IN SEARCH OF A MENTAL-MODEL-LIKE CONCEPT FOR GROUP LEVEL MODELING

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Abstract

In system dynamics, we care about mental model, because it is what we attempt to describe, understand, and improve using computer simulation models. But if we are developing our simulation models from a group of individuals, can we still call what we are trying to study a mental model? The main difference between individual and group level phenomenon is that in a group setting, interaction and communication among individuals shape what is represented in the maps and models. This paper attempts to clarify the object of our group level modeling by surveying existing literature looking for concepts similar to "mental model" at the group level. The survey leads to an insight that what we attempt to represent with our maps and models vary widely by our selection of modeling methods, and how we define our object will draw a different set of theoretical literature.

Key words

Mental model, collective mind, group model building

Relevance of Mental Model Concept in Group Setting

In system dynamics, we create causal loop diagrams and computer simulation models to describe, understand, and improve mental models. The field's popular use of the term "mental model" led to a need to define the term more explicitly. The definition suggested by Richardson, Andersen, et al. (1994) integrated rich theories of human judgment processes involving the means/ends model, Brunswikian lens model, and identification of designer and operator logic. Their study describes how one perceives a system, selects and interprets information, plans action, and modifies goals and models. They argued that a mental model that underlies this process is "not directly accessible or observable, and efforts to elicit mental models distort what is elicited." (p. 182) Doyle and Ford (1998; 1999) attempted to define mental model by emphasizing various attributes of a mental model identified in system dynamics and cognitive psychology literature. With an input from Lane (1999), Doyle and Ford defined mental model of a dynamic system as "a relatively enduring and accessible, but limited, internal conceptual representation of an external system whose structure is analogous to the perceived structure of the system." (p. 414, 1999)

Two key assumptions are shared by the aforementioned studies and many other studies on mental models (for example, Rouse and Morris 1986). The assumptions are that mental models are metaphysical entities residing in individual minds and that we need a method or a tool to access mental models. The method employed by system dynamicists are causal loop diagramming and simulation modeling. However, what is represented in our maps and models does not always come from an individual.

Much of our modeling work is carried out in a group environment. Important decisions in organizations usually made by a group of experts (Steiner and Miner 1977; Walsh, Henderson et al. 1988). Recognizing the importance of group decision making, system dynamics modeling and systems thinking interventions have been actively carried out in group settings, and techniques for group model building have been developed and elaborated (Richardson and Andersen 1995; Vennix 1996; Andersen and Richardson 1997; Rouwette, Vennix et al. 2002; Luna-Reyes, Martinez-Moyano et al. 2006).

A modeling at the group level raises a few questions: if we are developing causal loop diagrams or simulation models from a *group* of individuals, what are we representing with our maps and models? What is it that we are trying to describe, understand, and improve using our methods? Should we still call it a mental model? The main difference between individual and group level phenomenon is that in group settings, interaction and communication among individuals play an important role in determining what is captured through representation methods used by the modeler. In other words, in a group level modeling, what the modeler attempts to portray using maps and models may be quite different from what we call a mental model.

This paper attempts to clarify the issue by surveying existing literature looking for concepts similar to "mental model" at the group level. The definitions of mental model laid out by Richardson, Andersen, et al. (1994), Doyle and Ford (1998; 1999), and Lane (1999) all have strong ties to cognitive psychology. This study will expand its scope of literature review from cognitive psychology to organizational behavior and sociology. The survey leads to an insight that the group-level concepts defined in the literature have different assumptions about the group decision making process, and the paper introduces a framework to identify such differences. The

framework is then applied to the system dynamics context to discuss how different modeling methods implicitly make different assumptions about what is represented in the maps and models at the group level, and how those assumptions connect the different modeling methods to a different set of theoretical literature. The goal of this paper is to promote a discussion on the nature of our maps and models, and to introduce relevant literature to the system dynamics community that will enrich our theoretical understanding of what is generated from our modeling efforts.

Boundary of the Study: Decomposing Maps and Models

This paper will begin by setting a boundary for its theoretical discussion. We use maps and models to access what we loosely call "mental models." If this process of accessing a mental model is decomposed, there is an elicitation of information about the mental model and a representation of the elicited product. The process of generating maps and models is described in Figure 1. The object of interest, or what we often refer to as a mental model, is portrayed in the maps and models, but it is filtered—and likely it is distorted—by the elicitation and representation methods used as well as the modeler's mental models and priors. In other words, the product of our modeling has only a partial relationship to what we intend to study, because it is influenced by (1) the true object of interest, or what we have been calling mental model, (2) the elicitation and representation methods being used, and (3) the modeler's mental model.

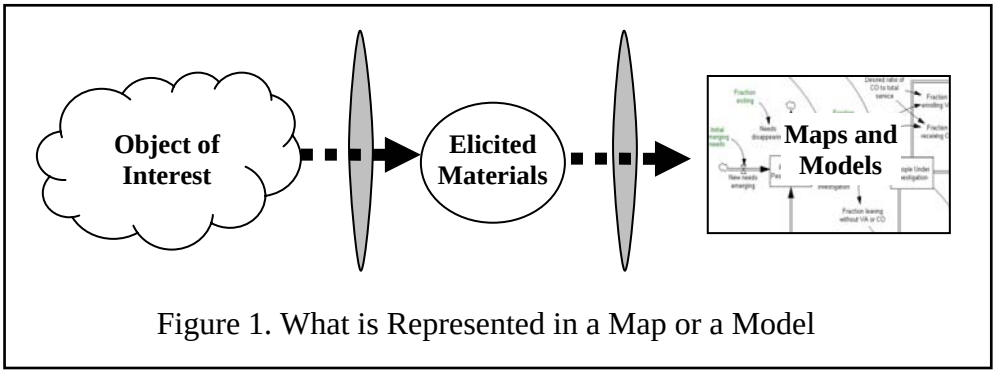


Figure 1. What is Represented in a Map or a Model

The first part of paper will discuss how the existing literature defines the object of interest of our maps and models in a group setting. If the group level phenomenon is different from that of the individual level and if the term mental model does not appropriately capture the object of interest at the group level, we need a group level alternative for the mental model concept.

