Interaction	
how to communicate with each other [a]	Lee and Johnson (2008)
sharing information with each other [a]	Johnson et al. (2007)
how we should interact with each other [a]	Lee and Johnson (2008)
the best methods to communicate with each other [b]	N/A
Composition	
each other's knowledge	Lee and Johnson (2008)
each other's abilities [a]	Lim and Klein (2006)
each other's skills for doing various team tasks [a]	Johnson et al. (2007)
each other's individual strengths and weaknesses	Burtscher and Oostlander (2019)
Temporal	
our deadlines [a]	Levesque et al. (2001)
how quickly we need to work [a]	Marhefka et al. (2018)
appropriately timing our work [a]	Mohammed et al. (2015)
coordinating the timing of our work [a]	Levesque et al. (2001)

Note: All items share the item stem "Team members have a similar understanding about…"
[a] Items that were adapted from the original. [b] Newly created item.

2.4.3. Stage 3: Scale evaluation

2.4.3.1. Confirmatory factor analysis

Participants. To assess the fit of the items to the theoretical model, we recruited a third sample of 310 new participants using Prolific. We followed similar

procedures as before and obtained a dataset of 288 participants. Participants reported working in teams comprising 7.25 members on average (*SD* = 4.25) predominantly working in the following sectors: information services and data processing (12.85%), government and public administration (9.7%), finance and insurance (8.0%), and software (7.3%). Of the participants, 45.5% were female and 29.5% were leaders. The average age was 33.24 years (*SD* = 8.67) and the average team tenure was 5.52 years (*SD* = 5.32). Participants hailed from 30 countries, predominantly the UK (43.8%), Poland (10.4%), USA (9.0%), and Portugal (7.3%)[3].

Measures. Our survey had the SMMs items and the measures to assess convergent, discriminant, and nomological network validity. All measures used a 7-point scale.

SMMs. We measured SMMs with our 20 items (α = .94) and the existing four-item SMM scale of Santos et al. (2015a; α = .81) to assess convergent validity.

[3] Our sample was relatively heterogeneous in terms of nationality and industry. Therefore, we conducted ANOVAs (with Tukey's post hoc tests) to assess if the respondents' mean scores on our 5-PSMMS measure and the seven nomological variables differed for each particular nationality or industry compared to one another. We focused on nationalities/industries for which we had at least two responses and thus included 21 nationalities and 26 industries in these analyses (the list of nationalities/industries can be provided by the first author upon request). Of the 4280 tests, only one was significant at $p < .05$ (i.e., the difference in means between the 'Finance and Insurance' and 'Wholesale' industries for the reflexivity scale). Overall, measures in the study were quite stable indicating the robustness of our study, yet we acknowledge that future research might want to study the effects of nationality and/or industry in more detail.

Positively related variables. We measured TMS with the 15-item scale of Lewis (2003; α = .84) to test for discriminant validity. Team learning was assessed with the seven-item scale of Edmondson (1999; α = .76). Team reflexivity was assessed with the eight-item scale of Carter and West (1998; α = .76). Interdependence was assessed with the eight-item scale of Van der Vegt and Janssen (2003; α = .80).

Negatively related variables. Team cognitive diversity was assessed with the four-item scale of Van der Vegt and Janssen (2003; α = .64). Intrateam conflict was assessed with the nine-item scale of Jehn and Mannix (2001; α = .92).

Analysis. We conducted a series of CFAs using AMOS (version 25) to determine the model's adequacy, including an unconstrained model, a single factor model, and the theorized factor model. We took two steps in order to assess convergent, discriminant, and nomological validity. Firstly, we calculated the construct reliability (CR), average variance explained (AVE), and maximum shared variance (MSV) for the theorized model (Hair et al., 2018). In addition, we analyzed the correlations between our scale and the variables identified for testing convergent, discriminant, and nomological validity (Hair et al., 2018).

Results. Table 2.4 shows the results of the series of CFAs. We obtained acceptable model fit, which supports the structure of the scale and its ability to measure the theorized constructs (Hair et al., 2018). This supports *Hypothesis 1*.

The CR values for the five dimensions ranged from .80 (equipment) to .87 (interaction) as is shown in Table 2.5. Overall, further supporting Hypothesis 1.

Table 2.4
Confirmatory Factor Analysis – Model Fit Indices (Sample 3)

Model	$\chi 2$	*df*	$\chi 2$/ *df*	*p*	CFI	SRMR	RMSEA [90% CI]	PCLOSE
Model 1	3225.91	190	16.98	< .001	.00	.44	.24 [.23, .24]	.00
Model 2	757.21	170	4.45	< .001	.81	.07	.11 [.10, .12]	.00
Model 3	246.94	160	1.54	< .001	.97	.05	.04 [.03, .05]	.84

Note. Model 1: independent model; Model 2: single factor model; Model 3: five-factor model. CFI = comparative fit index; SRMR = standardized root-mean-square residual; RMSEA = root mean square error of approximation; CI = confidence interval.

Table 2.5
Construct Reliability, Average Variance Extracted, and Convergent and Discriminant Validity (Sample 4)

					Correlations				
Dimension	**CR**	**AVE**	**MSV**	**MaxR(H)**	**1**	**2**	**3**	**4**	**5**
1 Equipment	.80	.50	.61	.81	*(.71)*				
2 Execution	.81	.52	.71	.81	.78***	*(.72)*			
3 Interaction	.87	.63	.56	.89	.60***	.75**	*(.80)*		
4 Composition	.86	.61	.54	.87	.64***	.74**	.69***	*(.78)*	
5 Temporal	.85	.58	.71	.85	.63***	.84**	.71***	.65***	*(.76)*

Note. N = 288 individuals. CR = construct reliability; AVE = average variance explained; MSV = maximum shared variance; MaxR(H) = maximum reliability. Square root of AVE (H) on diagonal of correlation table in italics and between brackets; CR is computed "from the squared sum of factor loadings for each construct and the sum of the error variance terms for a construct" and >.70 is sufficient (Hair et al., 2018, p. 676). AVE is calculated as the sum of all standardized factor loadings divided by the number of items in the particular scale and the suggested cut-off value is .50. To establish discriminant validity the square root of AVE for a particular factor should be larger than its correlation with other factors (Hair et al., 2018).
*** $p < .001$.

Table 2.6 shows the correlations between the 5-PSMMS with other variables. In support of convergent validity, our scale correlated significantly with the SMMs scale of Santos et al. (2015a), $r = .66$, $p < .01$. This finding supported *Hypothesis 2a.* The scale also demonstrated that the correlation between the 5-PSMMS and the SMM scale of Santos et al. (2015a) exceeded those between the 5-PSMMS and all other included variables. By converting correlations to Fischer's Z scores we found that the correlation between the 5-PSMMS and the SMM scale of Santos et al. (2015a) was significantly larger than between the 5-PSMMS and all variables in this study at the $p < .01$ level, supporting *Hypothesis 2b*. In particular, the scale demonstrated a significant, large correlation ($r = .55$, $p < .01$; which was smaller than the correlation with the alternative SMM scale) with the TMS scale of Lewis (2003), supporting discriminant validity and lending support to *Hypothesis 3*. We also note significant moderate correlations with factors positively associated with SMMs (i.e., $r = .45$ for team learning, $r = .34$ for team reflexivity, and $r = .36$ for team interdependence; all $p < .01$), thus supporting *Hypotheses 4a, 4b,* and *4c*. Two factors negatively associated with SMMs showed significant negative correlations: $r = -.24$ for team cognitive diversity and $r = -.37$ for intrateam conflict (both $p < .01$), supporting *Hypotheses 5a* and 5*b*.

Table 2.6
Descriptive statistics and correlations for convergent and discriminant validity (Sample 4)

Variables		M	SD	1	2	3	4	5	6	7	8	9	10	11	12
1	Equipment	5.54	.88												
2	Execution	5.31	.91	.62**											
3	Interaction	5.47	1.02	.52**	.64**										
4	Composition	5.42	.91	.54**	.61**	.63**									
5	Temporal	5.40	1.01	.52**	.69**	.64**	.55**								
6	5-PSMMS (current study)	5.43	.78	.77**	.86**	.85**	.81**	.83**							
7	SMM (Santos et al. 2015a)	5.52	.82	.54**	.52**	.54**	.62**	.51**	.66**						
8	Transactive memory systems	5.48	.61	.36**	.45**	.49**	.49**	.47**	.55**	.61**					
9	Team learning	4.77	.92	.29**	.43**	.43**	.29**	.38**	.45**	.45**	.53**				
10	Team reflexivity	4.97	.77	.23**	.29**	.33**	.25**	.30**	.34**	.43**	.49**	.69**			
11	Interdependence	5.39	.79	.19**	.24**	.35**	.35**	.36**	.36**	.39**	.58**	.47**	.40**		
12	Team cognitive diversity	4.33	.93	-.17**	-.25**	-.21**	-.21**	-.18**	-.24**	-.20**	-.25**	-.17**	-.16**	-.19**	
13	Team conflict	2.70	.94	-.23**	-.29**	-.39**	-.31**	-.29**	-.37**	-.40**	-.47**	-.28**	-.19**	-.27**	.39**

Note. N = 288 individuals; We used the four item SMM scale of Santos et al. (2015a) as second scale measure of SMMs to compare to the 5-PSMMS.
*$p < .05$. **$p < .01$.

2.4.3.2. Aggregation

Our scale is intended for use at the team level, given its focus on the shared understanding of team members regarding different aspects of their work. As such we conducted a further study using responses from teams with three or more members and aggregated the data of each variable by calculating average scores per team.

Participants. To assess whether aggregation would be permissible using our scale, we conducted a fourth study and recruited 340 new participants from 100 organizational teams via the help of research students. Of the participants, 46.8% were female and 25.0% identified as team leaders. The average age was 32.51 years (*SD* = 11.19). The average reported team size was 8.70 members (*SD* = 5.65) and on average we received 3.40 responses per team[4]. Participants who specified their industry predominantly worked in retail (34.3%), health care and social assistance (21.0%), finance and insurance (9.7%) and software (6.1%). Participants hailed from 25 countries, predominantly Germany (31.2%), the Netherlands (10.0%), Finland (5.9%) and Belgium (4.1%)[5].

[4] To assess possible effects of team tenure and the response rate, we conducted a correlation analysis testing tenure (r = -.19, p = .22) and response rate (r = -.14, p = .17). Since neither coefficient was significant, we conclude that tenure and response rate do not significantly affect the 5-PSMMS.

[5] As per Sample 3, we conducted ANOVAs (with Tukey's post hoc tests) to assess if the respondents' mean scores on our 5-PSMMS measure differed for each particular nationality or

Measures. We used our 20 SMMs items.

Analyses. Aggregation can be justified if the F-test is significant as this indicates that variance between groups significantly exceeds variance within groups (Klein et al., 2000). Additionally, we calculated interrater reliability using the two intraclass correlation coefficients ICC1 and ICC2, where ICC2 values should be greater than ICC1 (Bliese 2000). We also calculated $r_{wg(j)}$ (the agreement between members within groups) where >.70 is deemed acceptable (James et al. 1993).

Results. Table 2.7 summarizes the data relating to aggregation. The F-test was significant at $p < .001$ for the whole SMM scale and all dimensions (except for composition, which was significant at $p < .01$. Aggregation is therefore justified for the whole scale and all five dimensions. The ICC1 value for the whole scale was .27 and values for the five dimensions ranged from .10 to .29. The ICC2 value for the whole scale was .62 and values for the five dimensions ranged from .32[6] to .65.

industry compared to one another. We focused on nationalities/industries for which we had at least two responses and thus included 13 nationalities and 18 sectors in these analyses (the list of nationalities/industries can be provided by the first author upon request). Of the 231 tests, none were significant. Thus, as expected, our findings are robust, similar to what we reported for Sample 3 in footnote 2.

[6] The ICC(2) value for composition (.32) was just below the .40 cut-off value. Therefore, we reinvestigated the dataset which revealed that six of the 100 teams might contain a possible outlier which could skew the results. We reanalyzed the aggregation data for composition using the updated sample (N_{teams} = 94, $N_{individuals}$ = 312) and found a sufficient ICC(2) value for the dimension (.46). This indicates that for 94% of teams in our sample, the composition dimension was acceptable. We kept the 100 teams in our main findings, as all other statistics are adequate for all these teams.

Fleiss (1986) considers ICC2 values <.40 to be poor, <.75 to be fair to good and >.75 to be excellent. Only the composition dimension had an ICC2 value below .40, hence the scale overall is acceptable. All ICC2 values exceeded their ICC1 counterparts, conforming to Bliese's (2000) recommendations. Lastly, the $r_{wg(j)}$ of the whole scale was .98 and ranged from .90 to .92 for the five SMM dimensions, meeting the requirement for aggregation (James et al., 1993). The scale is therefore suitable for measurement at the team level.

Table 2.7
Tests for data aggregation (Sample 4)

Dimension	*F*	MS between	MS within	ICC(1)	ICC(2)	Average $r_{wg(j)}$
5-PSMMS	2.61***	1.17	.45	.27	.62	.98
Equipment	1.74***	1.40	.81	.14	.42	.91
Execution	2.84***	1.92	.68	.29	.65	.92
Interaction	2.35***	1.86	.79	.23	.57	.92
Composition	1.47*	1.21	.82	.10	.32	.91
Temporal	1.99***	1.72	.87	.18	.50	.90

Note. N_{teams} = 100; $N_{individuals}$ = 340.
* $p < .05$. *** $p < .001$.

2.5. Discussion

Our aim was to consolidate the existing literature and from that create and validate a generally applicable SMM scale. To that end, we assessed more than 300 existing items and consolidate these divergent measurements from past research into a contemporary and utilitarian instrument that could be used to measure perceived SMMs across different tasks, teams, and organizational contexts. This

was needed, because despite a large number of items and measures used in past research, there is currently no scale that incorporates team perceptions on all five core dimensions of SMMs. Past research, applying a plethora of measures, scales, and items – based on different dimensions – has provided in-depth insight into SMMs, yet has complicated synthesizing the literature and this limits future research and the development of this field. Thus, we developed the 5-PSMMS and found support for its factor structure, convergent, discriminant and nomological validity, and aggregation to the team level. Specifically, the 5-PSMMS, with four items for each of the five dimensions, demonstrated psychometric adequacy over four separate datasets, containing 287, 275, 288, and 340 respondents.

2.5.1. Theoretical and methodological implications

This study makes three important contributions to the SMM literature. First, the 5-PSMMS is the first and only scale that reflects all the core dimensions of SMMs currently used in literature. It provides researchers with an instrument that can be used to study and compare perceptions of SMMs, in a range of team or organization contexts. The scale shows five SMM dimensions (i.e., equipment, execution, interaction, composition and temporal) and thus enables the study of perceived SMMs as a whole or in terms of these dimensions in isolation or combination with one another at the team level. In doing so we address the need for such an instrument which enables better research on perceived SMMs (e.g.,

Mohammed et al., 2010; Marhefka et al., 2020). The scale furthermore offers the potential for researchers to compare perceptions of SMMs with measures that assess SMMs' structure and content (Marhefka et al., 2018, 2020). Although a generic scale sacrifices some depth, it has the benefit that misspecification of measurement (e.g., drawing on outdated or otherwise flawed task analyses) and misinterpretation (e.g., incorrectly interpreting keywords used by team members) of results is far less likely while offering the potential for comparison of results from research, not only within the field of SMMs, but also across disciplines (e.g., organizational learning, teamwork, or leadership). Hence, besides being used on its own, the 5-PSMMS also has the potential to serve as basis – or anchoring point – for the development of tailored instruments that can be applied in very specialized contexts (e.g., specialized medical teams performing unique operations) and enables the comparison between such different measures.

Second, we reflect upon the current common practice of studying SMMs in terms of only the task and/or team dimensions (e.g., Lee & Johnson, 2008; Lim & Klein, 2006) by critically evaluating the factor structure. In finding support for the five-factor model of SMMs, we support the original conceptualization of Cannon-Bowers et al. (1993) and incorporate the recently emerged temporal dimension as well (Mohammed et al., 2015; Santos et al., 2015b). As such, we advise that future

research explicitly theorize why all five dimensions, or only some of them, are included in the particular study.

Third, our study incorporates *temporal* mental models into the general framework of SMMs in teams by highlighting that all five core dimensions are unique and should thus be acknowledged in future research. In addition, we also present important revisions to the temporal dimension of SMMs. Our deductive approach used items currently found in the literature and we discovered that, at present, the temporal dimension items include language explicitly linked to the execution dimension (e.g., Gevers et al., 2006; Marhefka et al., 2018; Mohammed et al., 2015; Santos et al., 2015b, 2016). Hinkin (1998) advocates using items which measure only one issue, are clear in tone and structure, and do not lead to biased responses. Thus, the past conceptualization of temporal mental models is not appropriate as temporal factors can be relevant to all facets of a team and should thus not overly lean on one SMM dimension or another. Hence, our third contribution is that we challenge the current conceptualization, operationalization, and measurement of temporal mental models and offer an empirically supported refinement to this important, and burgeoning, aspect of SMMs.

2.5.2. Practical implications

We also make two important practical contributions. First, our new scale offers practitioners an accessible and user-friendly tool to identify potential issues

involving SMMs in their teams. Alternative measures of SMMs often fall outside the ability of managers or consultants to apply, given their time-consuming nature and the limitation of not being applicable over a wide range of team and organizational contexts. The 20-item 5-PSMMS enables practitioners to identify whether teams have a shared understanding about their environment in general and allows for diagnosis of particular aspects of this environment by using one, or more, of the five sub-scales, which can be interpreted by computing teams' mean score on each dimension (or the global SMM dimension) and comparing means across teams. As an example, a manager, consultant, or HR professional may find that a team does not share a perception on interaction mental models and can then address this by improving the communication style of team members. Given that we focused on *perceived* SMM, it would even be possible to see which (groups of) individuals would benefit most from an intervention, yet privacy concerns should be taken into account when doing so.

Second, we demonstrate the relevance of SMMs for a number of issues practitioners may encounter in teams. Our scale (conforming to theory) also related positively, but uniquely to important concepts like team learning, team reflexivity, interdependence, and negatively to team cognitive diversity and intrateam conflict. By promoting the development and improvement of SMMs, it is likely that teams can avoid dysfunctional conflict (e.g., through the reduction of uncertainty about

key issues in the team environment; Santos et al., 2013) and improve learning (e.g., through improved information sharing and understanding about which members possess which skills, knowledge, and abilities; Santos et al., 2016). Teams with more cognitively diverse members may also be liable to have less similar perceptions of SMMs (Schilpzand, 2010). Thus, managers working with cognitively diverse teams may improve team functioning by bridging differences in knowledge, values, or beliefs via the establishment of a shared understanding of the team's environment.

Overall, through more widespread and repeated application of the 5-PSMMS, organizations can develop baseline assessments of SMMs in teams across the organization. In doing so they can identify teams that may benefit from intervention to develop a greater shared understanding about their environment and goals. This could enable targeted interventions to increase positive processes such as team learning and reflexivity, and reduce negative ones such as conflicts, and thus also to performance.

2.5.3. Strengths, limitations, and future research

Akin to any other study, our research has some strengths as well as some limitations. Key amongst the strengths is our deductive approach following established scale development procedures (DeVellis, 2016; Hinkin, 1998), as this allowed us to critically assess and improve the current way of measuring within the

SMM literature. Additionally, the use of four unique samples and the varied and detailed statistical tests are also strengths of the current research. A limitation is that our new scale refers to a perceived measure and not to a measure of SMM structure and context dependent content (DeChurch & Mesmer-Magnus, 2010a). We cannot exclude the possibility that team members may sometimes mistakenly identify SMMs whereas, in reality, these may have drifted apart. For example, given that we found that, in a few teams, agreement amongst team members might be less than ideal for the composition dimension, we recommend researchers interested in that dimension to be especially diligent when they select their teams and respondents. Inaccurate SMMs pose a risk to team outcomes (Marhefka et al., 2018), however while actual SMMs may relay the structure of SMMs, this collectively represented structure may also be inaccurate (Marhefka et al., 2020). Therefore, our items and dimensions could be used in future research on their own, but could also offer complementary insights to measures of SMM structure, given the demonstrated outcomes of both SMM perception and structure (Marhefka et al., 2020).

In this paper, we followed an established methodology (DeVellis, 2016; Hinkin, 1998) to consolidate the measures of perceived SMMs into a scale which is theoretically more representative than past measures of perceived SMMs have been (cf. Johnson et al., 2007; Santos et al., 2015a), as we include all five core dimensions in one measure. Moreover, we also identified – and then corrected – a

bias in how temporal mental models are conceptualized and measured in the contemporary literature. We then tested the nomological network and aggregation, to show that the 5-PSMMS is an interesting and appropriate tool for future researchers to use, and that it is suitable for use at the team level. One possible option would be to investigate the incremental and criterion related validity of our scale in more depth, as this was out of scope for our scale consolidation paper.

A related limitation is that our scale focused on generalized content of SMMs and thus loses some of the context-rich nature and thereby structure of SMMs captured, for instance, in card sorting or cognitive maps (DeChurch & Mesmer-Magnus, 2010a; Mohammed & Hamilton, 2012). However, these measures may also carry the risk of misspecification (Wildman et al., 2014), given that the structure of SMM is not immune to the risk of shared inaccurate representations among team members (Marhefka et al., 2020), and is very resource intensive to develop and use. For future research we advise that researchers consider why their studies require tailored measures such as card sorting or cognitive maps, given the difficulty involved in collecting large samples of data over time using such means. We also strongly advise to rigorously theorize and operationalize the five dimensions and measures, and suggest that our 5-PSMMS, as psychometrically adequate measure, can serve as a foundation, or benchmark, for doing so (Mohammed et al., 2010, 2017). Post hoc analyses indicated that neither nationality

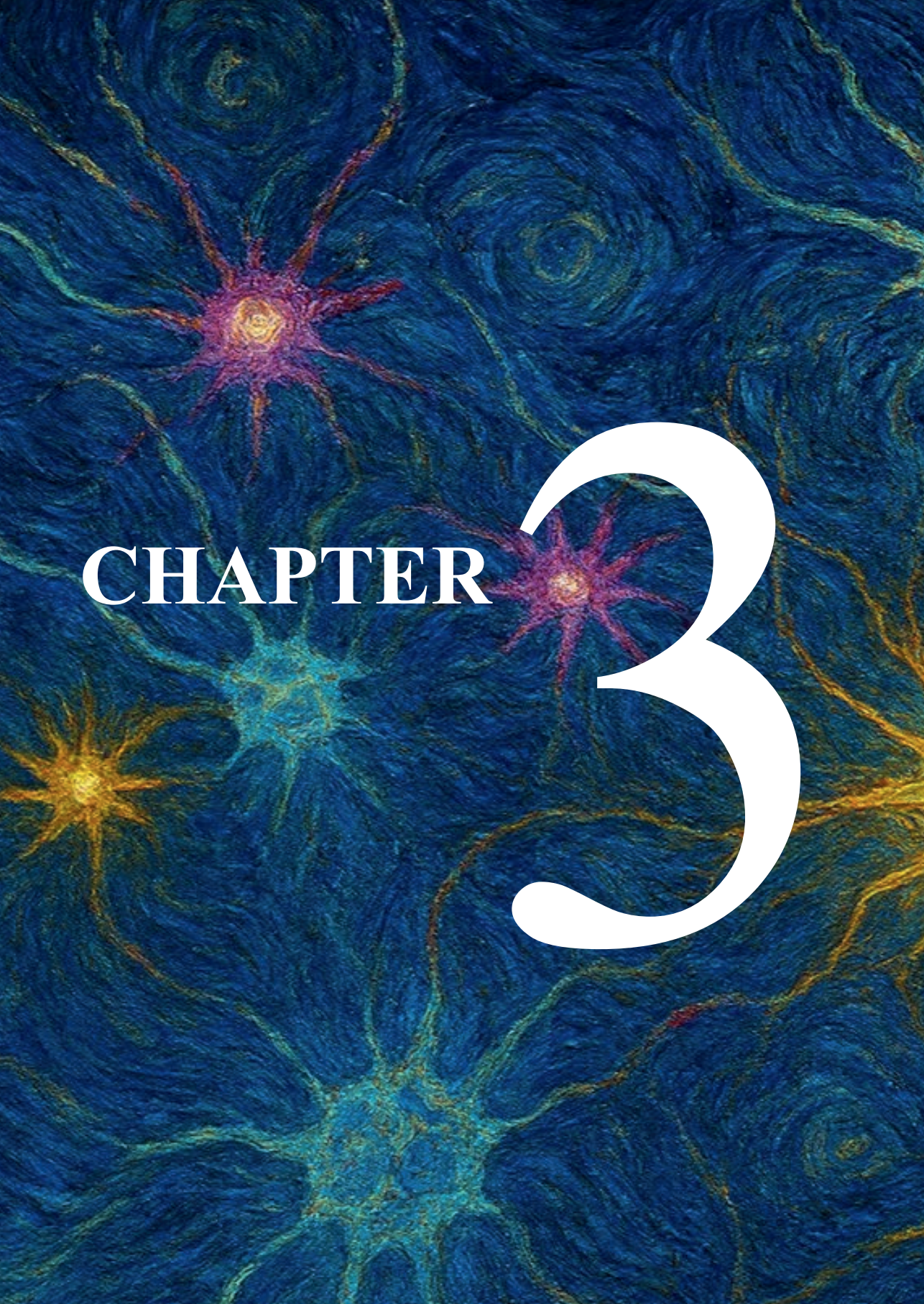
nor industry influenced results on the 5-PSMMS, supporting its robustness. Nonetheless, it is conceivable that nationality or industry could possibly influence perceived SMMs in some instances, and future research could thus also investigate the influence of such factors (cf. Niler et al., 2021). Overall, our scale allows for comparisons across a wide range of team and organizational contexts, permits easier longitudinal research, assists tailor-made studies, and facilitates the integration of research and practical findings across the SMM literature.

With regards to our data, although we used four unique datasets containing 1190 participants in total, the data was cross-sectional and self-reported. Such data is common in scale development papers (cf. Paulin & Griffin, 2015; Thomas & Lucas, 2019), yet our research design does much to allay these concerns as we draw on multiple samples, conduct multiple factor analyses, and actively screened responses based on a number of quality indications. Moreover, in our fourth dataset, the multilevel analyses go some way to address the risks posed by common method bias by aggregating the responses of multiple individuals to the team level. Future research could provide our scale to multiple sources (e.g., team members, leaders, HR specialists, etc.) and assess to what extent they agree about a team's SMM. Additionally, future research could test our scale, its items, and dimensions, over time by means of longitudinal research. Since our scale is generally applicable to a

wide range of team and organizational contexts such endeavors could be undertaken by different scholars, whilst still allowing their findings to quite easily be compared.

