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Perspectives

Mapping mental models in sustainability transitions

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ABSTRACT

Sustainability transitions inherently involve system change, which needs to be initiated and accepted by a wide variety of actors. How actors perceive the system or transition of interest can shape key decisions in a transition process. Still, little transition research has combined this system perspective with the actor's perspective. At this intersection lies the concept of mental models, which are actors' system perceptions, consisting of beliefs about the causal interrelations between system components. Mapping mental models of actors in sustainability transitions may (1) increase our understanding of the system that needs to transform, (2) reveal obstacles or opportunities for change, and (3) demonstrate similarities and differences in system perceptions between actors. We present three types of transition mental models and illustrate these with examples. We conclude with avenues for future mental model research and discuss how insights from mental models can inform strategies to develop or steer transitions.

1. Introduction

Sustainability transitions inherently involve a profound change in socio-technical systems that provide societal functions such as the provision of food, mobility, or energy (Geels, 2004; Markard et al., 2012). Two dominant transition models (MLP and TIS) depart from a socio-technical system perspective to analyse the dynamics of novelty emergence, breakdown of existing socio-technical systems and resulting societal transitions. Although these system-level perspectives form the foundation for a wealth of insights on the meso/macro dynamics of societal transitions (Markard et al., 2012), these approaches need to be complemented with actor-level perspectives as system change needs to be initiated, led, supported, and accepted by a wide variety of actors (IPCC, 2022). Indeed, *'it is people, not machines that design, build and give meaning to technologies and ultimately decide which ones to adopt and which ones to reject'* (Bijker and Pinch, 1987). Societal transitions are driven by a web of actors whose decision-making and interactions determine the direction and success of much-needed societal change.

Hence, the system-level perspective in transition research is increasingly enriched with more actor-oriented analyses (Avelino and Wittmayer, 2016; Farla et al., 2012; Jensen, 2012; Köhler et al., 2019; Sharp et al., 2024) and psychological approaches to understanding individuals' perceptions and decision-making in societal transitions (Bamberg et al., 2021; Bögel and Upham, 2018; Bögel et al., 2024; Bogner et al., 2024; de Vries et al., 2021; Kaufman et al., 2021; Upham et al., 2020). Furthermore, transition research explores the different roles of actors, such as policy-makers, entrepreneurs, consumers, producers, citizens and their interactions (Avelino and Wittmayer, 2016). Yet, few actor-oriented approaches explicitly link the individual-level with the system-level analysis in

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transition studies. At this intersection lies the concept of mental models.

Mental models reflect an actor's assumptions of the causal relations within the system of interest, linking the system-level perspective with an individual-level perspective. How actors perceive the system or transition of interest may shape key decisions in a transition process, and may thereby influence rules, norms and institutional practices. Sustainability transitions involve complex decision-making, in which actors rely on limited information regarding the societal transition that they are interested in. Hence, decisions can be made based on limited and differing perspectives on the dynamics of transitions.

Actors are likely to have different views on the socio-technical system based on their experience, knowledge, roles in the system, stakes, and responsibilities. By mapping and comparing mental models, we can identify differences and develop interventions based on these insights (Bruine de Bruin and Bostrom, 2013; Morgan et al., 2002). Identifying similarities in mental models can form the basis for uniting actors with shared mental models to develop a network of collaborating actors across institutions. Furthermore, identifying differences in mental models between actors may pave the way towards bridging differences between actors that obstruct transitions.

In this paper, we introduce the mental model approach, discuss the relevance of mental models for transition researchers, provide guidelines on measuring them, and illustrate relevant types of mental models for sustainability transitions.

2. What are mental models?

Mental models are sets of causal beliefs about the functioning of any system or process, which individuals run in their minds to infer what will happen in a given event or situation (Bostrom, 2017). These cognitive structures reflect an individual's implicit or explicit assumptions about a system or process, which can contradict scientific understandings or be incomplete as they are a simplified representation of reality (Johnson-Laird, 2010; Morgan et al., 2002; Vennix, 1999).

Mental models guide individuals to explain events or processes, facilitate interpretation, and make predictions about future developments (Jones et al., 2014). Mental models influence what kind of information is attended to and how this information is processed and stored (Genter and Stevens, 1983; Johnson-Laird, 1983; Kempton, 1986). Mental models form the foundation for people's attitudes, judgements, decision-making, and behaviour in relation to the system (Biggs et al., 2011; Goldberg et al., 2020; Güss and Robinson, 2014).

