TOWARD A METHODOLOGY FOR THE MEASUREMENT OF KNOWLEDGE STRUCTURES OF ORDINARY PEOPLE
The Conceptual Content Cognitive Map (3CM)

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ABSTRACT: Mental models guide people's perceptions, decisions, and behavior regarding environmental problems and other issues. Hence, understanding these models would aid in understanding how people perceive problems, in determining how information may be most effectively shared, and in designing strategies for behavior change. Given this need for assessment, it would be helpful to expand the repertoire of available measurement approaches. The 3CM method, based on an extended theory of cognitive maps, is proposed as a new approach to assessing people's mental models. This approach is unique in its emphasis on the notion of "ownership" of the concepts that serve as landmarks in the cognitive map. Two recently developed implementations of the approach, each suited to different contexts and purposes, are described. Preliminary results suggest that the approach meets the criteria of construct validity, of being user friendly, and of providing information complementary to that obtained using traditional measures.

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People's knowledge about environmental issues is, at least in principle, a central concern in environment and behavior research. A perusal of recent issues of *Environment and Behavior*, for instance, uncovers numerous articles exploring the relationships among environmental knowledge, behavior, and attitudes (e.g., Gamba & Oskamp, 1994; Syme, Beven, & Sumner, 1993; Vining & Ebreo, 1990). Interestingly, many of these studies focus not so much on what people know about a given topic or on how they use their knowledge but rather on what people do not know—that is, on the gaps in their knowledge.

Identifying these gaps in environmental knowledge is indeed important. An environmental educator, for instance, hoping to design an effective intervention, must first discover the types of information people need. By itself, however, the identification of knowledge gaps does not provide sufficient direction for devising education and communication strategies. Another important factor to consider is an individual's existing mental model, or "cognitive map," of the issue.

Cognitive maps (described more fully in the next section) are hypothesized knowledge structures embodying people's assumptions, beliefs, "facts," and misconceptions about the world. These assumptions and beliefs, in turn, provide a framework for interpreting new information and for determining appropriate responses to new situations (Kaplan & Kaplan, 1982/1989). Hence, current cognitive maps can exert significant influence over both how new information is understood and whether or not that information will impact behavior. Bartlett (1932), for instance, found that people tend to ignore or reinterpret new

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information that contradicts their current understanding. Others have found that even when contradictory information is attended to and processed, it may be stored in relative isolation; this "inert" knowledge is not integrated with existing cognitive maps and hence is presumably less accessible and less likely to influence thought and behavior (Bereiter & Scardamalia, 1985; Schank, 1991).

Because information provided does not equal information received, it is misguided to assume that one can identify the gaps in people's knowledge and simply provide the information necessary to fill these gaps. Rather, effective communication and education require an understanding of people's existing cognitive maps so that information may be framed in a way that encourages people to notice and integrate the new information rather than ignore or reinterpret it. To borrow a phrase from the education field, it is necessary to know "where they're at."

The importance of assessing people's cognitive maps is not limited to education efforts; indeed, many situations exist in which such an assessment would be beneficial. Nowhere is this more apparent than in the context of "wicked" environmental problems (Mason & Mitroff, 1981). These types of problems are complex, involve many parties, and have no easy solutions or right answers. In spite of this complexity, decisions must be made and, increasingly, they must be made by interdisciplinary teams comprised of people whose cognitive maps of the problem differ. Under such challenging circumstances, the benefits of externalizing decision makers' maps—bringing them to the surface so that they might be examined, compared, and discussed—cannot be underestimated. Doing so can expand people's conceptualizations of the problem, pinpoint areas of disagreement, highlight areas of potential agreement, and provide a foundation on which to base a discussion and, ultimately, a decision.

Extending cognitive map assessment from the decision makers to the public (or, depending on the context, the "locals" or "indigenous people") may also provide valuable information. Indigenous people, for example, have been shown to have remarkably detailed knowledge of environmental processes

(Clarkson, 1970; Goland, 1993) and the common failure of ignoring and even disdaining this kind of local information has repeatedly been shown to have disastrous consequences (R. Kaplan, 1993). As Parker (1992) points out (in reference to natural resource management in a Third World context), "Professionals in the United States have a lot to offer, but also a lot to learn" (p. 23). Assessment of locals' cognitive maps could contribute important new input to decision-making and problem-solving processes; further, integration of local knowledge in the decision-making process would presumably facilitate wider acceptance of the solutions that are finally reached.

Given the many situations where understanding people's cognitive maps of environmental issues would be beneficial, it is striking that more attention has not been given to assessment of these maps. A premise of this article is that this relative neglect stems not from disinterest, but from a lack of appropriate measures. Several assessment tools do exist and are used in such realms as science education, educational psychology, and anthropology. However, as will be pointed out below, these existing methods are limited in their capacity to assess crucial aspects of individuals' knowledge. Consequently, over the past few years, we have begun developing a method for assessing cognitive maps: the conceptual content cognitive map (3CM) method.

The 3CM method falls somewhere between traditional quantitative and qualitative methods and borrows from techniques used in "wayfinding" research. Researchers exploring how people perceive and move through a particular geographical environment commonly ask study participants to draw pictures of the region; these drawings are then used to assess the participants' cognitive maps of the area (e.g., Appleyard, 1970; Tversky, 1991). 3CM extends this technique by asking people to draw their cognitive maps of conceptual themes (e.g., environmental topics or problems). In the process, the 3CM approach does not purport to distinguish truth from falsity or belief from fact; it simply strives to measure what is already in an individual's head, related to a particular topic, as opposed to what one might have wished were there. The 3CM method is based on an extended theory of cognitive maps: one that uses the notion of the cognitive map in a relatively unfamiliar way. Although the cognitive map concept is traditionally used to characterize only spatial knowledge, it will be argued that it is a useful way to characterize knowledge in general. It is further argued that knowledge in cognitive maps is organized in a coherent and useful way such that the organization provides a good indication of how the knowledge is likely to be used.

The next section provides a theoretical overview, with special attention to aspects of the extended cognitive map theory that are pertinent to measurement design. Following that is a discussion of existing techniques for assessing cognitive maps and the problems associated with these techniques. Finally, we present the 3CM method in detail. Two different implementations of the method are discussed: an open-ended version and a structured version, each suited to different contexts and purposes. A variety of examples are provided to illustrate the range of contexts in which the method has been used.