2.5.4. Conclusion

Via our deductive scale consolidation approach, we were able to critically reflect upon the existing measures of SMM perceptions and dimensions in the contemporary literature and provide a new, theoretically and methodologically improved, scale that contains all five core dimensions. This allows researchers to more easily assess perceptions of SMMs in teams, and more easily compare findings across contexts, than is currently possible with custom-made, time- and resource intensive measures. Overall, our hope is thus that future research and practice on perceived SMMs can be done more rigorously, systematically, and easily with our new 20-item scale.


CHAPTER
3

SHARING TIME AND GOALS IN DYADS: HOW SHARED TENURE AND GOAL INTERDEPENDENCE INFLUENCE PERCEIVED SHARED MENTAL MODELS

Chapter based on: Van Rensburg, J. J., Santos, C. M., & de Jong, S. B. (2023). Sharing time and goals in dyads: how shared tenure and goal interdependence influence perceived shared mental models. *Team Performance Management: An International Journal*, *29*(3/4), 202-221.

Earlier versions of this chapter were presented at the 17th annual conference of the Interdisciplinary Network for Group Research (INGRoup), and the 24th International Workshop on Teamworking (IWOT) in 2022.

Abstract

An underlying assumption in the shared mental model (SMM) literature is that SMMs improve whilst team members work together for longer. However, whether dyad members indeed have higher perceived SMMs with higher shared tenure has not been explored. This study aims to, therefore, firstly investigate this idea, and we do so by focusing on perceived SMMs at the dyadic level. Secondly, because in today's fast-paced world perceived SMMs often need to be built quickly in order for dyads to perform, we assess if goal interdependence can reduce the dyadic tenure required for higher perceived SMM similarity. Thirdly, we analyse if these processes are related to dyadic performance. We collected a dual-source sample of 88 leader-member dyads across various industries. We conducted PROCESS analyses to test our first-stage moderated mediation model. Results showed that dyadic tenure was positively related to perceived SMM similarity, and that goal interdependence moderated this relationship. Additionally, perceived SMM similarity mediated the relationship between dyadic tenure and dyadic performance. Lastly, our overall moderated mediation model was supported. We contribute to the perceived SMM literature by: a) investigating perceived SMMs in dyads, b) testing a key idea regarding the influence of dyadic tenure on perceived SMMs, and c) investigating how goal interdependence may prompt perceived SMM similarity earlier in dyadic tenure and, ultimately, improve dyadic performance.

3.1. Introduction

When two team members start working together, they need to develop a working relationship and, therefore, they need to build a good understanding about, for example, how to execute their work and how to interact with one another. In other words, within a dyad, a shared mental model (SMM) – i.e., the "shared, organized understanding and mental representation of knowledge about key elements of the team's relevant environment" (Mohammed and Dumville, 2001: p. 90) – needs to arise. Importantly, without a mutual awareness that the mental model of each individual in a dyad is similar to that of the other – i.e., perceived SMM similarity – team members may not reliably act on and hence benefit therefrom (Burtscher and Oostlander, 2019; Marhefka et al., 2020; Müller and Antoni, 2020, 2022; van Rensburg et al., 2022).

Considerable team-level research on (perceived) SMMs has shown that SMMs increase team communication (Mathieu et al., 2000), coordination (Müller and Antoni, 2020), creativity (e.g., Santos et al., 2015), adaptation and performance (e.g., Uitdewilligen et al., 2018), and reduce team conflict (e.g., Santos and Passos, 2013). However, only one study was explicitly conducted at the dyadic level (Cassidy and Stanley, 2019), but this study did not focus on *perceived* SMMs. We argue this lack of dyadic perceived SMMs studies is an important oversight, as the most basic and fundamental way in which a mental model can first be shared is

within the relationship of two team members (Klimoski and Mohammed, 1994). This is notable, as the team-level focus of much of past research risks obscuring relational richness by neglecting this crucial dyadic level of analysis (Mohammed et al., 2021). Past studies on team cognition have typically glossed over dyads as the first instance of *sharedness* of cognition between individuals, opting instead for the aggregation of individuals into teams (DeChurch and Mesmer-Magnus, 2010a). While this is certainly useful and appropriate for numerous types of research, it does sacrifice a deeper understanding regarding the nuances that would firstly emerge in dyads before being carried over to the team (Mohammed et al., 2021). In truth, teams represent more than aggregated representations from individual sources. Instead, teams can be viewed as collectives of individuals who are dyadically linked to one another with unique interpersonal relationships (Mohammed et al., 2021; Park et al., 2020). We therefore take a critical step in understanding these fundamental dyadic relationships by adopting a focus on perceived SMMs (van Rensburg et al., 2022).

At present, how and when such perceived SMMs arise between two team members is largely unknown. Some insights can be extracted from a few past studies that have examined whether and how team members come to share mental models over time (e.g., Kneisel, 2020; Levesque et al., 2001; Santos and Passos, 2013). Yet, although tenure has been mentioned as a factor that *could* influence

SMMs (cf. Mohammed et al., 2021), and while this notion is implicit in much SMM research, it has never been explicitly developed nor tested. From these sources within the (perceived) SMM literature, we argue that the longer two team members work together (i.e., have longer shared *dyadic tenure*) the higher their perceived SMM similarity is. Thanks to a new measure of perceived SMM (van Rensburg et al., 2022), testing such ideas has recently become more feasible. Thus, we aim to put this core assumption underlying the SMM literature under empirical scrutiny.

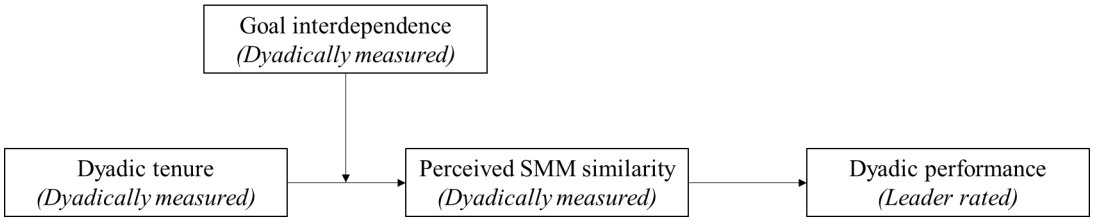
If we argue that the perceived SMM similarity is higher among two team members with increasing dyadic tenure, a next question becomes whether this process can be accelerated. Today's business world is becoming increasingly competitive and dynamic, and people have to collaborate, and achieve high levels of performance, in a short amount of time (e.g., Santistevan and Josserand, 2019). Additionally, they may need to work on a different project with different people, and again collaborate and perform in a short time, and so on. In such settings, getting high perceived SMM similarity quickly is very important. In other words, waiting for perceived SMM similarity to increase, just by working longer together, is no longer an option in many contemporary settings. Hence our question: what can be done to more rapidly increase perceived SMM similarity between two individuals?

While it may be possible to redesign work in a way that SMMs are required for effective task execution, it is a far simpler matter to reframe goals in such a way as to emphasise the existing interdependencies between members of a team. We therefore argue that an answer to this question can be found in a key notion underlying many literatures – such as work design (e.g., Raveendran et al., 2020) and leadership (e.g., Fausing et al., 2015) – namely that team members tend to share more information, collaborate more closely, and generally trust each other more when their goals are common, shared, and aligned (i.e., when they have high goal interdependence; Van der Vegt and Janssen, 2003). Therefore, we argue that perceived SMM similarity can be reached earlier in dyadic tenure by having high goal interdependence within the dyad, due to its motivational impact. We further expect that having higher SMM similarity should be beneficial for their dyadic performance.

Overall, we aim to contribute to scientific knowledge in three key ways. First, by conducting a study on *perceived* SMM similarity at the *dyadic* level we expand the limited knowledge on these topics in the SMM literature. Most prior research was on the team level and not on perceived SMMs and this has obscured its constituent relational foundations and the relevance of perceptions in SMMs (Mohammed et al., 2021). Second, we explore a core (yet often implicit) notion underlying much of the SMM literature, namely that perceived SMM similarity

increase the longer two team members work together. By exploring if this core idea has theoretical and empirical merit, we strive to provide more solid evidence-based management insights (cf. Rousseau and Barends, 2011) on which the field of

Figure 3.1
Hypothesised model



perceived SMMs can build in the future. Third, we contribute by assessing if, and how, the length of tenure needed to get to high perceived SMM similarity can be reduced. We do so by assessing the effects of goal interdependence, which also expands scholarly understanding about the role of work design for perceived SMMs. Our study also holds relevance for practitioners, as they can use this knowledge to increase and accelerate perceived SMM similarity in contemporary business settings. Figure 3.1 displays the conceptual model which we will elaborate on below.

3.2. Theory and hypothesis development

3.2.1. Dyadic tenure as an antecedent of perceived SMM similarity

SMMs are instrumental in enabling collaborative social groups, such as dyads, to work together effectively and ultimately achieve high performance (e.g.,

Cannon-Bowers et al., 1993; Klimoski and Mohammed, 1994; Mohammed et al., 2017, 2021). SMMs are emergent states and the product of complex collective processes (Marks et al., 2001). They emerge as team members collaborate, and are shaped by the team members' collective behaviour, for instance, through learning (e.g., Van den Bossche et al., 2011) or reflexivity (e.g., Abrantes et al., 2022; Kneisel, 2020). More specifically, if the two members of a dyad have higher SMM similarity they would be better able to predict each other's work behaviour and hence respond in a manner that better suits the task and dyad demands (Cannon-Bowers et al., 1993). Consequently, having higher SMM similarity amongst team members is usually beneficial.

A caveat to this statement is that SMMs may exist without the awareness of the dyad members. Mental models are inherently individual constructs regarding work, and sharedness is usually implied via SMM structure in terms of the similarity between mental model representations, and their accuracy relative to specific tasks (DeChurch and Mesmer-Magnus, 2010a; Edwards et al., 2006; Lim and Klein, 2006). However, such structural measures do not assess if the members are actually aware of their SMMs. Not being aware of SMMs prevents team members from drawing upon them and this limits their ability to predict or understand each other's behaviour (Rentsch et al., 2009). While research on perceived SMMs is sparse, some recent studies (e.g., Marhefka et al., 2020; Müller and Antoni, 2020, 2022)

have started to address the call for greater understanding of such perceptions of SMMs and how they influence team performance (Mohammed et al., 2010, 2021). For example, Marhefka et al. (2020) conducted a study with virtual teams and found that perceived temporal mental model similarity positively predicts team viability but negatively predicts team performance. Other studies with virtual teams have shown that mental model perceptions of information and communication technology (ICT) are positively associated with team coordination and team performance (Müller and Antoni, 2020, 2022). Nevertheless, past studies that have looked into perceived SMMs have faced critical limitations by drawing on instruments that were over-simplified, as most studies only considered one type of perceived SMM (e.g., temporal SMMs, Marhefka et al., 2020; ICT mental models, Müller and Antoni, 2022). We thus follow and expand recent development by investigating the scarcely studied perceived SMMs where they are likely to first emerge – i.e., in dyads.

We focus on the *antecedents* of perceived SMM, because in the wider research on SMMs, most attention has been paid to outcomes (e.g., Ellis, 2006; Mathieu et al., 2000, 2010; Marks et al., 2002; Santos et al., 2015). Past studies have shown that factors such as team composition, team interventions, and contextual factors contribute to SMMs (Resick et al., 2010; Santos et al., 2021), yet none have specifically studied tenure. The closest to studying tenure, were studies

that analysed SMMs over time (e.g., Levesque et al., 2001; Mathieu et al., 2000; Santos and Passos, 2013), however, this has generally been observed at specified moments spanning a specific period under controlled conditions (e.g., short-lived teams' lifespans in management competitions; Santos and Passos, 2013; Uitdewilligen et al., 2023). Additionally in the few studies that (implicitly) investigated time or tenure related constructs (Levesque et al., 2001; Mathieu et al., 2000; Santos and Passos, 2013), scholars did not account for the time team members *shared* in working together. We argue it is important to focus on *dyadic* tenure, as it is during this *shared and overlapping* experience that team members have the opportunity to obtain and understand information relating to one another's understanding of their work and in doing so develop perceived SMMs. Expanding upon prior work that showed that collective tenure is of particular relevance for motivational states (e.g., Gonzalez-Mulé et al., 2020) we focus on the time dyadic partners have spent working with each other.

Specifically, we argue that by working together longer, dyad members have more opportunity to develop their shared cognition through information sharing and collective learning (Grand et al., 2016; Van den Bossche et al., 2011). For example, with longer shared tenure, team members have more opportunities to listen to each other, share experiences to better understand their roles relative to one other another, and exchange ideas and points of view. By engaging in such behaviours,

the dyadic members can get higher perceived SMM similarity. We therefore hypothesise:

Hypothesis 1: Dyadic tenure positively relates to perceived SMM similarity.

3.2.2. The moderating role of goal interdependence

The extent of dyad members' perceived SMMs is not only a product of the processes described above, because the context in which the dyad works can influence the extent of these processes. A key context of collaborative structures in organizations, such as dyads, is that team members are dependent on each other to reach their goals to a greater or lesser degree (Van der Vegt et al., 2010). Goal interdependence refers to the collaborative nature of dyads' shared goals in terms of the extent to which one member of a dyad's goals achievement is conditional to his or her dyad partner's goals being met as well (Tjosvold and Halco, 1992; Van der Vegt and Janssen, 2003). For instance, dyads working in highly competitive sales contexts may have lower goal interdependence, given the emphasis placed on individual performance and achievement whereas surgical teams are likely to have higher goal interdependence, given the shared and aligned goal of assisting their patient. We therefore argue that when the dyad members have high goal interdependence they are more motivated, and able, to work together (Raveendran et al., 2020; Van der Vegt and Janssen, 2003) because members are expected to share more interpersonal knowledge, seek solutions and compromises to problems,

and hence come to shared representations of knowledge more readily (cf. Kozlowski et al., 1999, Uitdewilligen et al., 2023; Van den Bossche et al., 2006). Cronin and Weingart (2007) argue that shared goal representations and outcomes are essential for effective teamwork as goal interdependent members are more inclined to integrate their discrepant perspectives and knowledge. This can create a motivational state and underlying condition that enables and promotes high perceived SMM similarity (DeChurch and Mesmer-Magnus, 2010b; Mathieu et al., 2000).

Goal interdependence could therefore enhance and facilitate the processes dyad members engage in that shape perceived SMM similarity, such as information sharing and mutual learning, so that they engage in these processes earlier in their shared tenure. Research has shown that when goals are seen as being more interrelated, members are more motivated to interact, experiment, and collaborate (Park et al., 2013; Van der Vegt and Janssen, 2003). Such behaviours should facilitate building higher perceived SMM similarity, because they provide insights into members' roles and thereby enhance knowing what facets of each other's work are relevant at what point. Higher perceived SMM similarity can thus be reached earlier in dyadic tenure, and the need for longer dyad tenure reduced, when dyads have more interdependent goals. We expect a moderation effect in that high goal interdependence reduces the effect of dyadic tenure on perceived SMM similarity,

as goal interdependence enables higher perceived SMM similarity, earlier in dyadic tenure (i.e., relative to instances of similar dyadic tenure, but where dyad partners have low goal interdependence). As such, we hypothesise that:

> *Hypothesis 2: Goal interdependence negatively moderates the positive relationship between dyadic tenure and perceived SMM similarity.*

3.2.3. The influence of dyadic tenure and perceived SMM similarity on dyadic performance

Performance is a key outcome of past studies that focused on the dyadic level (e.g., Nahrgang et al., 2009), as it represents team members' fundamental contribution to organisational success (Raveendran et al., 2020). Past research has indicated that collective forms of tenure (Gonzalez-Mulé et al., 2020), such as dyadic tenure, provide team members with experience and knowledge that they can use to improve their functioning over time. As they become more familiar with their tasks and demands, they are more able to respond to the challenges their work entails which enables them to perform their duties better in an individual capacity (Kozlowski et al., 1999). We expect that increased knowledge and expertise is also important for dyadic function and performance. As explained above, when team members build individual and task related knowledge and then share that within their dyad, this leads to high perceived SMM similarity. Consequently, we argue that dyadic tenure can enable mechanisms that improve performance, but in their

absence dyadic tenure itself may not exert an influence on dyadic performance. To illustrate, simply working longer together – without actually engaging with each other, sharing knowledge, and increasing dyadic functioning – does not provide any process or mechanism by which performance could be improved.

Past research has yielded inconsistent results when studying the effects of perceived SMM similarity on team performance – Santos et al. (2015) found no effect of perceived SMM similarity on performance whereas Marhefka et al. (2020) found a negative relationship. We argue, however, that being aware of SMMs enables dyads to reap their benefits. We therefore draw from the wider SMM literature (e.g., Mathieu et al., 2000; Mohammed et al., 2010; Rentsch et al., 2009), and argue that dyadic team members' perceived SMM holds a number of benefits to their potential performance. For example, enabling them to predict one another's behaviour or respond to mutual needs, which then enables them to act swiftly and with better coordination when performing their regular tasks or when confronted with novel and challenging situations (Cannon-Bowers et al., 1993; Mohammed et al., 2010). We therefore argue that while dyadic tenure is likely to influence dyadic performance due to increased knowledge and experience, this effect is indirect and takes place via perceived SMM similarity. We therefore hypothesise:

Hypothesis 3: Perceived SMM similarity mediates the relationship between dyadic tenure and dyadic performance.

3.2.4. The moderated effect of goal interdependence on dyadic performance via perceived SMM similarity

From a goal interdependence perspective (Raveendran et al., 2020), meaningful shared consequences and outcomes within a specific interpersonal context ultimately influences motivation and performance (Tjosvold and Halco, 1992). Goal interdependence is likely to create conditions where the shared goals motivate the dyadic team members to perceive, understand, and complement each other's points of view (Raveendran et al., 2020; Tjosvold and Halco, 1992). We therefore argue that under conditions of high goal interdependence, dyad members are likely to be more motivated to share knowledge and experiences and therefore get high perceived SMM similarity earlier in their shared tenure, whereas low goal interdependence will have the opposite effect and hamper perceived SMM similarity. Furthermore, we argue that, via the above, higher levels of goal interdependence will drive higher performance, whereas performance will be constrained under conditions of lower goal interdependence. We therefore expect a moderated mediation effect in that high goal interdependence not only reduces the direct positive effect of dyadic tenure on perceived SMM similarity, but also the positive indirect effect thereof on performance via perceived SMMs. As such, we expect that dyadic performance is higher earlier in dyadic tenure (relative to instances of similar dyadic tenure, but where dyad partners have low goal interdependence). We therefore hypothesise:

Hypothesis 4: Goal interdependence acts as a negative first stage moderator in the indirect relationship of dyadic tenure on performance via perceived SMM similarity.

3.3. Methodology

3.3.1. Participants

We collected a dataset of 88 leader-member dyads, with matched data from both respondents. Dyads reported a mean shared tenure of 2.59 years, ranging from one month to 10.5 years. The mean age of leaders was 38.26 years, 53.4% identified as female, and predominantly hailed from the Netherlands (72.7%) and Spain (11.4%). Members' mean age was 32.16 years, 47.7% identified as female, and also hailed predominantly from the Netherlands (73.9%) and Spain (9.1%). The sample was drawn from a range of industry sectors, mostly manufacturing (22.7%), healthcare and social assistance (15.9%), and retail (12.5%). The vast majority of dyads shared the same nationality (89.8%).

3.3.2. Procedure

We designed a dual-source dyadic-level study to test our hypotheses. To obtain the dyads, we invited one leader and one member (who reported directly to the leader) working together in the same team.

3.3.3. Measures

We adapted all measures to be suitable for use at the dyadic level, by implementing a referent shift to focus on the leader-member dyad. Scales for goal interdependence and perceived SMM similarity were computed by taking the item mean of the reported scores from the member and the leader (cf. Arthur et al., 2007). Dyadic performance was measured via the leader, as leaders are in a unique position to evaluate performance in their working units, given that performance evaluation and associated intervention typically form part of their responsibilities (Janssen and Van Yperen, 2004). It is for this reason that past research has frequently drawn on leader ratings of performance as a valid and reliable source of data (e.g., Aube and Rousseau, 2005; Nahrgang et al., 2009). To determine the similarity of measures between leader and member, we calculated intraclass correlation coefficients (ICC) for perceived SMM similarity (ICC(1)=.557, ICC(2)=.715), goal interdependence (ICC(1)=.414, ICC(2)=.585), and dyadic tenure (ICC(1)=.994, ICC(2)=.997). In addition, we computed $r_{wg(j)}$ values for perceived SMM similarity (.990) and goal interdependence (.902). This supports use of the data at a 'group' level as the ICC(2) values exceeded ICC(1) and the average $r_{wg(j)}$ values were above the required criteria (>.70; Bliese, 2000; James et al., 1993).

Dyadic tenure. Participants were asked to enter the number of years and months they had worked together with their dyadic counterparts within the same

team. We then calculated the proportional years and used the mean scores between the leader and employee to measure dyadic tenure. Dyadic tenure ranged from .08 to 10.5 years.

Goal interdependence. We used a three-item scale by Van der Vegt and Janssen (2003) to measure goal interdependence (e.g., "In this relationship, gain for either *Partner* or me means gain for the other"). A 7-point scale (1=*Completely disagree* to 7=*Completely agree*) was used (α=.87).

Perceived shared mental model similarity. We used a 20-item scale by van Rensburg et al. (2022) to measure perceived SMM similarity (e.g., "*Partner* and I have a similar understanding about how we should interact with each other"). A 7-point scale (1=*Strongly disagree* to 7=*Strongly agree*) was used (α=.94).

Dyadic performance. Leaders rated dyadic performance using the 3-item scale by Aube and Rousseau (2005). An example item is: "*Partner* and I produce high quality work". A 7-point scale (1=*Strongly disagree* to 7=*Strongly agree*) was used (α=.80).

Controls. We controlled for contextual aspects, namely task interdependence (Van der Vegt and Janssen, 2003; α=.65), task complexity (Maynard and Hakel, 1997; α=.83), and dyadic intent to remain working within the dyad, as well as demographic aspects, namely, leader and member age, gender, and qualification

respectively as these variables can influence perceived SMMs and dyadic performance (cf., Niler et al., 2021).

3.3.4. Discriminant and convergent validity

We conducted a confirmatory factor analysis to determine the suitability of our measurement model. Since this included a single item measure for dyadic tenure, we followed the procedures of Richardson and Vandenberg (2005) and set the factor loading of this measure to be the square root of a conservative estimated reliability of .70. Then we set the error term to a value of one minus the estimated indicator reliability, multiplied by its variance. All other latent constructs were measured by their respective items. Our (unmodified) model fit (χ^2=493.448, *df*=314, p<.001, CFI=.906, TLI=.895, SRMR=.077, RMSEA=.081) fell slightly below values suggested by Hu and Bentler (1999). However, in light of caution against strict adherence to rules of thumb that face their own limitations (Marsh et al., 2004) and the fact that our model's fit statistics were close to those suggested by Hu and Bentler (1999), we deemed our model to show acceptable fit. In addition, we show that this model fit better to the data than three alternative measurement models (Table 3.1). Our measurement model is therefore considered appropriate[7].

[7] In order to control for common method variance, we conducted Harman's single factor test as well as an unobserved latent variable test (Podsakoff *et al*., 2003). Harman's test showed that one factor did not account for the majority of variance in our model. The unobserved latent variable test showed

Table 3.1
Confirmatory factor analyses

Models	χ^2	df	χ^2/df	$\Delta\chi^2$ (Δdf)	CFI	TLI	SRMR	RMSEA
4-factor model	493.448	314	1.571	-	.906	.895	.077	.081
3-factor model	641.057	317	2.022	147.609*** (3)	.831	.813	.094	.108
2-factor model	714.765	320	2.234	221.317*** (6)	.794	.774	.092	.119
1-factor model	780.811	321	2.432	297.363*** (7)	.760	.738	.102	.128

Note. χ^2 = Chi-square; df = degrees of freedom; CFI = Comparative Fit Index; TLI = Tucker-Lewis Index; SRMR = Standardized Root-Mean Square Residual; RMSEA = Root-Mean Square Error of Approximation; 4-factor model = hypothesised measurement model; 3-factor model = grouped goal interdependence with perceived SMM similarity; 2-factor model = grouped dyadically rated variables under one factor; 1-factor model = grouped all variables under one factor. All models are compared with the 4-factor model. ***p<.001

3.3.5. Analytical strategy

We conducted a moderated mediation analysis using model 7 of Hayes' (2022) PROCESS macro (version 4.1) in SPSS (version 28) to test our hypothesized direct effects, moderation, statistical mediation, and moderated mediation. Except for the outcome, all variables were standardized. We draw on 5000 bootstrap samples using 95% confidence intervals to conduct these analyses (Hayes, 2022).

that including the unobserved variable to the four-factor main measurement model had little impact on our results and only minor changes were observed in model fit, factor loadings, standardised regression weights, and squared multiple correlations when compared to our main model (Johnson *et al.*, 2011). Common method bias was therefore unlikely to be a concern in this study.

Table 3.2
Correlations, means, and standard deviations

	M	*SD*	1	2	3	4	5	6	7	8	9	10	11	12
1 Leader age	38.261	10.496												
2 Member age	32.159	9.598	.160											
3 Leader gender	1.534	.502	-.282**	.013										
4 Member gender	1.477	.502	-.146	-.135	.163									
5 Leader qualification	4.296	1.063	.123	.116	-.062	-.289**								
6 Member qualification	3.841	1.231	-.001	.075	-.177	-.173	.555**							
7 Intent to remain in dyad	4.057	.957	-.082	.215*	.080	-.093	.164	-.124						
8 Task complexity	4.693	.986	-.374**	-.132	.079	.110	.164	.337**	.082					
9 Task interdependence	5.690	.552	-.060	.066	.207	.101	-.095	-.170	.108	.027				
10 Dyadic tenure	2.588	2.181	.155	.436**	.003	-.064	-.077	-.142	.281**	-.079	.179			
11 Goal interdependence	5.271	.919	-.099	-.146	-.031	-.080	-.138	-.002	.031	.266*	.322**	.080		
12 Perceived SMM similarity	5.677	.593	.088	.030	-.036	-.150	.067	.111	.055	.084	.144	.406**	.455**	
13 Dyadic performance	6.072	.628	-.163	.128	.047	-.049	-.090	-.015	.038	.161	.155	.163	.376**	.368**

Note. N=88 leader-member dyads; *p<.05; **p<.01; Gender: participants could identify as (1) male, (2) female, or (3) not disclose gender (no participant selected this third option); Qualification: participants were asked to indicate their highest completed qualification ranging from (1) No formal qualifications to (6) Doctoral degree.