A multitude of factors shape the development of mental models, including the individual's contextual environment, education, experience, knowledge, values, and culture (Bender, 2020; Biggs et al., 2011; Carley and Palmquist, 1992; Genter and Stevens, 1983; Hmelo-Silver and Pfeffer, 2004; Klein et al., 2021; Senge, 1992; van den Broek et al., 2023). Due to individual differences in physical and social contexts, learning, and the actor's roles, mental models are likely to differ within and between actor groups. Besides individual-level factors, system-level characteristics (such as institutions, rules, regulations, and norms) are also likely to shape an individual's mental model. For example, if regulations dictate that farmers are not allowed to use toxic pesticides to treat their crops, individual mental models of sustainable farming practices (among consumers, policy-makers, and farmers) will likely echo the negative impacts of toxic agricultural chemicals. Hence, mental models may mirror structural rules, meaning the system-level context can be reflected in individual mental models.

Similar physical, social and institutional contexts can hence result in shared mental models between actors *within* regions (Langan-Fox et al., 2001; van den Broek et al., 2023). Shared mental models contain similar elements or relationships (Jones et al., 2014; Lynam et al., 2012), and may represent a shared cultural understanding and form a basis for joint action (Langan-Fox et al., 2001; Schusler et al., 2003). In the same vein, differences in physical, social and institutional contexts can result in differences in actors' mental models *between* regions. For example, farmers have been found to have region-specific elements in their mental models (Hoffman et al., 2014). Hence, actors in different regions are likely to differ in their mental models about transitions, echoing calls for considering spatial and geographical dimensions of transitions (Truffer et al., 2015; Truffer and Coenen, 2012).

Besides context, learning processes heavily shape the development of mental models, as individuals use their experience with the system or environment to update their mental models (Kelly, 1955). Individuals tend to evaluate new experiences against their pre-existing mental models, maintaining or modifying their mental model if the new information aligns, but they may reject new information that conflicts with their mental model (Narayanan et al., 2023; O'Garra et al., 2021). Increased system experience is associated with more complex mental models (Jaques, 1986; Levy et al., 2018) and the development of more integrated, stable, overarching patterns, reflecting more abstract representations of the system (Carter et al., 1988; Hmelo-Silver et al., 2007; Tanaka and Taylor, 1991; Trafton et al., 2002). Furthermore, how the actor learns about the system influences their mental model; actors with formally acquired knowledge about the system (i.e. learning through educational processes) have different system understandings than actors who acquired their knowledge about the system through informal routes (i.e. learning in daily life or work-settings) (Klein et al., 2021). Hence, actors with different types of experiences in a transition may differ in their mental models.

Furthermore, the actor's, stake, role, or profession in the transition may shape their perceptions of the transition. Such differences may arise from a process of selective attention or selective acceptance of new information. For example, confirmation bias (a tendency to favour information that confirms one's existing beliefs or values; Nickerson, 1998), may prevent actors from being exposed to novel information to change their mental models. Similarly, motivated reasoning (when individuals consciously or unconsciously allow emotion-loaded motivational biases to affect how new information is perceived; Kunda, 1990), may prevent actors from integrating information into their mental models that is incongruent with their role or stakes in the transition. Indeed, mental models can systematically differ between actors such as community members, NGO-staff, managers, and scientists (Aminpour et al., 2020; Vassliades and Jensen, 2016), but within actor-group differences in mental models have also been found (Mehryar et al., 2019; van den Broek et al., 2023). Hence, it is critical to assess under what conditions mental models differ across actors in transitions, and how these differences influence the development of the transition.

3. Why assess mental models in transition studies?

Mental models have been identified as a leverage point for addressing sustainability challenges such as climate change (Goldberg et al., 2020). A mental model approach may be particularly relevant for transition studies as it addresses the call for more work on the connection between the individual-level and system-level in transitions (Köhler et al., 2019). Mapping mental models can help to bridge the individual and system levels in transition in three ways: (1) it provides insights into individual-level perceptions of the system, (2) it can provide a new way to classify actors that goes beyond their roles and institutions and focuses on the (similarities and differences) in the perceptions of the transition among actors and (3) it can bridge or integrate different individual-level perspectives of the system between actors.