The second part of the paper will discuss how different lens used by the modeler influence how the modeler defines his or her object of interest. A modeler's lens is a combined product of his or her prior or and a selection of research methods. Different lens will look at different aspects of the object, and thus influence what is represented in the maps and models.

Who Studies Mental-Model-Like Concepts in Group Setting?

There are studies from various disciplines that have been interested in human cognition and interactions as a processor for information and a generator for new decision or action. Broadly stated, these researchers have been exploring the mediator that connects stimulus and response, the decision processor that lies between decision input and decision output, and the model that is used to perceive and understand environment. The processor has been often referred to as a black box, because one cannot directly observe the mental process that individuals or groups go though in converting information into decisions. The black box has been labeled in many different ways, including *mental model*, *schema*, *mind*, *knowledge structure*, and *interpretation system*. For a group or organizational level phenomenon, the concept has been referred to with a qualifier that stands for collectivity, such as *shared*, *team*, or *organizational*. An example would be a *shared mental model* or an *organizational mind*. Group or organizational level studies gained much attention as one saw limitations in the application of individual level analysis to understanding of a group or organizational phenomenon. Levine et al. (1993) noticed that while cognition is frequently collaborative in reality, most experiments and academic studies focus on individual cognition.

Researchers interested in the mental-model-like concept for group environments come from disciplines such as cognitive psychology, organizational behavior, sociology, artificial intelligence, and decision sciences.[1] Their research topics include- but are not limited to- perception, interpretation, attention, memory, knowledge representation and learning, problem solving, and social cognition (Huff 1990). While they all share a common interest in mental-model-like concepts at the group or organizational level, their research motivation is quite different.

Simon's (1947/1997) bounded rationality argument has been one of the major motivations for research focused on information processing. It led to a recognition that different individuals or organizations may come to different decisions in a given environment. Growing interest in what drives these differences motivated researchers to focus on selection and interpretation of information in organizations (Lant 2002). In psychology, a group of researchers (for example, Cannon-Bowers and Salas 2001) studied shared mental model in an effort to improve team performance. They assumed that shared knowledge among team members leads to better team performance, and their research has been devoted to identifying and measuring shared knowledge. The recent growth in the knowledge industry was another reason for the stream of research on information processing and knowledge management in organizations (Gibson 2001). And finally, there are those motivated by decision support. System dynamics researchers and practitioners belong in this category. System dynamicists attempt to understand how decisions are made in order to improve future decision performances. They believe that mental models are inherently limited, and that by using various decision support tools, one can substantially improve the decision making capacity (Forrester 1961; Sterman 1994).

A Plethora of Descriptors for the Black Box

Despite the common interest in defining and analyzing mental-model-like concepts at the group level, there has been a little effort toward cross-fertilization among these disciplines.

[1] There may be an overlap in the listed disciplines as some of these disciplines are highly interdisciplinary in nature. For example, there are psychologists and sociologists who pursue organizational behavior or decision sciences.

Klimoski and Mohammed (1994) noted that while there is a rich opportunity for interdisciplinary cooperation, researchers from different fields rarely cite one another.

One barrier for not seeing inter-disciplinary communication as much as one would hope for is the use of different terms to describe the black box. Researchers are interested what lies between somewhat observable information inputs and decision outputs, but they use different names for this black box. There are several factors contributing to the plethora of terms used to describe the black box. One reason is a lack of communication between researchers. Although it may seem like a circular argument, use of different terms in different disciplines discourages interdisciplinary communication which then widens the language gap. But a more important reason is that researchers using different languages are not looking at the same side of the black box. In other words, what they are discussing is in fact not one concept, but it is more likely different aspects of one concept or different concepts with similar attributes.

In order to discover a group-level mental-model-like concept that is grounded in the established literature, it is necessary to explore various terms and definitions used in the literature to describe the black box. For analytical convenience, the black box will be called "the processor" in this study. The processor includes all aspects of cognition, information and judgment processing in a group. The processor generates one or more decisions or actions in a group. The term processor is comprehensive and general enough to be used as a higher level concept for various mental-model-like concepts used in the literature. However, the term is used only for an analytical purpose in this study, and it is not proposed as a name for mental-model-like concept at the group level.

Lists formulated by Schneider and Angelmar (1993), Klimoski and Mohammed (1994), and Walsh (1995) give a good overview of some of the terms used to describe the processor in the literature. Schneider and Angelmar found over 65 terms from literature under what they call "research on organizational cognition" (p.350). Klimoski and Mohammed listed over 30 terms under "variations on a theme: application of the team mental model concept (p. 408-409)." Walsh listed over 75 terms under "cognition in organization: the language of management theory" (p.284-285). Even considering overlaps among these lists, there are over 200 variations in the terms used. The number increases if we consider those not listed in the aforementioned three studies but identified by other studies.