3.4. Results

3.4.1. Descriptive results

The means, standard deviations, and correlations of variables in the study are presented in Table 3.2. There were significant positive correlations between the main variables, such as dyadic tenure and perceived SMM similarity (b=.406, p<.01) and goal interdependence and perceived SMM similarity (b=.455, p<.01). Furthermore, there were some significant positive correlations between the main and control variables, such as goal interdependence and task interdependence (b=.322, p<.01), and dyadic tenure and partners' age (b=.436, p<.01).

3.4.2. Direct effect of dyadic tenure on perceived SMM similarity

We analysed if dyadic tenure positively related to perceived SMM similarity. Our results showed this was the case (b=.595, p<.001, 95%CI [.388, .802]; see Table 3.3). Hypothesis 1 was supported.

3.4.3. Moderation effect of goal interdependence

We expected an interaction effect of goal interdependence on the relationships between dyadic tenure and perceived SMM similarity. As Table 3.3 shows, the main effect of goal interdependence on perceived SMM similarity was positive and significant (b=.393, p<.001, 95%CI [.201, .586]). The interaction effect between dyadic tenure and goal interdependence on perceived SMM similarity was significant and negative (b=-.308, p<.001, 95%CI [-.474, -.142]).

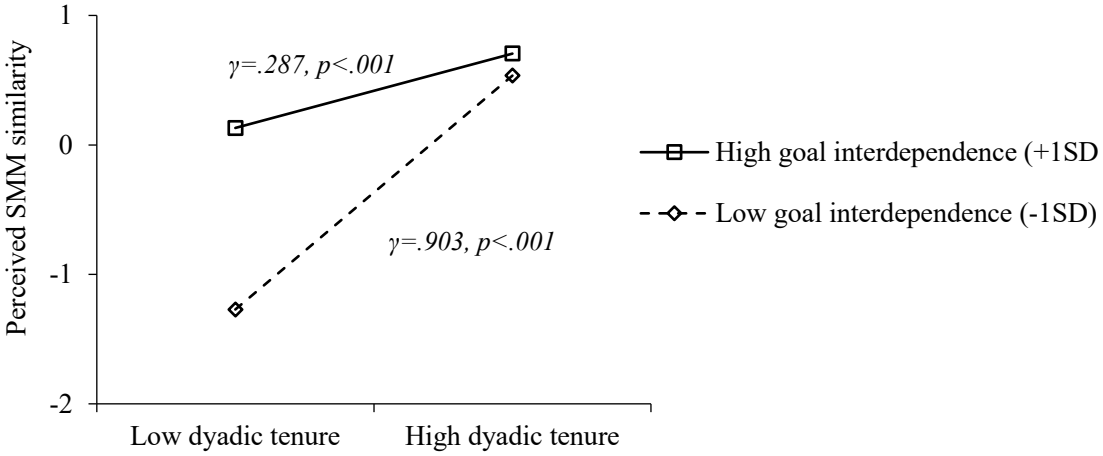
Table 3.3
Results for moderated mediation

	Main model		Alternative A		Alternative B		Alternative C	
	b	***SE***	***b***	***SE***	***b***	***SE***	***b***	***SE***
Step 1 Outcome: Perceived SMM similarity								
Controls								
Task interdependence	-.092	.093	-	-	-.106	.091	-	-
Task complexity	-.055	.102	-	-	.018	.088	-	-
Intent to remain in dyad	-.039	.093	-	-	-.048	.088	-	-
Leader age	.037	.096	.062	.088	-	-	-	-
Member age	-.158	.097	-.166†	.095	-	-	-	-
Leader gender	.112	.092	.092	.089	-	-	-	-
Member gender	-.060	.091	-.077	.088	-	-	-	-
Leader qualification	.106	.110	.077	.103	-	-	-	-
Member qualification	.155	.113	.163	.102	-	-	-	-
Main effects								
Dyadic tenure (DT)	.595***	.104	.569***	.100	.506***	.095	.470***	.089
Moderation								
Goal interdependence (GI)	.393***	.097	.348***	.087	.397***	.093	.371***	.085
DT × GI	-.308***	.083	-.296***	.081	-.278**	.083	-.266**	.082
Step 2 Outcome: Dyadic performance								
Controls								
Task interdependence	.047	.067	-	-	.063	.065	-	-
Task complexity	.089	.076	-	-	.083	.065	-	-
Intent to remain in dyad	-.022	.072	-	-	-.005	.067	-	-
Leader age	-.104	.074	-.133†	.068	-	-	-	-
Member age	.131	.075	.120	.073	-	-	-	-
Leader gender	-.014	.069	-.004	.068	-	-	-	-
Member gender	-.037	.069	-.021	.067	-	-	-	-
Leader qualification	-.070	.083	-.070	.079	-	-	-	-
Member qualification	-.048	.087	-.019	.079	-	-	-	-
Dyadic tenure	-.049	.084	-.045	.081	.014	.074	.010	.069
Mediation								
Perceived SMM similarity	.247**	.074	.261**	.072	.210**	.070	.227**	.069
R^2 Step 1	.496		.486		.431		.418	
F Step 1	6.151***		8.198***		10.214***		20.114***	
R^2 Step 2	.232		.212		.163		.136	
F Step 2	2.086*		2.658*		3.197**		6.670**	

Note. N=88 leader-member dyads; $^{\dagger}p<.10$; $^{*}p<.05$; $^{**}p<.01$; $^{***}p<.001$; *Alternative A:* hypothesised model with only demographic controls; *Alternative B:* hypothesised model with only contextual controls; *Alternative C:* hypothesised model with no controls.

To further explore this interaction effect, we assessed simple slope effects at the ±1SD values of goal interdependence (Aiken et al., 1991). The slopes were significant at low (b=.903, p<.001, 95%CI [.597, 1.209]) and high (b=.287, p<.05, 95% CI [.070, .504]) values of goal interdependence (see Table 3.4). As can be seen in Figure 3.2, these results indicate that with high goal interdependence perceived SMM similarity are higher earlier in dyadic tenure. Hypothesis 2 was supported.

Figure 3.2
Interaction effect between dyadic tenure and goal interdependence on perceived SMM similarity



3.4.4. Mediating effect of perceived SMM similarity

We expected that perceived SMM similarity mediates the relationship between dyadic tenure and dyadic performance. The traditional approach of Baron

and Kenny (1986) would suggest that mediation is only possible if the independent variable has a significant direct effect on the outcome variable, however recent methodological advances (Hayes, 2022; Kenny and Judd, 2014) have shown that a significant direct effect is not a requirement for mediation. In our case we note such an insignificant direct effect of dyadic tenure on performance (see Table 3.3). Nevertheless, our results (see Table 3.4) showed a positive indirect effect of dyadic tenure on performance via perceived SMM similarity (*b*=.147, bootstrapped 95%CI [.059, .247])[8] and we therefore find evidence of statistical mediation from our analyses. Hypothesis 3 was thus supported.

Table 3.4
Results for conditional indirect effects

	b	***SE***	**LLCI**	**ULCI**
Step 1: Moderation				
Dyadic tenure × goal interdependence → perceived SMM similarity				
Low	.903***	.154	.597	1.209
Moderate	.595***	.104	.388	.802
High	.287*	.109	.070	.504
	Effect	**BootSE**	**BootLLCI**	**BootULCI**
Step 2: Conditional indirect effect				
Dyadic tenure × goal interdependence → perceived SMM similarity → dyadic performance				
Low	.223	.073	.093	.380
Moderate	.147	.048	.059	.247
High	.071	.037	.002	.145
	Index	**BootSE**	**BootLLCI**	**BootULCI**
Index of moderated mediation	-.076	.031	-.150	-.027

Note. N=88 leader-member dyads, $^{*}p<.05$; $^{***}p<.001$

[8] Simple mediation analysis using Hayes' (2022) PROCESS macro model 4 showed a similar indirect effect (*b*=.125, bootstrapped 95%CI [.048, .234]), supporting this finding.

3.4.5. Moderated Mediation

As Table 3.4 also illustrates, the index of moderated mediation for the model was significant (Index=-.076, bootstrapped 95%CI [-.150, -.027]), supporting Hypothesis 4[9]. Overall, we conclude that our theorizing is supported by our analyses. Furthermore, as the last three columns of Table 3.3 illustrate, this was supported by three alternative models that showed that our results remain robust regardless of the inclusion of only demographic controls (age, gender, highest qualification; Alternative A); inclusion of only contextual controls (task interdependence, task complexity, intent to remain in the dyad; Alternative B); or exclusion of all controls (Alternative C).

3.5. Discussion

Our study shows that when dyad members work together for longer their perceived SMM similarity is higher, which also improves dyadic performance.

[9] Simple moderation analysis using Hayes'(2022) PROCESS macro model 1 showed an insignificant overall model coefficient (p=.088), an insignificant direct effect of dyadic tenure on performance (b=.056, p=.489), and an insignificant interaction effect of goal interdependence and dyadic tenure on performance (b=-.001, p=.983), further supporting our hypotheses. In addition, moderated mediation analysis using Hayes' (2022) PROCESS macro model 7 with task interdependence as moderator instead of goal interdependence showed an insignificant effect on perceived SMM similarity (b=-.049, p=.624), an insignificant interaction with dyadic tenure (b=-.128, p=.253), and an insignificant index of moderated mediation (Index=-.024, bootstrapped 95%CI [-.076, .026]).

Moreover, as theorized, we found that goal interdependence can reduce the need for longer shared tenure between a dyad leader and member, such that higher levels of perceived SMM similarity are achieved in less time working together.

3.5.1. Theoretical implications

This study makes various key theoretical contributions to SMM research specifically (e.g., Mesmer-Magnus et al., 2017), and team cognition research more generally (e.g., Grand et al., 2016; Niler et al., 2021). First, we respond to the call of Mohammed et al. (2021) to shift focus in SMM research to include the core interpersonal units underpinning perceived SMM similarity (i.e., dyads) that has been neglected in past research. Mental models in their simplest form are contained in the minds of individuals (Johnson-Laird, 1983). Any *shared* mental model will by necessity emerge between a *pair* of individuals (i.e., the dyad). Dyads have been noted as an important grouping by Klimoski and Mohammed (1994), but are still not being widely represented in SMM research nearly three decades later (Mohammed et al., 2021). In this paper, we therefore contribute to the scarce research on perceived SMMs in this core interpersonal building block of any team. In particular, we analyse a key dyadic pairing (i.e., the leader-member dyad) that occurs in most contemporary teams (e.g., Beenen et al., 2022, Toader and Martin, 2023), and show that perceived SMM similarity is important to foster dyadic performance. The relevance of our study is not limited to the specific field of

SMMs, but also has bearing on the broader field of team cognition. With dyads becoming increasingly important in the broader team cognition literature, given their critical relevance as *the* starting point for emerging shared cognition (cf., Toader and Martin, 2023), we contribute to the broader understanding of dyads' shared tenure in shaping the emergence of team cognition and suggest that, as with perceived SMMs, other types of team cognition (e.g., transactive memory systems or team situation awareness; Guastello et al., 2022; Smith-Jentsch et al., 2009) could be similarly influenced by *shared* tenure as well as job design features like goal interdependence.

Connected to this, we provide additional insight into the relevance of *perceived* SMM similarity. Past research has been predominantly focused on SMM structure and relatively few studies looked at perceptions of SMMs to date (e.g., Marhefka et al., 2020; Müller and Antoni, 2022). As we show, however, perceived SMM similarity is an important field of study as these perceptions are also relevant to dyads' functioning. Specifically, we highlight the importance of being aware of a SMM's existence so dyad partners are able to act thereon and use it to predict one another's behaviour, and in doing so foster dyadic performance. While team cognition has typically organised under structured and perceptual cognition (Mesmer-Magnus et al., 2017), strictly dividing cognition along these lines may limit our understanding of constructs like SMM and, in reality, structural and

perceptual elements of cognition could be more intertwined. As such, future research can delve deeper into such representations of cognition by examining both structured and perceptual elements thereof (cf., Marhefka et al., 2020; Müller and Antoni, 2022).

Second, we contribute to the field of collective tenure by theorising and demonstrating that shared cognition is a mediating mechanism on the relationship between collective forms of tenure and performance (Gonzalez-Mulé et al., 2020; Subramony and Chadwick, 2021). The meta-analysis of Gonzalez-Mulé et al. (2020) indicated the relevance of different forms of collective tenure for performance via shared cognition, yet as Subramony and Chadwick (2021) show, more research is needed to unravel the effects of different types of collective tenure. We specifically contribute to this discussion by investigating the *shared* tenure between dyad partners. In doing so we highlight, and find support for, a key (implicit) assumption underlying the SMM and team cognition literature (e.g., DeChurch and Mesmer-Magnus, 2010b) by illustrating that perceived SMMs are contingent not only on one's task experience, but also on the *shared* experiences between individuals. We further contribute to these fields by demonstrating the relevance of job design and motivational factors that contribute to this relationship.

Third, we contribute to a greater understanding of the intersection of the goal interdependence (e.g., Park et al., 2013; Van der Vegt and Janssen, 2003) and the

team cognition literature (e.g., DeChurch and Mesmer-Magnus, 2010b; Mathieu et al., 2000). Researchers have argued that more work is required to fully understand how team cognition is shaped by interdependencies in teams' work (e.g., Mesmer-Magnus et al., 2017). We specifically demonstrate the relevance of goal interdependence (Raveendran et al., 2020) as a motivational factor in shaping perceived SMM similarity. While we did not investigate task interdependence as a main variable in our model, we did include this as a control and note the insignificant direct effect on perceived SMM similarity compared to goal interdependence, thus extending from past SMM work that grouped goal and task interdependence as one variable (cf., Van den Bossche et al., 2006). Task interdependence was not only insignificant in our main analysis, we also erred on the side of caution and tested task (instead of goal) interdependence as a moderator, finding further insignificant effects and thus supporting our theorising. Past SMM research has focused more on working structures, instead of working contexts, and hence emphasised the role of tasks over other aspects of job design (e.g., DeChurch and Mesmer-Magnus, 2010b). This past focus on structures is understandable given the dominant orientation towards studying SMMs in terms of task execution and performance (e.g., Lim and Klein, 2006). However, this focus did mean that other contextual features (e.g., shared experience beyond short-lived interactions; Santos and Passos, 2013; Uitdewilligen et al., 2023) are less understood in this literature. Our study thus contributes to the SMM field, by showing that goal interdependence

can motivate two individuals to come to a shared perception on important features of their work. More broadly, our study illustrates the importance of context when studying perceived SMMs and their consequences. This further contributes to the team cognition literature and augments past findings on different forms of shared cognition, such as transactive memory systems (Aggarwal and Woolley, 2019) or information processing (Nijstad and De Dreu, 2012), that showed in different applications of interdependence as a mechanism by which shared cognition can be better motivated and leveraged.

3.5.2. Strengths, limitations, and future research

One strength of our research is that we focused on dyads and could thus explore these often overlooked interpersonal building blocks of teams and their effect on perceived SMMs (Klimoski and Mohammed, 1994; Mohammed et al., 2021). Since teams are constructed from several sets of dyads, perceived SMMs are likely built up from multiple unique dyadic perceptions rather than a singular shared (team) perception from content being shared between individuals (Kozlowski and Bell, 2013). Building upon this, future research can investigate triads or networks (cf. King and Sweet, 2021) within teams or conduct cross-level analyses to see how higher levels of analysis, such as the department or organizational level, emerge from lower levels (Kozlowski et al., 1999). In this sense, future research can expand on current work regarding collective tenure (cf., Gonzalez-Mulé et al., 2020;

Subramony and Chadwick, 2021) by considering the roles of different dyad pairings and whether some members' shared experience makes a greater contribution than others'. Researchers may even want to explore beyond the organizational level, to focus on the effects of different country-level cultures or industries. In this research, we focused on the dyadic level, yet we hope that others can expand on these foundations to develop such follow-up studies.

Another strength was that we focused on *perceived SMM similarity*, as this has not often been studied in past SMM research (e.g., van Rensburg et al., 2022). However, this is also a limitation, as it makes it more difficult to connect to most other research that has focused mostly on SMM structure (e.g., DeChurch and Mesmer-Magnus, 2010b; Mesmer-Magnus et al., 2017). While some studies are starting to do so (e.g., Müller and Antoni, 2022) future research can do more to compare SMM structure concepts (such as similarity and accuracy; Mohammed et al., 2010) with perceptions. It should be noted that capturing SMM structure is challenging and time-consuming given that this would typically require extensive task analyses (DeChurch and Mesmer Magnus, 2010a; van Rensburg et al., 2022). As such, future research on combining SMM structure and perceptions can benefit from focusing on more structured settings, such as student samples, as field study settings might be too complex and cumbersome at this early stage of this research area.

Finally, although we used previously published and established scales, our study also contains two minor measurement limitations. Firstly, we studied a temporal construct (i.e., dyadic tenure) cross-sectionally. As tenure is a relatively straightforward construct, which is often assessed in the way we do (e.g., Smith-Jentsch et al., 2009), we contend that this is valid at this early stage of knowledge development in this area. Especially, since we expand what most prior studies have done in this regard, as we draw on the perspectives of both leaders and members, aggregated to the dyadic level and then used dyadic (dyadic tenure, perceived SMM similarity, goal interdependence) and individual leader (dyadic performance) data. Hence, our use of two sources, is an improvement on many prior studies (e.g., Buvik and Tvedt, 2016). While causality cannot be inferred from our cross-sectional data, statistical mediation analyses similar to our have been conducted using such research designs and datasets in other research (cf. Buvik and Tvedt, 2016; Schreuder et al., 2020). Future research can therefore analyse dyads over long periods to determine how changing tenure influences perceived SMM similarity. Secondly, we made use of a perceptual measure of performance (i.e., leader-rated dyadic performance). While future studies may attempt to obtain objective data on dyadic performance, past research has shown that leader-rated measures of performance are valid (cf. Aube and Rousseau, 2005; Nahrgang et al., 2009). Overall our paper adopts a novel lens in addressing an important assumption in

SMM literature. In doing so we make contributions not only to the specific field of SMM research, but also to the broader theory on team cognition.

3.5.3. Practical implications

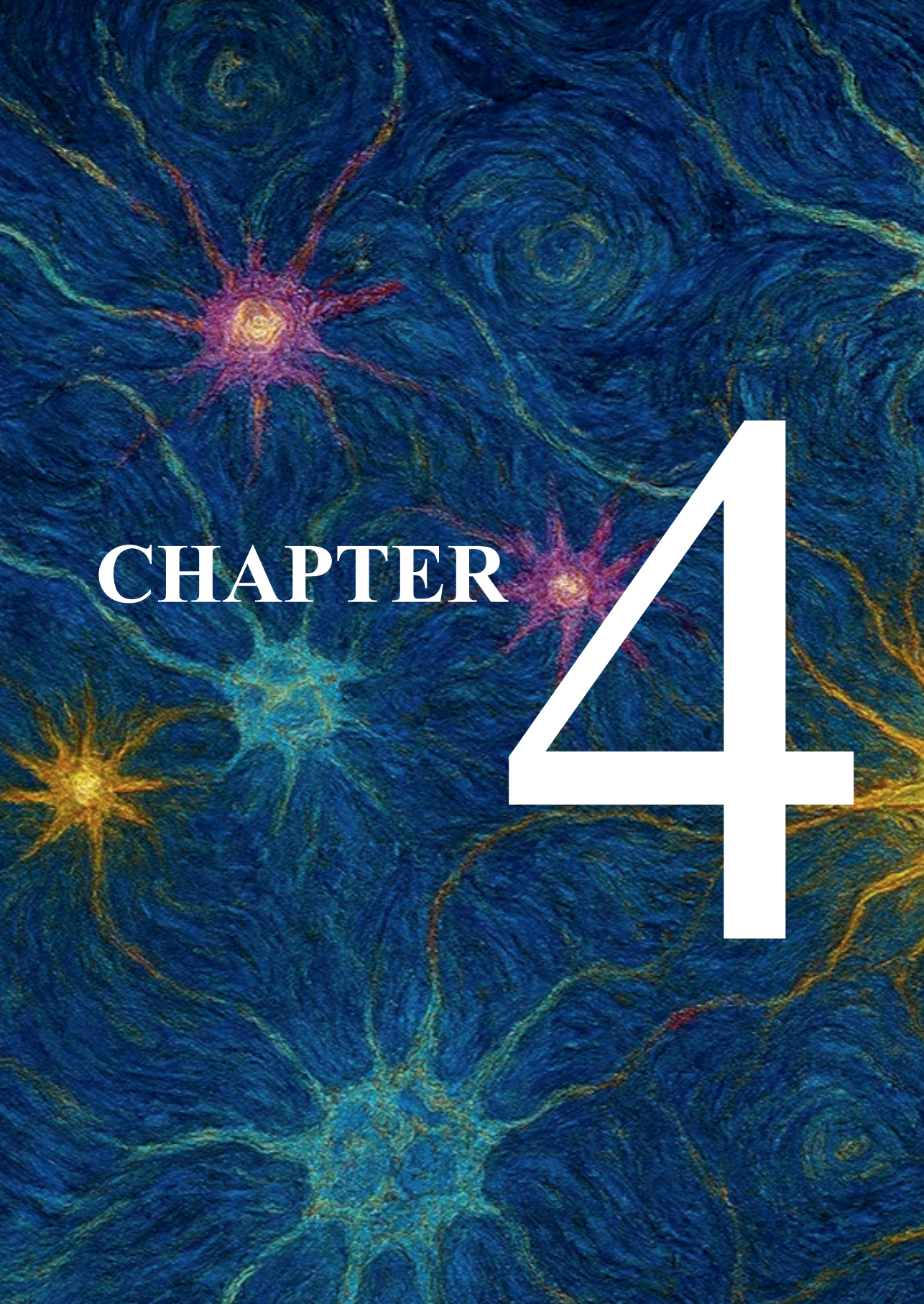
This study makes important practical contributions. Firstly, we show that practitioners and managers can benefit from designing work in a way that emphasises mutual goals and success so that dyads can become aware of their SMMs sooner. Higher goal interdependence between leaders and members can foster trust and interest in each other's work and in doing so secure more regular interaction regarding their work (Van der Vegt and Janssen, 2003), which is fundamental to SMM development.

Secondly, given that we found a link between perceived SMM similarity and dyadic performance, practitioners might want to facilitate the development of perceived SMMs. This can, for example, be done via cross-training (e.g., Marks et al., 2002) as this would improve mutual understanding between both team members, via a concept mapping intervention (Santos et al., 2021), as this would allow the dyadic partners to share and integrate important information, or via reflexivity, drawing on shared reflection on successes and failures to integrate information from feedback processes (Abrantes et al., 2022; Gabelica et al., 2014) . This would serve not only to develop SMMs, but also raise individuals' awareness

of their SMMs, thus enabling them to draw on their SMMs to predict one another's behaviour and function better together.

3.6. Conclusion

We set out to understand how dyadic tenure could influence perceived SMM similarity, and subsequently dyadic performance, under different levels of goal interdependence. Our results support our theorizing by demonstrating that perceived SMM similarity gets higher with increased tenure and by showing that higher goal interdependence enables higher perceived SMM similarity, earlier in dyadic tenure. We also demonstrated that this affects dyadic performance. By studying perceived SMM similarity at the dyadic level, we open the avenue for theoretical and empirical work on the nuances underlying a construct which has so far been predominantly studied at the team level. Overall, our study makes novel and important theoretical contributions to the SMM literature, which we hope can help practitioners and scholars alike to better understand perceived SMMs, especially in dyads.


CHAPTER
4

HOW TEAM LEARNING AND SELF-EFFICACY INFLUENCE PERCEIVED SHARED MENTAL MODELS OVER TIME

An earlier version of this chapter was presented at the 12th Biennial International Conference of the Dutch HRM Network in 2022.

Abstract

The shared mental models (SMMs) literature there has recently seen increasing interest in the scarcely researched *perceived* SMMs. Not much is currently known on how, and why, such perceived SMMs develop over time within teams. This is troubling since it implies an assumption in the SMM literature that teams that possess SMMs are automatically aware thereof, yet this is rarely tested. Drawing from literature on team learning and social cognitive theory (SCT), we investigate how develop a new perspective in which self-efficacy interacts with two key aspects of team learning, namely co-construction and constructive conflict, to investigate how team learning behaviours influence perceived SMMs over time and do so differently in teams where team members have high vs low self-efficacy. We collected a sample of 165 student teams, consisting of three or four team members, that worked on a seven-week project based on a real company problem, collecting three wave longitudinal data. We obtained an 86% response rate and conducted random coefficient modelling to test our longitudinal model. As theorised, our results showed positive growth in perceived SMMs, positively influenced by co-construction and constructive conflict. This relationship was generally stronger when team members had high (vs low) self-efficacy, while, unexpectedly, teams with high co-construction or constructive conflict and *low* self-efficacy developed perceived SMMs more rapidly. Overall, our research shows the value of taking a SCT perspective and investigate team processes (i.e., two key team learning

behaviours) as well as team member personal attributes (i.e., self-efficacy) when studying perceived SMMs over time.

4.1. Introduction

Teams, with their rich collective skills and perspectives, are critical to organisations' success. Their effectiveness, however, is contingent on their ability to work as organised units over time (Cronin et al., 2011; Kozlowski & Bell, 2013; Mathieu et al., 2019). To do so, team members have to systematically develop a collective awareness and interpretation of their shared understanding regarding key aspects of the team's working environment – a perceived shared mental model (perceived SMM; Burtscher & Oostlander, 2019; Gevers et al., 2020).

Possessing a similar understanding about the team's work offers teams substantial benefits (cf. Carraro et al., 2024; Mohammed et al., 2021), however this similarity between members may go completely unnoticed until members are made aware thereof through their exchanges. Ignorance regarding the existence of a SMM (i.e., low perceived SMMs) precludes the team from drawing on their shared understanding to predict behaviour (cf. Marhefka et al., 2020; Van Rensburg et al., 2023). Research on perceived SMMs is still in its infancy. A few recent studies have shown the relevance of perceived SMMs in understanding important team processes such as team coordination (Müller & Antoni, 2020) and outcomes such as team performance (Ellwart et al., 2014; Marhefka et al., 2020; Van Rensburg et al., 2023), however the antecedents of perceived SMMs have not enjoyed the same scrutiny. One promising way in which teams can develop such perceived SMMs is

through collectively constructing, evaluating and integrating new information via team learning (Van den Bossche et al., 2011).

