

Using Cognitive Mapping in Management Research: Decisions about Technical Innovation

Jacky Swan

Warwick Business School, University of Warwick, Coventry CV4 7AL, UK

Case studies of firms attempting to adopt a particular type of technological innovation have demonstrated that the process of technological innovation may be mediated by decision-makers' access to knowledge and by their cognitions – reflected in belief systems. This paper highlights the importance of cognitions in decisions about technological innovation. However, cognitive processes have been under emphasized in empirical work on technological innovation and part of the problem may have been lack of availability of research tools and techniques with which to explore cognitions. Cognitive mapping methodologies are reviewed in terms of their potential to fill this gap in the research into technological innovation. The paper discusses these methodologies, evaluates their limitations and argues that a distinction should be made between cognitive maps and the output of mapping techniques. The paper concludes that cognitive mapping may provide a useful addition to existing management research tools provided researchers are clear about what is revealed by the particular methodology used.

Introduction

Successes and failures with technological innovation have been attributed, at least in part, to the decision-making processes of the adopting organization (Gerwin, 1988). This paper highlights the importance of cognitions of key actors for decisions about new technology but suggests that empirical work in this area has been limited. The paper therefore critically evaluates the potential for cognitive mapping techniques to be used for investigating the role of cognitions in decisions about technological innovation and considers how these techniques might complement other methodologies.

My interest in this topic stems from involvement in research projects¹ that have investigated

the organizational context and decision-making practices surrounding the adoption of a particular technology – computer aided production management (CAPM). This research involved a series of case studies of medium and large-sized manufacturing firms that were attempting to adopt CAPM technologies (Swan and Clark, 1992; Robertson *et al.*, 1996). In Britain during the 1980s CAPM technologies (under a variety of different guises) were being promoted as *the* best practice technology for production control in manufacturing industry. In theory, CAPM technologies can optimize production flows and inventory levels in manufacturing firms by integrating the data that is used across the different functional areas within the firm (e.g. sales, purchasing, production, etc.) and using this for production planning. Academic literature at the time reinforced this view (e.g. Corke, 1985).

In reality, numerous case studies – including our own – were demonstrating that many firms were experiencing severe difficulties in implementing CAPM and were not using the technology

¹ One project was supported by EPSRC and conducted together with Peter Clark, Sudi Sharifi and Sue Newell at Aston University. Another was supported by ESRC and conducted with Maxine Robertson and Sue Newell at University of Warwick. The author thanks these collaborators.

as prescribed by the software suppliers (see also Wilson *et al.*, 1994). The main problems seemed to occur when firms tried to move from having modules of CAPM working independently in different functions to having integration across functions (Waterlow and Monniot, 1986). Earlier case studies revealed that key players in the different functional areas of firms often held quite diverse beliefs about CAPM and its likelihood of success. These inter-functional differences in understandings of CAPM appeared to cause problems in implementing the technology (Swan and Clark, 1992; Bessant *et al.*, 1989). For example, in one of our cases a purchasing manager believed that CAPM would disadvantage the firm, contrary to the belief held by other functional managers that CAPM would offer numerous advantages. This particular manager had not been involved in design choices but his involvement was crucial to the firm's plans to implement CAPM. His commitment to the project was low, with the result that implementation was delayed and there was political infighting between this function and other functional areas in the firm (Swan and Clark, 1992). In keeping with other studies of innovation diffusion, CAPM was adopted because it was perceived to offer relative advantage (Rogers, 1983) but these perceptions were not shared by those needed to implement the system.