TOWARD A THEORY-BASED MEASURE

PROPOSED THEORETICAL BASIS: THE COGNITIVE MAP AS A GENERAL PURPOSE KNOWLEDGE STRUCTURE

Many of the most fundamental human cognitive processes, including prediction, decision making, and planning, would not be possible if people did not have some way of internally representing the external environment. Mental, or cognitive, models of both physical and conceptual aspects of the world are necessary to enable people to think about things that are not present in the environment and to access information related to the problem at hand. These models must both represent important objects and concepts and code the relationships (e.g., causal, temporal, spatial) among these objects and concepts. The term *cognitive map* is used to denote such mental models. Cognitive map theory was first applied to mental representations of the physical environment (Tolman, 1948) and most cognitive map theories and research have continued to focus on spatial contexts (for reviews, see Evans, 1980; Holahan, 1986; Russell & Ward, 1982). In recent years, however, the notion of the cognitive map has been extended to include conceptual as well as physical environments (Kaplan & Kaplan, 1982/1989; Siegel & White, 1975) and cognitive maps are now referred to in a variety of fields such as anthropology (Furbee & Benfer, 1983), organizational management (Cossette, 1992), education (Anderson, 1977), and political science (Bonham, 1993).

The growing popularity of the cognitive map concept does not, however, imply that a coherent theory of cognitive maps exists. In reality, the cognitive map idea is often employed more as metaphor than as theory. There is, however, a theory that is both reasonably rigorous and that emphasizes the generality of the concept as an all-purpose knowledge structure (S. Kaplan, 1973, 1976; Kaplan & Kaplan, 1982/1989). This theory is referred to as the SESAME approach in honor of the Seminar on Environmentally Sensitive Adaptive Mechanisms that has worked on the larger model of cognition, of which this theory is a part, for more than 20 years (cf. Chown, Kaplan, & Kortenkamp, 1995; Kaplan, Sonntag, & Chown, 1991; Kaplan, Weaver, & French, 1990).

Unique to the SESAME position is the view that a cognitive map can be conceptualized as a network of associated internal representations of objects. As used in this context, "object" includes a range of elements from concrete objects to abstract concepts. To translate to more traditional cognitive map terminology (e.g., Lynch, 1960),[1] the SESAME theory describes the cognitive map as a network of mental objects serving as nodes, or landmarks, with associations serving as paths. Although the SESAME model has not been the subject of extensive research, it has been successfully simulated (Levenick, 1991) and empirically tested (O'Neill, 1991).

The purpose of this section is not to explore the SESAME theory of cognitive maps in great detail but rather to point out several key theoretical concepts relevant to a measurement procedure. These key concepts are discussed below.

Nodes and Associations

Cognitive maps are not the only hypothesized knowledge structures made up of nodes and associations. A network in semantic net theory is composed of concept nodes connected by labeled arcs (Barr & Feigenbaum, 1981; Sowa, 1991). Hence, "associations" are often thought of in terms of labels between concepts, or ideas. There is, however, a quite different meaning of association that has a long and honorable history. In the context of traditional theories of learning, decades of research have led to an extensive literature concerning an association concept that had its origins with the British empiricists (Hilgard, 1948). This formulation of an associative bond is seen as unlabeled, but directional and capable of varying in strength. The SESAME approach is based on associations in this classical sense. Although not a primary focus of most modern cognitive research, this use of the association concept long ago proved itself to be capable of substantial explanatory power. Attneave (1962), in calling for a return to this tradition, cited James, Woodworth, and Hebb as leading proponents spanning the history of psychology. Modern work in the area of connectionism similarly relies on the classical association concept.

The "nodes" in the SESAME model are viewed as mental objects rather than symbols or concept labels. This interpretation of the mental object reflects the long history of development of the theory of the internal representation (Neisser, 1967; Posner & Keele, 1968), or unit of thought. Initially viewed as a "category" (or equivalence class; cf. Bruner, Goodnow, & Austin, 1956), the conceptualization then advanced to "schema" (permitting missing information; cf. Anderson, 1980; Chi, Feltovich, & Glaser, 1981) and then to "prototype" (involving a central tendency; cf. Posner, 1973; Rosch, 1977). The use of the term *object* in this context dates back to James (1892/1962).

The object construct as used here builds on the prototype idea; in addition to the notion of central tendency, two further properties are proposed. "Manipulability" refers to the susceptibility of the object to mental modification—for example, being able to add qualifiers (e.g., color), as in a pink penguin; or combination with other things—for example, a penguin sitting in a tree. "Experienced concreteness" refers to a subjective experience; the mental object feels thing-like even if it is in fact abstract. "Margin" for the economist, "reinforcement" for the behaviorist, the "Oedipus complex" for the psychoanalyst, and "ambiance" for the designer are all highly abstract concepts that are experienced (and treated) as concrete by experts in their respective fields. Given the way James (1892/1962) used the term object, one might suspect he would be quite untroubled by this extended prototype notion.

These mental objects, or internal representations, are postulated to arise through learning, based on the association of co-occurring features. Representations of concrete objects are assumed to arise through the association of feature detectors representing perceptual features that have occurred together in the environment. For example, one's representation of the object "cat" presumably arises through the association of feature detectors representing the perceptual features "ear," "whiskers," "small nose," and so on. Similarly, representations of abstract concepts are presumed to arise from the associations among these more concrete internal representations. Internal representations' reliance on the association of perceptual features (or, in the case of more abstract internal representations, on the association of concrete objects) implies that these representations are as much defined by their properties as by their other associates. By contrast, concepts in semantic net theories gain their meaning solely through their associations with other concepts and hence, have no inherent meaning.

Once an internal representation has been created, it can be activated by an object or concept in the world if that object contains enough of the representation's core features. Thus, the nodes in the SESAME model of cognitive maps are perceptual units, serving as the basis of recognition.

Although the postulate that the unit of perception and the unit of thought are one and the same is not the currently favored view in cognitive science, the position taken here is by no means unique. The list of students of cognition who share this perspective includes James (1892/1962), Bruner (1957), Attneave (1962), Shepard (1975), Rosch (1977), Hebb (1980), and Margolis (1987).

The role of the internal representation in cognition does not end with recognition. Once formed, it acts as a relatively independent unit and can become activated internally, allowing one to think about something that is not present. The internal representation can also become associated with other units, permitting more complex cognitive structures. In addition, it can become associated with affect (e.g., pain, pleasure) (Kaplan & Kaplan, 1982/1989); these affective codes give an individual important information on whether to approach or avoid a particular object or situation in the future.

In short, internal representations, or mental objects, reflect the content of one's knowledge and are the basis for cognition (Posner, 1973). This point is worth emphasizing. Because cognition is based on one's existing internal representations, we would postulate an overwhelming bias in favor of represented concepts in decision making and problem solving. From this perspective, an appropriate method of assessing knowledge structure would necessarily reflect the centrality of the internal representation.

The use of internal representations, in place of symbols or concept labels, as nodes in the cognitive map sets the SESAME position apart from most other theories of how information is stored. This position has three important implications. First, because the internal representation is a perceptually based unit, there is direct access from the things in the environment to the things in that mind that represent them. It is less evident how a traditional symbol is addressed by what corresponds to it in the environment. This is an important issue for any theory of mind, and particularly important for a theory that is concerned with how the environment relates to mental activity.