A further oversight in the study of (perceived) SMMs has been that many studies on have adopted methodological approaches (e.g., cross-sectional designs) that have failed to capture the nuances of (perceived) SMM *development* (DeChurch & Mesmer-Magnus, 2010b; Mohammed et al., 2010, 2021). This is a particularly problematic, since (perceived) SMMs are dynamic and prone to change and develop over time, but often not adequately treated as the emergent states they are (Kozlowski & Chao, 2012; Marks et al., 2001; Mohammed et al., 2010; Rapp et al., 2021). Although SMMs have in some cases been studied over time (cf., Guchait & Hamilton, 2013; Santos et al, 2016), few studies have adopted the view that time itself is important in their development (cf., Gevers et al., 2020; Santos et al., 2015b, 2021). Current literature therefore falls short of clearly demonstrating the developmental trajectories of perceived SMMs over time. This severely constrains the current understanding of perceived SMMs as emergent states, with the status quo being an assumption that such perceptions develop over time as team members work together and share experiences. While the assumption itself is not unreasonable, it is vital to test not only whether perceived SMMs do develop over time, but *how* this development looks as time passes. The importance of appeals for increased longitudinal research on the topic therefore cannot be overstated (cf.,

Fyhn et al., 2023; Mohammed et al., 2021). In this paper, we build on recent developments in the perceived SMM literature (e.g., Marhefka et al., 2020; Mohammed et al., 2012; Van Rensburg et al., 2022, 2023), and address the call to research the development of perceived SMMs over time.

While the time team members spend working together can be expected to influence their perceived SMMs (cf., Van Rensburg et al., 2023), this does not take place in a vacuum and key processes can influence this development over time. In particular, we draw on the work of Van den Bossche et al. (2006, 2011) which shows that a key way in which teams can develop SMMs is through collectively constructing, evaluating and integrating new information via team learning. Team learning is the process of interaction between members that leads to the development of shared knowledge (Edmondson, 1999). Team members can learn about their work individually through the construction of meaning, and as a team by means of: 1) the *co-construction* (or collaborative construction) of meaning, where members construct meaning by adding to, or modifying, existing knowledge via interaction; and 2) *constructive conflict*, where members resolve differences in their representations of knowledge through critical discourse (Van den Bossche et al., 2006, 2011). Past research has made some inroads into the fundamental relationship between SMMs and team learning (cf., Guchait & Hamilton, 2013; Van den Bossche et al., 2011), but the temporal dynamics of team learning have not been

investigated in those studies. Past research has (implicitly) assumed that learning (and SMMs) can be aggregated from stable individual factors (cf. Roe et al., 2012). This is an inaccurate assumption, as team learning behaviour varies in its frequency and intensity over time (Edmondson, 1999; Rapp et al., 2021; Van den Bossche et al., 2006, 2011). At present, however, it is not clear if the learning processes of co-construction and constructive conflict evolve over time and if they do so similarly or differently, nor is it clear how perceived SMMs relate to these changes. In light of this, the second objective of this paper is to expand scholarly understanding of the relationship between team learning and perceived SMMs over time.

To do so, we draw on research that has shown that learning is dependent on individual cognitive and affective factors, but takes place via interpersonal exchanges and social processes (Edmondson, 1999; Van den Bossche et al., 2006). This is clearly captured in Bandura's (1986) social cognitive theory of learning, which positions self-efficacy (i.e., team members' confidence in their ability to achieve a given goal) as a key component in the translation of learning into a desired output (e.g., Bandura, 1993). Team learning behaviours (cf., Van den Bossche et al., 2006) and perceived SMMs (cf., Rouse & Morris, 1986) are both aggregated functions of individual cognition and behaviour, thus we argue that it is vital to study the role of team member self-efficacy in their emergence, given the role of efficacy beliefs in regulating behaviour. Therefore, our third objective is to account

for the role of team member self-efficacy in the temporal relationship between team learning behaviour and perceived SMMs.

We contribute to the literature on teamwork and team cognition in general, and more specifically on the literature on SMMs, in three ways. Firstly, we continue the emerging work on perceived SMMs (cf., Marhefka et al., 2020; Müller & Antoni, 2020; Van Rensburg et al., 2022, 2023), further demonstrating the importance of not only having a SMM, but having members who are aware of its existence. In addition, we start digging into the antecedents of perceived SMMs by expanding on the current understanding of the relationship between perceived SMMs and team learning. In doing so we embark on early explanations of the emergence of perceived SMMs in teams. Despite their importance in understanding how teams work, the topic of team learning and SMMs faces challenging questions and the absence of perceived SMMs in this literature is conspicuous in that the process of learning is likely to not only convey knowledge between team members, but also raise awareness of one another's thinking. We therefore clarify how team learning and SMMs relate, specifically taking into account the crucial perceptual component of SMMs.

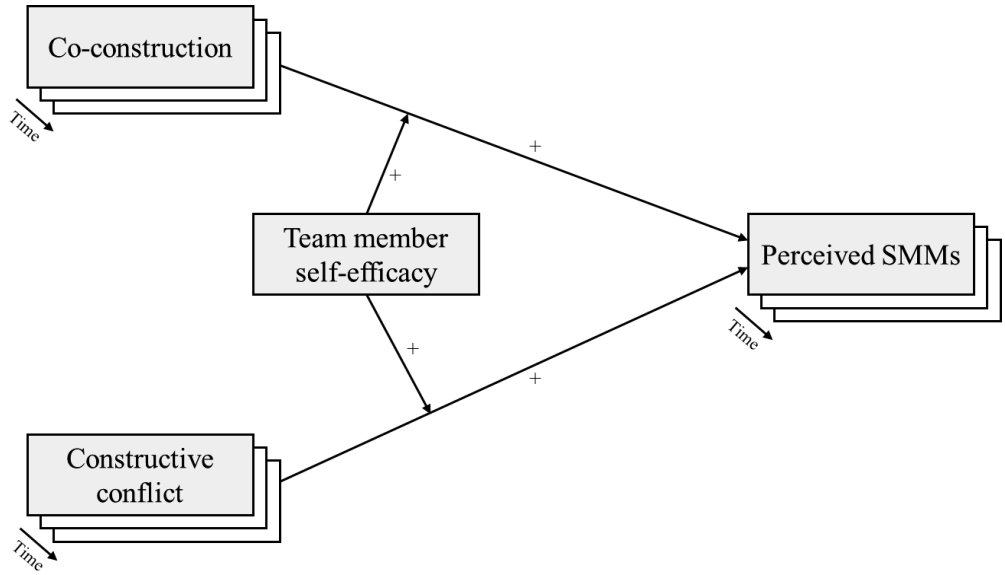
Secondly, we clarify the murky theoretical foundation of team learning and SMMs by taking a step back and drawing on social cognitive theory of learning (Bandura, 1986; Johnson et al., 2008) to explain how two key social processes

influence the way in which team members learn from one another, and from that can then develop perceived SMMs. A key insight from taking up this theoretical lens, is that team member self-efficacy is likely to be a key moderator, as the development of perceived SMMs is probably contingent on the confidence team members have in their ability to translate learning into their SMMs.

Thirdly, we take a longitudinal view of learning and perceived SMMs, with a focus on their development and relationship over three points in time. This enables us to investigate the (implicitly) assumed, but never before explicitly theorized or tested emergence and development of perceived SMMs and team learning behaviour *over time*.

Overall, our aim is thus to take important steps towards a better understanding of the role of time in how perceived SMMs develop from team learning behaviours, while also providing a stronger theoretical foundation by using social cognitive theory (Bandura, 1986) and assessing the moderating effect of team member self-efficacy. Our conceptual model can be seen in Figure 4.1.

Figure 4.1
Conceptual model



4.2. Theory and hypotheses

4.2.1. The dynamic nature of perceived SMMs

Although time is an integral part of team members' perceived SMM development, it has never been explicitly studied. When studying SMMs, researchers often adopt the concepts of emergent states to explain how they come into existence and develop (Marks et al., 2001). Emergent states (such as perceived SMMs) are likely to follow a growing trajectory over time (Fyhn et al., 2023) as they represent "the echoes of repeated process interactions" Kozlowski and Ilgen (2006, p. 81). Emergent states are thus reflective of the quality of team processes

(such as team learning) in that more effective team processes will yield better growth in emergent states. In this sense, emergent states originate with individual characteristics – for example, affect, behaviour, and cognition – and grow into collective phenomena with interaction between members over time (Rapp et al., 2021). As time passes, team members have opportunity and cause to engage in team processes (Fyhn et al., 2023). This iterative process therefore shapes team members' cognition over time, as they directly and indirectly share experiences (Rapp et al., 2021). We expect perceived SMMs, as an emergent state, to follow this trend and to increase over time from the inception to the conclusion of a team's collaboration. This idea finds partial support in past research by Van Rensburg et al. (2023), who showed that dyads with longer shared tenure held more similar perceived SMMs, yet that study was based on cross-sectional data and can thus only provide circumstantial evidence. Based on the above, we expect the relationship between time and perceived SMMs to be positively linear in nature, under conditions of stable membership (Burtscher & Manser, 2012) and a short team lifespan (Mathieu et al., 2019; Niler et al., 2021). As such, we argue that perceived SMMs increase over time, leading to the following hypothesis:

> *Hypothesis 1: As time passes within a team, team members' perceived SMMs tend to increase.*

4.2.2. Team learning and perceived SMMs from a social cognitive perspective

Social cognitive theory (Bandura, 1986) provides us with a unique lens to use in studying team cognition (e.g., perceived SMMs) and its associated processes and emergent states. While this has been widely used as basis for team learning (cf. Rauter et al., 2018; Van den Bossche et al., 2006, 2011), there has been no use made of this seminal learning theory in explaining the development of perceived SMMs. Bandura's (1986) theory presents us with a conceptualisation of learning resulting from the interaction between reciprocal personal, behavioural, and environmental factors. Under the theory, cognition is a product of individuals' interpretation of information from behavioural choices taken in a defined environment subject to unique personal cognitive characteristics (Schunk & DiBenedetto, 2020).

Social cognitive theory builds on the concept of observational learning, where the (social) observation of peers enables replication of behaviour in a collective format, in turn influencing the effectiveness of actions in a particular setting (Bandura, 1986; Cook & Artino, 2016). Co-construction and constructive conflict are interpersonal behaviours that reflect teams' collaboration in constructing shared meaning and critical evaluation of collective knowledge representations (Van den Bossche, 2006, 2011). As Wiedow et al. (2013) show, the basis of team members' task related cognition can be influenced by their exhibition of team learning behaviour such as co-construction and constructive conflict. In addition, the

effectiveness of translating behaviour (and social observations thereof) into cognitive outcomes relies on team members' confidence in their ability to replicate this behaviour (i.e., their self-efficacy beliefs; Ellington & Dierdorff, 2014; Schunk & DiBenedetto, 2020). Therefore, we argue that social cognitive theory offers an insightful lens to explore why key interactions in teams, such as team learning, affect the development of shared perceptions regarding key aspects of their work.

Perceived SMMs also fit in the reciprocal framework proposed by the social cognitive theory as cognitive constructs that are both informed by team members' behaviour, but can contribute thereto – e.g., perceived SMMs can become increasingly shared based on newly integrated information while at the same time forming part of the basis of team members' decision-making (cf., Abrantes et al., 2022; Santos et al., 2015b; Van Rensburg et al., 2023). In this instance, shared exposure and observation form part of the team learning process and can function as sources of knowledge contributing to the construction of meaning and reconciliation of different views, which in turn enable members to develop their knowledge relating to their work. This process is temporally bound, thus leading to the emergence of perceived SMMs, as knowledge is systematically transferred between members over time, rather than instantaneously (Fyhn et al., 2023; Grand et al., 2016; Mohammed et al., 2021). Mutual access and exposure between team members make time itself a crucial environmental factor in the development of

knowledge since this enables team members to engage in social cognitive processes that eventually shape their cognition (Fyhn et al., 2023; Pinheiro et al., 2022; Roe et al., 2012). Thus, we argue that the time team members spend working together is an essential component to the process of engaging in learning behaviour and translating this into (shared) cognition.

Time is emphasised as an important environmental factor in past research. Mohammed et al. (2021) point out that representations of knowledge (such as perceived SMMs) are relatively stable over time. This seemingly contradicts the status of perceived SMMs as emergent states, but can be explained at the hand of team longevity and stability (Mathieu et al., 2019). Teams that are more stable in membership over time, may require fewer updates to their perceived SMMs, compared to teams with unstable membership and subsequent entry of new members who need to integrate with the team's ways of working. Similarly, teams that have worked together for a long period may require fewer updates to their perceived SMMs, whereas newly formed teams (especially short-lived project teams) would not have had the opportunity to develop perceived SMMs prior to their inception and face increased pressure to do so (Burtscher & Manser, 2012; Pinheiro et al., 2022; Niler et al., 2021). The time teams have available for working together therefore not only provides opportunity, but we also expect it can stimulate

the translation of team learning that stems from interaction, into shared cognition (and specifically perceived SMMs).

Social cognitive theory therefore describes an interactive process that enables team members to exchange and verify information that is then incorporated into their perceived SMMs. This process is temporally bound as the knowledge is transferred between team members over time, thus enabling perceived SMMs to emerge as time passes. We therefore conclude that, from a social cognitive perspective, the relationship between team learning and perceived SMMs is deeply dependent on the time team members spend working together.

4.2.2.1. Co-construction and perceived SMMs

Team learning is built on collective learning behaviours (Edmondson et al., 2007), and a key behaviour is the co-construction of meaningful representations of factors related to the team's task, goals, or environment (Van den Bossche et al., 2006, 2011). When engaging in the process of co-construction, team members actively share information and in doing so refine, expand, or modify original representations of knowledge (Baker, 1994; Van den Bossche et al., 2011). As such, intrateam knowledge transfer is a cumulative process where team members gain new insights regarding their work environment from one another.

Van den Bossche et al. (2011) warn that knowledge accumulated in the team does not automatically constitute shared cognition, because team members need to

reach agreement on knowledge suitable to their particular environment. Co-construction operates by means of repeated cycles where information is shared and included in the team's generally accepted framework (Decuyper et al., 2010). The acceptance of co-constructed knowledge into a team's SMM is the first step in developing perceived SMMs. Team members engage in the social-cognitive act of collectively contributing meaningful information into a shared framework via communication (cf., Gurtner et al., 2007). They can then use this pooled knowledge to develop an understanding of their individual representations of knowledge and how this fits with that of their team (Van der Haar et al., 2013).

While engaging in co-construction through the act of communicating with – or actively listening to – others, team members demonstrate explicit learning behaviour within their work context (cf., Van den Bossche et al., 2011). This represents a social cognitive process that enables members to draw conclusions about their own understanding of the collective knowledge in the team and thus develop awareness of correspondence (or divergence) in their SMMs (Guchait & Hamilton, 2013). By engaging in co-construction, team members can therefore develop greater shared perceptions regarding the similarity of their mental models.

Although never studied, prior research (implicitly) assumed that perceived SMMs therefore emerge and develop over time as team members consciously obtain and integrate new information from their shared work environment through

co-construction (see Figure 4.1; Santos et al., 2016, 2021; Van den Bossche et al., 2011). As such, we hypothesise that:

> *Hypothesis 2: Growth in co-construction is positively related to growth in perceived SMMs, such that the positive relationship between co-construction and perceived SMMs increases over time.*

4.2.2.2. Constructive conflict and perceived SMMs

Conflicts or discrepancies in representations are likely to occur as team members engage in team learning. While co-construction can be viewed as a process of accumulation of knowledge and discovery of meaning in teams over time, constructive conflict requires debate, and then ultimately acceptance, of the different knowledge content by team members (Van den Bossche et al., 2011). If team members have divergent understandings about the team's work, acceptance of an alternative point of view would imply discarding one's own point of view. For this, constructive engagement with these conflicts is important. Such constructive engagement is not guaranteed to happen during co-construction, since team members could opt to ignore the discrepancies or reject these contributions out of hand (De Dreu & Weingart, 2003). Therefore, constructive conflict is a separate construct as, rather than rejecting contributions out of hand or accepting one another's submissions blindly, team members can engage in constructive conflict (i.e., a constructive resolution of conflicts in representations of knowledge; Van den

Bossche et al., 2011). In this process, team members not only share information with one another, but critically evaluate and discuss its relevance (Van den Bossche et al., 2006, 2011). This offers team members the chance to have an open discussion on the content of the knowledge they share and to reach shared conclusions on its application and utility in their shared context (Decuyper et al., 2010; Tjosvold, 2008).

In this sense, divergence in opinion is viewed as a positive and constructive phenomenon. The discussion and review of pooled knowledge in the team represent enacted behaviour that only offers further opportunity for team members to develop SMMs via increased interaction (Klimoski & Mohammed, 1994), and also provides a mechanism to refine this knowledge by means of improved communication (Edmondson et al., 2007). The active and open discussion of team members' knowledge contributions enables each member to gain deeper insights into its content through repetition and critical review. From the social cognitive perspective (Bandura, 1986), contributing and debating knowledge can be viewed as enacted behaviours. When replicated these behaviours can demonstrate their prominence as socially acceptable conduct and hence increase team members' comfort participating in the process of constructive conflict over time (Edmondson, 1999). This increased acceptance of constructive conflict in the team can therefore directly improve their perceived SMMs over time, since *constructive* conflict leads to

mutual agreement on the content of shared knowledge and understanding (Decuyper et al., 2010). Constructive conflict as a process takes place over time as members offer new submissions of knowledge for the team's consideration and review (Guchait & Hamilton, 2013; Van den Bossche et al., 2011; Van der Haar et al., 2015), but its effect on perceptions or awareness of shared understandings remains untested. Constructive conflict can therefore be viewed as a dynamic process that enables growth in shared understanding and perceived SMMs among team members (see Figure 4.1), leading us to hypothesise that:

> *Hypothesis 3: Growth in constructive conflict is positively related to growth in perceived SMMs, such that the positive relationship between constructive conflict and perceived SMMs increases over time.*

4.2.3. The moderating role of team member self-efficacy

For learning to be truly effective, it needs to take place in a context where team members feel comfortable and confident that their inputs and participation will be appreciated (Edmondson, 1999). In addition, co-construction and constructive conflict are behavioural tasks that team members will master over time and that are likely to become more effective in the results they yield along the trajectory of this development (Schunk & DiBenedetto, 2020; Tams, 2008). As outcomes of learning, (perceived) SMMs are inextricably linked to the social cognitive driver of motivation (DeChurch & Mesmer-Magnus, 2010a; Van der Haar

et al., 2013). Team learning behaviours are collective in their conceptualisation, but represent the efforts of individual team members who pool and critically review knowledge in the team (Van den Bossche et al., 2006, 2011). From a social cognitive perspective, team members need to possess sufficient confidence in their ability to replicate behaviour (i.e., self-efficacy), in order to do so in a continuous and sustainable manner (Bandura, 1986; Cook & Artino, 2016).

Efficacy beliefs can influence the willingness of team members to participate in communicating their views and thus shape the degree of comfort they have in engaging with behavioural norms in their teams (Edmondson, 1999; Rico et al., 2008). Team members' self-efficacy is likely to influence how comfortable and willing they are to share and critically discuss issues that contribute to their collective learning via co-construction and constructive conflict (Edmondson, 1999). Examples are found in Cannon and Edmondson (2005) who highlight that a lack of self-efficacy could serve as a barrier to team members' ability to acknowledge difficult topics, such as failures, thus potentially inhibiting effective constructive conflict; and Du et al. (2022) who demonstrate that self-efficacy enables more effective translation of learning into creativity. As a result, team member self-efficacy forms the motivational basis to replicate key behaviours in their teams. Applied to team learning behaviour, we posit that when team members'

self-efficacy is high, they should be more motivated to engage in co-construction and constructive conflict.

Team member self-efficacy is likely to influence the way in which co-construction and constructive conflict lead to the development of perceived SMMs over time. When team members possess higher self-efficacy, they are likely to replicate learning behaviour more frequently and with more comfort than under conditions of lower self-efficacy (Cook & Artino, 2016). Thus we argue that the higher self-efficacy is among team members, the more conducive their shared environment should be in facilitating the development of co-construction and constructive conflict, which we then expect to translate into increased development of perceived SMMs over time (see Figure 4.1). We therefore hypothesise that:

Hypothesis 4: Average team member self-efficacy moderates the relationship between growth in co-construction and growth in perceived SMMs over time, such that the positive effect of growth in co-construction on growth in perceived SMMs over time is stronger when team member self-efficacy is higher.

Hypothesis 5: Team member self-efficacy moderates the relationship between growth in constructive conflict and growth in perceived SMMs over time, such that the positive effect of growth in constructive conflict on

growth in perceived SMMs over time is stronger when team member self-efficacy is higher.

4.3. Methods and results

4.3.1. Participants

Our sample is composed of 165 student teams (513 participants), enrolled in a Master-level course that formed part of a management programme at a Dutch university. Teams were composed of three to four members (in three cases the team size differed – two teams of two and one team of five members). The average team size was 3.43 members (*SD*=.60, one missing value). Overall, participants represented 43 nationalities, yet predominantly hailed from the Netherlands (33.9%), Germany (28.1%), and Belgium (10.2%). Participants were between 20 and 40 years old, with an average age of 23.67 years (*SD*=2.30), and 63.7% were female.

4.3.2. Procedure

Teams were created via random allocation to work on a team project for the duration of an academic term of seven weeks. The project involved creating an organisational learning intervention for a real company based on publicly available information and the materials assigned in the course. While the project was mandatory, participation in the study was voluntary and students received no credits for participating. To encourage participation, students were informed that a

donation would be made to a charity based on the number of complete team responses. The students were given an opportunity to nominate and later vote for a charity of their choice, provided the organisation was registered in the Netherlands. The study was briefly introduced in class by teachers and a video with a short introduction shown during the first class where data were collected. Students were provided with a link that directed them to our online surveys and asked to enter a code that would serve to aggregate the individual answers to the team level. Data were collected using online surveys that were made available to students during three classes specifically allocated to working on the team project. Surveys were opened during the first such class (Time 0, T0), one class in the middle of the term (Time 1, T1), and the last such class before the project was due (Time 2, T2). The surveys each took between 10-15 minutes to complete and students were given time during class to complete them. We included responses from solitary team members, and responses that only included one measurement moment, in our analysis as research has shown that the practice of selecting only high-representation teams for analysis was less appropriate as individual members' representations could still be reflective of team-level constructs (Hirschfeld et al., 2013; Maloney et al., 2010). Missing values were observed, generally due to attrition over time, with 165 unique teams of which all teams' responses were recorded at T1, 158 teams at T2, and 151 teams at T3 yielding 145 complete cases (86%) over all three measurement points.

Values were missing for all measured variables for eight teams at T1 and 15 teams at T2.

4.3.3. Measures

4.3.3.1. Co-construction

We measured the co-construction at all three data collection points using the three-item scale (e.g., "Team members elaborate on each other's information and ideas") from Van den Bossche et al. (2011). Participants were asked to indicate their agreement on a 7-point scale (1=*Strongly disagree* to 7=*Strongly agree*) yielding good reliability (α=.75 to .85).

4.3.3.2. Constructive conflict

We also used the four-item scale from Van den Bossche et al. (2011) to measure constructive conflict (e.g., "This team tends to handle differences of opinions by addressing them directly"). Participants were asked to indicate their agreement on a 7-point scale (1=*Strongly disagree* to 7=*Strongly agree*), yielding good reliability (α=.72 to .77).

4.3.3.3. Perceived SMMs

We used the 20-item scale from Van Rensburg et al. (2022) to measure perceived SMMs at all three data collection points. Participants were asked to indicate their agreement with each item (e.g., "Team members have a similar understanding about how best to perform our tasks") on a 7-point scale (1=*Strongly*

disagree to 7=*Strongly agree*). The scale yielded good reliability at all three data collection points (α=.93 to .95).

4.3.3.4. Team member self-efficacy

We used the eight-item general self-efficacy scale of Chen et al. (2001) to measure team member self-efficacy at the first data collection point (T0). Participants were asked to indicate their agreement with each item (e.g., "I am confident that I can perform effectively on many different tasks") on a 7-point scale (1=*Strongly disagree* to 7=*Strongly agree*). The scale yielded good reliability (α=.86).

4.3.3.5. Controls

We controlled for variables that can influence perceived SMMs and team learning. All control variables were measured at T0. More specifically, we controlled for team familiarity (four-item scale of Webber 2008; α=.87), since team members who are more familiar may be biased in their perceptions of one another relative to the project (cf., He et al., 2007; Mohammed et al., 2010), and mindset (three-item scale of Dweck et al., 1995; α=.88), since teams with higher growth mindsets may be more inclined to seek out and engage in team learning (cf., Bligh et al., 2018). In addition, we controlled for the potential effects of team size, direct proportional representation of different countries of birth, direct proportional composition of gender (cf., Bradley et al., 2021), and mean age, given their potential

influence on factors such as perceived SMMs and learning (Mathieu et al., 2019; Niler et al., 2021).

4.3.3.6. Analytical strategy

For our main analyses, we conducted random coefficient modelling following the stepwise process specified by Bliese and Ployhart (2002). First, we analysed a Level 1 model to test within-team and between-team variability in perceived SMMs, accounting for the fixed effect of time, but without adding random effects. Second, we introduced a set of Level 2 predictors (i.e., co-construction, constructive conflict, and team member self-efficacy) to explain differences in perceived SMMs between teams at the start of the study (intercept) and how these changed over time (slope). We estimated all stepwise models in the study using the statistical software R (version 4.3.1), using the nlme (version 3.1-164) package (Pinheiro et al., 2023). We coded time as 0, 1, and 2 for the three measurement points. This enabled us to interpret the slope and intercept of co-construction, constructive conflict, and perceived SMMs over time (Bliese & Ployhart, 2002). We grand mean centred the measures of co-construction, constructive conflict, and self-efficacy prior to conducting our main analyses, to ensure greater interpretability of the results (Cregan et al., 2023; Curran & Bauer, 2011).

4.3.4. Results

4.3.4.1. Aggregation

Since our data were collected at the individual level, we tested whether measures were suitable for aggregation to the team level (Bliese, 2000; Costa et al., 2013; James et al., 1993). Aggregation to variable means at the team level was suitable as the variables included in our models could be categorised as referent shift consensus variables (Chan, 1998). To justify aggregation to the team level, we calculated intraclass correlation coefficients (ICCs; Bliese & Ployhart, 2002) and agreement indices ($r_{wg(j)}$; James et al., 1984). ICC(1) values indicate the size of effects resulting from team membership, ranging from .01 to .25. ICC(2) values indicate how reliably the mean score on a scale can be used to distinguish between groups (LeBreton & Senter, 2008). Where ICC(2) values are larger than ICC(1), aggregation is supported since this indicates that there are significant differences in scores across teams which exceed the effects of individual members within these teams (Bliese, 2000).