The transformative capacity of a mental model approach lies in its ability to provide insights into individual-level perceptions of the system. Mental models reveal an actor's assumptions of the causal relations in a socio-technical system, a key feature for making sense of the external world. By assessing an actor's perceptions of the interrelations within the system, one can gain insights into the actors' systems thinking, a skill that is critical for making complex decisions for sustainability transitions (Lezak and Thibodeau, 2016). Furthermore, mental models reveal an actor's beliefs that shape how the systems and structures are viewed, and what types of solutions or pathways are considered (Ó'Brien and Sygna, 2013). Mental models can, therefore, provide insights into the wide range of possible transition pathways or the cognitive frames related to technological opportunities (Grodal et al., 2023). Hence, how an actor makes sense of a socio-technical system and the interrelations of the different components of a system, will influence how they envision transition pathways and, consequently, may influence their decision-making in relation to the transition. Similar to system dynamics modelling being suitable for studying emergent properties found in transitions (Köhler et al., 2019; Papachristos, 2019), a mental model approach allows the researcher to capture *perceptions* of emergent properties in socio-technical systems. Indeed, transition scholars have called for research focusing on civil society's understanding of transitions, and their perceived role in the political and economic systems that are to be transitioned (Feola and Jaworska, 2019).

Importantly, a mental model approach moves away from a behaviour/social practice perspective as only relevant to consumers, and illuminates the perceptions of diverse types of actors, that are all part of the socio-technical system and need to collaborate for the transition to succeed. Their mental models may (1) provide new insights into the system, (2) reveal obstacles or opportunities for change, or (3) demonstrate similarities and differences in system perceptions between actors (Forrester, 1992; Morgan et al., 2002; van den Broek, 2018).

Mapping mental models in transition studies can provide a new method to classify actors, which goes beyond their roles and institutions, and focuses on the (similarities and differences) in the perceptions of the transition among actors. Current theoretical approaches in transition studies typically classify actors according to their role in the transition, and the logics that drive them to be part of that actor group or network. With the mental model approach, we consider the multiple roles that actors may have in the transition, and how commonalities in beliefs and perceptions can be leveraged to design intervention strategies that resonate with the perceptions of each actor. Similar to Heiberg and Truffer (2022), who suggest grouping actors in terms of value-based proximities, we propose that mental models can form the foundation for classifying actors that transcend their roles or activities. By classifying actors based on shared mental models, a network of actors that surpasses roles and institutions can be created, forming a powerful leverage point to elicit change. This, in turn, allows for the implementation of more targeted strategies.

Such targeted strategies may aim to stimulate first-order learning within existing mental models, or to change mental models through second-order learning (Kolb, 1984; Raven and Geels, 2010). Changing mental models may be particularly valuable when actors' mental models inhibit transitions in static contexts where operations are fairly constant and changes in mental models are critical for the success or direction of a transition. Although changing mental models can be difficult in the absence of a change in the environment (i.e. organizational procedures), experimental and educational approaches to change mental models have been found successful in changing mental models (O'Garra et al., 2021; Shepardson, Roychoudhury, and Hirsch, 2017). For example, by providing regulators with new information that allows them to update their mental model, risk perceptions can change, and acceptance of innovations can be stimulated. Furthermore, specific lobbying and knowledge campaigns can be tailored based on the mental models of consumers, financial institutions, and regulators to stimulate the acceptance of transition-relevant policy (Morgan et al., 2002; van den Broek et al., 2017). Clear expectations and visions can be communicated to researchers, entrepreneurs, and investors whose mental models may currently obstruct transitions.

Mapping mental models can also serve as a tool to bridge perspectives between actors within a transition. Mental models are particularly likely to differ across actors when the system is complex or when dealing with wicked problems for which no single solution exists due to ill-defined or uncertain solution pathways. Furthermore, the various roles actors take in the transition are likely to result in different mental models of the transition. These differences in perceptions may be valuable, as they provide diverse perspectives on the transition that may complement each other. However, differences in mental models may obstruct collaboration between actors and significantly delay urgently needed societal change (van den Broek, 2018; Wanzenböck et al., 2020). Exposing such differences in mental models, by mapping individual mental models and presenting the similarities and differences *within* and *between* actor groups and institutions, may provide a stepping stone for discussions between actors to understand the different perspectives, which could help to integrate knowledge, bridge differences and could foster collaborations between actors to facilitate transition pathways. Furthermore, a participatory mental model mapping method in a group setting can provide actors with insights into each other's mental models and allow them to construct a common understanding of the system. Indeed, mental models can serve as boundary objects that unite stakeholders to integrate different perspectives on the transition (Caccamo et al., 2023).