Table 1 shows some of the words used by researchers to formulate a descriptor for the processor. Although what to include in the list would vary by how the boundary of the processor is defined at the group level, there is a tendency to formulate a term by combining a qualifier describing group-ness of the phenomenon with one or two words describing the processor. In a number of cases, a qualifier that describes some specific attributes of the processor, such as 'situated' (Elsbach, Barr et al. 2005) or 'transactive' (Wegner 1986), is used instead of the ones that show group-ness. If one reviews the previous research on the processor, he or she is likely to come across many of the combinations of the listed words: shared mental model (Levesque, Wilson et al. 2001; Mohammed and Dumville 2001; Salas and Cannon-Bowers 2001), team mental model (Klimoski and Mohammed 1994; Mohammed and Dumville 2001), social cognition (Schneider and Angelmar 1993), collective cognition (Gibson 2001), collective mind (Weick and Roberts 1993), group mind (Wegner 1986; Sandelands and Stablein 1987), etc. How they define and use these terms varies even more. There are cases where the same terms mean significantly different concepts and cases where different terms are used interchangeably to mean one concept.

Table 1. Examples of Words Used to Formulate a Descriptor for the Processor

Qualifiers for Group-ness:	**Name for the Processor:**
Shared Team Social Collective Group Organizational Negotiated …	Knowledge Structure Cognitive Structure/System/Framework Cognition Memory Mental Model Schema Culture Minds Representation Interpretation System Belief Structure/System Social Order Perceptual Filters …
Special Qualifiers: Managerial Situated Transactive …	

Having diverse terms and definitions has some benefits. It demonstrates the fact that researchers have explored various attributes of the processor and exhibited that what they are discussing is in fact not one concept, but different concepts with possible overlaps among them. However, a problem is that there has been little effort to identify how these concepts differ from one another. When a cross-referencing occurs, do the authors mean the same thing?

A failure to clearly identify differences among the terms and definitions resulted in several problems. First, cases of circular definition can be found in the literature. Circular definition exists when a term used to describe the processor is defined with another term for the processor and the descriptor term requires a further clarification of definition. An example would be defining a *team mental model* as a *collective knowledge structure.* Then, what is a collective knowledge structure? Second, there are cases where the same words have different meanings. For example, some use 'shared' to mean *aggregated*. Others use the same word to mean *commonly-held*. It can also mean *communicated* in a group. Which one is it? A more serious problem exists with the level of analysis. Schneider and Angelmar (1993) pointed out that studies based on assumptions and methods from cognitive psychology tend to focus on the individual level of analysis while those based on sociology and anthropology focus on group or organization as the level analysis. They argued that these differences led to problems when interdisciplinary integration results in use of the same term to describe cognitive phenomenon at different levels of analysis. Finally, there has been confusion about what the content of the study is: is it about a static product such as knowledge or memory or is it about process such as interaction and communication in a group? It is an important distinction, because selection of measurement and analysis methods depends on the form of the content being studied.

The most extensive work on classification of the processor concepts can be found in Schneider and Angelmar (1993) and Walsh (1995). The former categorized previous studies on the processor by the level of analysis (individual-group-organization) and the form of cognition (structure-process-style). The latter used the level of analysis (individual-group-organization-industry) and the content of knowledge structure (representation-development-use). These two studies provided a useful framework for organizing various processor concepts and addressed the

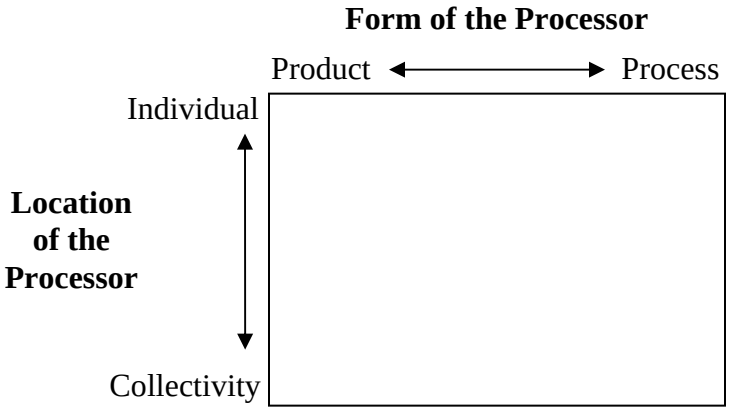
problem of confusion in level of analysis and in the attributes of the processor being studied. However, there are two issues that require further consideration:

First, some studies on the processor cannot be clearly categorized by level of analysis, especially when studies are interested in the group or organization level processors. For example, if cognition occurs at the individual level, but sharing of knowledge occurs at the group level, what should be the level of analysis? The answer is closely related to the content of the study. Is the focus of the study cognition at the individual level or sharing at the group level? What if one phenomenon cannot be studied without looking at the other? In other words, because the phenomenon at different levels interact and influence one another, it is not always possible to identify one study with one level of analysis. Second, we cannot directly use the form or the content categories proposed by the aforementioned studies, because the categories were introduced to organize the previous research on the processor rather than the definitions of the processor. For example, Walsh's (1995) three-tier model categorized the previous studies on knowledge structures into those that focused on representation, development, or usage aspects of knowledge structures. Since this paper is interested in the organization of different processor concepts rather than research objectives of the previous studies, it was necessary to develop a framework that can be used to identify different contents of the processor. To address these issues, the author developed a framework that has been modified from the aforementioned works.

A Model to Capture Conceptual Differences in the Terms

The framework proposed in this study is different from the previous works in that it is based on the idea of a continuum (See Figure 2). It recognizes that it is not always easy to identify different terms and definitions with clear-cut categories.