We subsequently computed ICC(1) and ICC(2) values for co-construction (ICC(1)=.16 to .22, ICC(2)=.40 to .50), constructive conflict (ICC(1)=.08 to .15, ICC(2)=.17 to .38), perceived SMMs (ICC(1)=.15 to .30, ICC(2)=.37 to .59), and team member self-efficacy (ICC(1)=.06, ICC(2)=.17) to index interrater reliability (see Table 4.1). All ICC(2) values exceeded their ICC(1) counterparts, supporting

our use of the data at the team level (Bliese, 2000). In addition, we computed $r_{wg(j)}$ values (see Table 4.2) for co-construction (.92 to .94), constructive conflict (.93 to .94), perceived SMMs (.98 to .99), and team member self-efficacy (.97). These values were all above the required criteria (≥.70), indicating good interrater reliability and further supporting aggregation to the team level (Chan, 1998; James et al., 1993).

Table 4.1
Aggregation statistics

	rwg(j)	F	DF (within)	DF (between)	ICC1	ICC2
Familiarity	.93	1.42 **	164	298	.11	.29
Mindset	.71	1.08	164	298	.02	.07
Self-efficacy	.97	1.20	164	298	.06	.17
Perceived SMMs						
Time 0	.98	1.59 ***	164	298	.15	.37
Time 1	.99	2.18 ***	157	247	.26	.54
Time 2	.98	2.45 ***	150	205	.30	.59
Co-construction						
Time 0	.92	1.65 ***	164	298	.16	.40
Time 1	.94	1.99 ***	157	247	.22	.50
Time 2	.93	1.80 ***	150	205	.19	.45
Constructive conflict						
Time 0	.93	1.31 *	164	298	.08	.23
Time 1	.94	1.62 ***	157	247	.15	.38
Time 2	.94	1.21	150	205	.06	.17

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

4.3.4.2. Means, standard deviations, and correlations

Means, standard deviations and correlations are presented in Table 4.2. In line with our expectations, we generally found significant correlations between team member self-efficacy, co-construction, constructive conflict, and perceived SMMs, at all three points in time.

4.3.4.3. Random coefficient modelling

Following Bliese and Ployhart's approach (2002), we computed the ICC(1) value for perceived SMMs over time using a random intercept model, to test how much variance in the model was attributed to differences within teams compared to between teams. The ICC(1) value for perceived SMMs over time was .43 indicating that 43% of variance was attributable to between team differences and 57% of variance to within team differences over time. The non-independent nature of perceived SMMs as a team-level variable therefore makes it suitable for analysis as growth models (Bliese, 2000; Bliese & Ployhart, 2002).

To test the change in perceived SMMs over time, we determined the fixed relationship between time and perceived SMMs. This showed a positive and significant estimate for the linear function of time (t=5.58, p<.001), indicating a significant increase in perceived SMMs over time. Next, we analysed whether significant variance existed between teams in the intercept and slope of perceived SMMs over time. We first added a random intercept term to our model to test for

Table 4.2
Correlations, means, and standard deviations

Variables	M	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1 Gender composition	.64	.31															
2 Mean age	23.68	1.59	-.10														
3 Countries of birth	.29	.36	.02	-.05													
4 Team size	3.43	.60	-.03	.11	-.06												
5 Mindset (T0)	3.19	.88	-.12	-.01	-.04	-.06											
6 Familiarity (T0)	1.40	.44	.00	.10	-.01	-.01	.10										
7 Self-efficacy (T0)	5.65	.42	.03	-.04	.12	-.16 *	-.04	.00									
Perceived SMM																	
8 Time 0	5.20	.50	.19 *	-.02	.12	.13	-.02	.20 **	.20 **								
9 Time 1	5.44	.64	.06	.01	.17 *	.04	.01	.03	.27 **	.38 **							
19 Time 2	5.59	.70	.17 *	-.10	.14	-.09	-.10	.03	.22 **	.29 **	.62						
Co-construction																	
11 Time 0	5.63	.55	.27 **	-.08	.03	.13	-.08	.22 **	.18 *	.63 **	.23 **	.18 *					
12 Time 1	5.72	.63	.24 **	.03	.14	.12	.03	-.01	.31 **	.45 **	.74 **	.51 **	.29 **				
13 Time 2	5.82	.69	.20 *	-.08	.20 *	.00	-.08	.03	.20 *	.32 **	.50 **	.80 **	.21 *	.49 **			
Constructive Conflict																	
14 Time 0	5.40	.50	.23 **	.01	.01	.08	.01	.06	.22 **	.57 **	.22 **	.11	.62 **	.29 **	.13		
15 Time 1	5.63	.55	.17 *	.03	.16 *	.07	.03	-.01	.35 **	.34 **	.73 **	.47 **	.27 **	.79 **	.45 **	.39 **	
16 Time 2	5.81	.52	.22 **	-.11	.13	-.11	-.11	.01	.26 **	.22 **	.52 **	.79 **	.22 **	.50 **	.77 **	.19 *	.53 **

Note: N=151-165 teams; *p<.05, **p<.01; gender composition: the proportional representation of male and female team members where 0=all female and 1=all male and; country of birth: the proportional representation of different countries of birth between team members; self-efficacy: the mean self-efficacy between team members

differences between teams in their initial perceived SMMs (see Table 4.3). When comparing the chi-square differences (i.e., −2 log-likelihood ratios; −2LL) between the random intercept model (i.e., where teams have significant differences in initial levels of perceived SMMs; −2LL=813.49; see Model 2 in Table 4.3) and the baseline model (-2LL=888.88; see Model 1 in Table 4.3), the model fit significantly improved (Δ2LL=75.39, $p<.001$). The model that allows teams to vary in their initial perceived SMMs thus fit the data better. Next, we tested if the variability in change in perceived SMMs (i.e., slope variation) differed significantly between teams. The random slope model (-2LL=782.75; see Model 3 in Table 4.3) significantly improved in fit on the random intercept model (Δ2LL=30.73, $p<.001$)[10]. These results supported the use of random slopes and random intercepts in the analysis of Level 2 models (Bliese & Ployhart, 2002).

Prior to analysing Level 2 models, we first evaluated the error structure of our data, by, firstly, testing for autocorrelation by including a first-order autoregressive structure in our baseline model (Bliese & Ployhart, 2002). While some degree of autocorrelation could be expected due to the underlying stability of cognitive factors (like team learning and perceived SMMs) in the model (Bliese & Ployhart,

[10] We tested whether a quadratic model would fit the data, however the results showed a non-significant quadratic function for time with a random intercept (t=-.70, p=.49) and random slope term (t=-.78, p=.44), confirming the suitability of a linear model (Bliese & Ployhart, 2002)

2002), we found that this effect was insignificant (Δ2LL=.77, p=.38). Next, we tested for heteroskedasticity by specifying variance as an exponent of time. This effect was also insignificant (Δ2LL=.94, p=.63). Since accounting for autocorrelation and heteroskedasticity did not improve model fit, we conclude that our error terms are appropriately specified and thus do not include these terms in further analyses (Bliese & Ployhart, 2002).

Table 4.3
Comparison of fixed vs random coefficient models for perceived SMMs over time

	Model 1: Linear function for time			Model 2: Random intercept			Model 3: Random intercept and slope		
Parameter	Estimate	SE	t	Estimate	SE	t	Estimate	SE	t
Fixed effects									
Intercept	5.22***	.04	119.31	5.22***	.05	114.90	5.22***	.04	137.54
Time	.19***	.04	5.58	.19***	.03	7.28	.19***	.03	6.59
Goodness of fit									
-2 log-likelihood	888.88			813.49			782.75		
Δ2LL	--			75.39***			30.73***		
AIC	894.88			821.49			794.75		
BIC	907.35			838.11			819.69		

Note: N=165 teams; ***p<.001

Based on these findings, we proceeded to analyse Level 2 models using random intercept and slope terms for perceived SMMs, following Bliese and Ployhart (2002). All Level 2 models include the control variables mindset, familiarity, team size, country of birth, gender, and age. Hypothesis 1 states that as time passes within a team, team members' perceived SMMs tend to increase. To test this hypothesis, we created a longitudinal model including time as a predictor,

along with all control variables. Time was significantly and positively related to perceived SMMs (γ=.19, p<.001, t=6.55; see Model 4 in Table 4.4). Time therefore had a positive influence on the growth of perceived SMMs, supporting Hypothesis 1.

Hypothesis 2 states that growth in co-construction is positively related to growth in perceived SMMs, such that the positive relationship between co-construction and perceived SMMs increases over time. To test this hypothesis, we added co-construction to the longitudinal model as a time varying predictor. Co-construction was significantly positively

related to initial perceived SMMs (γ=.58, p<.001, t=11.62; see Model 5 in Table 4.4). The interaction between time and co-construction also showed a significant positive relationship on perceived SMMs (γ=.09, p<.05, t=2.29). Co-construction therefore had a positive influence on perceived SMMs, both initially as well as over time, supporting Hypothesis 2.

Hypothesis 3 states that growth in constructive conflict is positively related to growth in perceived SMMs, such that the positive relationship between constructive conflict and perceived SMMs increases over time. We tested this by adding constructive conflict to the longitudinal model as a time varying predictor (see Model 6 in Table 4.4). Constructive conflict was significantly positively related to initial perceived SMMs (γ=.61, p<.001, t=11.43). The interaction between time

Table 4.4
Results of random coefficient modelling

	Model 4			Model 5			Model 6			Model 7			Model 8		
Parameter	Estimate	SE	t	Estimate	SE	t	Estimate	SE	t	Estimate	SE	t	Estimate	SE	t
Fixed effects															
Intercept	4.87***	.58	8.46	5.67***	.37	15.30	5.87***	.42	13.99	5.66***	.37	15.51	5.88***	.42	14.00
Time	.19***	.03	6.55	.13***	.02	5.71	-.03	.02	-1.58	-.14***	.02	6.34	.05*	.02	2.25
Predictors															
Co-construction				.58***	.05	11.62	--	--	--	.56***	.05	11.12	--	--	--
Time × co-construction				.09*	.04	2.29	--	--	--	.09*	.03	2.40	--	--	--
Constructive conflict							.61***	.05	11.43	--	--	--	.58***	.06	10.36
Time × constructive conflict							.17***	.04	4.24	--	--	--	.18***	.04	4.43
Team member self-efficacy										.11	.07	1.52	.09	.08	1.21
Time × team member self-efficacy										.00	.06	.02	-.02	.05	-.37
Co-construction × team member self-efficacy										.25*	.10	2.39	--	--	--
Time × co-construction × team member self-efficacy										-.30***	.08	-3.59	--	--	--
Constructive conflict × team member self-efficacy													.18	.11	1.64
Time × constructive conflict × team member self-efficacy													-.25**	.10	-2.61
Control variables															
Mindset	-.00	.04	-.11	-.01	.03	-.38	-.02	.03	-.72	-.01	.03	-.25	-.02	.03	-.62
Familiarity	.16*	.08	2.05	.05	.05	1.04	.11	.06	1.92	.06	.05	1.13	.11	.06	1.92
Team size	.08	.06	1.26	-.02	.04	-.39	.03	.04	.75	-.01	.04	-0.23	.03	.04	.71
Countries of birth	.21*	.10	2.14	.11	.06	1.71	.12	.07	1.66	.10	.06	1.64	.11	.07	1.60
Gender composition	.24*	.11	2.15	-.06	.07	-.83	-.02	.08	-.30	-.07	.07	-1.01	-.03	.08	-.35
Mean age	-.01	.02	-.66	-.02	.01	-1.15	-.03*	.02	-1.99	-.02	.01	-1.26	-.03*	.02	-2.04
Goodness of fit															
-2 log-likelihood	788.43			531.71			515.20			530.50			521.42		
AIC	812.43			559.71			543.20			566.50			557.42		
BIC	862.14			617.64			601.13			640.83			631.74		

Note: N=165 teams; *p<.05, **p<.01, ***p<.001; Model 4: the growth of perceived SMMs over time (H1); Model 5: the influence of change in co-construction on change in perceived SMMs over time (H2); Model 6: the influence of change in constructive conflict on change in perceived SMMs over time (H3); Model 7: the moderating effect of team member self-efficacy on the influence of change in co-construction on change in perceived SMMs (H4); Model 8: the moderating effect of team member self-efficacy on the influence of change in constructive conflict on change in perceived SMMs (H5).

and constructive conflict on perceived SMMs also showed a significant positive relationship (γ=.17, p<.001, t=4.24). Constructive conflict therefore had a positive influence on perceived SMMs, both initially as well as over time, supporting Hypothesis 3.

Hypothesis 4 states that team member self-efficacy moderates the relationship between growth in co-construction and growth in perceived SMMs over time, such that the positive effect of growth in co-construction on growth in perceived SMMs over time is stronger when team member self-efficacy is higher. We tested this by including the interaction term of co-construction and team member self-efficacy in the model (see Model 7 in Table 4.4). The results showed a negative and significant (γ=-.30, p<.001, t=-3.59) [11] three-way interaction term between time, co-construction, and team member self-efficacy on growth in perceived SMMs.

Following Cregan et al. (2023), we used the web-based tool of Preacher et al. (https://www.quantpsy.org/interact/hlm3.htm), which is based on Preacher et al. (2006) to compute intercepts and simple slopes. We also used the template of Dawson (http://www.jeremydawson.com/slopes.htm), which is based on Dawson

[11] In order to control for reverse causality, we created a model showing the effect of the interaction between time, grand mean centred perceived SMMs, and self-efficacy on co-construction. This effect was insignificant (γ=-.06, p=.50, t=-.68), supporting the causal direction adopted in our model.

and Richter (2006) and Dawson (2014), to conduct slope difference tests. These results are represented visually in Figure 4.2 (for co-construction) and Figure 4.3 (for constructive conflict).

Figure 4.2
Interaction effect of team member self-efficacy and growth in co-construction on perceived SMMs over time

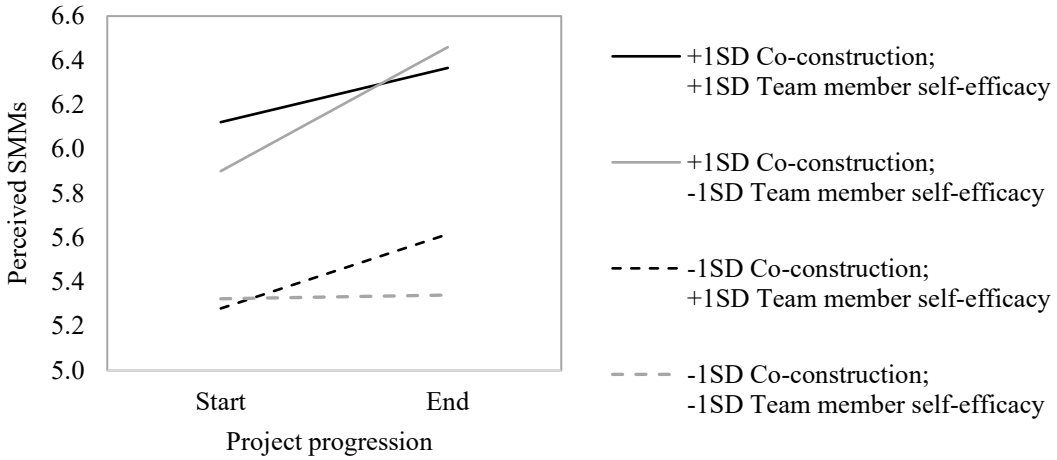
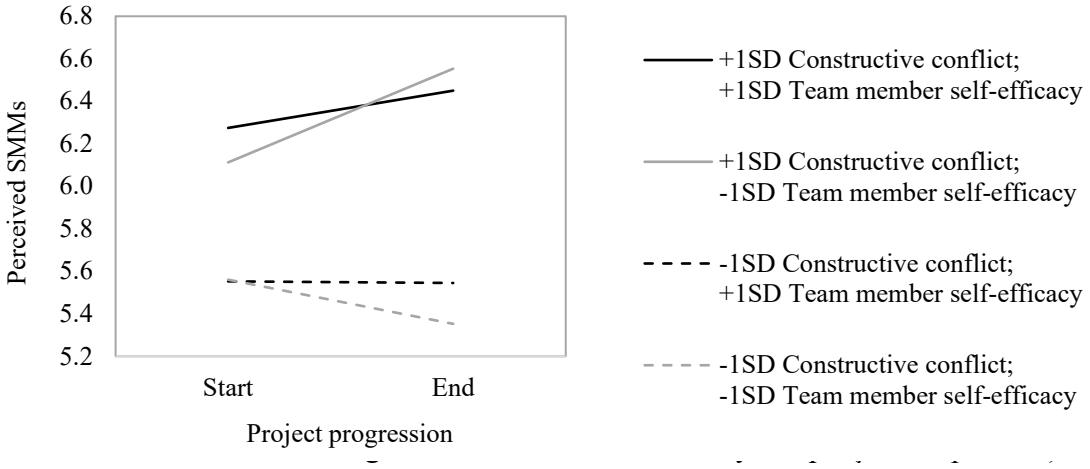


Figure 4.3
Interaction effect of team member self-efficacy and growth in constructive conflict on perceived SMMs over time



and an insignificant effect for the 'low co-construction and low team member self-efficacy' slope (β=.01, p=.84). The slope difference tests (see Table 4.5) revealed a nuance in these results in that the difference between the slope of 'high co-construction and high team member self-efficacy', and the slope of 'high co-construction and low team member self-efficacy' was significant, but negative. This suggests that teams that show high growth in co-construction tend to develop perceived SMMs more rapidly when team member self-efficacy is low, rather than high, and that high growth in co-construction will generally be associated with higher growth in perceived SMMs. Hypothesis 4 is therefore partially supported as we found support for our general theorising, yet also found an unexpected insight which we will elaborate on in the discussion section.

Hypothesis 5 states that team member self-efficacy moderates the relationship between growth in constructive conflict and growth in perceived SMMs over time, such that the positive effect of growth in constructive conflict on growth in perceived SMMs over time is stronger when team member self-efficacy is higher. We tested this hypothesis by including the interaction term of constructive conflict and team member self-efficacy in the model (see Model 8 in Table 4.4). The results showed that the three-way interaction term between time, constructive conflict, and

team member self-efficacy on perceived SMMs was negative and significant (γ=-.25, p<.01, t=-2.61; see Model 8 in Table 4.4)[12].

Table 4.5
Results of slope difference tests

Pair of slopes						
Condition A		*Condition B*				
Co-construction	*Team member self-efficacy*	*Co-construction*	*Team member self-efficacy*	Slope difference	t-value	p-value
High	High	High	Low	-.16*	-2.42	.02
High	High	Low	High	-.05	-.71	.48
High	High	Low	Low	.11	1.92	.06
High	Low	Low	High	.11	1.55	.12
High	Low	Low	Low	.27***	4.18	.00
Low	High	Low	Low	.16*	2.54	.01
Condition A		*Condition B*				
Constructive conflict	*Team member self-efficacy*	*Constructive conflict*	*Team member self-efficacy*			
High	High	High	Low	-.13*	-2.15	.03
High	High	Low	High	.09	1.47	.14
High	High	Low	Low	.19***	3.50	.00
High	Low	Low	High	.22***	3.10	.00
High	Low	Low	Low	.32***	4.82	.00
Low	High	Low	Low	.10	1.58	.12

Note: *p<.05, ***p<.001; Results obtained using Dawson's templates (http://www.jeremydawson.com/slopes.htm) , based on Dawson (2014) and Dawson and Richter (2006)

[12] In order to test for reverse causality, we created a model showing the effect of the interaction between time, grand mean centred perceived SMMs and self-efficacy on constructive conflict. This effect was negative and significant (γ=-.14, p<.05, t=-1.97), yet smaller than the effect observed in our hypothesised model. This supports the causal direction adopted in our model, but suggests that a reciprocal effect may exist between perceived SMMs and constructive conflict.

Figure 4.3 shows the interaction between time and high and low levels of constructive conflict (+1SD and -1SD) and high and low team member self-efficacy (+1SD and 11SD) on perceived SMMs. We found a significant positive effect for the 'high constructive conflict and high team member self-efficacy' slope (β=.09, p<05), and for the 'high constructive conflict and low team member self-efficacy' slope (β=.22, p<.001), an insignificant positive effect for the 'low constructive conflict and high team member self-efficacy' slope (β=.00, p=.94), and a significant negative effect for the 'low constructive conflict and low team member self-efficacy' slope (β=-.10, p<.01). The slope difference tests (see Table 4.5) revealed a similar nuance in these results as seen with co-construction, in that the difference between the slope of 'high constructive conflict and high team member self-efficacy', and the slope of 'high constructive conflict and low team member self-efficacy' is significant, but negative. This suggests that teams that show high growth in constructive conflict tend to develop perceived SMMs more rapidly when team member self-efficacy is low, rather than high, and that high growth in constructive conflict will generally be associated with higher growth in perceived SMMs. Similar to Hypothesis 4, Hypothesis 5 is therefore partially supported, as it supported our underlying theorising whilst also revealing an unexpected insight.

4.4. Discussion

We identify and address three objectives in this paper, namely to better understand: (1) the development of *perceived* SMMs *over time*, (2) the role of team learning behaviour in this development, and (3) how team member self-efficacy can play a role in this relationship. Overall, our model and theorising was supported. More specifically, we found that perceived SMMs grow and become stronger the longer team members work together on a project. Moreover, our results show that both co-construction as well as constructive conflict lead to higher perceived SMMs over time. Lastly, we expected these relationships to be affected by team member self-efficacy. Overall, our findings supported this expectation, because when team members possess greater self-efficacy, their perceived SMMs were greater towards the end of the project than in teams with lower team member self-efficacy. However, as we will discuss below, we also found some interesting and unexpected nuances to this which may warrant more research in the future.

4.4.1. Theoretical implications

In this study, we contribute to the literature on SMMs by specifically responding to the call of prominent scholars in the field to study the development of SMMs *over time*, as well as to develop a better understanding of *perceived* SMMs (DeChurch & Mesmer-Magnus, 2010a; Mohammed et al., 2021). Past research on SMMs has largely (implicitly) assumed that team members who share

mental models are also aware of their existence and correspondence between one another, but this has generally gone untested. Research on perceived SMMs aims to rectify this and is steadily emerging (cf., Marhefka et al., 2020; Müller & Antoni, 2020; Van Rensburg et al., 2022, 2023). In this study, we build on this emerging field, and explore the temporal nature of perceived SMMs as emergent state that is dynamic and prone to change over time (Gevers et al., 2020; Marhefka et al., 2020; Rapp et al., 2021; Waller et al., 2016). Consequently, we draw on RCM to test the growth of perceived SMMs *over time* and observe a positive trend. This finding expands on the cross-sectional work of Van Rensburg et al. (2023), who suggested that perceived SMMs are likely to (positively) develop over time, as they found that dyad pairs with greater shared tenure also possessed greater perceived SMM similarity. Our findings further support the conceptualisation of perceived SMMs as emergent state (Gevers et al., 2020; Marhefka et al., 2020; Rapp et al., 2021; Waller et al., 2016) and indicates that perceived SMMs are likely to increase over time for newly formed and stable (project) teams.

Our conceptual model draws from social cognitive theory (Bandura, 1986), recognising that team learning behaviour is a social process where team members can observe and learn from one another's actions, and that this, in turn, enables them to develop perceived SMMs. Our robustness checks included a test for reverse causality, and this supported the causality of our main model overall, as perceived

SMMs did influence constructive conflict over time, but did so to a lesser degree than in our main analyses, whilst there was no reversed causality effect for co-construction. Social cognitive theory highlights the relevance of motivation and at the core of this lies self-efficacy (Bandura, 1986; Cook & Artino, 2016), since greater confidence in their ability to replicate learning could reinforce their motivation to do so. Drawing upon this theory, we expected to see teams comprised of members with higher self-efficacy to display more confidence in translating the team learning behaviours of co-construction and constructive conflict into perceived SMMs as time goes by. Our results supported this, by showing that the rate of growth in perceived SMMs (i.e., the slope) was influenced as expected. We note that, contrary to expectations, when co-construction and constructive conflict were high, teams with *lower* team member self-efficacy started from a lower intercept, but showed a higher pace of perceived SMM development than those with high team member self-efficacy. This suggests that co-construction and constructive conflict are more beneficial to the development of their perceived SMMs when team member self-efficacy is low.

We extend the current understanding of how perceived SMMs develop by being the first to take a temporal perspective in showing how they grow from two key learning behaviours – co-construction and constructive conflict (e.g., Van den Bossche et al., 2011; Van Rensburg et al, 2023). Given the reciprocal nature of team

processes and emergent states (also noted in our reverse causality test that shows that growth in perceived SMMs can influence constructive conflict over time), different scholars have conceptualised the direction of this relationship in different ways. For example, Guchait and Hamilton (2013) found that team learning in general positively influences SMMs. On the other hand, Van den Bossche et al. (2011) found that co-construction had a negative influence, while constructive conflict had a positive influence. These seemingly divergent results illustrate the complex relationship that exists between team processes and emergent states, and highlight that team learning and perceived SMMs are yet to be fully understood in relation to each other. We contribute to this debate by arguing that, for project teams, team learning behaviour is a fundamental precursor to perceived SMMs. In doing so, we introduce the awareness of the existence of a SMM (i.e., a perceived SMM) to the literature as a critical outcome of team learning behaviour. Our assertions find support in that the development of co-construction and constructive conflict over time respectively have a positive influence on the development of perceived SMMs over time.

4.4.2. Strengths, limitations, and future research

In the current study, we took up a social cognitive theoretical lens (Bandura, 1986), to study how team learning behaviour (a behavioural process) influences perceived SMMs (an emergent state), and does so under different levels of team

member self-efficacy (a personal process). We do so by making use of a large contingent of student project teams (i.e., 165 teams) over time (i.e. three time points) using a recently developed measure for perceived SMMs (Van Rensburg et al., 2022). Our dataset has a very high response rate of 86%, which is notably higher than other longitudinal studies on SMMs (e.g., Uitdewilligen et al., 2023). Yet, despite these strengths, akin to any other study, our work also has several limitations. One such limitation is that we had a specific environmental or contextual setting, namely student teams working on a short-lived project in small teams. Although research has shown that student teams can be as valid as other teams to study a phenomenon (cf., Santos et al., 2016; Uitdewilligen et al., 2023), our theory and evidence could still benefit from future studies that include teams from more diverse environmental or contextual settings to assess the role such settings play in the development of perceived SMMs (e.g., where team members have more extensive contact with one another and therefore more opportunity to learn from and replicate each other's behaviour).