The second implication concerns how the meaning of a conceptual unit is determined. This is sometimes referred to as the "symbol grounding problem" (Harnad, 1990), and is a matter of some dissatisfaction and controversy in the domain of symbolic theories. The internal representations discussed here, however, are clearly grounded; their meaning arises not only from relationships to each other but also from the feature set that gives rise to them. The properties of the object in the environment are, in other words, an essential component of the internal representation of that object. And, as we have seen, abstract objects enjoy the same grounding, albeit indirectly.

A third implication is that mental objects have traceable origins. A perceptual learning theory, like that of Hebb (1949), provides a coherent account of how neural structures could arise corresponding to objects in the environment.

Internal Representations and the Concept of Ownership

Because internal representations derive much of their meaning from their underlying feature set, we would predict that an individual who learns the name of a concept (say, in a college course), and even learns what other words are appropriately associated with it, might have little idea of the concept's properties and at best limited capability of recognizing what it refers to should the concept be encountered in the environment. In the context of the SESAME model, then, it is appropriate to distinguish between a "purely verbal understanding" and a deeper grasp of the concept and what it refers to.

We also would predict that there would be affective and behavioral consequences of this distinction. An individual with purely verbal knowledge, lacking the corresponding perceptually based representation, would not only tend to be deficient in recognition capability but also in the cognitive benefits of experienced concreteness and manipulability. Such an individual would presumably be less comfortable with the information, less confident of its use, and less competent to apply it to a real situation; the term *ownership* is used here to stand for this set of interrelated factors.

Imagine an individual who had studied concepts A, B, and C for many years. Then, immediately before an exam, the individual was told about concepts D, E, and F, given their definitions, and told the primary associates of each. If the exam permitted one to solve a problem using concepts of one's choice, it would hardly be surprising to find that the answer was based on A, B, and C, and that the other concepts were ignored. Further, asking the same individual to demonstrate her knowledge by organizing the entire set of concepts A, B, C, D, E, and F, would likely lead to a distorted picture of what she actually knows. The difference in both cases is illustrative of the concept of ownership.

Ownership is not a meaningful concept in the context of semantic and symbolic theories, since information provided is assumed to be information received. This assumption is an expression of the fact that it is unclear where the symbols came from (how they could have been learned). The inclination to assume an identity between input and storage may be a reflection of the theoreticians having spent too much time with computers (and perhaps too little time with students). Alternatively, it may be a consequence of the tendency of this type of theory to ignore perception and hence to be insensitive to the highly selective nature of the human input function.

Sequential Coding

As mentioned, internal representations, once formed, can become associated with other internal representations. These linkages have been postulated to underlie the sequential nature of thought (cf. Macphail, 1987), and to permit some of the most fundamental cognitive abilities, such as prediction and planning (cf. Craik, 1943). The basic rule for learning associations is much the same as that for learning the internal representations themselves. Features appearing together tend to become associated, forming the internal representation; likewise, internal representations appearing together (i.e., activated at the same time or in short succession) tend to become associated, forming sequences and networks.

The term *cognitive map* is used here to refer specifically to a group of associated internal representations, or mental objects.[2] Cognitive maps can vary in their complexity from a single chain of linked objects to an interconnected set of objects constituting a complex network. Though the capacity to build cognitive maps presumably evolved to represent concrete things in the environment and the largely spatial relationships among them, the mechanism underlying this capacity also permits the creation of structures representing more abstract objects and their relationships (S. Kaplan, 1976; Kaplan & Kaplan, 1982/1989; Siegel & White, 1975). The sequential associations in cognitive maps (reflecting spatial, causal, conceptual, and temporal relationships in the world) allow thoughts to follow one another in an orderly and meaningful fashion and provide access to information that is relevant to the thought at hand. In other words, once a particular internal representation in a cognitive map is activated, that activation can spread to associated representations, bringing them into awareness. An appropriate measurement procedure should be sensitive to this pattern of sequential relationships.

Hierarchical Structure

Cognitive maps can occur at numerous levels of abstraction, with each internal representation in a higher level map representing an entire lower level map (Kaplan & Kaplan, 1982/1989; Rosch, 1977). For example, the nodes in one's cognitive map of a college campus would consist of internal representations of familiar buildings and other landmarks. At a more abstract level, the campus may be represented by a single node in a cognitive map of the city. This city map may, in turn, be represented hierarchically by a single node in a cognitive map of the state. The same holds true when the cognitive maps are more conceptual in nature. One's cognitive map about carpooling, for instance, may contain the following mental objects: gas cost, parking, conversation, friends, stress, flexibility, and reliability. These objects may be represented hierarchically by the following abstract concepts: financial consideration (including gas cost, parking); social aspects (conversation, friends, stress); and drawbacks (flexibility, reliability). A method capable of capturing hierarchical structure, as well as identifying the constituent mental objects, would yield considerable information about the structure of a person's knowledge.

Variation in Cognitive Maps Among Individuals

Cognitive structure (including internal representations, cognitive maps, and hierarchical structure) is created over time and results from numerous experiences. It is thus reasonable to suppose that the cognitive structures of different individuals will show substantial variation. For example, experts in a particular domain would presumably have numerous strong internal representations corresponding to that domain; they presumably also would have well-formed cognitive maps and hierarchical structures. In contrast, one would expect novices in the same domain to have impoverished cognitive structures, resulting, in part, in lower levels of perceived competence—or sense of ownership—about the domain. Even individuals who share the same level of expertise presumably often hold different cognitive maps, due to differences in experience and training. An adequate technique for measuring cognitive maps must allow for the expression of these types of differences.

The Hidden Nature of Cognitive Structure

Individuals are often not fully aware of the cognitive structure underlying their decisions and problem solutions (James, 1892/1962; Kaplan & Kaplan, 1982/1989). Cognitive maps tend to be used efficiently and unconsciously; hence, there may be little incentive to explore the cognitive antecedents of a decision. Further, the quantity of information involved may exceed the individual's channel capacity, making such exploration difficult. (Channel capacity refers to the limited number of elements the brain is able to simultaneously hold in working memory, Mandler, 1975.) Yet, as Socrates demonstrated many centuries ago, individuals can be aided in discovering information that had been in their heads all along but whose relatedness and implications they had failed to fully grasp. Ideally, a technique for measuring cognitive maps with conceptual content would aid participants in exploring their knowledge structure in the very process of externalizing it.[3]

INTEGRATING THEORY AND MEASURE

The SESAME theory of cognitive maps presented above offers direction and constraints on both evaluating and designing methods for measuring cognitive maps.