In the literature, CAPM is often presented as a technology with fixed, mostly technical, parameters which, provided it is implemented properly, will deliver advantages to the user (e.g. Corke, 1985). Research has therefore tended to focus on how to implement the technology (e.g. Wilson *et al.*, 1994). However, other research into technology and organization has questioned this conceptualization of technology (e.g. Scarbrough and Corbett, 1992; Weick, 1990a) and has argued that the notion of CAPM as a singular 'best practise' technology is flawed (Clark and Staunton, 1989). Our cases revealed that adopting CAPM was not simply a question of inserting a technology with fixed parameters into an organization. Rather, CAPM represented a complex bundle of technical and organizational knowledge. Successful usage required that the technical systems were unpacked and reconfigured along with the organizational knowledge and infrastructure. Clark (1987) refers to this process as 'appropriation' of technology, suggesting that appropriation entails

a process of *innovation design* that requires *choices* on the part of the adopting organization about how to reconfigure the technology as presented by the technology supply side within the unique organizational context of the user. These choices can include the decision not to adopt a technology where it is not appropriate. Thus managerial choices about technology design can influence whether or not later implementation is successful. Crucial to these choices with regard to decisions about CAPM were the managerial cognitions in the adopting firms at the time (Swan and Clark, 1992). Our case studies revealed that appropriation of CAPM was difficult for user firms. In particular, failures in implementing these technologies could be traced to inappropriate choices about technology design in some firms.

The term 'cognitions' refers here to both cognitive structures (mentally represented concepts and relationships) and cognitive processes whereby those mentally represented concepts are constructed, manipulated and used in the decision-making process. Both comprise individuals' belief systems or 'mental models' (Rummelhart and Ortony, 1977). The paper adopts the view that these structures and processes are constantly evolving and changing over time (Bartlett, 1932) and therefore 'cognitions' are not seen as fixed sets of 'things' but rather as ways of constructing and utilizing knowledge. This is an important point because the noun 'cognition/s' is underpinned by particular methodological assumptions – that cognition can be understood using methodologies that describe and identify its component parts (some cognitive mapping techniques do this). In contrast, if 'cognitions' are seen as ways of processing information, incorporating both fluid structures and processes, then a more complete understanding will be developed using methodologies that describe cognitive structures at particular points in time as well as methodologies that reveal the processes through which knowledge is structured and used for decision-making. A limitation with cognitive mapping methodologies may be their tendency to focus on cognitive structure rather than on process. This paper begins by discussing the role and relevance of cognitions for decisions about technological innovation. Cognitive mapping techniques are then reviewed as potential tools for management research and, in particular, for gaining further insights into the innovation process.

The role of cognitions in decisions about technological innovation

Technology is seen here as knowledge which is embodied in technical (e.g. hardware, software and physical layout) and organizational (e.g. strategies, routines and structures) knowledge bases (Berniker, 1987; Clark and Staunton, 1989). Both technical and organizational knowledge bases are important for making decisions about complex technologies like CAPM because their appropriation is context specific, requiring a blending of technical systems with organizational practices (Clark and Staunton, 1989). However, particular individuals will select and utilize existing knowledge differently when making choices about which particular design of new technology to adopt. These choices will depend to some extent upon both the beliefs that particular individuals hold about the new technology but also upon their ability to influence the decision-making process (Swan and Clark, 1992). Here then, 'cognition' is used to describe individuals' belief systems or mental models that form common-sense social theories (Rummelhart and Ortony, 1977). In this way complex information is framed and simplified so that problems may be constructed and more easily understood (March and Simon, 1958). Cognitions, then, refer to the belief systems that individuals use to perceive, construct and make sense of their world and to make decisions about what actions to take (Weick, 1979; Weick, 1995; Walsh, 1995).

Research into cognition has been dominated by constructivist ideas which argue that retinal codes are inadequate for specifying how objects are perceived, and that knowledge is added to the retinal code such that what we 'see' is actually a construction of the object as it really is, based on our own mental models. Thus perception is seen as a cognitive, mental activity where our brains interpret incoming stimuli in the light of prior knowledge. This research has led to useful ideas about schemas (Bartlett, 1932; Rummelhart and Ortony, 1977), cognitive maps (Tolman, 1948), scripts (Schank and Abelson, 1977) and frames of reference (Minsky, 1975). Schemas, scripts, frames and cognitive maps represent organized generic knowledge that is used to perceive incoming sensory inputs that would otherwise be overly complex (Fiske and Taylor, 1984).