Another possible limitation is imposed by our data which only supports linear models. Scholars, such as Fyhn et al. (2023), have argued this has the limitation of assuming that emergent states follow a continuous positive developmental trajectory. Prior research has shown that SMMs can sometimes have negative or curvilinear developmental trajectories (cf., Santos et al., 2021). We acknowledge

the limitation imposed by our data in our study of perceived SMMs, however we argue that perceived SMMs follow a positive developmental trajectory because of the constructive role of team learning and self-efficacy on cognition (cf., Cook & Artino, 2016; Van den Bossche et al., 2011). Future research can draw on a sample of teams where (unexpected) changes to their tasks, and/or changes to team membership, occur over the measurement period to determine if teams display different trajectories of learning behaviour and perceived SMMs. In such cases, the data may be explored with quadratic or polynomial models, which can also be tested using RCM (Bliese & Ployhart, 2002).

Critics could also see our use of relatively short-lived project teams as a possible limitation, for example, by arguing that team members are less likely to be familiar with each other or their tasks (cf. Niler et al., 2021). As such, it could be argued that in short-lived project teams, team members may have less existing insight into their team tasks and goals, which could mean that their perceived SMMs might be built from a lower base than would be the case in teams which have been previously worked together and/or who have a longer project period. It could therefore be that in our study, initial perceived SMMs are based on rather limited initial knowledge and assumptions of the project. Future studies may thus benefit not only from tracking teams over more than three measurement moments as we described above, but also by studying teams with a longer lifespan and/or more

prior work experience together, to determine if a curvilinear developmental trend exists.

Relatedly, a limitation of our study could be that we used *student* project teams, as this might hinder generalisation to other contexts. However, student teams have been shown to be a suitable approximation for project teams in field settings (cf. Konradt & Eckardt, 2016). Our longitudinal study of perceived SMMs in such teams give us valuable insights into the development of perceived SMMs in a context where team members are not necessarily familiar with one another and where they have limited pre-existing task knowledge. The temporal stability of teams has previously been identified as a key boundary condition in the development of shared cognition (Mathieu et al., 2019; Niler et al., 2021). Short-lived project teams are likely to have stable membership for the duration of their collaboration, however members typically start with limited shared cognition that grows over time (Mathieu et al., 2000). Teams with greater temporal stability may see different developmental trends to perceived cognition, since knowledge is typically retained and passed on to newcomers as these teams change (Kang & Sauk Hau, 2014; Niler et al., 2021). As such, future research could build on our findings by comparing the developmental trajectories of perceived SMMs of low vs high temporal stability teams.

Future research could also go in more depth about *what* our team members learned, as the two learning behaviours we study ultimately imply that teams experience growth in knowledge, skills, and/or abilities over time (Edmondson et al., 2007; Pinheiro et al., 2022). Expanding upon prior research on team learning and SMMs (Guchait & Hamilton, 2013; Santos et al., 2015a; Van den Bossche et al., 2011), our goal was to investigate if, and if so how, these learning behaviours relate to perceived SMMs over time under different conditions of team member self-efficacy. Yet, future research could take another approach to learning and study if, and how, team members saw growth in their knowledge, skills, and/or abilities, as such research could provide more insight into the process of learning.

Similarly, and lastly, a limitation could be our focus on the growth in *perceptions* of SMMs. We chose to focus on perceived SMMs, as our aim was to shed more light on this important emerging field (Marhefka et al., 2020; Mohammed et al., 2021; Van Rensburg et al., 2023). However, by doing so, we did not take into account growth in teams' structured representations of key elements in their work (i.e., their structural SMMs), but rather their growing awareness thereof (i.e., their perceived SMMs). Future research could build upon our study, and combine it with structural SMMs research (Mohammed et al., 2021), to investigate if, and how, both views on SMMs relate to each other and to team learning behaviours. We hope our research can serve as a basis, as we tried to set

forth the work of Marhefka et al. (2020) and Van Rensburg et al. (2022, 2023) to provide important new insight into perceived SMMs and their development over time.

4.4.3. Practical implications

One of the core goals of learning in organisations is to obtain new knowledge that enables better team functioning (Marlow & Lacerenza, 2024; Rupčić, 2022). Our results show that the benefits of team learning extend to the shared awareness of SMMs in the team. This means that, as teams engage in learning behaviour, they can be expected to not only become more familiar with their task environment, nor just with one other (Maynard et al., 2019), but also with how team members understand one another's competencies and roles within the team. Practitioners, such as managers and human resources development (HRD) professionals, stand to benefit from this understanding, as they can use this knowledge in organisational learning interventions such as cross-functional training or team building events that serve to improve shared understandings, and an awareness thereof, of work between team members. Specifically, these professionals can design such interactive developmental events in a way that facilitates co-construction of knowledge by having team members actively share knowledge that builds on one another's ideas and conceptualisations, and to critically discuss and evaluate these contributions (i.e., engage in constructive conflict).

Motivation to learn has been shown to be an important factor in influencing the effectiveness of learning events (Cook & Artino, 2016). Managers and HRD professionals can therefore benefit from measuring team member self-efficacy, which offers teams an important motivational resource to draw on when engaging in learning. By assessing team member self-efficacy beforehand, managers and HRD professionals can identify teams where team member self-efficacy is unsuitable for development by being too high (suggesting over-confidence) or too low (suggesting insecurity). This would enable them to intervene in a timely manner and prime teams for maximised success from team learning events.

Our findings specifically apply to new project teams with a lifespan of a few weeks, but there are cases where established, and/or longer duration, teams may also benefit from the findings of these results. In established teams, there are often shifts and changes in membership and in such cases, teams are likely to confront similar challenges to newly formed project teams (Li & van Knippenberg, 2021; Niler et al., 2021). Their new composition may mean they have to re-establish, or at least update, their perceived SMMs. Therefore, practitioners could also draw on our theory and results to navigate the challenges of increasing team learning and perceived SMMs between new and established team members in such cases.

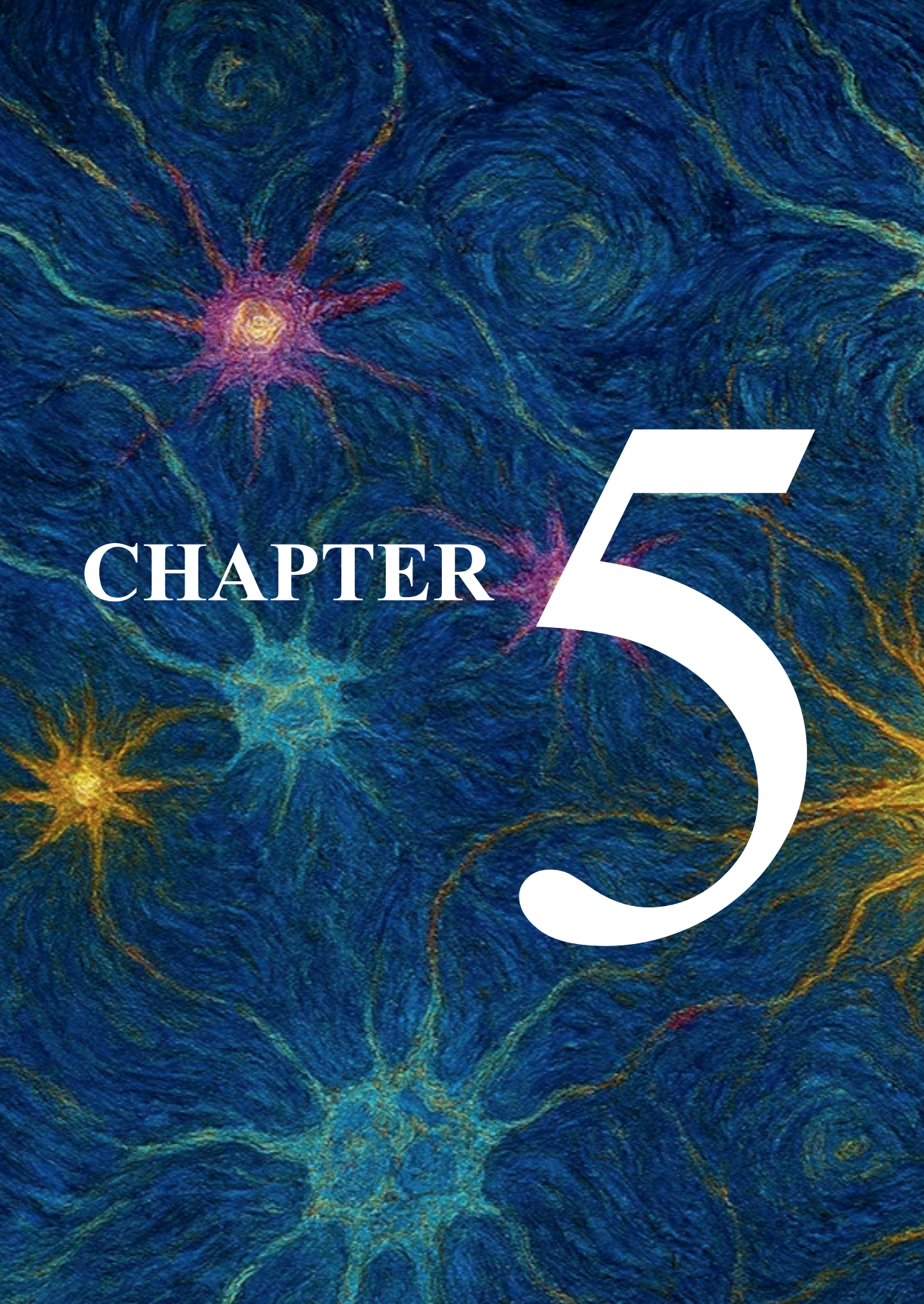
Our results further hold important implications for team members and leaders in developing better tools to perform their work in the form of improved perceived

SMMs and team learning behaviour. By investing their time in engaging with either construction or constructive conflict, team members can make a meaningful contribution to their perceived SMMs. Beyond the positive impact of learning on the team's knowledge, skills, and abilities (Edmondson et al., 2007; Rupčić, 2022), the extent to which members share a perception of their mental models is likely to enable more robust discourse on the topic and could enhance their underlying shared understanding of their work as well.

4.5. Conclusion

With the diverse representations of relationship between team learning and SMMs found in the existing literature (cf., Guchait & Hamilton, 2013; Santos et al., 2016; Van den Bossche et al., 2011), it becomes clear that this field of research has some way to go in reaching maturity. The field is characterised by some key assumptions, namely that team members who share mental models are also *aware* of this SMM (yet this is rarely tested) and that learning influences (perceived) SMMs over time. We explicitly address these two assumptions by introducing perceived SMMs to the field and demonstrate that these perceived SMMs increase over time with increases in co-construction and constructive conflict. Using a social cognitive theory perspective, we also show that self-efficacy influences this relationship in an unexpected way, with teams with high co-construction and constructive conflict showing stronger growth in perceived SMMs when team

member self-efficacy is low. To do so, we draw on a three-wave longitudinal sample that boasts a high response rate that in turn enables us to conduct robust longitudinal analyses using RCM. As expected, our findings indicate that short-lived project teams will develop better awareness of their SMMs over time if they engage in co-construction and constructive conflict, but that the course of this development may depend on team member self-efficacy.


CHAPTER
5

GENERAL DISCUSSION AND CONCLUSION

5.1. Introduction

The primary purpose of this dissertation was to embark on an investigation into perceptions of SMMs, since SMM literature has neglected the role of perception in shaping (shared) cognition (cf., DeChurch & Mesmer-Magnus, 2010b; Goldstone et al., 2015; Kastanakis & Voyer, 2014; Rentsch et al., 2008). Given that SMMs are crucial to team functioning (Mathieu et al., 2000; Maynard et al., 2014), this prompts the question: *Are team members aware that they share understanding about their work?* In this dissertation, my co-authors and I set out to address three questions in the perceived SMM literature as indicated in the introduction of this dissertation: 1) How can perceived SMMs best be measured?; 2) How is shared tenure between team members associated with perceived SMMs and does interdependence influence this relationship?; and 3) Do perceived SMMs evolve over time, and if so, what is the role of team learning in their development?

Past research has been fixated on the measurement of SMM structure, and those perception measures that do exist did not sufficiently capture the current conceptualisation and dimensionality of SMMs (cf., Johnson et al., 2007; Millward & Jeffries, 2001). In response, we clarified conceptualisation of the construct of, and created and validated a sound measurement instrument for, perceived SMMs (Chapter 2), drawing on numerous publications that used a range of different measurement items. While doing this, we identified the five dimensions of SMMs

most commonly studied (i.e., execution, equipment, interaction, composition and temporal mental models), that are likely relevant to a broad range of teams' work environment.

The developed scale from Chapter 2 enabled further study of perceived SMMs. Much is known about the outcomes of SMMs (and to a lesser extent the outcomes of perceived SMMs), but their antecedents are less commonly studied. This has led to an assumption emerging in the literature: that the longer two people work together the more they will share a (perceived) mental model. To address this assumption, we studied the first point at which perceptions of mental models can become shared, i.e., the dyad, while starting to expand on the conditions under which this could happen by taking into account goal interdependence and shared tenure (Chapter 3). Together with my co-authors, I developed, and used, the measurement instrument to show that perceived SMMs are influenced by interpersonal and motivational factors, and can yield positive outcomes for dyads. We also note that perceived SMMs are emergent states (i.e., they are dynamic and prone to change due to numerous factors over time), but have not been studied *over time.* This is a limitation that has been noted in the general SMM literature (cf., DeChurch & Mesmer-Magnus 2010a; Mohammed et al., 2010, 2015, 2021) as well as the literature on emergent states (cf., Waller et al., 2016). In the next, and final study, we present this argument and conduct a longitudinal study to investigate how

perceived SMMs can develop over time (Chapter 4). In doing so, we adopted a social cognitive approach (Bandura, 1986) and included team learning behaviours (Van den Bossche et al., 2011) as a dynamic team process predictor of perceived SMMs, in addition to team member self-efficacy.

These three distinct studies build on the theoretical and empirical positioning of perceived SMMs by establishing a measurement instrument, which we developed and validated according to stringent guidelines (DeVellis et al., 2016; Hinkin, 1998), and then used in real settings via different designs (i.e., cross-sectional dyadic data and longitudinal team data). We therefore address criticism of how the measurement of perceptions of SMMs was done until this dissertation (e.g., DeChurch & Mesmer-Magnus, 2010a), as well as the need to develop a deeper understanding of perceived SMMs (Mohammed et al., 2021). We expand on current conceptualisations of SMMs by critically reviewing the dimensional structure of SMMs in a general context while showing that perceived SMMs yield positive team outcomes and develop over time in a dynamic manner. In this chapter (Chapter 5), the dissertation is concluded with an overview of these studies that comprise the dissertation as well as summaries of their theoretical, empirical, and practical implications.

5.2. Overview of empirical chapters and summary of main findings

5.2.1. Chapter 2: The measurement and study of perceptions in SMM research

Perceived SMMs has often been implicitly studied in the past (DeChurch & Mesmer-Magnus, 2010b), with researchers relying on perception-based measures to estimate SMMs (e.g., Santos et al., 2015a). This approach has drawn criticism from renowned team cognition scholars (DeChurch & Mesmer-Magnus, 2010a; Mohammed et al., 2000) and highlights a major concern in the SMM literature: if perceptions are deemed to equate to structure, conclusions drawn about SMMs in past research may be problematic. By not adequately specifying the form of cognition (structured or perceptual), SMM researchers risk drawing conclusions about two different aspects of SMMs (Rentsch et al., 2008). As such, they risk attributing the outcomes of perceived SMMs to structured SMMs or vice versa. Secondly, the measurement of one of these aspects of SMMs (perceived vs structural) cannot provide researchers with key information about the other, potentially misinforming conclusions when their conceptualisation and measurement do not match. In levelling this criticism, however, perceived cognition may be cast as a less relevant or important field of study, rather than a complimentary avenue to pursue (Mohammed et al., 2021).

In order to effectively study perceived SMMs, there must first be a clear instrument with which to do so. Instruments to measure perceived SMMs have thus

far been either limited by the limited rigour of their development (cf., Santos et al., 2015b), or the theoretical scope they comprised (e.g., Ellwart et al., 2014; Johnson et al., 2008, Müller & Antoni, 2020b). We addressed this concern in Chapter 2, by following a rigorous scale development approach (DeVellis, 2016; Hinkin, 1998) built on an in-depth review of existing measures of perceived

and structured SMMs and its theoretical content domain. In doing so, we identified an important theoretical issue in the conceptualisation of shared temporal mental models, since current definitions of the construct construe it as being predominantly related to the execution of team tasks (e.g., Mohammed et al., 2015; Santos et al., 2015a), while we emphasize that temporal considerations can apply to *any* work related behaviour and cognition. We therefore made the argument that shared temporal mental models needed to reflect a broader concept of time and be distinguished from shared task execution mental models more clearly (see Table 5.1 for an overview of the hypotheses and outcomes from the three empirical chapters).

Starting with a review of 216 published papers on SMMs, we identified 314 questionnaire items for review and reduction, from which we created and validated a 20-item scale over three stages comprising four separate samples of 287, 275, 288, and 340 respondents. Following a review of the content and an evaluation by a panel of experts, the initial 314 items could be reduced to 56. Exploratory factor analysis

Table 5.1
Overview of empirical chapters' hypotheses and main outcomes

Chapter	Hypothesis	Outcome
2	H1: The 5-PSMMS is multidimensional, reflecting a five-factor model representing equipment, execution, interaction, composition and temporal mental model similarity and providing good fit to the data across samples.	Supported
	H2a: The 5-PSMMS is positively correlated with the SMM scale of Santos et al. (2015b).	Supported
	H2b: The 5-PSMMS is more strongly correlated with the SMM scale of Santos et al. (2015b) than with other variables in the nomological network.	Supported
	H3: The 5-PSMMS and its dimensions correlate positively with TMS.	Supported
	H4: The 5-PSMMS and its dimensions are positively correlated with (a) team learning, (b) team reflexivity, and (c) interdependence.	Supported
	H5: The 5-PSMMS and its dimensions are negatively correlated with (a) team cognitive diversity and (b) intrateam conflict.	Supported
3	H1: Dyadic tenure positively relates to perceived SMM similarity.	Supported
	H2: Goal interdependence negatively moderates the positive relationship between dyadic tenure and perceived SMM similarity.	Supported
	H3: Perceived SMM similarity mediates the relationship between dyadic tenure and dyadic performance.	Supported
	H4: Goal interdependence acts as a negative first stage moderator in the indirect relationship of dyadic tenure on performance via perceived SMM similarity.	Supported
4	H1: Perceived SMMs grow over time.	Supported
	H2: Growth in co-construction is positively related to growth in perceived SMMs, such that the positive relationship between co-construction and perceived SMMs increases over time.	Supported
	H3: Growth in constructive conflict is positively related to growth in perceived SMMs, such that the positive relationship between constructive conflict and perceived SMMs increases over time.	Supported
	H4: Average team member self-efficacy moderates the relationship between growth in co-construction and growth in perceived SMMs over time, such that the positive effect of growth in co-construction on growth in perceived SMMs over time is stronger when team member self-efficacy is higher.	Partially supported
	H5: Team member self-efficacy moderates the relationship between growth in constructive conflict and growth in perceived SMMs over time, such that the positive effect of growth in constructive conflict on growth in perceived SMMs over time is stronger when team member self-efficacy is higher.	Partially supported

(EFA), however, showed six factors in comprised of these items. A review of the content of the items revealed a conceptualisation issue in the temporal SMM items, as per existing literature. In a second EFA with a revised list of 60 items, we extracted five factors, matching the dimensions of perceived SMMs we identified (i.e., equipment, execution, interaction, composition, and temporal), each measured using four items and yielding a 20-item scale. We found acceptable model fit for these 20 items from confirmatory factor analysis (CFA). In a final test of the scale, we found support for convergent, discriminant, and nomological validity for the 20-item scale. As expected, we found significant positive correlations between the full scale and its sub-dimensions with transactive memory systems, team learning, reflexivity, and interdependence. We also found a significant positive correlation with a (non-validated) measure of SMMs that exceeded the other positive correlations. In all, these results empirically support the use of the questionnaire we developed for measuring perceived SMMs in Chapter 3 and Chapter 4 as well as future research in the field, but also introduces a new conceptualisation of temporal SMMs and thus perceived temporal SMMs.

5.2.2. Chapter 3: Shared tenure and perceived SMMs in small work units

Perceived SMMs are seeing an increase in interest as theme in SMM research in recent years, and a few studies have begun demonstrating their impact on team outcomes (cf., Ellwart, 2014; Marhefka et al., 2020; Müller & Antoni, 2022, 2023).

We noted two important issues in the study of SMMs generally, and perceived SMMs specifically, when it comes to the fundamental building blocks of (perceived) SMMs: 1) the antecedents of perceived SMMs need to be researched in much greater depth, especially core antecedents like shared tenure; and 2) a general trend in SMM literature is to focus on teams as the unit of analysis, meaning that the *first* point of emergence of *shared* understanding, i.e., the dyad, is rarely studied. Using the scale developed in Chapter 2, we start addressing these concerns.

We set out to address these issues in Chapter 3 by collecting and analysing data from a cross-sectional field sample of 88 leader-member dyads. Our results supported the hypothesis that perceived SMMs were higher among dyads with higher shared tenure. This means that, at the very first point at which mental models can become shared (i.e., between *two* individuals), time spent working together is related to a deeper understanding of one another's mental models and a shared perception thereof, supporting an assumption that has been an inherent aspect in the SMM literature. We also showed that this relationship is moderated by goal interdependence (Van der Vegt et al., 2010), indicating that dyad partners' dependence on one another to successfully reach their goals acts as an important motivator for dyad partners to seek a shared understanding of their work. Their perceived SMMs furthermore led to greater leader-rated dyadic performance (i.e., a moderated mediation model was supported), further supporting similar past

findings (e.g., Marhefka et al., 2020) and highlighting the relevance of perceived SMMs in team functioning. Task interdependence was included as a control variable in this study and did not show a significant effect in the tested model. Taken together, these findings indicate that the longer a dyad have worked together, the more similar their perceived SMM will be and the better they are likely to perform. However, by designing their work in such a way that they are more reliant on each other for goal attainment reduces the need for more extensive shared tenure and gets the dyad to a higher level of performance, earlier in their tenure.

5.2.3. Chapter 4: Time and perceived SMMs: Of learning behaviour and self-efficacy

Research on perceived SMMs has fallen short of operationalising them as emergent states via longitudinal study (cf., Müller & Antoni 2020a). Measuring perceived SMMs at one or two points in time implies that they are either static phenomena or that they follow linear developmental patterns. These perceptions are dynamic, however, and can develop over time, especially as teams engage in various team processes such as reflexivity (e.g., Gurtner et al., 2007), communication (e.g., Boies & Fiset, 2018), and learning (e.g., Guchait & Hamilton, 2013; Van der Haar et al., 2015). In Chapter 3 we showed that shared tenure positively influenced perceived SMMs. Building on the idea that shared tenure represents time that team members spend collaborating, in Chapter 4 we argued that

as time passes, perceived SMMs in teams will grow. We adopted a social cognitive theory (Bandura, 1986, 1993) perspective and argued that team learning behaviour – specifically co-construction and constructive conflict (Van den Bossche et al., 2006; 2011) – are essential processes that would accelerate this growth, aided by team member self-efficacy (Bandura 1986; Cook & Artino, 2016).

We collected a longitudinal sample of 165 student project teams with an 86% response rate over three measurement points to test our hypotheses, using random coefficient modelling. The results showed that perceived SMMs grow over time, following a linear trend. This means that perceived SMMs grow continuously in student teams that work on a defined project over a defined period of time, at a consistent rate. Co-construction and constructive conflict, respectively, positively contributed to their growth as time passed, therefore teams that shared and critically discussed project-relevant information more rapidly developed perceived SMMs. Team member self-efficacy was found to significantly interact with both co-construction and constructive conflict in influencing perceived SMMs. While perceived SMMs were higher later in the project due to the added influence of team member self-efficacy, lower team member self-efficacy coupled with higher co-construction or constructive conflict, surprisingly, led to the strongest growth in perceived SMMs. As such, teams whose members were initially less confident of

their abilities more effectively drew on the information being shared and critically discussed in order to develop stronger perceived SMMs more quickly.

5.3. Summary of main theoretical and empirical contributions

In this dissertation, we argue that without a shared awareness and interpretation of perceived SMMs, team members would not be able to realise the benefit such SMMs offer – fundamentally, ignorance to the existence of a SMM precludes any utility they may offer. Therefore, while studying perceived SMMs we make a number of important contributions to the theoretical, empirical, and methodological knowledge on perceived SMMs, summarised in the sections below.

5.3.1. Creation and use of a validated perceived SMM measure

While a few scholars have studied perceived SMMs (e.g., Marhefka et al., 2018; Müller & Antoni, 2020a, 2020b), the way this has been measured has been marred by limitations, either in terms of the development and validation of the instruments used (cf., Santos et al., 2015b) and/or in scope of the theoretical content included (cf., Johnson et al., 2008; Müller & Antoni, 2020b). In Chapter 2 we present the development of the five-factor perceived SMM scale (5-PSMMS), following rigorous scale development processes (Hinkin, 1998; DeVellis, 2016) and incorporating the theoretical factor structure most commonly used in prior research on SMMs. Having validated the instrument, we put the scale to use in Chapter 3 and Chapter 4. Across the three chapters, we demonstrate that perceived

SMMs can be measured using this scale in a variety of team contexts, at different levels, and over time. This enables future research on the topic of perceived SMMs in any work environment where teamwork is important. It also provides a springboard for studies that look to compare perceived with structured mental models as an accessible and generally applicable measure.

5.3.2. Clarification of the temporal mental model construct

The creation of the 5-PSMMS involved an in-depth review of the factor structure of SMMs as they had been researched in the past. Here we found that shared temporal mental models are generally presented as being primarily relevant to the tasks teams perform (e.g., Gevers et al., 2006; Mohammed et al., 2015; Santos et al., 2015a). Considering the interactive nature of teams, in Chapter 2 we argued that this emphasis is misplaced, as temporal mental models are relevant to more than only the execution of tasks. In this sense, we argue that communication between team members needs to take place at appropriately timed moments, the use of particular sets of equipment needs to take place at the most suitable time, team members need to possess timely insights into each other's unique skills, and they need to adhere to deadlines in delivering team outcomes. We therefore conclude that the understanding of time is not only important to how team members *do* their work, but also *what tools* they need to use, *whose* skills they need, and how they need to *communicate* with each other.