Figure 2. Framework of Location-Form Continuum



One dimension of the continuum is the *location of the processor,* or where the black box is located. At one extreme, the entire processor could be located at the level of an individual. In

other words, thinking is done at the individual level only, and even in a group setting, the locus of study is on individual mind process. At the other extreme, the entire processor could be assumed to be located at the collective level. The collective level refers to the group, organization, or even industry, and it is the collectivity that receives information, processes information, and generates action. A similar criteria is briefly mentioned by Lant (2002). He explained that the "locus of organizational cognition" (p. 355) is dependent on the perspectives of organizational cognition studies, and he identified two key perspectives. In the information processing perspective, organizational cognition takes place in individual minds, while from the enactment perspective, it takes place at the collective level.

The location of the processor is an alternative framework to the level of analysis. It is different from level of analysis in several ways. First, it explicates researchers' assumptions about the locus of thinking. Second, it differentiates where thinking takes place (i.e. location of the processor) from where thinking is observed (i.e. level of analysis). Third, by using a continuum, it acknowledges that definitions for the processors cannot be always clearly categorized into one of the two locations.

The second dimension of the proposed continuum is the *form of the processor*. At one extreme, researchers are interested in a static product form such as memory and knowledge. At the other extreme, researchers are interested in process that changes in the course of group dynamics. Examples would be communication and interaction. Again, there are studies that define the processor in terms of both products and processes. Therefore, the continuum idea will be useful to deal with such a problem.

With this framework, it is now possible to organize different terms and definitions for the processor in the continuum.

Terms and Definitions and their Positions on the Continuum

Cognitive psychologists have been inclined to use the term *mental model* or *cognition*. Although *mental model* became a wide spread term and is used in general to mean *thinking*, many researchers using the term, including Doyle and Ford (1998), reference back to Johnson-Laird (1983)'s book *Mental Models*. When used in a group setting, a mental model is often referred to as a *shared mental model* or a *team mental model*. Cannon-Bowers and Salas have been working on the development of a shared mental model concept since early 1990 (Cannon-Bowers, Salas et al. 1993). They define a shared mental model as "knowledge held by a team member that is either compatible, complementary, and/or overlapping with teammates" (Salas and Cannon-Bowers 2001: p.87). Similarly, Klimoski and Mohammed (1994) define a team mental model as "what is being shared and operating among team members as a collectivity" (p. 414). In the same study, they use the term *shared cognition* interchangeably with *team mental model*, and emphasized that a team mental model or shared cognition is one's knowledge about his or her team members' knowledge and is different from unarticulated subconscious knowledge. In other words, their definition of team mental model is narrower than that of Cannon-Bowers and Salas, because to qualify as a team mental model, the knowledge not only has to be shared among team members, but in addition the fact that it is being shared must be known to all members. Related to these definitions, Smith-Jentsch, Campbell et al. (2001) used the term *mental model of teamwork,* to mean "individual's understanding of the components of teamwork that are critical for effective team performance" (p.180). In all these aforementioned

definitions, location of the processor is within individuals, and the processor is in product form, i.e. knowledge. In sum, these studies are interested in the part of individual knowledge that is shared among the team members. Therefore, the position of their definitions in the continuum framework is at the individual-product ends (See Figure 3).

In contrast to the above definitions, *shared mental model* defined by Levesque, Wilson et al. (2001) moves slightly towards the collectivity-process ends of the continuum. Their interest is in overlapping cognition which they associate with enhancement in team performance. Since overlapping can only occur though coordination and communication, they look at interaction leading to convergence of mental models over time. In other words, while mental models are primarily located in individuals, the process of sharing modifies the individuals' mental models.

When the location of the processor is at the individual end of the continuum, the same concept may be used to describe a phenomenon at both the individual level and the group level. One example would be the concept of a *schema*. Many definitions of schema can be found in the literature (Fiske and Taylor 1984; Walsh 1995; Elsbach, Barr et al. 2005), but in general, schemas are defined as cognitive templates or simplified representation of knowledge that are used to identify elements of a situation and relationships between these elements (Elsbach, Barr et al. 2005). Because schemas are individually held, are relatively stable, and are seldom observed, schema discussions rarely differentiate between the individual and group/organizational level processes. A concept similar to schema is *knowledge structure*. According to Walsh (1995)'s definition, "a knowledge structure is a mental template that individuals impose on an information environment to give it form and meaning" (p. 281). If positioned in the location-form framework, schema and knowledge structure would be located at the individual-product ends of the continuum.

There is a group of researchers who use the term cognition at the collective level. Nicolini (1999) identifies *organizational cognition* as "social process of cognition and thinking at organizational level" and differentiates it from "cognitive process at individual level in organizational setting" (p.834). He makes it clear that organizational cognition is a social process and the locus of the processor is at the collectivity. However, Tegarden and Sheetz (2003) use the same term to mean "shared understanding that managers have in common with each other" (p. 114). Compared to Nicolini's perspective, Tegarden and Sheetz's organizational cognition closely resembles the shared mental model defined by Cannon-Bowers and Salas (1993). There are others who prefer to use the terms *collective cognition*. Gibson (2001) defines collective cognition as the four phases of accumulation, interaction, examination, and accommodation that take place at the group level. Langfield-Smith (1992) also emphasized that collective cognition is an outcome of social process or collective encounter, and stressed its transitory nature. With an exception for Tegarden and Sheetz's, the definitions of organizational or collective cognition can be positioned near the collectivity-process ends of the continuum.