There are several essential requirements such a method would have to meet:

1. *Focus on mental objects (i.e., the content of one's knowledge structure).* As explained, internal representations of objects and concepts are the basic building blocks of cognitive maps. To adequately measure a cognitive map about a particular domain, then, the relevant objects (i.e., those concepts or things that an individual considers important in relation to a particular domain or issue) must be identified.
2. *Reflect those objects (and only those objects) that a participant owns.* An appropriate method of measurement will capture those objects, and only those objects, that correspond to an individual's existing internal representations. The focus on "owned" objects presumably allows the expression of misconceptions and helps ensure that the researcher's own ideas are not imposed on study participants.
3. *Capture relationships among objects.* An appropriate method of measurement will capture perceived relationships among the relevant objects (e.g., which objects are more closely associated and which objects are more distantly related). The relationships captured should correspond to the hierarchical and sequential structure of the relevant cognitive map.
4. *Allow for exploration and discovery of one's knowledge structure.* As previously discussed, it cannot be assumed that individuals have direct and immediate access to their cognitive structure. Thus, an appropriate measurement technique would ideally enable participants to reveal their structure to themselves in the very process of externalizing it.

In addition to these minimum requirements, a measurement method would ideally also meet the following criteria:

5. *Be humane.* By their very nature, techniques assessing how people understand issues place high cognitive demands on participants by asking them to access, explore, and externalize their knowledge. Given this, the measurement task itself should not be an additional burden; the ideal method would be one that facilitates thought, provides a means of dealing with limited channel capacity, and assists participants in the externalization of their knowledge.

6. *Be applicable in a variety of situations.* The ideal method would lend itself to both qualitative and quantitative approaches, permitting in-depth exploration and larger studies.
7. *Be relatively easy to administer.* Ease of administration is especially important when dealing with a large sample size.

CURRENT METHODS FOR MEASURING KNOWLEDGE STRUCTURE

A variety of methods (often called cognitive mapping techniques) are currently used to assess knowledge structure. These methods fall into three general categories and are examined here in light of the constraints outlined above.

Semantic Proximity (Word Association) Tasks

Perceived semantic proximity of words is frequently used as a proxy for cognitive structure, or mental models (Preece, 1976). Though semantic proximity techniques focus on capturing verbal organization in memory, it is assumed that verbal organization is synonymous with knowledge organization; that is, the more similar two words are perceived to be, the more proximate their referents (i.e., the concepts or meanings symbolized by the words) are assumed to be.

A variety of semantic proximity techniques exist, including using similarity ratings (Jonassen, 1987), examining word clustering in free or cued recall (Naveh-Benjamin, McKeachie, Lin, & Tucker, 1986; Reitman & Rueter, 1980), having participants construct linear graphs (trees) or "pattern notes" (Jonassen, 1987), and using word association tasks. Analysis is typically performed on the distance between terms in a list or diagram (Jonassen, 1987) or on the length of pause during recall (Reitman & Rueter, 1980) and is based on the underlying assumption that the order of response retrieval from long-term memory is indicative of one's cognitive structure.

Perhaps the most widely used of the semantic proximity techniques is the word association task (Gussarsky & Gorodetsky, 1988; Preece, 1976; Shavelson, 1972). Typically, subjects are given a list of words related to a particular domain and are asked to list as many associated words as they can. Gussarsky and Gorodetsky (1988) used this technique to explore students' understanding of the chemical equilibrium phenomenon. Participants were given a booklet, each page of which contained 1 of 18 key concepts (as identified by the researchers) related to this domain. For each key concept, participants were given one minute to "provide chemical associations at their utmost ability" (p. 321). Data analysis was based on an 18 by 18 matrix of relatedness coefficients; each coefficient represented the average number of intervening concepts between a given pair of key concepts. Participant-generated concepts that did not correspond to one of the 18 key concepts were not included in the analysis.

Similar techniques have successfully shown differences among groups and changes over time. Shavelson (1972), for example, found that following physics instruction, students' structuring of 14 key physics concepts was more similar to the structure of the course text. Although it is possible that this finding reflects an increased understanding of physics, it is equally possible that it merely reflects a strengthening of semantic associations, with no corresponding change in the associations among the objects to which the semantic symbols refer. We would expect verbal labels that appear together frequently to become associated; this is true whether the labels are key physics concepts appearing together frequently in a text or whether the labels are unrelated words that study participants are asked to rehearse and memorize. Word associations alone cannot provide confident information about the way in which an individual actually understands a particular domain. Thus, although it cannot be claimed that semantic proximity tasks are invalid, the uncertainty associated with the outcome of these tasks calls into question their reliability as a measure of cognitive structure.

This uncertainty stems from three major problems. First, and most serious, is the underlying assumption of semantic proximity tasks that linguistic structure is synonymous with (or at least representative of) cognitive structure. Furth's (1971) analysis of numerous studies on the differences in thought processes between hearing and nonhearing children provides strong support for the hypothesis that cognition is not language based. Others also have explored the differences between language and thought (for an overview, see Reed, 1988); taken as a whole, these results suggest that verbal and imagistic thought are represented by two distinct, albeit partially interconnected, systems (Bruner, 1986; Damasio & Damasio, 1992; Paivio, 1978; Tulving, 1983). Therefore, it is possible (as in the example given above of a memorized list of unrelated words) for semantic organization in memory to differ significantly from the organization of objects or concepts in memory (i.e., a cognitive map).

A second problem with semantic proximity tasks is that participants are required to deal with a highly constrained set of words that have typically been generated by experts in a field or have been extracted from a textbook. For example, in free and cued recall tasks (Naveh-Benjamin et al., 1986; Reitman & Rueter, 1980) students are asked to memorize a particular set of words and the order of recall is subsequently used as a measure of cognitive structure. Similarly, in both free-association tasks (e.g., Shavelson, 1972) and pattern-note tasks (e.g., Jonassen, 1987), students are presented with what the researchers believe are the key concepts related to a particular domain. It is interesting to note that though students typically generate many other words in the association task, these enter the analysis only as the number of intervening words between a pair of key concepts. Thus, these techniques are likely to result in a distorted image of knowledge structures both because participants are required to consider concepts they might not understand or think important (i.e., concepts that are not part of their knowledge structure), and because indicators of participants' unique structures (i.e., concepts that are part of the participants' knowledge structure but not part of the expert's knowledge structure) are ignored.

A final problem with semantic proximity tasks and, in particular, with the word association tasks, is that by their very nature, they require (and even encourage) minimal information processing.

The tasks are geared toward rapid generation of associations (there is usually a limit on the amount of time a participant can think about each word stimulus) and thus are unlikely to allow individuals to explore and discover their knowledge structure in the process of externalizing it.

Open-Ended Interviews

Open-ended interviews address some of the problems with semantic proximity techniques. Interviews are typically performed with a small number of participants and models (either descriptive or visual) of how an issue is conceptualized and are extracted from interview transcripts. Kempton (1991) used this technique to study people's mental models of global warming and to identify a number of misconceptions about the process. In this case, the models he reported were descriptive. Others (Bonham, 1993; Bostrom, Fischhoff, & Morgan, 1992; Carley, 1992; Langfield-Smith & Wirth, 1992) have constructed pictorial models based on analysis of interviews. In these cases, the researcher extracted what appeared to be the most important concepts and then diagrammed the concepts and the causal linkages among them. An obvious advantage of interviews over the semantic similarity techniques is that participants' responses are not nearly as constrained by the researcher. This makes it possible to measure misconceptions and idiosyncrasies in people's understanding of an issue. We also can hypothesize that during an open-ended interview, individuals might be encouraged to explore their own knowledge structures.