Although actors' mental models can inform critical decision-making in transitions, it needs to be noted that other factors also shape decision-making processes among transition actors. Decision-making processes may be restricted by current institutional logic, such as

rules, norms, and regulations (Lounsbury, 2002). Furthermore, due to power structures and politics, it is likely that some actors' mental models, and any change in them, are more influential than others due to their social position, role, or critical network function (Avelino and Wittmayer, 2016). The abovementioned intervention points are, therefore, dependent on the transition context that the decision-makers are in. That is, a change in mental models, or alignment of mental models between actors can play an important role in transition-relevant decision-making, but alone may not be sufficient to change macro or meso structures in society. Hence, we advise transition scholars to consider how factors such as power and institutional logic may shape mental models, and affect the influence of mental models on the transition process.


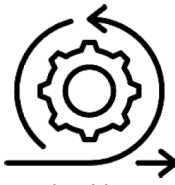
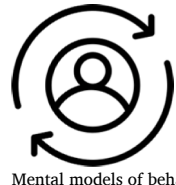
4. How to measure mental models?

Many methods are available to measure mental models, including free-drawing, interviews, free-listing, sorting tasks, attitudinal surveys, and diagram-drawing software (Doyle et al., 2022; Moon et al., 2019). Diagram-drawing tasks may be particularly insightful for transition studies as they provide a visual representation of the participant's assumptions of the direction and strength of causal relations of relevant system variables (Abel et al., 1998; Johnson-Laird, 1983; Wood and Linkov, 2017). A recently developed tool to map such mental models, the M-Tool, facilitates a systematic comparison between (groups of) actors, or assessing change in mental models across different stages of a transition (van den Broek, Klein, et al., 2021, 2021b). This quantitative approach may complement the conceptual or case-study-focused transition literature well, facilitating the further implementation of qualitative-quantitative 'bridging' (Köhler et al., 2020; Truffer et al., 2022; Turnheim et al., 2015).

Mental models can be elicited on an *individual* level to *compare* mental models within and between actor groups. Mapping the individual mental models of relevant actors in a transition helps to understand their perspectives, and similarities and differences between actor groups can be identified. Comparing the mental models between actor groups may reveal critical collaboration barriers that may hamper transitions (van den Broek, 2018). For example, one could compare mental models of users (Schot, 2016) and non-users (Kahma and Matschoss, 2017), or compare other groups that differ in their roles and influence on the transition (Seyfang and Smith, 2007). Such individual-level mental models provide an understanding of the shared mental models across actors and institutions.

Mental model elicitation may also be employed to map *group* mental models to *integrate* the mental models of diverse actors, by eliciting mental models in a group setting to co-develop a joint representation of the system. Such a participatory approach to systems modelling can help tackle system complexity and integrate the perspectives of various system actors. With such an approach, mental model elicitation can be valuable for knowledge co-production (Rouwette, 2016), and this exercise may result in more complete individual mental models (Vennix, 1999; Voinov and Bousquet, 2010). For example, a mental model approach can be implemented in a workshop where actors from a particular sector or value-chain gather different perspectives on a transition (Wojtynia, 2023). Mapping mental models together may provide a valuable exercise for actors to learn about other actors' perceptions, integrate knowledge, and bridge differences. Such an exercise will likely increase the complexity of an actor's mental models and thereby stimulate their systems thinking. Furthermore, mapping group mental models can boost mutual understanding, empathy, and perspective-taking, which is likely to foster trust and stimulate collaboration between actors (Smeenk et al., 2019). Hence, this approach to mental model elicitation

Table 1
Three types of mental models relevant to transition studies.