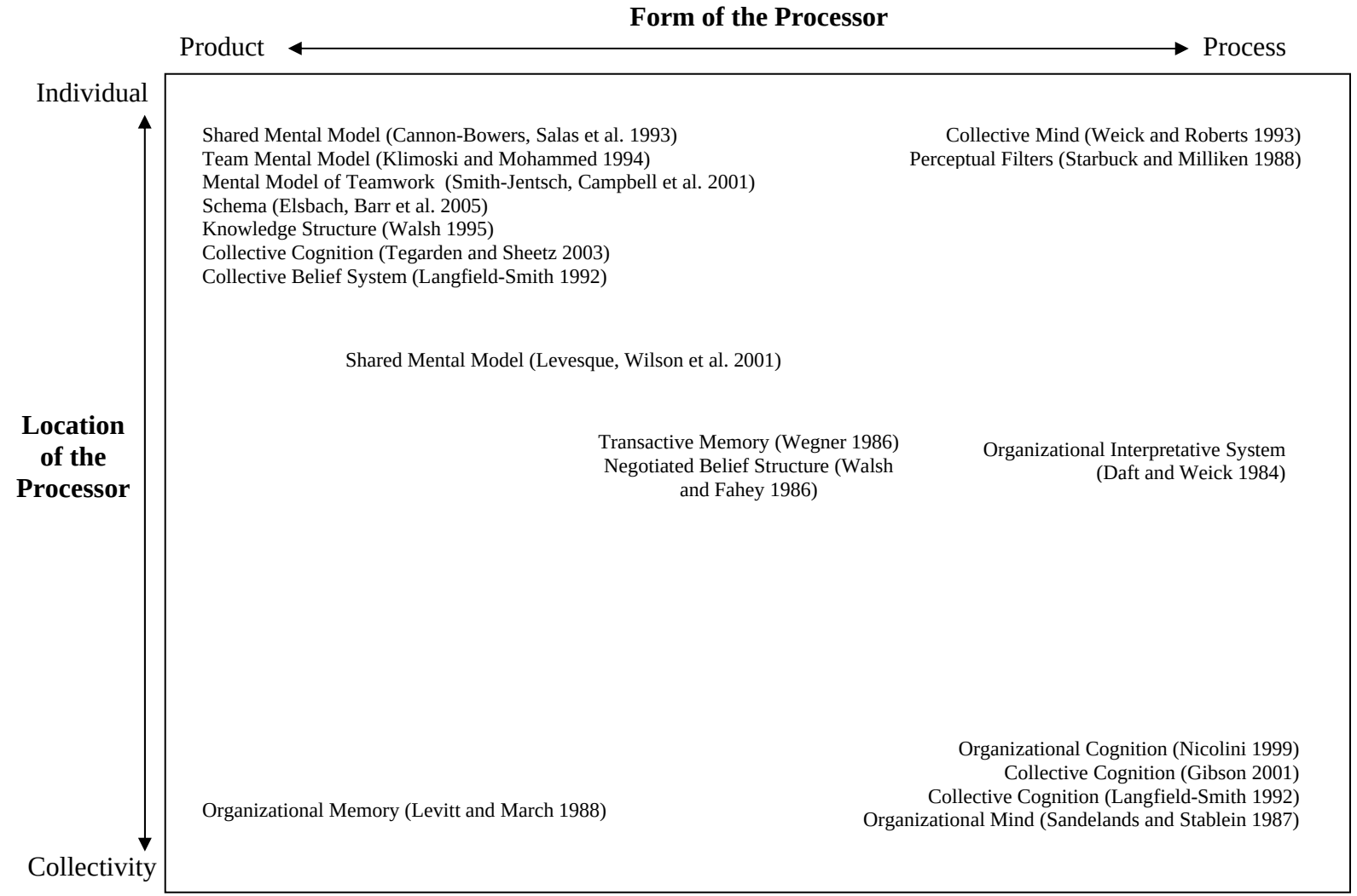
Weick and Roberts (1993) called the processor *collective mind* or *group mind*. They defined a collective as individuals in a group who inter-relate their actions with care, and mind as an activity and not as an entity. They explained that collective mind is located in the process of "heedful interrelating" (p.361). Therefore, their definition can be interpreted as individually located processors which operate during an interrelating process among the individuals. This definition thus falls on the individual-process side of the continuum. A similar term used is *organizational mind*. Sandelands and Stablein (1987) defined organizational mind as an ideational process that is carried out by organizational behavior. They contrast their view with

others who regard mind as "a substance or static pattern of relationships" (p.138), and emphasized that complex interaction of ideas is at the heart of the organizational mind. According to Sandelands and Stablein, organization *is* mind, and the criteria for it to qualify as mind should be different from that for the human mind. Their definition of organizational mind is clearly on the collectivity-process ends of the continuum. As a theory of group mind, Wegner (1986) proposed the idea of *transactive memory*. He defined it as "a set of individual memory systems in combination with the communication that takes place between individuals" (p.186). It is cognitive interdependence among team members: a way that individuals use other people's memory as an external memory. In organizations, transactive memory is a "shared system for encoding, storing, and retrieving information" (Wegner, Erber et al. 1991: p. 923) and Wegner explains that it is neither memory of individuals nor process of interaction among these individuals, but it is combination of these two. Therefore, the position of transactive memory would be somewhere in the middle of the product-process and the individual-collectivity continuum.