The open-ended interview technique does, however, have some drawbacks. The obvious ones are that it is exceptionally time intensive (effectively limiting studies to very small numbers) and the highly qualitative results do not permit statistical analysis, making comparisons across groups difficult. In addition, the reliance on researchers to extract important concepts and relationships from interview transcripts opens the technique up to potential biases and misjudgments.

Free Card-Sorting Methods

Free card-sorting techniques are used fairly extensively to measure cognitive structure, particularly in the fields of educational psychology, science education, and cognitive anthropology (for an extensive overview see Miller, Wiley, & Wolfe, 1986). During a typical card-sort task, participants are asked to sort (categorize) some number of items (e.g., concepts, pictures, descriptions, actual objects) related to a particular issue or subject. Participants are simply asked to sort the items into categories according to how they think they go together; no constraints are placed on the number of categories or on the number of items within a category. Item organization is assumed to reflect knowledge organization (i.e., participants' cognitive maps). The set of stimulus categories generated by each participant can then be aggregated across groups and analyzed with a variety of multivariate techniques.

The use of the free card-sort in anthropology has largely been restricted to the investigation of folk taxonomies (classification systems) (e.g., Atran, 1990; Kempton, 1981) and differences between novice and expert classification schemes (Boster & D'Andrade, 1989; Boster & Johnson, 1989). Burling (1964) went so far as to say, "I believe we should be content with the less exciting objective of showing how terms in language are applied to objects in the world, and stop pursuing the illusory goal of cognitive structures" (p. 27). More recently, others have disagreed, arguing that anthropologists also must start paying attention to the role of these categories in cognition (Furbee & Benfer, 1983).

Researchers in education and psychology have used card-sorting tasks to deal more directly with the question of cognitive structure. In this context, the technique is commonly termed *F-sort* (Miller et al., 1986). The F-sort, though similar in name to the more familiar *Q-sort*, was developed independently and is methodologically quite dissimilar. The F-sort followed from early categorization tasks used in clinical psychodiagnosis and results in categories completely defined by the sorter (Miller et al., 1986). In contrast, the traditional Q-sort involves assigning stimuli to fixed categories (predetermined by the researcher) along a single dimension (e.g., from *strongly like* to *strongly dislike*); in addition, the number of stimuli that can be placed in each category is often constrained (Stephen, 1985).

The F-sort has been used in a variety of contexts, including the study of what makes teaching effective (Whitely & Doyle, 1976), what accounts for exam performance (Wilson & Palmer, 1983), and what makes science experiments interesting (Martinez & Haertel, 1991). The technique also has been used to show differences between groups of varying levels of expertise and to show that changes in the direction of an "expert" (or idealized) categorization scheme occur with instruction (e.g., in biology (Hauslein, Good, & Cummins, 1992), chemistry (Gorodetsky & Hoz, 1985), and educational psychology (Kozminsky, 1992).

Despite their relatively wide usage, traditional card-sorting techniques have several limitations. The largest problem with these techniques is their failure to identify those concepts, and only those concepts, that an individual perceives to be relevant to the domain in question. There are several reasons for this failure. First, although these tasks are called "unconstrained" or "free," they are actually highly constrained. As with the semantic proximity tasks, participants are typically given a specific set of items and are then required to sort all of the items, regardless of whether they understand a particular item or perceive it to be important. It cannot be assumed that an individual's cognitive map is comprised of an exhaustive set of concepts. On the contrary, we would expect someone who has little experience with a particular issue to own relatively few concepts related to that topic. Requiring such an individual to sort all of a given set of cards—when some of the cards bear no relationship to what is inside that individual's head—is unlikely to provide an accurate assessment of the individual's knowledge.

Second, the problem of expert-generated concepts, mentioned earlier, also applies here. Items used in the typical card-sort are generated by experts and, thus, important aspects of participants' actual knowledge structures are likely to be missed. For example, Kempton's (1991) interviews on global warming, described earlier, revealed the widely held misconception that ozone is a key factor in global warming. A card-sorting task on the same topic that used only expert-generated concepts would not have included ozone, and this misconception would have gone undetected. In addition, the failure of free card-sorting techniques to focus on those concepts an individual perceives to be pertinent precludes the opportunity for that individual to explore her or his own unique knowledge structure.

None of the three techniques reviewed here meet all of the necessary and desirable constraints outlined in the previous section. In particular, there are the problems of assuming that linguistic structure is representative of cognitive structure, of using only expert-generated concepts, and of mandating the usage of all concepts. The next section proposes an alternative measurement approach that does meet the outlined constraints.

TOWARD A THEORY-BASED MEASURE: THE 3CM

The 3CM method, derived from the SESAME model and designed to meet the criteria set out earlier, is a technique for measuring people's perspectives on, or cognitive maps of, complex domains. Participants are asked to identify the concepts they believe are important in explaining their view of a particular domain and are then asked to organize these concepts in a way that depicts how they perceive the domain. The result is a visual display that expresses a participant's unique knowledge structure.

Experience with the 3CM technique supports the claims that it is a valid measure of cognitive structure and provides the type of environment that permits people to make contact with their knowledge and express it effectively. 3CM appears to facilitate the thought process, perhaps because it produces the kind of verbal/spatial array that has been shown to be highly compatible with human information processing (Pezdek & Evans, 1979). Further, use of the cards to externalize the thought process presumably takes advantage of the highly parallel nature of visual information processing and may permit participants to be less restricted by usual channel capacity constraints. It is not uncommon for participants, upon completion of the 3CM task, to report discovering feelings and relationships they had previously been unaware of and to express satisfaction with how well their card arrangement reflects their view of the topic.

The 3CM technique has two implementations, each of which has both qualitative and quantitative aspects. The open-ended implementation is suitable for small sample sizes and allows in-depth exploration, whereas the structured implementation permits larger sample sizes. The two different implementations of the 3CM method are described below along with the criteria by which the construct validity of the measure has been assessed.

Construct Validity and the 3CM Method

Construct validity reflects the degree to which a measurement technique assesses the construct it is meant to assess. High validity is indicated by the following: (a) The measure performs in accordance with theoretically derived expectations; (b) The measure shows the expected relationships with other measures (Brewer & Hunter, 1989; Carmines & Zeller, 1979).