Whilst the term 'cognition' refers here to mental models, the limitations of taking a strong

constructivist position should be recognized. The constructivist approach focuses on a subjective mind, suggesting that what we see is a product of the mind and therefore it makes no sense to talk about a reality that exists somehow outside of the mind. Environments are treated as enacted or projected such that 'unless something is attended to "it" does not exist' (Weick, 1979, p. 28). However, this does not explain how stimuli are selected for processing in the first place. Nor does it seem adaptive in evolutionary terms to have a system where understanding is separated from reality (Solso, 1993). Bateson (1979) argues instead for a 'unity of mind and nature' such that, although the conscious perception of images is carried out in the mind, the formation of those images perceived is unconscious and mediated by peripheral senses such as our eyes and our ears. For example, you may detect a red glow (image) and 'see' a fire (perception) but what led you to attend to the glow in the first place over the multitude of other possible stimuli depends on the features of the stimuli and their processing in the unconscious. The process of cognition is therefore distributed, not just mental, as we 'see' with our senses as well as our brains (Gardner, 1994). However, Bateson maintains that even these unconscious processes of image-making are guided by a range of 'presuppositions' that are built into the finished image (Bateson, 1979). Thus mental models and territory are intrinsically and dynamically related, because mental models shape unconscious attention but stimuli that are attended to are perceived, and therefore shape mental models.

Unconscious processes are not easily accessible for study so the focus here is on ways of exploring cognitions that are conscious and reflected in peoples' uses of concepts. It is these concepts, which are assumed to reflect underlying cortical schema and cognitive maps, that are the focus of many cognitive mapping techniques (Bougon, 1983). However, it is worth remembering that underlying schema and cognitive maps may be shaped by unconscious peripheral image-processing through a variety of senses. They are also socially constructed because individuals operating in social territories derive meanings through their ongoing interactions that will become embedded in their schema and shape future interactions (Bartlett, 1932; Weick, 1979). A point made in this paper then is that the cognitive maps revealed using

mapping techniques are not the same as underlying psychological schema or cognitive maps – a distinction needs to be drawn between internal psychological schema and cognitive maps, and the output of cognitive mapping techniques.

To summarize, cognitions are seen here as the specific belief systems of individuals which draw upon some subset of available knowledge bases in formulating expectations and making decisions about which course of action to take. Our cases with CAPM suggested that cognitions of key decision-makers play a key role in the innovation process by mediating the relationship between available knowledge and outcomes of decisions about technology design (Swan and Clark, 1992). To give an example from one of our earlier cases, fairly sophisticated computing systems were in place before the firm decided to adopt an integrated CAPM system. An internal team of technical experts evaluated the feasibility of constructing a CAPM system using existing hardware and software and recommended this as the best solution for the organization. Meanwhile, the managing director employed a consultant who recommended a CAPM solution based on different hardware and software to that already in place in the firm. So this firm had a knowledge base internally and also via the consultant. From this knowledge base the key decision-makers chose to adopt the consultant's recommendations for the design of the new technology and dismissed those of the internal team. The decision was based largely on the beliefs of the managing director which were, first, that the consultants advice was certain to be valid (i.e. the belief that expert knowledge lies with consultants) and second, that new technology was sure to be better than old technology (i.e. the belief that new is good). The later failure of the new system was blamed largely on the incompatibility of the new technology with existing technical systems. Further, most hands-on users lacked the skills needed to operate the new system and, in any case, felt it to be the wrong choice (i.e. held the belief that there was nothing wrong with the existing systems) but they had not been involved in the decision-making process.

These case studies illustrated the importance of available knowledge bases in determining a firm's potential to adopt innovations but also showed that social-political interactions, and cognitions of key decision-makers and of end-users were crucial to the outcome of decisions (Swan and

Clark, 1992). In particular, appropriation was difficult when users across different functional areas and different levels of the firms' infrastructure did not share the belief that the technology would be advantageous. This problem was exacerbated when users in some functional groups were left out of decisions about the design of the CAPM systems but were none the less needed to implement these systems. As stated earlier, CAPM is a technology that impacts on different functions within the firm and the individuals that worked in very different functional areas often had very different ideas, not just about the CAPM solution, but also about what their problems were (Robertson *et al.*, 1996). Difficulties in implementing CAPM also occurred when individuals based decisions on heuristics (for example, over-generalizations such as all new technology is good, all consultants are experts) or analogies with prior experience (such as, 'if CAPM works for them it will work for us'). Such analogies were often inappropriate and ignored the importance of the organizational context for appropriating CAPM technology (Swan and Clark, 1992; Swan, 1995).