Shared belief system and *collective belief system* are used interchangeably with many of the terms listed previously. Usually they are regarded as a higher level construct that embraces attributes of the processor discussed by different researchers, and when used in the literature, the definition for shared belief system or collective belief system is rarely provided. One special case is the study by Langfield-Smith (1992). She differentiated the collective belief system from collective cognition and explained that collective action or decision can exist without a collective belief system as long as collective cognition takes place. In other words, Langfield-Smith regarded collective belief system as shared value among a group of people. In contrast to his definition of collective cognition, the definition of collective belief system places the term towards the individual-product ends of the continuum.

In discussing the collective belief system, Walsh and Fahey (1986) and Walsh, Henderson et al. (1988) focused more on the political process within a group. They posited that power differences among individuals influence whose knowledge structures are better represented in the group's collective knowledge structure. They called the aggregated model a *negotiated belief structure*. The position of the negotiated belief structure in the continuum framework is somewhat less clear. Although the negotiated belief structure is a knowledge structure, i.e. a product, what generates the product is a political process of negotiation and influence. The location of the processor is also a combination of individual and collectivity, because while negotiation takes place in collectivity, influence of powerful individual in creating negotiated belief structures is substantial.

Figure 3. Positions of the Terms Used in the Literature to Describe the Processor



There is a group of researchers who emphasize interpretation and meaning-creation aspects of the processor. Daft and Weick (1984) called the processor *organizational interpretation systems*. They defined it as "the process of translating events and developing shared understanding and conceptual schemes among key managers" (p.286). Daft and Weick explained that organizations differ in their attitudes towards interpretation and these attitudes are determined by managers' assumptions about the environment and by the organization's intrusiveness into the environment. A similar term used is *organizational sensemaking* (Weick 1995). Starbuck and Milliken (1988) combined the process of noticing and sensemaking and called it *perceptual filters*. Noticing is a process of looking for information that matters, and Starbuck and Milliken explain that individual's previous experiences influence what information he or she selects to look at. Sensemaking is creating meaning from the selected information, and this process is also influenced by one's previous experience. Perceptual filters operate at the individual level, but the perceptual filters of executives or managers play a critical role at the organization level. Daft and Weick's organizational interpretation system and Starbuck and Milliken's perceptual filters are both process-oriented concept. However, while the former assumes interpretation at both the individual and collective level, the latter is about individual interpretation. Therefore, their positions the continuum differ in terms of the location of the processor.

Levitt and March (1988) used the term *organizational memory* to describe the organizational learning process. It is defined as routines, rules, and procedures in organizations where organizational members' experience and knowledge are accumulated and maintained. This organizational memory is an artifact of organizational behaviors and is separate from members of the organization. This leaves organizational memory at the product-collective ends of the continuum.

Modeling Methods and the Processor

The survey of terminology and definitions for the processor reveals that while researchers appear to discuss similar concepts, there are subtle differences among the concepts discussed. When placed on the continuum framework, the differences become explicit and clear. The literature review and the positioning exercise in the previous section lead to the conclusion that the mental-model-like concept at the group level may not be one concept, but are more likely different concepts along the continuum. Then how do the conceptual subtleties described in the previous section allow system dynamicists to clarify what is represented in our maps and models?

Maps and models are created, because we are interested in describing, understanding, and improving the processor. However, the maps and models are not "the processor" per se, because they are created from observable behaviors of individuals or a group which only partially reflects the processor. What is represented in our maps and models is a combined product of the processor of individuals or a group subject to study, the modeler's own mental model, the modeler's preferred methods of eliciting and representing the processor.

In this section, five ideal types of group-level modeling modes will be identified. Each modeling modes makes different assumptions about the processor's location and form. In other words, depending on the modeling modes used, the modeler will approach different aspects of the processor.

The variation along the continuum is mainly determined by when and how a modeler or facilitator intervenes with the subject or client group. The modeling process can be divided into the elicitation, representation, and reflection/analysis phases. In the elicitation phase, the raw data about the processor is collected from the subject of the study. If a system dynamics modeler attempts to understand a mental model of an individual, the modeler would interact with the subject or the client in order to obtain data that tells something about the person's perception of the system. A typical method for elicitation includes interview, survey, content analysis, and observation. In the representation phase, the elicited part of the processor is represented using causal loop diagrams or formal simulation models. Then in the reflection phase, the represented maps or models are analyzed for insights.[2] Group level modeling adds another layer to the process. There is a phase where individual level processors are integrated into a group level processor. And when and how this integration takes place shapes what end up being elicited from the subject or the client group and represented in the maps and models.

The following is a list of five ideal modes of group level modeling. Each modeling modes are characterized by (1) a different sequence of the four phases of elicitation, integration, representation, and reflection, and by (2) main player in each phase.

Mode 1: Interview with Individuals in a Group

A modeler can create a map or a model from the data collected from interviews of individuals in the subject or the client group. In this case, the elicitation phase comes prior to the integration phase. In order to understand the group level phenomenon, the modeler integrates the data collected at the individual level. When data is collected at the individual level and combined later by the modeler, there is no group interaction taking place among the individuals during the data elicitation or integration period. In both phases, it is the modeler who takes the leading role. In this modeling mode, the modeler is studying the processors located at the individual level and the form of the processor is static knowledge or memory related to a problem (See Figure 4).