In this case, three major theoretical expectations were derived from the SESAME model. First, we would expect participants to be able to differentiate objects they own from those they do not. Hence, given the opportunity, participants should ignore those objects for which they have no corresponding internal representation. At first glance, some might disagree with this statement and counter that learning theory presumes new objects are incorporated into existing knowledge structure. Although knowledge integration is indeed an important aspect of learning, the evidence is overwhelming that when presented with new concepts that contradict existing knowledge structure, people are inclined to ignore, or reinterpret, these concepts (Bartlett, 1932; Kearney, 1993; Resnick, 1983).

Second, due to the brain's limited capacity to hold elements in working memory, one would expect, following Mandler (1975), that hierarchical relationships would express themselves in terms of 5 ± 2 categories. (Note that this limit does not apply to the total number of concepts an individual might use during a 3CM task as each category may contain numerous concepts.)

Finally, one would expect participants to express satisfaction with the measurement process. This rests on the assumptions that the process of completing the 3CM task, as well as the resulting organization of concepts, increases one's sense of clarity about the domain being measured (i.e., through the discovery process) and that a state of cognitive clarity is a satisfying state (Kaplan, 1978/1982; Kaplan & Kaplan, 1982/1989).

In addition to meeting these theoretical expectations, the data resulting from the 3CM technique should show the expected relationships to other knowledge measures such as level of expertise. For example, based on the SESAME model, one would expect both the number of objects in one's map and the degree of object organization to increase with one's level of expertise in a particular domain.

3CM: OPEN-ENDED IMPLEMENTATION

The open-ended 3CM technique was developed by Austin (1994a, 1994b) in collaboration with S. Kaplan.[4] It is particularly useful in exploratory studies and when dealing with a relatively small sample size. The open-ended 3CM is generally implemented in several steps. First, the participants are introduced to the topic or issue under study and asked to think about how they would explain their own view of the topic to someone unfamiliar with the domain. Next, the participants are asked to list the components or aspects of the issue that they perceive to be important. (These factors presumably correspond to the objects, or internal representations, in the participants' cognitive maps.) As the factors are mentioned, the researcher writes each one on a separate card and places the cards in front of the participants. When the participants feel they have listed all the relevant factors, they are asked to group or arrange the cards to illustrate how they perceive the issue. The participants are free to add more factors at any time and no constraints are placed on the number or organization of factors.

Austin's initial study used the open-ended 3CM to explore the perspectives of people involved in the siting of a hazardous waste incineration facility on tribal land. A variety of individuals participated in the study, including tribal members, waste company employees, government employees (including government representatives and employees of the Bureau of Indian Affairs, the Environmental Protection Agency, and the National Park Service), and members of environmental organizations. Study participants varied in their level of involvement and degree of expertise with the issue.

Participants' cognitive representations of the siting issue were generated during a series of open-ended interviews. Toward the end of each interview, participants were reminded about the proposed siting and were then asked to complete the 3CM task as previously described. In addition, Austin asked participants to code each factor for affect (whether they considered the factor to be a positive or negative aspect of the issue), importance (whether they considered the factor very important, important, or less important), and how much knowledge they had about the factor (a lot, some, a little). Upon completion of each 3CM task, Austin read a list of factors that others considered important and invited the participants to add any of these factors to their own 3CM arrangement.

Since this work, the open-ended 3CM has been used in a variety of other contexts, most recently to assess stakeholders' perspectives on appropriate forest management in the Pacific Northwest (Kearney, Bradley, Kaplan, & Kaplan, 1996). Here, a number of general categories capturing the range of participants' perspectives were identified through both quantitative and qualitative analyses of the data. Next, differences and similarities among the stakeholder groups, in terms of whether or not participants tended to include items from a particular general category, were explored; again, this analysis employed a combination of analytical tools.

The open-ended 3CM meets the constraints imposed by the SESAME theory of cognitive maps: it focuses on factors that are relevant to the issue, captures only those factors (objects) that a particular participant owns, and allows the relationships among these factors to be expressed through an exploration process. The problem of limited channel capacity is dealt with through use of the cards, which allows the participant to generate and organize a large number of concepts without losing track of them. In addition, the technique is applicable in a variety of situations and appears particularly useful in assessing people's perspectives concerning complex domains (arguably a category that includes most environmental issues).

Construct Validity of the Open-Ended 3CM

Validation of the technique comes from examining how study results meet the expectations set out above. The open-ended 3CM does perform in accordance with the three major theoretical expectations described earlier. First, participants are able to differentiate those factors (objects) that they "own" from those they do not. In Austin's study, for instance, participants were quite sure about which factors belonged in their representation and generally declined to add additional factors when given the opportunity. (Only 4 of 57 participants chose to add factors when read a list of suggestions.) Though some might suspect that this general disinterest in additional factors was the result of fatigue rather than a reflection of ownership, there is no indication that fatigue played a role. On the contrary, in both formal and informal use of this procedure, people have been found to be highly interested and engaged in the process. In fact, on more than one occasion a participant had to be coaxed to the next phase of the interview.

Also as expected, participants tend to organize their factors into 5 ± 2 categories. That is, regardless of how many factors an individual identifies, these factors are typically categorized so that the resultant representation can be viewed in terms of 5 ± 2 meta-factors. The 3CM technique also appears to facilitate discovery, as participants repeatedly comment on the utility of the process in helping them clarify their own understanding of the issue. After completing her card arrangement, one participant in the forest management study remarked, "Oh, that comes together quite nicely—I'm amazed." Another commented, "It's [the 3CM task] really an interesting approach. It really facilitates the interview and stimulates the whole thought process."

Though few studies have directly explored the relationship between 3CM and other knowledge measures, Amtmann (1996) did find the expected relationship between knowledge structure, as measured by 3CM, and level of expertise. Experts (in this case, on the topic of wild and scenic rivers) tended to have more richly structured card arrangements (including a greater number of concepts, more categories, and more clearly defined relationships among the categories) than did novices.

Although the open-ended 3CM has yielded interesting and useful results in a variety of contexts, it is highly time intensive and thus is effectively limited to relatively small sample sizes. The technique proposed in the next section follows from the open-ended 3CM and has the advantage of compatibility with larger sample sizes.

3CM: STRUCTURED IMPLEMENTATION

The structured version of the 3CM method was developed for implementation in situations where one is dealing with a large sample size and when more rigorous statistical analysis is desired. In this version, all participants begin the 3CM task with the same set of initial concepts. The general procedure is described below, followed by a specific example. First, a list of concepts is generated that captures the range of perspectives on the topic or issue in question. Elicitation of concepts may occur through use of an open-ended 3CM, a survey, or open-ended interviews. In addition, concepts may be generated through examination of existing studies or other literature. Generation of concepts by a representative group (i.e., rather than a group of experts) results in a concept list that presumably reflects participants' actual knowledge structure.