Investigating cognitions in decisions about technological innovation

In the innovation literature there has been a good deal of empirical work aimed at establishing what sort of knowledge bases a firm needs to have in order to adopt technological innovation. For example, there is research that suggests that innovation is more likely if a firm has a clear technology strategy (Rosenbloom and Cusamano, 1987), if the new technology is compatible with existing technical knowledge (Robertson *et al.*, 1996) if the firm has a commitment to education and training, if top management provide adequate support and resources and so on (Wilson *et al.*, 1994). However, there has been relatively little empirical investigation of the role of cognition in the context of research on technological innovation, even though recent work has indicated that managers' cognitions are important for shaping both technology and organization (Weick, 1990a; Lowstedt, 1985). For example, Weick (1990a) argues that new technologies are equivocal (i.e. subject to a variety of interpretations) and therefore require 'sensemaking' in order to be managed (see also Weick, 1995). Lowstedt (1985) suggests that researchers looking for direct

relations between technology and organization have, on the whole, ignored the cognitions of principal actors, which are crucial in mediating these relations. In keeping with others, he adopts the view that organizations and technologies are socially constructed by the people that describe and interpret organizations so that there is no objective 'real' organization or technology independent of the cognitions of the people involved. People design technology and organization in keeping with their perceptions and explanatory frameworks and new technology allows new social systems which in turn determine new organizing processes (cf. Giddens, 1984). Lowstedt (1985) argues for a 'cognitive actors' approach to technology and organization where the cognitive views that the principal actors have of the technology help to determine the emergent organizational structure. This is similar to the view taken here which suggests that outcomes of decisions about new technology are not predictable solely from existing knowledge bases at the level of the firm, and that cognitions may also mediate decision outcomes (Swan, 1995).

More generally, researchers have noted that managerial cognition is an essential element in strategic decision-making which has been under-researched in the management literature (e.g. Stubbart, 1989; Porac and Thomas, 1989). Stubbart (1989) notes that this 'neglect' of managerial cognition may be because many studies of decision-making, carried out by psychologists and management researchers alike, have focused on producing normative idealized models rather than descriptive models of decision-making (see Koopman and Pool, 1994). These normative approaches have attempted to produce generalized models in which the variability caused by individual differences in cognition has been minimized. All decisions are made in the same way, therefore there is no need to examine individuals' beliefs except in as much as these add 'noise' to the data.

Other research has recognized that it is crucial to investigate individuals' cognitions in order to understand decision-making in organizations (March and Simon, 1958; Weick, 1979; Jelinek and Litterer, 1994). Jelinek and Litterer, for example, put forward a cognitive theory of organizations that:

'is able to link individual level phenomena – for example, cognitions and actions – with organisational level phenomena – for example, output,

co-ordinated actions, organisational change and organisational learning.' (p. 3)

They argue that this kind of theory is necessary because:

'much that occurs at the organisational level is indeed the outcome or product of individual level phenomena.' (p. 5)

According to this view, an individual's beliefs are not just noise in the organizational decision-making process but they may actually guide the direction of an organizational decision, and the actions that occur as a result of that decision in turn shape and modify the beliefs of the individual. Jelinek and Litterer also acknowledge the problems of using individual-level phenomena to explain organizational-level phenomena and their theory is explicit in stating that individual-level constructs, whilst crucial, do not translate directly into organizational outcomes. Organizational decisions derive from collections of individuals engaged in coordinated social activity who are themselves shaped by the socio-political context of the organization (Jelinek and Litterer, 1994). Organizational decisions and outcomes may therefore transcend the decisions of any particular individual (Simon, 1991). An understanding of organizational decisions would therefore benefit from descriptive models of decision-making which address cognitions of individuals and groups but within the social and institutional context of the organization.