Mental model type			
	Mental models of the system	Mental models of transition pathways	Mental models of behaviour
Definition	Mental models of the system components and the interaction between these components	Mental models of the current or envisioned solution pathway(s) towards a new system	Mental models of the drivers of a decision-making process or behaviour
Mental model components	System components (actors, institutions, and infrastructure) and the interaction between these components	Available and missing system components that drive or inhibit a transition process	Psychological, demographic, or contextual drivers
Actors of interest	(Academic) experts, policy-makers, the general public, resource users, producers, incumbents	Entrepreneurs, policy-makers, civil society, NGO's, lead users, intermediaries	Consumers, policy-makers, producers, citizens, resource users, financiers, intermediaries
Can help to:	<ol style="list-style-type: none"> (1) increase our understanding of the system that needs to transform (2) facilitate the identification of similarities and differences in mental models across actors (3) reveal misunderstandings of the system 	<ol style="list-style-type: none"> (1) evaluate the barriers and facilitators and their interactions (2) map an actor's perceived role in the transition (3) identify pathways toward a transition (4) assess support for transition pathways 	<ol style="list-style-type: none"> (1) uncover predictors of decision-making and behaviour (2) identify gaps in actors' understanding of their own or others' behaviour (3) reveal differences in decision-making between supporters and opponents (4) provide insights into how transition-interventions can change behaviour.

may serve to bridge perceptions across actors.

5. Types of transition mental models

Individuals hold mental models of a wide variety of systems, processes, or concepts in relation to sustainability transitions. We present three types of mental models that may be relevant to transition studies: (1) mental models of the system, (2) mental models of the transition pathways, and (3) mental models of behaviour. In the following sections, we present these types of mental models and describe how mapping these mental models may be valuable to better understand decision-making in sustainability transitions (see Table 1).

5.1. Mental models of the system

Mental models of the system that needs to be transformed (e.g. a socio-technical or socio-ecological system) consist of the system components, defined as actors, institutions, and infrastructure (Hekkert et al., 2007), and the interaction between these components. A system consists of an interconnected set of elements that is coherently organized in a way that achieves something (Meadows, 2008). These mental models can reflect the dynamics within a socio-technical system (or socio-ecological system), and show the perceptions of the causal relations between different system components. For example, one could map mental models of the perceived causes and consequences of locked-in industries, the perceived relations between components of a socio-ecological system, or how actors perceive new societal developments such as a pandemic (de Ridder et al., 2022). Such mental models may be assessed among the established actors in the socio-technical system, such as (academic) experts, policy-makers, the general public, resource users, producers, and/or other incumbents. Eliciting such mental models can increase our understanding of the system that needs to be transformed by bringing together multiple perspectives, facilitating the identification of similarities and differences in mental models across actors, and revealing misunderstandings of the system among decision-makers. Since changing one component in a system can have cascading effects on the rest of the system, it is imperative to optimise the system understanding among decision-makers in a transition.

An example of the elicitation of this type of mental model can be found in (van den Broek et al., 2023). Here, mental models of the drivers of the Nile perch stock fluctuation were assessed among 185 Tanzanian fishers to understand how these actors perceive the pressures on the Lake Victoria socio-ecological system. Research and stakeholders have identified a need to transform this socio-ecological system into a more sustainable resource management system to ensure the riparian communities' future livelihoods (Njiru et al., 2018; van den Broek, 2019). The resulting aggregated mental model demonstrated high levels of complexity and systems thinking, although this differed across regions (Fig. 1). Furthermore, the mental models of fishers tended to focus on destructive fishing activities such as fishing in breeding grounds, the use of destructive fishing gear and overfishing. These findings suggest that key actors of the Lake Victoria socio-ecological system may feel responsible for their impact on the Nile perch fishery. Such insights into the fishers' mental models can be leveraged to engage these fishers in taking an active role in the transition towards more sustainable