Once the concepts have been gathered (generally between 30 and 50), the complete set is presented to each study participant along with a scenario or description of the particular topic under study. Participants are asked to think about how they would explain their views on the issue to a friend who is unfamiliar with the topic. They are then asked to choose from the list of concepts only those that are important to them in explaining their views. In addition, participants are invited to add concepts they perceive important but that are not included on the list provided. Finally, participants are asked to organize the concepts into groups according to how they think the concepts go together, and then to label each group with a descriptive word or short phrase.

Asking participants to choose only those concepts that are meaningful to them is an essential component of the procedure. This step helps ensure that individuals' final sortings reflect only those objects they own (i.e., that correspond to their actual cognitive structure). The task also meets the other criteria outlined earlier. The focus on mental objects is explicit as the task consists of choosing and sorting concepts. Hierarchical relationships are captured during the grouping and labeling process (the labels provide insight into how a particular group of concepts is united by some, more abstract, concept). Finally, exploration and discovery are encouraged in two ways. First, using a scenario at the beginning of the task encourages participants to focus on the appropriate knowledge structure (i.e., activates the relevant cognitive map). Second, the very process of sorting and grouping the cards allows participants to both visually and spatially explore their own knowledge structures.

As with the open-ended 3CM, use of the cards in the structured version eases the constraint of limited channel capacity while helping participants externalize their knowledge. The structured version has the added advantage of being relatively easy to administer. An average task takes 15 to 25 minutes to complete and can be administered to large groups with minimal instruction. Statistical analysis can be performed with existing multivariate techniques, giving a measure of how a group, as a whole, tends to organize its knowledge about the issue in question. In addition, differences in the content (concepts chosen) of various groups' knowledge can be assessed and measures of within-group cohesion and between-group distance can be obtained (Fillenbaum & Rappaport, 1971; Romney, Weller, & Batchelder, 1986).

THE STRUCTURED 3CM METHOD IN PRACTICE: A DETAILED EXAMPLE

An early application of this procedure examined the impact of two different forms of information (stories and fact sheets) on employees' views of carpooling to work.[5] Employees at each of five sites were randomly assigned to either a story-based information group ($N = 76$), a fact-sheet-based information group ($N = 74$), or to a control ($N = 41$). Participants in the information groups daily received written information about carpooling for a period of 2 weeks. In addition to several surveys throughout the study, all participants were asked to complete a structured 3CM task at the end of the intervention period.

Collecting Concepts

The concepts used in the 3CM task were generated by surveying 19 attendees of the 1992 Association for Commuter Transportation National Conference. The group included experts (e.g., ride-share coordinators), nonexperts, people who carpooled, and those who did not. Additional concepts were compiled by reviewing several studies on people's perspectives and attitudes toward carpooling (Angell & Ercolano, 1991; Horowitz & Sheth, 1978; Margolin, Misch, & Stahr, 1978; Oppenheim, 1979). A total of 46 concepts were used in the structured 3CM.

The Sorting Task

Participants were given the list of 46 concepts along with an envelope containing 50 blank 2-inch x 2-inch cards, 8 paper clips (for securing the final categories), and a set of written instructions explaining the task. The instructions began with the following scenario:

> Imagine that you have been asked to share your perspective on carpooling from home to work with a coworker who hasn't thought much about the issue. What will you choose to talk about? How will you organize your thoughts?

Participants were asked to choose and organize concepts as described earlier.[6] When participants had finished sorting their concepts and labeling their groups,[7] they were asked to paper-clip each group together along with its label and place the groups back in the envelope.

Results and Discussion

Structured 3CM data were combined across sites (as described below) and analyzed with three separate multivariate techniques: latent partition analysis (LPA),[8] multidimensional scaling, and hierarchical clustering. Results of the three analyses were very similar—in the interest of space, only the results of the hierarchical clustering analysis are reported here.

Data from each of the three study groups were compiled in three separate similarity matrices. The similarity matrix is a Concept × Concept (in this case, 46 × 46) matrix where each entry *ij* reflects the percentage of participants who grouped concept *i* and concept *j* together.[9] Individual to group correlations were obtained with the PILESORT procedure in the statistical package *Anthropac* (Borgatti, 1992). These correlations can be used to identify outliers (individuals who did not understand the task, did not perform the task adequately, or had a very different knowledge structure from the rest of the group). For purposes of this analysis, all individuals whose categorization scheme had a less than .25 correlation to the group matrix were omitted from subsequent analysis. Five individuals were omitted from the story group (leaving an *N* of 71), 9 individuals were omitted from the fact-sheet group (leaving an *N* of 65), and 5 individuals were omitted from the control group (leaving an *N* of 36).

New similarity matrices were computed as above for each of the three revised groups. These new matrices were then subjected to Johnson's (1967) hierarchical clustering (an agglomerative technique) using the method of average linkage (Sokal & Michener, 1958) to determine order of clustering. The analysis was performed using *Anthropac's* CLUSTERING procedure. Results were interpreted by examining the cluster coefficients (Aldenderfer & Blashfield, 1984) and considering only those concepts chosen by at least 30% of the participants in the treatment group.[10]

Results (Table 1) indicate how each group, as a whole, tended to organize the concepts (i.e., tended to think about the domain of carpooling to work). Both the control and the fact-sheet groups had very similar clusters: a "negative aspects" cluster and a "positive aspects" cluster, which was divided into two subclusters ("environmental aspects" and "economic aspects"). The story group had three distinct clusters: negative aspects, positive aspects (again, comprised of the subclusters environmental aspects and economic aspects), and "social aspects." Cluster names are based on an analysis of participants' 3CM category labels.

These results suggest that the story-based intervention was more effective than the fact-sheet-based intervention at changing how the participants think about carpooling. In particular, it was effective at communicating the intangible (i.e., social) aspects of carpooling. This finding is supported by a number of other studies (for a review, see Kearney, 1994; Kearney & De Young, 1995).

CONSTRUCT VALIDITY OF THE STRUCTURED 3CM

In addition to meeting the constraints imposed by the SESAME model, the structured 3CM technique is presumed to have high construct validity as it performs in accordance with theoretical expectations. Participants appear to have no difficulty differentiating those objects they own from those they do not. In the carpool example, no one chose to categorize all 46 concepts; the average participant chose to categorize roughly

Table 1
Results of Hierarchical Clustering for Each of the Three Treatment Groups