Mode 2: Content Analysis of Data Collected from Individuals in a Group

A modeler can create a map or a model from the data collected by individuals in the subject or the client group. As in the modeling mode 1, the elicitation phase comes prior to the integration phase, but the elicitation phase is now controlled by the subject or the client group. In order to understand the group level phenomenon, the modeler integrates the individual level data provided by the clients. Again, there is no group interaction taking place among the individuals during the elicitation or integration period. The position of the processor being studied is similar to the modeling mode 1: the individual-product end of the continuum. Integration is done either by modeler identifying overlapping structures from individual mental models or by combining all the structures mentioned by every individual. If the former is the case, what the modeler is trying to capture is similar to that of a *shared mental model* or *team mental model* defined by Cannon-Bowers and Salas (1993) and Klimosky and Mohammed (1994). If the latter is the case,

[2] What is represented in maps and models are determined by elicitation, integration, and representation phase. However, if a modeling is a reiterative process, reflection phase also influence what is represented in the maps and models.

the term *aggregate*, *congregate*, or *composite* used by Bougon (1992) may replace the term *shared*.

Mode 3: Content Analysis of Data Collected from a Group Process

When individuals in a group interact and communicate, integration takes place prior to elicitation. The degree of modeler's participation in the integration phase determines the nature of the elicited product. In the modeling mode 3, a modeler does not observe interactions among individuals during the integration process. Rather, the integrated output from the group process is compiled by the subject group and it is later presented to the modeler. In other words, the modeler does not have influence over the elicitation or integration process, and it is the subject or the client group who takes the leading role in these modeling phases. In this case, the processor studied by the modeler is at the product-collective end of the continuum. It is a product, because the modeler can only study an artifact of an organizational process. The processor is located at the level of collectivity, because the modeler is forced to see the data as it is collected from the group without having access to individual mental models.

Mode 4: Non-participant Observation of a Group Process

In some cases, a modeler has access to the integration process and is able to observe group interactions and is thus able to collects data during the observation. The degree of modeler participation in the integration phase differentiates the modeling mode 4 from 5. When a modeler observes the group process and collects data during the observation, it is a non-participant observation method. The processor studied is located somewhere in between the individual and the collectivity. It is so, because the interaction of individuals within the collectivity is where the processing takes place. In terms of the form of the processor, a modeler as a passive observer will focus more on the process than the product, because instead of exploring what one may think, the modeler is paying attention to conversation taking place in the meeting. What is being said in the group process is often shaped by one's motivation to influence others' and a substantial part of this is inseparable from the political and social process.

Mode 5: Modeler-leading Group Process

Finally, there is a modeler-leading group process, as in group model building (Richardson and Andersen 1995; Vennix 1996; Andersen and Richardson 1997). In this mode, the modeler plays an active role in the integration process. An active modeler becomes a leading facilitator and induces the subject or client group to discuss parts of their mental models that are more relevant or important to the problem at hand. The modeler also explores where the mental models conflicts, and by promoting group communication, the modeler allows the group to come to an agreement. As in the non-participant observation, the processor studied is located somewhere in between the individual and collectivity. However, an active modeler may have access to a product form of the processor as well as a process form, because the modeler can probe knowledge and memory from individuals in the group.

The five modeling modes and their modeling sequences are summarized in Table 2. The parentheses indicate the main player of each phase, which is either modeler or the subject/client group. Figure 4 summarizes the location and form of the processor studied by each ideal modes of modeling.

Table 2. Five Ideal Modeling Modes

	Modeling Sequence			
1. Interview with individuals in a group	Elicitation (modeler)	Integration (modeler)	Representation (modeler)	Reflection (both)
2. Content analysis of data collected from individuals in a group	Elicitation (subject)	Integration (modeler)	Representation (modeler)	Reflection (both)
3. Content analysis of data collected from a group process	Integration (subject)	Elicitation (Subject)	Representation (modeler)	Reflection (both)
4. Non-participant observation of a group process	Integration (subject)	Elicitation (modeler)	Representation (modeler)	Reflection (both)
5. Modeler-leading group process	Integration (both)	Elicitation (modeler)	Representation (modeler)	Reflection (both)