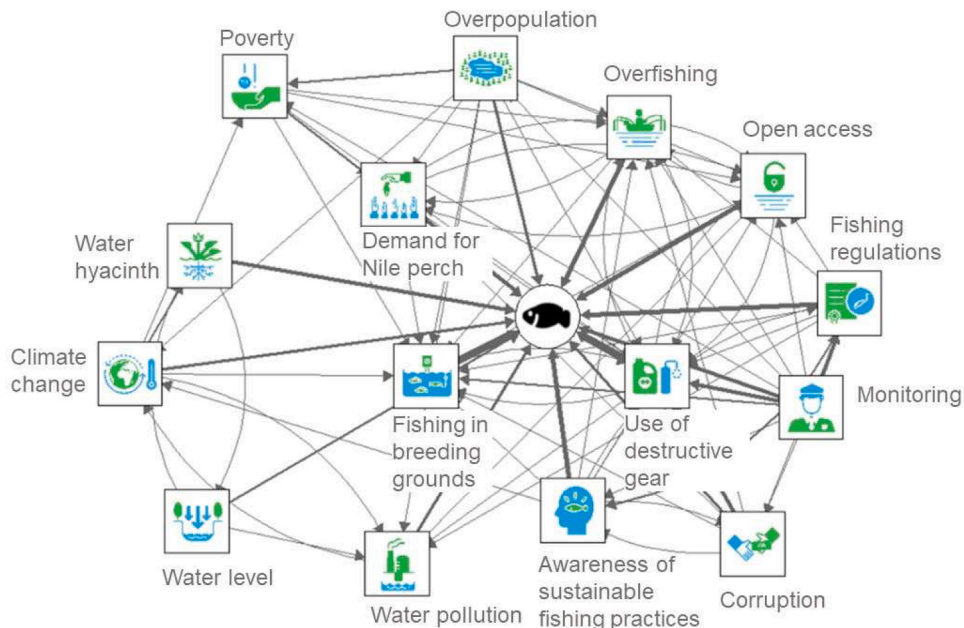


Fig. 1. Example of mental models of a (socio-ecological) system. The aggregated mental model of (N = 185) Tanzanian fishers of the drivers of the Nile perch stock fluctuation (van den Broek et al., 2023). Arrow width indicates the sum of the weights of the connections of the individual mental models (thicker arrows indicate stronger connections). Only connections with a minimum aggregated weight of 20 are displayed.

ecosystem management of Lake Victoria.

5.2. Mental models of transition pathways

Mental models of transition pathways show the current or envisioned routes toward a new system. Transition pathways are patterns of changes in a system that result in new ways of achieving societal functions (Geels and Schot, 2007; Turnheim et al., 2015). These mental models focus on the process leading to a transition and can include the available and missing system components that drive or inhibit a transition process. For example, mental models of transition pathways could focus on the drivers of the energy transition (Böhm et al., 2018, 2019; Doran et al., 2023; van den Broek et al., 2024), a transition from a linear to a circular economy, or a transition from bureaucratic health care to human-centred care. These mental models can be assessed among relevant transition actors, including opponents of a particular innovation or transition pathway, such as entrepreneurs, policy-makers, civil society, NGO's, lead users, and/or intermediaries. This type of mental model can help evaluate transition barriers and facilitating factors and their interactions, understand an actor's perceived role in the transition, identify (new) pathways towards a transition, and assess what type of transition pathways will gain support from which type of actors.

An example of a study examining mental models of a transition is (van den Boom et al., 2023). This study explored mental models of the plant-based protein transition among 214 Dutch consumers. The results demonstrate low levels of systems thinking, indicated by low connectivity between mental model concepts, and a key focus on animal well-being and environmental concern (see Fig. 2). Furthermore, the mental models revealed divergent views on the actor(s) that drive the transition, and consumers with different levels of behavioural engagement with the plant-based transitions focused on different actors and factors in their mental model. The mental models provide insights into consumers' perceived role in the transition, which can inform how one could engage consumers in the plant-based protein transition. For example, consumers who perceive an active role for themselves can be united with other stakeholders who believe in a shared responsibility through working groups or think tanks, to facilitate collaboration on the common goal of reducing the environmental impact of the food system (Obradovich and Guenther, 2016).