Control Group (n = 36)	*Fact-sheet Group (n = 65)*	*Story Group (n = 71)*
Negative aspects	Negative aspects	Negative aspects
Independence	Independence	Independence
Freedom	Freedom	Freedom
Convenience	Convenience	Convenience
Personal emergency	Personal emergency	Personal emergency
Flexibility	Flexibility	Flexibility
Scheduling demands	Scheduling demands	Scheduling demands
Time spent waiting	Time spent waiting	Time spent waiting
Errands	Errands	Errands
Fixed schedule	Fixed schedule	Fixed schedule
Mobility	Mobility	Mobility
Reliability	Reliability	
Privacy		
Positive aspects	Positive aspects	Positive aspects
Environmental aspects	Environmental aspects	Environmental aspects
Air pollution	Air pollution	Air pollution
Energy use	Energy use	Energy use
Economic aspects	Economic aspects	Economic aspects
Parking costs	Parking costs	Parking costs
Automobile maintenance	Automobile maintenance	Automobile maintenance
Gasoline costs	Gasoline costs	Gasoline costs
	Automobile insurance	
		Social aspects
		Company
		Conversation
		Driving-related stress
		Shared driving responsibility

one third of the concepts (presumably ignoring those concepts that they did not understand or did not consider relevant). Use of structured 3CM in the classroom to identify students' misconceptions about course context provides additional support for participants' ability to differentiate owned and unowned concepts. In these exercises, a concept list was generated by polling both students and instructors about the concepts they perceived important and relevant to course content. This list was subsequently presented to students along with the standard structured 3CM instructions. Results indicated that students tended to ignore advanced concepts (i.e., those that had not yet been discussed in class and that students presumably did not yet own). Also, as expected, participants completing structured 3CM tasks tend to group their chosen concepts into 5 ± 2 groups. This result has been consistent across a range of contexts.

CONCLUSIONS

Internal representations can be viewed as knowledge structures that compete for the right to represent new input. In other words, there is a bias in the direction of classifying new stimuli in terms of old categories. Reactions to 3CM are consistent with this expectation. Some colleagues have interpreted the 3CM method as just another card-sorting technique, whereas others have described it as a permutation of a Q-sort. It is neither. Crucial differences exist between 3CM and the other card-sorting techniques reviewed here: Most important are the unique theoretical underpinnings of the 3CM method and the focus on owned (vs. unowned) objects, which permits a more accurate assessment of knowledge structure. With respect to the Q-sort, the only similarity may be the fact that both techniques use cards. The cognitive processes involved in 3CM (i.e., in identifying concepts perceived to be important and then organizing these concepts—often along multiple dimensions simultaneously) have little in common with the cognitive processes involved in the standard Q-sort (i.e., in arranging a given set of cards along a single, researcher-defined, dimension). These differences in process leave no reason to suspect that the two techniques are similar in function.

Others may question whether 3CM yields results that other, more traditional techniques, do not. Comparison of the structured 3CM results in the carpooling study to the results of a survey used in the same study (Kearney & De Young, 1995) highlights the unique contributions of the 3CM technique and points to the complementarity of this technique with others. Though the survey and the structured 3CM were designed as redundant measures, they actually captured very different aspects of the knowledge construct. The 3CM task proved much more useful in identifying differences in the groups' perspectives, or cognitive maps, on carpooling, whereas the survey captured information on (among other things) the groups' comfort with, or ability to use, that knowledge.

Interestingly, no significant difference on participants' level of comfort with their knowledge was found between the story group and the fact-sheet group (though both were significantly higher than the control group). Reliance on the survey alone would have led to the conclusion that knowledge did not differ between the two treatment groups. Results from the 3CM task, however, showed that while comfort with knowledge did not differ, significant differences between the two groups did exist in terms of the structure of their knowledge (the most significant difference being the story group's inclusion of the social aspects category).

Thus, despite the superficial similarities to other approaches, the 3CM method (including both the open-ended and structured implementations) appears to contribute new and useful information in a variety of contexts. In keeping with its origins, in the SESAME theory of cognitive maps, 3CM meets a variety of key constraints and expectations. It focuses on mental objects, reflects those objects (and only those objects) that an individual owns, approximates hierarchical relationships among objects, and allows individuals to explore their knowledge structure in the process of externalizing it. And, as one would hope from a theory-based measure, its construct validity is reasonably high. The 3CM method also fills a gap between standard qualitative and quantitative approaches. And finally, the technique is user friendly. By facilitating the thought process and reducing the impact of limited channel capacity, 3CM provides an experience that many participants find both satisfying and enlightening.

NOTES

1. Although Lynch (1960) distinguished between nodes (i.e., path intersections) and landmarks, our model does not. The reason for this discrepancy is that we, along with

the majority of researchers in the area, feel that landmarks are learned first, and, in turn, anchor the cognitive map structure. Thus, a node in our model is not where paths cross, but where a landmark exists to provide an attachment point for a path.

2. Throughout this article we will use the terms *cognitive map, cognitive structure,* and *knowledge structure* interchangeably.

3. A reviewer argued that the fact of unconscious cognitive material precludes any meaningful externalization process. In other words, the concept of ownership, of recognizing what is in one's mind and what is not, might seem to be undermined by the existence of unconscious material. This is not, however, a valid concern. Consider dividing the universe into three categories of concepts: (a) those that a given individual owns, (b) those the individual does not own, and (c) those that are a part of the individual's cognitive structure but that are unconscious and thus inaccessible. The claim here is that an individual can distinguish category (a) from (b). Any concept in (c) will constitute noise as far as our procedure is concerned. However, in the context of natural resource and other environmental decision making, which is the focus here, we would suspect that the latter category is not large.

4. This method is termed the AID (association-driven issue display) procedure in Austin's (1994b) dissertation.

5. This study was conducted as part of a master's thesis (Kearney, 1993) and a more detailed description of the study design can be found in Kearney and De Young (1995). The data included here have not been previously published.

6. In this early implementation of the structured conceptual content cognitive map (3CM), participants were not invited to generate their own concepts as the concept list provided was assumed to be broad enough to adequately capture a wide range of perspectives on carpooling. In subsequent usage of the structured 3CM, participants have been invited to add their own concepts.

7. Participants' labels and category content were analyzed to provide additional data about differences in knowledge structure among the three study groups. These results can be found in Kearney (1993).

8. Latent partition analysis (LPA) (Wiley, 1967) was formulated to study the relationships among two or more partitions of the same set of items. Items that are consistently combined by group members are considered to form a latent category. These latent categories are assumed to represent the way the group, as a whole, structures their knowledge. In this respect, LPA is similar to factor analysis, though it is suited to categorical, rather than ordinal or interval, data.

9. The large amount of missing data in these matrices may cause some to question the validity of results. However, in this case, concepts that were not chosen by participants translate into meaningful data (a statement of nonimportance or nonrelevance) rather than missing data. In this sense, the matrix is complete though it may not have values of 1 in the diagonal. (Rather, the diagonal entries will reflect the percentage of participants who chose to sort a particular concept.)

10. Because participants were not required to categorize all of the concepts, a number of concepts were categorized by a relatively small percentage of people. The 30% criterion was used to weed out concepts that may have otherwise been included in a cluster. This cutoff was arrived at by examining the average number of concepts participants in each group chose. Because people tended to select approximately one third of the total number of concepts available, it follows that if all concepts were equally salient, they would be chosen by 30% of the participants. Setting the cutoff

point at 30% captures those concepts that were most salient (chosen more often than chance) to the group.

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