5.3.3. Demonstration of the role of shared experiences and time in perceived SMMs

Time, with its important link to (shared) cognition, was shown to be important in understanding perceived SMMs in several ways in this dissertation. We showed that the time spent working together was positively related to perceived SMMs in Chapter 3. This addressed a long-standing assumption (cf., Mathieu et al., 2000) regarding the role of shared tenure and perceived SMMs, confirming that greater shared tenure indeed led to higher perceived SMMs. Simply working together for longer does not seem sufficient to guarantee greater perceived SMMs, since some dyads may share more information than others, or reflect more on their understanding of their work environment, yet, despite these potential differences, longer tenure has a positive influence on perceived SMMs. Building on this, we expanded on the role of time in the development of perceived SMMs by also showing, in Chapter 4, that perceived SMMs followed a positive linear growth trend. Taken together, these findings clearly indicate that as team members spend time working together, they will develop greater perceptions of SMMs. This illustrates commonly held assumptions about perceived SMMs being emergent states and thus dynamic over time. Chapter 4 is also the first paper that explicitly tests this relationship between time and perceived SMMs, where other works studied more general forms of perceptual cognition over time (e.g., Gevers et al., 2020).

5.3.4. Unlocking perceived SMMs not only in teams, but also in dyads

Shared cognition, whether in large teams or between two individuals, originates in the minds of individuals and only emerges when two (or more) individuals develop a mutual understanding about their individual cognition (Klimoski & Mohammed, 1994). This implies that there are multiple levels of analysis at play when we study perceived SMMs. Individuals have unique understandings about their work and may have matched (or mismatched) understandings, compared to one (or more) colleagues. While the fundamental building block of cognition in general rests in the individual, the fundamental building block of *shared* cognition rests in the dyad –a pair of team members who possess a similar understanding of their work form the simplest form of a SMM. Literature on SMMs has typically skipped over this particular unit of analysis (barring one exception in Cassidy & Stanley, 2019) and most scholars have opted to aggregate from the individual to the team level. This implies that past research missed out on the multiple SMMs that exist in teams with more than two members.

We challenged this common approach in Chapter 3, where we studied leader-member dyads to understand how perceived SMMs are influenced by shared tenure and in turn influence performance. This offered unique insight into how perceived SMMs at their most basic point of emergence. In doing so, we draw on interdependence theory (Tjosvold & Halco, 1992) to hypothesise and uncover that

goal interdependence is a significant moderator in the relationship between shared tenure and perceived SMMs, while task interdependence (a control variable in Chapter 3), was insignificant. We contribute to the interdependence literature by showing that different interdependencies have different roles to play in shaping dyadic mental models and outcomes and that emphasising mutual goals is more relevant than task interdependence. It would therefore appear that motivation is an important ingredient to shared cognition, more so than direct task relationships.

5.3.5. Social cognitive learning and its effects on perceived SMMs

In Chapter 3 and Chapter 4 we show that team members' experience and time spent working together positively influences their perceived SMMs, however this growth in perceived SMMs is unlikely to occur without the presence of certain key team processes. One vital team process that shapes cognition, and that has been shown to contribute to the development of SMMs, is team learning behaviour - by actively developing their knowledge and understanding of their work, team members are able to develop more similar SMMs (Guchait & Hamilton, 2013; Santos et al., 2015a; Van den Bossche et al., 2006, 2011). We argued that this process extends to *perceived* SMMs and that engaging in co-construction and constructive conflict, team members will develop a greater sense of similarity in their awareness and interpretation of their SMMs (i.e., perceived SMMs). In other words, as team members observe the social process of learning by means of each

other's sharing and critically discussion of information, the more rapidly they will develop perceived shared understandings about their work.

Using social cognitive theory (Bandura, 1986; Cook & Artino, 2016) in Chapter 4, we demonstrated that this was indeed the case and found that both co-construction and constructive conflict positively influenced the growth of perceived SMMs. We extended this understanding by also incorporating team member self-efficacy as a moderator in this relationship, expecting a stronger positive effect when team member self-efficacy was high given its central, positive role in social cognitive theory (Bandura, 1986). Our findings generally support this idea and show that team member self-efficacy does positively moderate the relationship between both co-construction and constructive conflict, and perceived SMMs. However, we unexpectedly found that when either co-construction or constructive conflict were high, *low* team member self-efficacy led to higher growth in perceived SMMs. This surprising finding highlights that team members who generally possess high self-efficacy beliefs, may potentially overestimate their abilities and invest less effort in translating learning into perceived mental models. It suggests that, in social cognitive theory, there may be room to consider *when* it would be beneficial for teams to have high self-efficacy and when they may benefit from being more critical of their efficacy beliefs.

5.4. Overview of main practical implications

In addition to the theoretical and empirical implications from this dissertation, we also noted four key practical implications. Firstly, understanding if teams are aware of being on the same page regarding their work could be of benefit to practitioners who wish to promote greater shared understanding in their teams in order to leverage the benefits this has shown to hold for coordination (e.g., Müller & Antoni, 2020a), creativity (Santos et al., 2015b) and performance (e.g., Marhefka, 2020). This is made much easier with the validation of the 5-PSMMS, since the scale allows for easy distribution, data collection, and analysis that would enable practitioners to diagnose over- or underestimations of shared understanding among team members. They would then be in a position to directly intervene and support teams where this would have the greatest impact (i.e., where low or unrealistically high perceived SMMs are reported and warrant intervention). By administering the scale, managers can identify what dimensions of perceived SMMs team members agree on and have clear whether they are on the same page regarding different facets of their work. They can then offer tailored feedback and guidance to ensure more accurate perceptions of SMMs or use this data to identify training needs (e.g., to support teams in adopting new technology or using new communications services effectively).

Practitioners may be particularly interested in ensuring that perceived SMMs are (realistically) high, since we show that this enables greater performance. One way in which they can do this is by emphasising mutual goals and success between team members, since this would create the motivation for them to more rapidly get on the same page and reduce the shared tenure typically required to have more similar perceived SMMs. This motivation and accuracy of perception may also link to how team members engage in team learning behaviours in developing perceived SMMs. By exercising reflexivity about individual and shared understandings of work in their teams (cf., Konradt et al., 2016; Abrantes et al., 2022), members could identify the benefits of perceived SMMs and where team members may have limited insights, they can start identifying opportunities for team learning that could serve to improve their shared understanding of their work.

The benefits of team learning go beyond a superficial understanding of the team's work – teams that engage in learning behaviour become more familiar with their task environment, each other, as well as their mutual understanding of one another's competencies and roles (Maynard et al., 2019). Practitioners can therefore implement interventions such as cross-training (where team members learn skills needed in different functions in their teams thus contributing to SMMs; Marks et al., 2002) and observational learning (where team members observe one another in performing their individual roles; Hoover et al., 2012) in order to provide team

members with opportunities to engage in co-construction and constructive conflict, and in doing so develop greater perceived SMMs.

These interventions could be further enhanced by testing whether team members have potentially (under-)inflated perceived SMMs or self-efficacy, in which case reflexivity interventions may aid in adjusting these perceptions to more realistic levels. This would mean that teams can obtain more insight into the effectiveness of their learning behaviour and maximise the impact of their team learning behaviour. Based on Kolb's (2014) experiential learning model, this would assist team members in reflecting on their experiences of working in their teams and enable them to determine whether their perceived SMMs were realistic. If not, they would be able to identify opportunities to refine their perceived SMMs via, for example, further collaboration and interaction with their fellow team members. By doing so, practitioners can ensure that teams gain not only benefits in increased work-related knowledge from learning experiences, but also shared understanding that enables them to better coordinate and perform as teams.

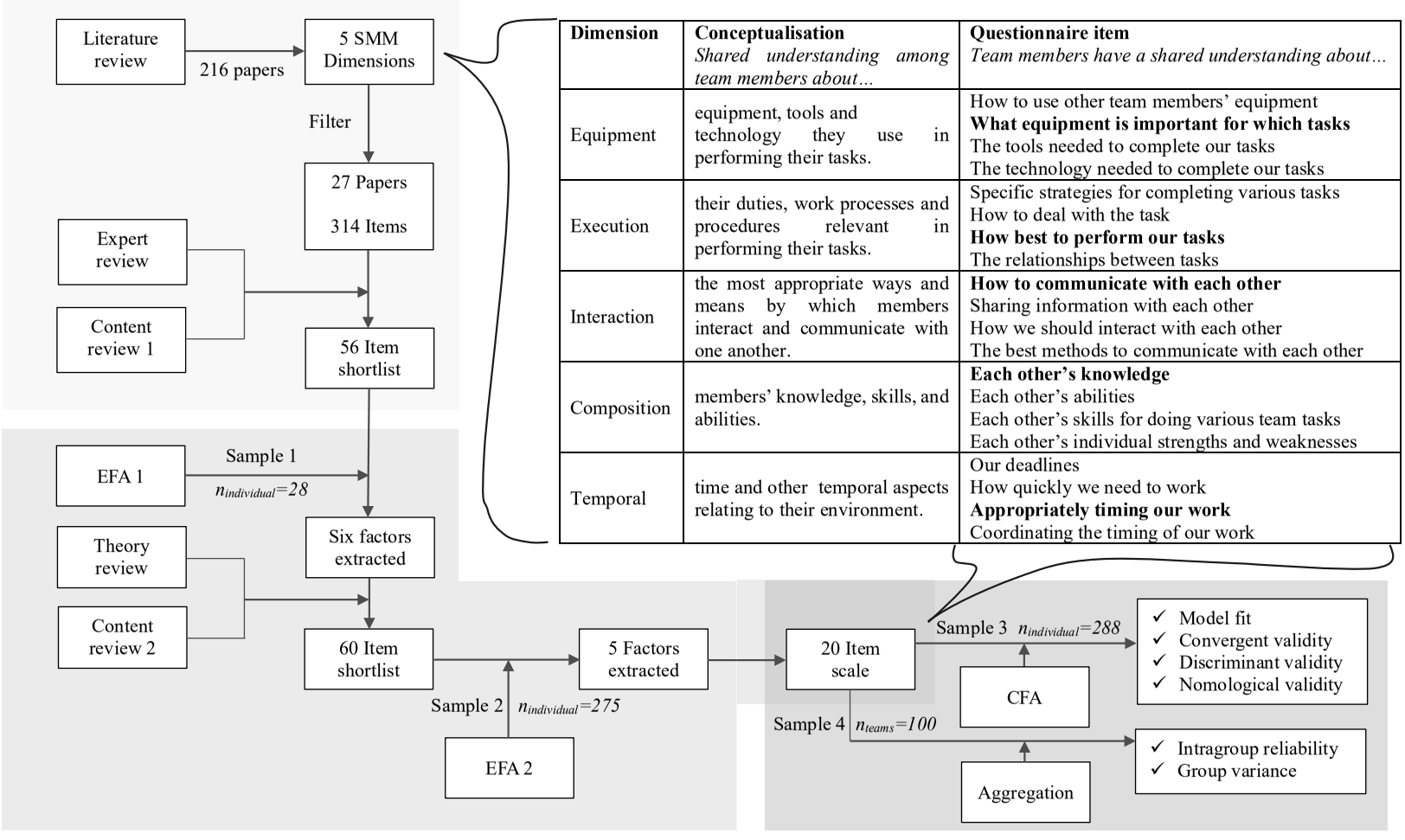
5.5. Strengths, limitations, and future research

In this dissertation we adopt a robust, but what some have argued to be unconventional approach to studying SMMs by focussing on perceived SMMs (e.g., DeChurch & Mesmer-Magnus, 2010a). In doing so we addressed unique challenges in the literature and identified limitations when studying SMMs using

this lens. The three empirical papers in this dissertation are characterised by a number of strengths and limitations that warrant discussion.

A key strength of this dissertation is built on the observation of Mohammed et al. (2021), who note the potential relevance of perceived SMMs, but argue that more needs to be done to understand the *roles* of perceived and structured SMMs. In response to this point, we rigorously developed a suitable measurement scale that we applied across different levels of analysis to test vital aspects of perceived SMMs and demonstrate their value as a stand-alone construct within the SMM literature. In doing so, we have provided future scholars with a validated measure of perceived SMMs across five dimensions, as well as a solid theoretical groundwork to continue building future research on this topic. From the results of Chapter 3 and Chapter 4, we note that the scale is rather extensive for a single-factor measure, and there exists the opportunity for future research to validate a shortened version of the 5-PSMMS. Reducing the overall scale to a five-item measure using one item per dimension, based on the strongest factor loading from our results (see items in bold text in Figure 5.1), could offer researchers and even more accessible tool to measure perceived SMMs. Mohammed et al. (2021) further highlight the importance of comparing perceived and structured SMMs. The study of structured SMMs fell outside the scope of feasibility in the research of the three empirical chapters, limiting our ability to comment on the relationship between these two

Figure 5.1
The 5-PSMM scale development and dimensions



Dimension	**Conceptualisation** *Shared understanding among team members about…*	**Questionnaire item** *Team members have a shared understanding about…*
Equipment	equipment, tools and technology they use in performing their tasks.	How to use other team members' equipment **What equipment is important for which tasks** The tools needed to complete our tasks The technology needed to complete our tasks
Execution	their duties, work processes and procedures relevant in performing their tasks.	Specific strategies for completing various tasks How to deal with the task **How best to perform our tasks** The relationships between tasks
Interaction	the most appropriate ways and means by which members interact and communicate with one another.	**How to communicate with each other** Sharing information with each other How we should interact with each other The best methods to communicate with each other
Composition	members' knowledge, skills, and abilities.	**Each other's knowledge** Each other's abilities Each other's skills for doing various team tasks Each other's individual strengths and weaknesses
Temporal	time and other temporal aspects relating to their environment.	Our deadlines How quickly we need to work **Appropriately timing our work** Coordinating the timing of our work

views of SMMs. We nevertheless mirror the sentiments of Mohammed et al. (2021) in highlighting this as a crucial area for future research. Given that the measurement of structured SMMs is highly resource intensive and involves in-depth task-analyses prior to data collection on representations of SMMs, our scale makes the goal of studying perceived and structured SMMs more feasible for future research, since its use as a measure of SMM perceptions can be readily applied in parallel to any measure of structured SMMs.

Our 5-PSMMS presents five dimensions of SMMs that could clearly be distinguished during its development and validation in Chapter 2. We encountered a limitation in the use of our scale in that it was more suitable for use as single factor scale due to high cross-loadings between factors in smaller samples. The 20-item scale performed very well as a single factor measure, achieving high reliability (alphas between .93 and .95) and aggregation statistics ($r_{wg(j)}$ between .98 and .99, ICC1 between .15 and .56, and ICC2 between .37 and .72; Bliese & Ployhart, 2002; James et al., 1984) in Chapter 3 and Chapter 4. Taken together, these results indicate reliable, consistent performance of the scale in various samples, leaving us confident that future research can use the 20-item scale as a general measure of perceived SMMs. Since the scale was developed as a five-factor measure, future research could use this to better understand the relationships between the different dimensions of perceived SMMs by, for example, testing what perceived SMMs are

the first to emerge in teams and how this could shape the development of other dimensions.

Perceived SMMs can be categorised as emergent states (dynamic and prone to change over time; Marks et al., 2001). This means that they should ideally be studied under conditions that allow researchers to identify their developmental trends and, more specifically, the role of time in their development. Since time is an important factor in the development of SMMs (Mohammed et al., 2021), we progressively work towards a more comprehensive study of temporal aspects of work in this dissertation. We show that (1) historical time spent together (i.e., shared tenure) positively influences perceived SMMs (Chapter 3) and also, when studied longitudinally, perceived SMMs demonstrate positive linear growth in teams (Chapter 4). Viewing shared statically offered us some preliminary insights into how time may be relevant to, and positively influence, perceived SMMs. With this positive indication, we more directly explored time in Chapter 4, where we conducted a longitudinal study and measured perceived SMMs at three points in time. This enabled us to model the growth of perceived SMMs over time and take into account team learning behaviour and team member self-efficacy. This provides a basis for future research to continue the study of the relationship between various other team processes (cf., Marks et al., 2001) and perceived SMMs longitudinally and provides some insight into the expected developmental trajectory of perceived

SMMs in such research. We find support for linear growth in perceived SMMs; however, their emergent nature means that perceived SMMs may develop differently in different circumstances. Further longitudinal study is therefore crucial to understanding how their growth might look under different conditions (e.g., when teams face change or instability; Abrantes et al., 2018; Santos et al., 2021).

Our focus in this dissertation is on the measurement and antecedents of perceived SMMs, since this is where current research is lagging behind. A number of studies have demonstrated the influence of perceived SMMs on team outcomes such performance (Marhefka et al., 2018, 2020), potency (Gevers et al., 2020), creativity (Santos et al., 2015b), and coordination (Müller & Antoni, 2020b). While not our primary interest in this dissertation, we contribute to this body of knowledge by finding support for the positive influence of perceived SMMs on leader-rated dyadic performance in Chapter 3. These works have been of great value in demonstrating the impact and utility of perceived SMMs, however the antecedents of perceived SMMs, which have not been explored in any depth. This warrants deeper investigation in order to realise the benefits and team outcomes perceived SMMs are associated with. We now show that shared tenure, goal interdependence (Chapter 3), team learning and self-efficacy (Chapter 4) are important factors in the development of perceived SMMs, creating an opportunity for future research to

study the effects of related team processes such as team reflexivity (Abrantes et al., 2022) or team adaptation (Santos et al., 2021; Uitdewilligen et al., 2013).

In teams there are various levels of analysis that are relevant to cognition and decision making, including the team, dyadic, and individual levels (Hollenbeck et al., 1995). The implication is that the differences in teams' authority differentiation, skill differentiation, and temporal stability lead to substantial relational complexity that have an impact on individual and shared cognition (Hollenbeck et al., 2012; Niler et al., 2019). In the individual chapters, we faced the same challenges shared by most research using primary data in that the effects of various processes and dynamics at, and between, different levels of analysis fell outside the scope of the studies we conducted. To address this, we draw on the individual (Chapter 2), dyadic (Chapter 3), and team (Chapter 2 and Chapter 4) levels of analysis throughout this dissertation. We specifically studied the emergence of perceived SMMs at the team level, however we also acknowledge that the origin of shared cognition is in the mind of the individual (Goldstone et al., 2015; Kastanakis & Voyer, 2014). As such, future research could study the development of perceived SMMs from an individual level construct into a shared, team level construct. Our research (Chapter 3) provides scholars with fundamental groundwork by being the first to study perceived SMMs at the dyadic level. By opening the study of perceived SMMs at the dyadic level, we are led to ask whether (or when) there may

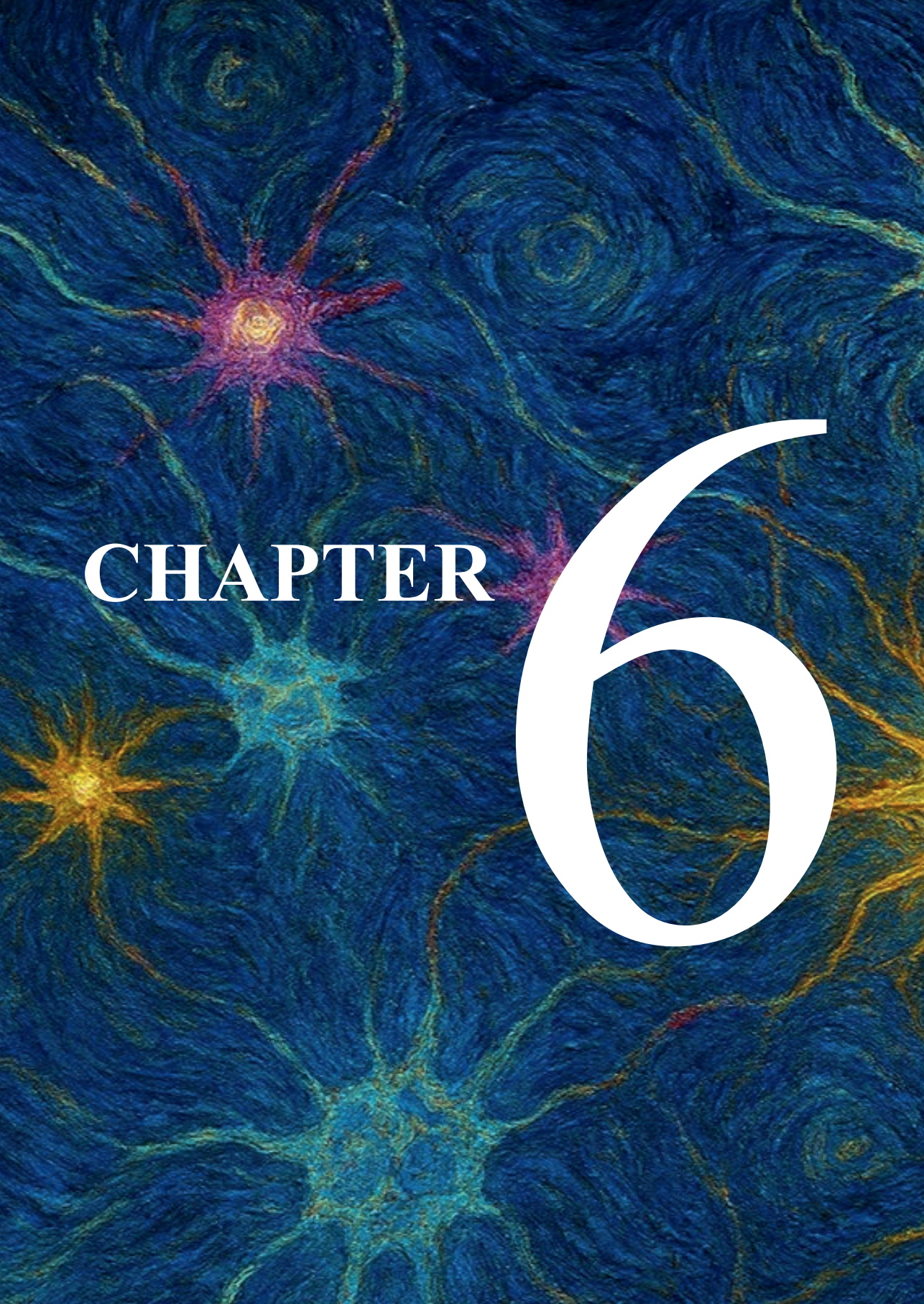
be differences in the development of perceived SMMs between dyad partners, and what the implications of such asymmetry may be. Future SMM research could adopt a different approach to aggregation and study such asymmetries (cf., Pearsall & Venkataramani, 2015; Van der Vegt et al., 2010). Given that teams consist of networks of dyads (Mohammed et al., 2021), a further opportunity is to study how these different dyads within a team develop perceived SMMs and to conduct social network analyses to explain why this development may (or may not) be uniform (Brass, 2021; Mohammed et al., 2021).

The uniformity of perceived SMMs is not only related to potential differences between dyads. The SMM literature generally utilises consensus-based aggregation (Chan, 1998; Mohammed et al., 2010). Our research, and SMM research in general, follows consensus-based approaches to aggregation that assume a degree of similarity in the representation of a particular construct among team members (Chan, 1998). Future research could therefore investigate the divergence in perceived SMMs. This may yield interesting insights into whether team members generally hold similar perceptions of their SMMs and the outcomes they may encounter when perceived SMMs are more divergent vs. more similar.

5.6. Conclusion

In conclusion, this dissertation advances the understanding of perceived SMMs. Together with my co-authors, I started by clarifying the extant theoretical

composition of perceived SMMs as it encompasses five dimensions (i.e., execution, equipment, composition, interaction, and temporal mental models), and then subsequently distilled a five-factor scale reflecting this structure and validated it. By using this scale, we then explored how dyadic shared tenure and goal interdependence interact to influence perceived SMMs and, in turn, performance. Building on the theme of time and shared experience, we conducted longitudinal research to show how perceived SMMs develop over time as teams engage in learning behaviour. We also find some unexpected results along the way and noted that team member self-efficacy is a boon, but may also introduce some risk into the team if it is too high. Overall, we make numerous theoretical contributions to the fields of perceived SMMs, team learning, social cognitive theory (Bandura, 1986), and interdependence theory (Tjosvold & Halco, 1992) and establish this construct as a valuable component of team cognition. This bodes well for future research in this field, where we encourage future researchers to look both structural and perceived SMMs in their research in order to determine how these two factors are related. Since there was no validated measure of perceived SMMs that reflected the five core dimensions in SMM literature before this dissertation, we believe that now is the time to fully engage in this line of research and hope that other scholars share our cognition in this regard.


CHAPTER
6

IMPACT STATEMENT

6.1. Introduction

Teams take centre stage in the modern, fast-paced, and complex world of work. Success in this particular climate often rests on team members being on the same page and have a shared understanding of what needs to be done, how, and with whom. This shared understanding is known as a shared mental model (SMM). While SMMs are crucial to team functioning, surprisingly little attention has been given to a core question: *Are team members aware that they share understanding about their work?*

This dissertation dives into this question, by focusing on *perceived* shared mental models (perceived SMMs) – which is defined as team members' beliefs about the sharedness of their mental models. Across three empirical studies, this dissertation aimed to: (a) explore how perceived SMMs are measured, (b) what contributes to their formation between individuals, and (c) how they evolve over time in teams. While traditional SMM research has largely emphasized the similarity and accuracy of knowledge shared among team members, this dissertation highlights that awareness of, and belief that, cognition is shared among team members is critical in enabling teams to consciously utilise their SMMs in reaching shared goals. This chapter provides a reflection on the impact of my dissertation, firstly in terms of its scientific impact and secondly in terms of its societal impact.

6.2. Scientific impact

The dissertation makes three major scientific contributions: firstly, in Chapter 2, it offers a rigorous and validated measurement tool – the Five-Factor Perceived Shared Mental Model Scale (5-PSMMS) – that captures five key dimensions of perceived SMMs: *equipment*, *execution*, *interaction*, *composition*, and *temporal* mental models. Developed through a deductive, multi-sample process grounded in nearly 30 years of literature, the 5-PSMMS addresses major concerns in the field about measurement rigour, dimensional ambiguity, and construct clarity. In doing so, a key oversight is identified in how past literature viewed temporal mental models and addressed by arguing that time is relevant not only to task execution but also to interaction, composition, and coordination in teams. The scale provides a foundational resource for future research and offers scholars a standardised, yet flexible, tool to study perceived SMMs across contexts.

Second, in Chapter 3, the research advances the understanding of perceived SMMS as well as interdependence theory (Tjosvold & Halco, 1992) by exploring perceived SMMs at the *dyadic* level – the smallest interpersonal unit of analysis at which a construct that is *shared* between team members can be identified. Using data from 88 leader–member dyads, Chapter 3 shows that the longer a team leader and team member work together (i.e., share tenure), the higher their perceived SMM similarity becomes. This was found to be accelerated by high goal interdependence

(i.e., dyads with a shorter shared tenure also had higher perceived SMM similarity when they were dependent on one another for successfully reaching their work goals). It also shows that shared tenure influences performance (as rated by the team leader) via perceived SMMs. This provides support for a long-held assumption in the SMM literature: that the longer two individuals work together the more similar their perceived understanding of their work will be. In addition, it shows the importance of mutually dependent goals, rather than mutually dependent tasks, in seeking shared understanding.