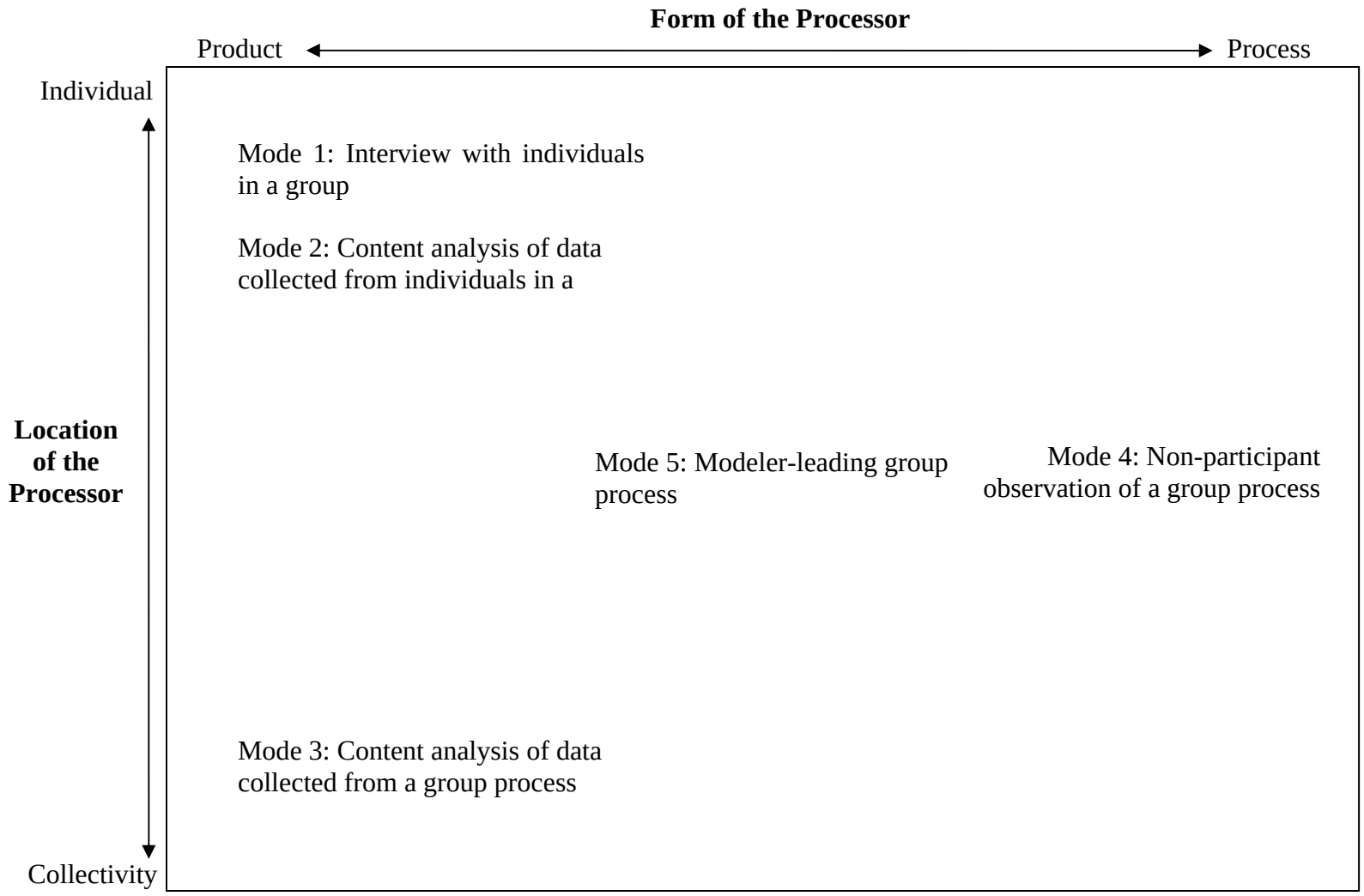
Implications for the System Dynamic Group Level Modeling

The five ideal types of modeling mode implicitly make different assumptions about the processor. In other words, depending on our selection of modeling modes, we will look at different aspects of a black box.

In real modeling practices, we rarely resort to one type of modeling mode. Rather we use combination of different methods. A modeler using multiple methods will move along the location-form continuum exploring different aspects of the processor. Depending on the location and form of the processor, a set of theoretical literature relevant to the processor will be different. For example, if a modeler is interviewing individuals in a group, the processor is relevant to a set of literature on the individual-product end of the continuum. Schema (Elsbach, Barr et al. 2005), knowledge structure (Walsh 1995), and collective cognition (Tegarden and Sheetz 2003) would be a few examples. On the other hand, if the modeler is conducting a modeler-leading group process, he or she might want to look at a different set of literature such as Walsh and Fahey (1986)'s work on negotiated belief structure.

Although an organization of the processor using the location-form continuum provide a useful guide to relate the processor assumed in our maps and models to the theoretical literature, a co-location of a map-building method and a theoretical work does not mean that the two are assuming the exactly the same processor. The co-location is a loose categorization, since the location and the form are not the only criteria defining a processor. A similarity in the location and the form does not necessarily guarantee the two processor share the exactly the same characteristics.

Figure 4. Positions of the Processor Represented in SD Maps and Models



Conclusions and Limitations

This paper attempted to find an alternative concept to "mental model" in a group environment. The concept was called "the processor" for the convenience of the analytical discussion. In order to ground the alternative term in the literature, this study surveyed terms and definitions that have been used to describe the processor at group or organizational level.

The main finding from the survey was that different terms used to describe the processor have differences in terms of their assumptions about location and form of the processor. This finding led to an insight that what system dynamics modelers try to understand, represent, and improve in a group intervention processes is not a single concept that parallels mental model at individual level. Depending on the data collection and integration methods, the concept can vary in terms of the location and form of the processor. In other words, we cannot have one single term that describes the mental-model like concept at the group level, because sometimes we are studying an interaction process within a group and at other times we are looking for knowledge held by individuals in a group.

This study concludes without providing "the" alternative term that can be used like "mental model" in group environment. However, this study highlights that the substance of our study may differ despite we are all engaged in system dynamics group intervention, and it is important to explicitly recognize what is represented with our maps and models.

The location-form continuum framework proposed in this study has some limitations. Because it uses the concept of a continuum, determining relative positions of different terms in the space requires the author's subjective interpretation of the definitions given in the literature. While some definitions have clear statement of location and forms of the processor, there are other definitions which are conceptually vague on these factors. If that was the case, more in-depth study of the literature was carried out for clarification.

The scope of literatures reviewed in this paper may pose another problem. There are terms and definitions relevant to the processor not included in this study. However, the main goal of this paper was to show the diversity of terms used to describe the processor, and to highlight the subtle differences among these terminologies, and to propose a way to organize them.

Finally, it must be noted that there is a difference between what we are interested to study and what has been actually elicited and represented using our maps and models. We may say we are trying to understand, describe, and improve mental model. If we are studying a group level phenomenon, we may say we are interested in eliciting shared mental model, or negotiated belief structure, or whatever the descriptor we prefer to use. However, we must stay away from referring to our maps and models as mental models or the similar concept at the group level, because maps and models are only representation tools used by modelers.

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