5.3. Mental models of behaviour

Mental models of behaviour are mental models of a transition-relevant decision-making process or the drivers of a particular behaviour. This type of mental model can include psychological drivers (such as social norms, habits, or attitudes), demographic factors (such as gender, age, or education), or contextual factors characterise the environment in which the behaviour takes place (such as economic constraints, facilities); similar to behaviour system mapping, (Hale et al., 2022). This type of mental model can be elicited by mapping an actor's mental model of the drivers of their own behaviour to understand an actor's perceptions of the driving forces and barriers to their behaviour (change). For example, policy-makers could map their decision-making process to roll out a transition

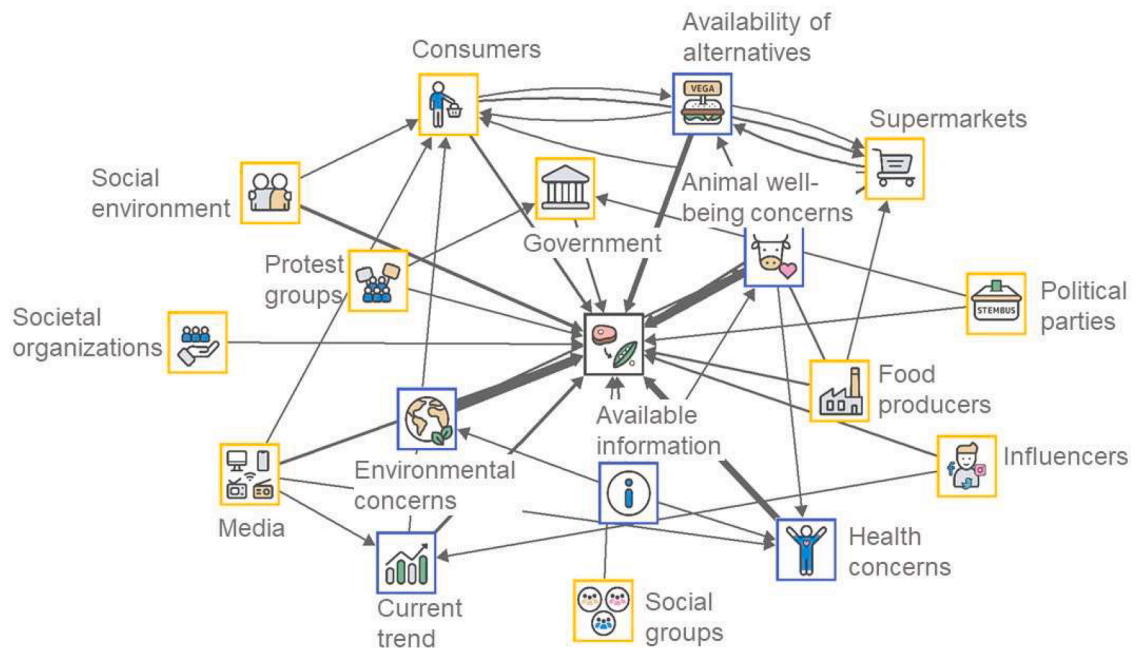


Fig. 2. Example of mental models of a transition. An aggregate mental model of ($N = 214$) consumers of the drivers of the plant-based protein transition (van den Boom et al., 2023). A blue border indicates factors, a yellow border indicates actors. Only connections with a minimum aggregated weight of 20 are displayed.

policy, consumers could show their perceptions of the factors that influence their decision to purchase a sustainable product or adopt innovative technology, or householders can reflect on the factors that inform their energy behaviour (van den Broek and Walker, 2019). Alternatively, actors can map their mental models of the drivers of another (group of) actors' behaviour, to reveal the assumptions of the drivers of other actors in the transition processes. Mental models of behaviour can provide insights into the predictors of transition-relevant decision-making and behaviour, reveal gaps in actors' understanding of their own or others' behaviour, show differences in decision-making between supporters and opponents of a transition, and demonstrate how transition-interventions can influence behaviour. These insights can illuminate leverage points to facilitate such decision-making and behaviour.

Mental models of behaviour have been assessed in a study by (Murken et al., 2024). In this study, 253 Ugandan smallholder farmers mapped their mental model of their decision-making process to invest in agricultural production innovations. This study compared households enrolled in a land demarcation and land registration program with households that did not receive such support. No systematic differences in mental models between the two groups were found. The findings show that tenure security and land certificates are among the least important factors influencing household decisions to invest in improved seeds, suggesting the intervention aimed to stimulate the adoption of improved seeds to accelerate a sustainable agricultural transition was unsuccessful (see Figs. 3). Such findings can inform the evaluation and (re)design of programs aimed at behaviour change to accelerate transitions. For example, interventions that are designed to address factors deemed as more important for the decision in the mental models, such as recommendations (referring to advice on farming practices from family, friends and neighbours), may be more successful in stimulating the adoption of agricultural innovations that can accelerate a sustainable transition.