Third, Chapter 4 brings a *longitudinal* and *dynamic* perspective to the development of perceived SMMs in teams. Building on social cognitive theory (Bandura, 1986), Chapter 4 shows that perceived SMMs grow over time, particularly when teams engage in co-construction (where team members contribute to shared knowledge in an additive manner) and constructive conflict (where differences in knowledge and understanding are actively discussed and resolved). These learning behaviours are expected to be most effective when team members have high self-efficacy (i.e., a stronger belief in their capabilities). Curiously, however, low self-efficacy enabled a more rapid development of perceived SMMs when teams demonstrated learning behaviours. This suggests that team member self-efficacy has a more complex role to play in the development of perceived SMMs from team learning: having high self-efficacy in a team may yield higher

perceived SMMs earlier in a project, but teams where self-efficacy is lower may more actively try to develop better perceived SMMs as time goes by. As such, lower self-efficacy could promote the effects of learning and speed up the alignment of perceived SMMs.

Collectively, these three studies frame perceived SMMs as one that can be measured, predicted, and cultivated in teams over time. In doing so, this dissertation contributes to research on the topic by integrating emergent states literature, social cognitive learning theory, and the idea that perceptions are not merely a by-product of cognition, but central to how teams function.

6.3. Societal impact

While the dissertation offers important scientific contributions, it also yields practical implications for society. Many modern organisations rely on teams to solve complex problems in challenging environments. Time can be a luxury in such cases and team stability can be rare. Teams therefore need to be able to rapidly and successfully align their understanding, make critical decisions, and coordinate among one another to execute tasks. By determining the degree to which team members perceive themselves to have SMMs, managers, human resource practitioners, and learning providers can better support this need. Taken together, the empirical chapters of the dissertation offer practitioners a tool with which to measure perceived SMMs in an accessible and convenient manner (Chapter 2), as

well as how they can design the work environment (Chapter 3), and support learning and development initiatives to improve perceived SMMs (Chapter 4).

More specifically, the 5-PSMMS developed in Chapter 2 is a key tool for addressing these challenges. It provides a reliable way to assess team members' *perceptions* of shared understanding about their work environment. Practitioners can use the scale to identify (mis)alignment in perceived SMMs early in the team lifecycle and intervene according to the needs or demands of the team or situation. For example, team members may overestimate their shared understanding (a false consensus effect), leading to communication breakdowns, and consequently to reduced team performance and effectiveness, or even crises or disasters in case of teams working in hazardous or high-risk environments. By diagnosing this gap, interventions such as team debriefs, reflexivity exercises, or cross-training can be implemented to ensure more accurate perceptions of SMMs exist and thus facilitate more effective communication and, eventually, performance.

Chapter 3 offers guidance for team composition and onboarding processes. In settings where individuals must collaborate quickly and for specific periods (e.g., project teams, temporary task forces), shared tenure cannot be relied upon to foster shared perceptions and understandings among dyad partners. This study shows that designing work with high *goal interdependence* can help team members gain greater perceived SMMs faster, even if they do not share an extensive working

history. This provides managers with a means to facilitate team development by clearly articulating, and emphasising, mutual goals and shared responsibilities between team members and leaders early in their tenure.

By identifying co-construction and constructive conflict as key drivers of perceived SMM development, Chapter 4 demonstrates the value of team learning behaviours for driving awareness of shared understanding among team members. Leaders can foster these learning behaviours by cultivating work environments where team members feel encouraged to voice opposing points of view and collaborate to resolve disagreements. Moreover, team member self-efficacy emerged as a crucial contextual factor in this relationship. Teams with members who generally have high self-efficacy showed stronger and more consistent growth in perceived SMMs. However, in a practical sense it would serve leaders and learning and development professionals well to ensure that high levels of self-efficacy do not lead to complacency in learning, since teams with lower team member self-efficacy developed greater perceived SMMs more rapidly when engaging in learning behaviours. In addition, this suggests that even teams with a limited life-span and low team member familiarity can quickly develop perceived SMMs under the right social conditions.

6.4. Dissemination and impact

To enhance the impact of this research, both academic and practitioner audiences were actively engaged throughout the PhD. Each study was presented at international conferences [13], obtaining valuable feedback on the research and leading to insightful discussions on the importance of perception in capturing SMMs. All three empirical chapters have been submitted to peer-reviewed academic journals, with Chapter 2 and Chapter 3 being published and generating citations in new research. Chapter 4 is under review with at the time of writing. Additionally, the findings were shared via public channels such as LinkedIn, where summary posts on the published papers garnered attention from professionals in organisational psychology, consultancy, and education. These posts not only disseminated findings, but also opened conversations with practitioners interested in applying the work directly (e.g., the potential impact of perceived SMMs following safety briefings at a construction company). This supports part of a broader effort to translate academic insights into usable tools for organisations navigating the complexity of teamwork.

[13] Conferences included Academy of Management Annual Meeting, Interdisciplinary Network for Group Research (INGRoup) Conference, European Association for Work and Organizational Psychology (EAWOP) Congress, International Workgroup on Teamworking (IWOT) and the Dutch Human Resource Management (HRM) Network Conference

6.5. Concluding reflections

Beyond its empirical and applied contributions, this dissertation offers a broader reflection on the nature of shared understanding in teams. Much of the historical criticism toward perceived SMMs in the literature stems from the notion that perceptions are unreliable proxies for actual mental *models* (i.e., structured and organised frameworks of knowledge). This criticism is not without basis, but has regrettably led to perceptions being undervalued in their relevance to the field of SMMs. A fundamental rebuttal raised in this dissertation is that without *perceived* sharedness (i.e., an awareness of or belief in) a SMM, team members are unlikely to effectively draw on these SMMs to coordinate their actions, predict one another's behaviour, and adapt to changes in the team's environment.



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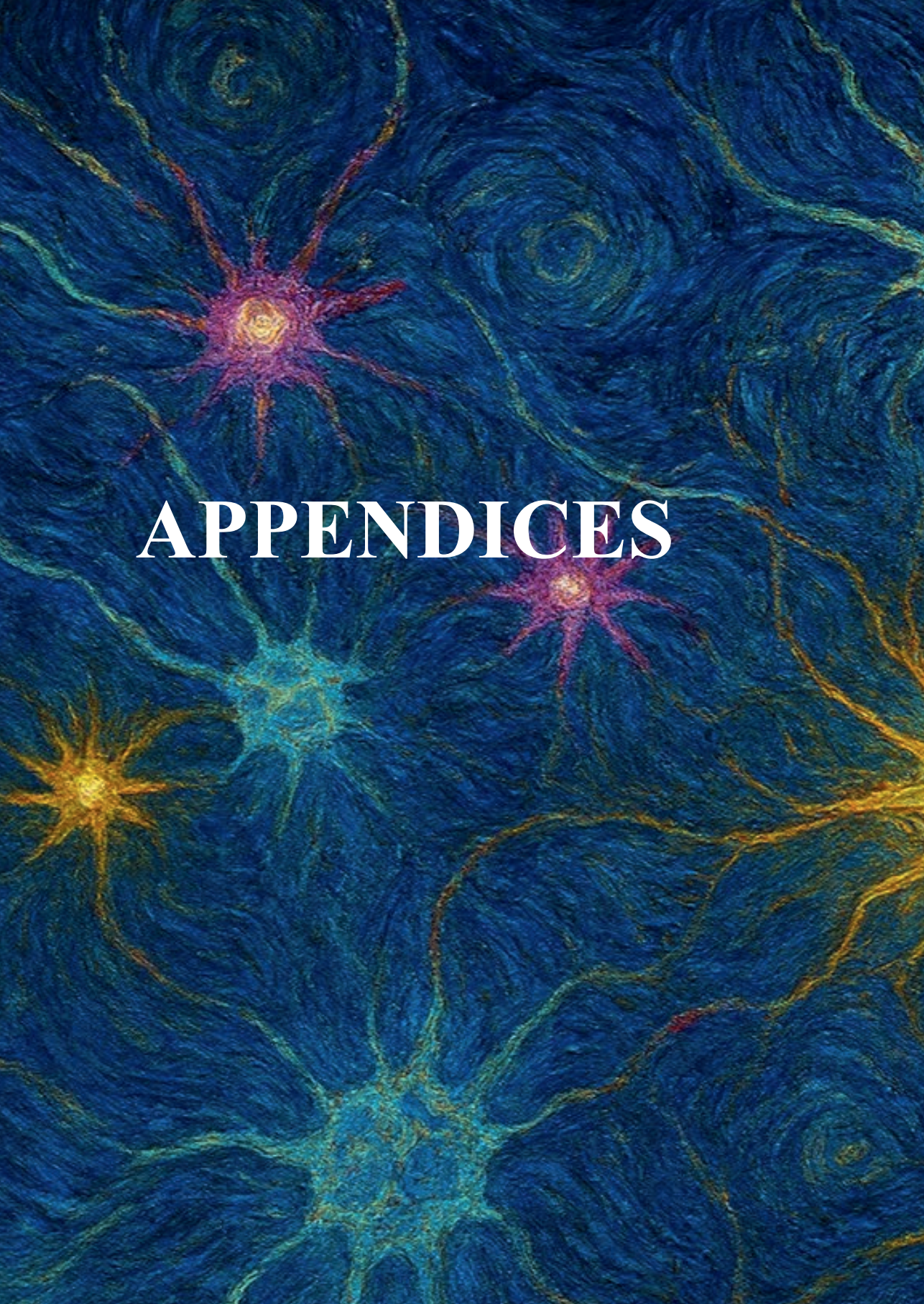
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APPENDICES

SUMMARY

As is discussed in Chapter 1, this dissertation addresses a notable gap in the shared mental model (SMM) literature by focusing on *perceived* SMMs. While past research has tended to prioritise the *structural* assessment of SMMs, the extent to which team members are aware or believe in the existence of SMMs has received considerably less explicit attention. In this dissertation, I argue that *perception* forms an integral part of (shared) cognition and plays an important role in shaping team outcomes. More specifically, in this dissertation, I: (a) investigate how perceived SMMs can be systematically measured (i.e., by developing a rigorous and generalisable scale to measure perceived SMMs in Chapter 2); (b) identify conditions that influence perceived SMMs (i.e., by examining the effect of shared tenure and goal interdependence in leader-member dyads in Chapter 3), and (c) examine how perceived SMMs develop over time (i.e., by modelling their development as an emergent state due to team learning behaviour and team member self-efficacy in project teams in Chapter 4). Below are summaries of these chapters, as well as a summary of Chapter 5 in which I provide an overarching discussion of the whole dissertation.

Chapter 2 addressed a need in the literature for a validated scale to measure perceived SMMs that is also representative of the core dimensions of SMMs. This chapter therefore introduces the Five-Factor Perceived Shared Mental Model Scale

(5-PSMMS). Drawing on a structured, deductive (and exhaustive) scale development process, it consolidates and refines existing measures comprising 273 measurement items across nearly three decades of SMM research. The result is a 20-item instrument covering five dimensions of perceived SMMs, grounded in the development of the construct since its inception: equipment, execution, interaction, composition, and temporal. This study not only delivers a validated tool for assessing perceived SMMs but also offers a critical conceptual contribution by arguing for the distinctiveness and breadth of temporal mental models, which have typically been framed in a manner more reflective of task execution in existing literature. The scale is positioned as a flexible measurement tool for researchers and practitioners aiming to assess perceived alignment in teams' understanding of their work environment across a variety of contexts.

Chapter 3 turns to the dyadic level – because the first point at which a mental model can become shared is between two individuals. In this chapter, a fundamental assumption in the literature is addressed, i.e., that shared experience leads to more similar perceived SMMs. Drawing on a field sample of 88 leader–member dyads, this chapter examines how shared tenure and goal interdependence interact to influence perceived SMMs. As hypothesised, shared tenure is positively associated with perceived SMMs; however, substantially shorter tenure was required for higher perceived SMMs in dyads with greater goal interdependence. Moreover,

perceived SMMs are vital in translating shared tenure into performance, highlighting their relevance for dyadic functioning. These findings address key concerns in the literature in: (1) demonstrating that the longer two individuals work together, the more they will perceive a SMM to exist; (2) finding support for the motivational impact of goal interdependence in promoting perceived SMMs; and (3) highlighting the role perceived SMMs can play in dyadic performance.

Chapter 4 addresses a need in the literature to better understand the developmental trajectories of perceived SMMs over time. While perceived SMMs are dynamic and prone to change over time, they have not been studied in a way that reflects this up to now. This chapter adopts a longitudinal perspective grounded in social cognitive theory. Data were collected from 165 student project teams at three time points (i.e., at the start, middle, and end of their project). Our findings show that perceived SMMs are shown to exhibit linear growth over time and this development is positively influenced by two forms of team learning behaviour: co-construction and constructive conflict. The interaction of these learning behaviours with team member self-efficacy produce novel insights. High team member self-efficacy generally amplify the benefits of learning behaviour, but under high degrees of team learning, low team member self-efficacy is associated with steeper increases in perceived SMMs. This study extends the emergent states literature by

modelling perceived SMMs as a dynamic cognitive construct influenced by both behavioural and motivational inputs.

Finally, in Chapter 5, I explain how the three empirical chapters of this dissertation together make a number of notable contributions to the shared cognition literature, with the main ones being: (1) perceived SMMs are emphasised as a distinct, measurable component of SMMs; (2) a rigorously developed scale (5-PSMMS) that can be applied across different team settings and levels of analysis is presented; (3) empirically, perceived SMMs are influenced by contextual (i.e., shared tenure), behaviour (i.e., team learning behaviour), and motivational factors (i.e., goal interdependence and team member self-efficacy), and relate positively to performance outcomes; and (4) by operationalising perceived SMMs as emergent states this dissertation captures PSMMs over time in and thereby shows how they can develop in teams. Overall, this dissertation thus responds to recent calls for a better understanding of perceptions relating to SMMs in teams, while addressing concerns raised with the way past research has drawn on perceived SMMs without explicitly naming them so. It advances the theoretical and empirical knowledge on perceived SMMs, further contributing to the broader fields of SMMs and team cognition. The findings also have practical implications for leaders, HR professionals, learning and development professionals, team members, and practitioners who aim to facilitate shared understanding among team members in

diverse and dynamic work environments. Ultimately, the work contributes to a broader conceptualisation of perceived SMMs as emergent, context-sensitive, and relevant to the wider SMM literature and show its relevance for future research. In this dissertation I also show how practitioners can foster and accelerate perceived SMMs via creating shared goals for team members, and by engaging in and promoting team learning behaviour.

SAMENVATTING

Dit proefschrift richt zich op een duidelijke lacune in de literatuur over gedeelde mentale modellen (*shared mental models;* GMM's) door te focussen op *waargenomen* GMM's. Waar eerder onderzoek vooral aandacht heeft besteed aan de meting van de *structuur* van GMM's, werd er veel minder expliciet gekeken naar de mate waarin teamleden zich bewust zijn van hun GMM's, of geloven dat deze daadwerkelijk bestaan. In dit proefschrift betoog ik dat perceptie een integraal onderdeel vormt van (gedeelde) cognitie en een belangrijke rol speelt in het vormgeven van teamuitkomsten. Meer specifiek onderzoek ik in dit proefschrift: (a) hoe waargenomen GMM's gemeten kunnen worden (Hoofdstuk 2); (b) welke factoren van invloed zijn op waargenomen GMM's door het onderzoeken van de effecten van gedeelde dienstjaren en doelafhankelijkheid in leider-lid-dyaden (Hoofdstuk 3); en (c) hoe waargenomen GMM's zich in de loop van de tijd ontwikkelen door hun ontwikkeling te modelleren als emergente staat (*emergent state*) die voortkomt uit teamleergedrag en zelfeffectiviteit van teamleden in projectteams (Hoofdstuk 4). Hieronder volgen samenvattingen van deze hoofdstukken, aangevuld met een samenvatting van Hoofdstuk 5, waarin ik een overkoepelende discussie van het gehele proefschrift presenteer.

Hoofdstuk 2 behandelt de behoefte in de literatuur aan een gevalideerd instrument om waargenomen GMM's te meten dat tevens representatief is voor de

kerndimensies van GMM's. Daarom introduceert dit hoofdstuk de '*Five-Factor Perceived Shared Mental Model Scale*' (5-PSMMS). Op basis van een gestructureerd, deductief (en uitvoerig) ontwikkelingsproces consolideert en verfijnt het instrument bestaande meetinstrumenten, die 273 items uit bijna drie decennia aan GMM-onderzoek omvatten. Het resultaat is een instrument van 20 items dat vijf dimensies van waargenomen GMM's omvat, in lijn met de ontwikkeling van het construct sinds het ontstaan ervan: apparatuur, uitvoering, interactie, samenstelling en temporaal. Deze studie levert niet alleen een gevalideerd instrument voor het meten van waargenomen GMM's, maar draagt ook conceptueel bij door temporale mentale modellen te positioneren als een factor met een bredere en meer onderscheidende rol dan in de bestaande literatuur wordt verondersteld, waar ze meestal worden voorgesteld als onderdeel van uitvoering. De 5-PSMMs wordt gepositioneerd als een flexibel meetinstrument voor onderzoekers en professionals die waargenomen GMM's in teams willen beoordelen in uiteenlopende contexten.

Hoofdstuk 3 richt zich op het dyadische niveau, omdat het eerste punt waarop een mentaal model gedeeld kan worden, tussen twee individuen ligt. In dit hoofdstuk wordt een fundamentele aanname in de literatuur onderzocht, namelijk dat gedeelde ervaring leidt tot meer vergelijkbare waargenomen GMM's. Op basis van een veldsteekproef van 88 leider-lid-dyaden wordt onderzocht hoe gedeelde

dienstjaren en doelafhankelijkheid samen invloed uitoefenen op waargenomen GMM's. Zoals gehypothetiseerd, blijkt gedeelde dienstjaren positief samen te hangen met waargenomen GMM's; echter, aanzienlijk kortere gedeelde dienstjaren waren voldoende voor hogere niveaus van waargenomen GMM's in dyaden met een hogere mate van doelafhankelijkheid. Bovendien blijken waargenomen GMM's essentieel in het omzetten van gedeelde dienstjaren naar prestaties, wat hun relevantie voor dyadisch functioneren onderstreept. Deze bevindingen helpen belangrijke vragen in de literatuur te beantwoorden door: (1) te laten zien dat hoe langer twee individuen samenwerken, hoe sterker zij het bestaan van een SMM zullen waarnemen; (2) bewijs te bieden voor de motiverende invloed van doelafhankelijkheid op het bevorderen van waargenomen GMM's; en (3) te benadrukken welke rol waargenomen GMM's spelen in dyadische prestaties.

Hoofdstuk 4 behandelt de behoefte aan een beter begrip van de ontwikkelingstrajecten van waargenomen GMM's. Hoewel waargenomen GMM's dynamisch zijn en geneigd zijn te veranderen, zijn ze tot op heden niet op deze manier onderzocht. Dit hoofdstuk hanteert een longitudinaal perspectief en is gebaseerd op sociale-cognitieve theorie. Data werden verzameld bij 165 studentenprojectteams op drie meetmomenten (aan het begin, midden en einde van hun project). De resultaten tonen dat waargenomen GMM's een lineaire groei vertonen en dat deze ontwikkeling positief wordt beïnvloed door twee vormen van

teamleergedrag: co-constructie en constructief conflict. De interactie tussen deze leergedragingen en de zelfeffectiviteit van teamleden levert nieuwe inzichten op. Hoge zelfeffectiviteit versterkt over het algemeen de voordelen van leergedrag, maar onder hoge niveaus van teamleren gaat lage zelfeffectiviteit gepaard met steilere toenames in waargenomen GMM's. Deze studie breidt de literatuur over emergente staten uit door waargenomen GMM's te modelleren als een dynamisch cognitief construct dat wordt beïnvloed door zowel gedragsmatige als motivationele factoren.

In Hoofdstuk 5 licht ik toe hoe de drie empirische hoofdstukken samen een aantal belangrijke bijdragen leveren aan de literatuur over gedeelde cognitie, waarvan de voornaamste zijn: (1) waargenomen GMM's worden benadrukt als een onderscheidbaar en meetbaar onderdeel van GMM's; (2) een rigoureus ontwikkeld instrument (5-PSMMS) wordt voorgesteld dat toepasbaar is in verschillende teamcontexten en analyseniveaus; (3) empirisch blijkt dat waargenomen GMM's worden beïnvloed door contextuele (gedeelde diensttijd), gedragsmatige (teamleergedrag) en motivationele factoren (doelafhankelijkheid en zelfeffectiviteit van teamleden), en positief gerelateerd te zijn aan prestatie-uitkomsten; en (4) door waargenomen GMM's te operationaliseren als een emergente staat laat dit proefschrift zien hoe ze zich over de tijd ontwikkelen in teams. Dit proefschrift beantwoordt daarmee recente oproepen voor een beter begrip van percepties met

betrekking tot GMM's in teams. Tegelijkertijd gaat het in op de zorgen over het feit dat eerder onderzoek sterk leunde op waargenomen GMM's zonder deze expliciet zo te benoemen. Het werk versterkt de theoretische en empirische kennis over waargenomen GMM's en draagt bij aan de bredere literatuur over GMM's en teamcognitie. De bevindingen hebben tevens praktische implicaties voor leidinggevenden, HR-professionals, L&D-specialisten, teamleden en andere praktijkprofessionals die gedeeld begrip in diverse en dynamische werkomgevingen willen bevorderen. Uiteindelijk draagt dit werk bij aan een bredere conceptualisering van waargenomen GMM's als emergent, contextgevoelig en relevant voor de bredere SMM-literatuur, en toont het hun relevantie voor toekomstig onderzoek. Daarnaast laat ik in dit proefschrift zien hoe praktijkprofessionals waargenomen GMM's kunnen stimuleren en versnellen door het creëren van gedeelde doelen voor teamleden en het bevorderen van teamleergedrag.

ACKNOWLEDGEMENTS

The completion of this PhD has been a long, challenging, and deeply rewarding journey, exemplifying ubuntu in action: this achievement was only possible thanks to those around me who encouraged and supported me, and to whom I owe my deepest gratitude.

First and foremost, to my family: thank you for your unwavering love, patience, and belief in me. You carried me through moments of doubt and fatigue, and your presence grounded me when I felt overwhelmed. A special thank you to Collette, who was whose exceptional support, humour, strength and resilience made this journey possible, and to Liam and Luca for daily reminders of what truly matters in life. To my parents, Barbera, Pieter, and my mother-in-law, Mariette, thank you for always keeping the faith and for supporting our family from afar over the past years. To my grandparents, living and departed, for their love and care. Thank you to my brother, in-laws, and friends for the conversations, the distractions, the reality checks, and the reminders that life exists beyond the boundaries of academia. Louis and Bayley, Johann and Natali, Lara and Adriaan, David and Ilze, Gavin and Zander, Chris, Melvyn and Yuliya, Frank and Luan, Chantal, Peter and Ronelle, Benjamin and Linda: your presence helped me maintain balance and perspective, and I am deeply grateful. A special thank you to my paranymphs, dear friends and the earliest friendly faces of my time in Maastricht,

Gavin and Chris-your friendship has always been as true as the tides. To those who are far away, but never far from my heart: Ouma Rita, Susan, Louise, Yolande, Dirk, Dirk, Jonita, Sam, Lee and Anna, Ignus and Lourenza, Pieter and Suretha, Lauritz and Ilze, Pieter and Elize. My fond remembrance, gratitude and love to dearest family who passed in recent years: Oupa Elwin and Ouma Sonia, and my father-in-law, Orin, we miss you every day.

This project would have been impossible without the guidance of my supervisory team. Catarina, without your support and, above all, patience, none of this would have been possible. Thank you to Simon for the "crazy uncle" moments that pushed ideas to their limits, and the frank and productive discussions that followed. Through trying times, both globally and personally, I was fortunate to have your backing every step of the way. This also extends to the valuable advice, feedback, and insight from our co-author, Sjir: thank you for your open and generous guidance on the projects in this PhD, and for your company and perspectives both at UM and during conferences.

My sincere thanks go to my UM colleagues in the OSE Department, who shaped not only my academic development but also my experience of being part of a research community. To Roman, Sonja, Irina, Anna, Désirée, Hannes, Juliette, Gerard, Wilko, Boris, Iwan, Jarrod, Jermaine, Jolien, and Martin: thank you for your critical questions, thoughtful discussions, and willingness to give your time

and expertise. To my fellow PhDs, lecturers and tutors, thank you for the camaraderie, shared struggles and collective motivation. Tim, Türkü, Sophie, Erna, Timo, Eline, Nina, Nina, Kasia, Dinah, Marc, Cesar, Bas, Peter and Hannah: your openness, humour and support made the journey far less lonely and all the more enjoyable. To Anita and Adela, thank you for the care, professionalism and kindness you have shown me over the years. Whether it was advice, logistical support or simply checking in, you fostered an environment that enabled me to focus on learning and research. A special word of thanks to colleagues from ERD who continued to support my development through new experiences, support and eye-opening conversations. Wim, Therese, Manon, Inken, Bas, René, Fatemeh, Wendy, Laurie, Eric, Alexandra, Marloes, Simon, Leon, Lara, Catherine, Aniko, Ainsley, Vivian and Sara: your perspectives broadened my horizons and enriched both my work and my outlook on research and education.

I am also grateful to researchers and collaborators from Maastricht University and beyond who provided guidance, feedback and encouragement through my PhD. Working with you sharpened my ideas and strengthened my confidence in contributing to the academic community.

ABOUT THE AUTHOR



Jandré first found his way to the halls of Maastricht University's School of Business and Economics as a student in the MSc International Business (Organisation – Management, Change and Consultancy) programme in 2013. At the time, he was also finalising his MCom (Industrial Psychology) at the University of Stellenbosch in South Africa. After completing his MSc, he returned to Cape Town where he worked as practicing organisational psychologist from 2014. Academia in general, and Maastricht University in particular, remained an alluring goal and Jandré started his quest of finding a suitable PhD programme. In 2018, he returned to Maastricht to start his PhD at the department of Organisation, Strategy and Entrepreneurship at Maastricht University's School of Business and Economics.

Under the supervision and guidance of Dr. Catarina Marques dos Santos and Prof. dr. Simon de Jong, he has published two papers from this PhD, one in Frontiers in Psychology, and the other in Team Performance Management, with the third submitted and under review at the time of writing. He has presented his work at numerous teams, management, and HRM conferences as well as internal seminars. Jandré continues to hone his research and teaching skills beyond the PhD.

Outside academia, he enjoys family life with his wife and their two sons, finding inspiration in environments where people can learn, grow, and work together effectively – much like the teams he studies.

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