6. Concluding remarks

This perspective has highlighted the need to bridge the dominant systems perspective in transition studies with an individual-level perspective focusing on actors' mental models. Mental model research can advance transition studies by considering the system perspective of different actors that are at the heart of the sustainability transition. By mapping mental models, transition researchers can gain a plethora of valuable insights that help navigate the human dimension of transitions. This paper has introduced three types of mental models that can help transition researchers foster a better understanding of the (perceptions of) systems, transitions, or transition-relevant behaviour.

Integrating a mental model approach into transition studies can provide insights that can pave the way to develop interventions that can accelerate sustainability transitions. We, therefore, invite transition scholars to explore mental models in their transition domains, such as energy, transport, or food. We encourage researchers to compare mental models across actor groups, different stages of the transition, and different types of transitions, comparing stable or dynamic systems or using mental model elicitation as an intervention tool to facilitate perspective-taking and systems thinking.

By mapping mental models, transition researchers can bridge the individual-system level because (1) it provides individual-level perceptions of the system, (2) it can facilitate a new way to categorise actors that goes beyond their roles and institutions and focuses on the (similarities and differences) in the understanding of the transition among actors and (3) it can serve to bridge individual-level system perspectives between actors. The resulting mental models can provide in-depth insights into actor's decision-making and

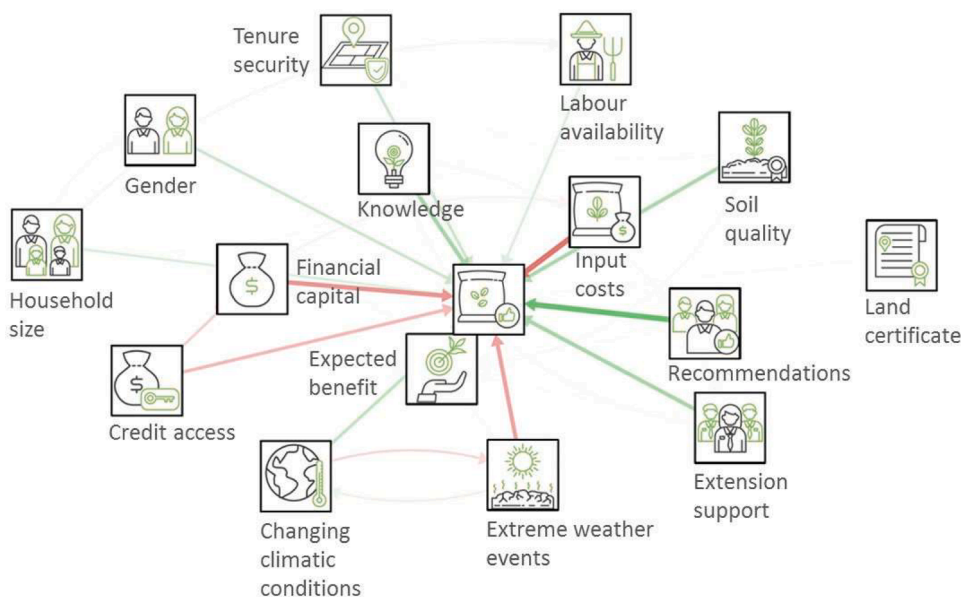


Fig. 3. Example of mental models of behaviour. The aggregate mental model of (N = 253) Ugandan farmers' decision-making process of investments in improved agricultural production (Murken et al., 2023). Note: green arrows display positive influences, red arrows display negative influences. No threshold was imposed, hence all connections are included.

behaviour in transitions, increase our understanding of the system that needs to be transformed, and reveal obstacles or opportunities for change. These insights are critical for understanding how transitions can be steered, fostered, or hindered.

CRedit authorship contribution statement

Karlijn L. van den Broek: Writing – review & editing, Writing – original draft, Visualization, Project administration, Methodology, Investigation, Conceptualization. **Simona O. Negro:** Writing – review & editing, Writing – original draft, Conceptualization. **Marko P. Hekkert:** Writing – review & editing.

Declaration of competing interest

None.

Data availability

Data will be made available on request.

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