Reasons for the lack of empirical studies

Despite a recent surge of interest in managerial cognition, empirical investigation of the role of cognition in organizational contexts is still lacking (Fiol and Huff, 1992) and empirical studies of cognition in the innovation process in particular are virtually non-existent. Stubbart (1989) noted that in the past there was a lack of tools with which to investigate managerial cognitions. Cognitive mapping methodologies may provide a set of techniques with which to investigate cognitions in organizational decision-making more closely. Whilst it is true that some cognitive mapping techniques have only been developed and validated relatively recently (e.g. Daniels *et al.*, 1994), others – such as repertory grid techniques – have

been available for quite some time. Although there may have been flurries of interest in cognitive mapping techniques in management research (e.g. Axelrod, 1976; Bougon *et al.*, 1977), they have not attracted sustained interest, that is until relatively recently. This may be because research tools developed in one discipline (for example repertory grids in psychology) are less accessible to researchers from others (for example management researchers). Research in the area of innovation is especially prone to problems of this kind because it potentially draws from a disparate range of literatures. However, clearly there has been some access to these mapping techniques in management research – repertory grids, for example, have been used for management research in the past (e.g. Smith and Stewart, 1977).

Perhaps a better explanation as to why cognitive mapping techniques have been relatively slow to catch on in management research is because of the difficulties of using methodologies where the unit of analysis is usually individuals or small groups (which is common in psychology) to assess organizational-level phenomena (which is common in management research). For example, Jelinek and Litterer (1994) argue that it is essential to understand the shared cognitions of organizational members because these form the link between individual cognitions and the ‘consciously coordinated behaviours’ that are central to organizational action (their definition). However, in the same volume, Scheper and Faber argue that existing cognitive mapping techniques:

‘do not, and cannot represent meaning at the collective level, that is, shared meaning.’ (p. 165)

Whilst other authors would take a less extreme view (e.g. Weick and Bougon, 1986), clearly there are theoretical and methodological problems associated with understanding organizational actions using techniques that begin with the individual as the unit of analysis, and these may have limited the use of cognitive mapping in the past. A final potential problem is that the tools developed for one area of study may be used inappropriately in another. This can be seen, for example, in cases where psychological tests designed to measure personality have been used inappropriately as selection instruments.

Recently there has been a growing interest in research in managerial cognition such that this

topic has attracted special interest in journals, at conferences and at workshops in Europe and North America.² Much of this interest has come from researchers who have used and, in some cases, developed a variety of cognitive mapping techniques to identify and describe managerial cognitions in strategy formulation. Hence, a critical review of cognitive mapping techniques here should be both useful and timely.

Cognitive mapping as a management research tool

In psychology, ‘cognitive map’ was a term that was developed to describe an individual’s internal mental representation of the concepts and relations among concepts that the individual uses to understand their environment (Tolman, 1948). Cognitive maps are thus seen as internally represented schemas or mental models for particular problem-solving domains that are learned and encoded as a result of an individual’s interaction with their environment. When the individual encounters similar problems again they will then draw upon their stored mental maps in order to understand the problem and initiate a course of action. Cognitive maps are also dynamic in that they can change as new information is processed but they also shape how information is selected for processing and are, therefore, to some extent self-confirming (e.g. Swan 1995; Bartlett, 1932). Cognitive maps may hold many types of relationships among concepts, for example proximity (A is close to B), similarity (A is similar to B), cause–effect (A causes B), category (A is a subset of B) and contiguity (A follows B).

In contrast, cognitive mapping describes a set of techniques that are used to try and identify subjective beliefs and to portray these externally (Fiol and Huff, 1992). The general approach is to extract statements from individuals about subjectively meaningful concepts and relations in particular problem areas and then to describe these concepts and relations in some kind of

² Seen, for example, in the recent EIASM workshops in managerial and organizational cognition and the Managerial Cognition Interest Group in the Academy of Management. This paralleled a new focus for the series, Advances in Managerial Cognition and Organizational Information Processing in 1994.

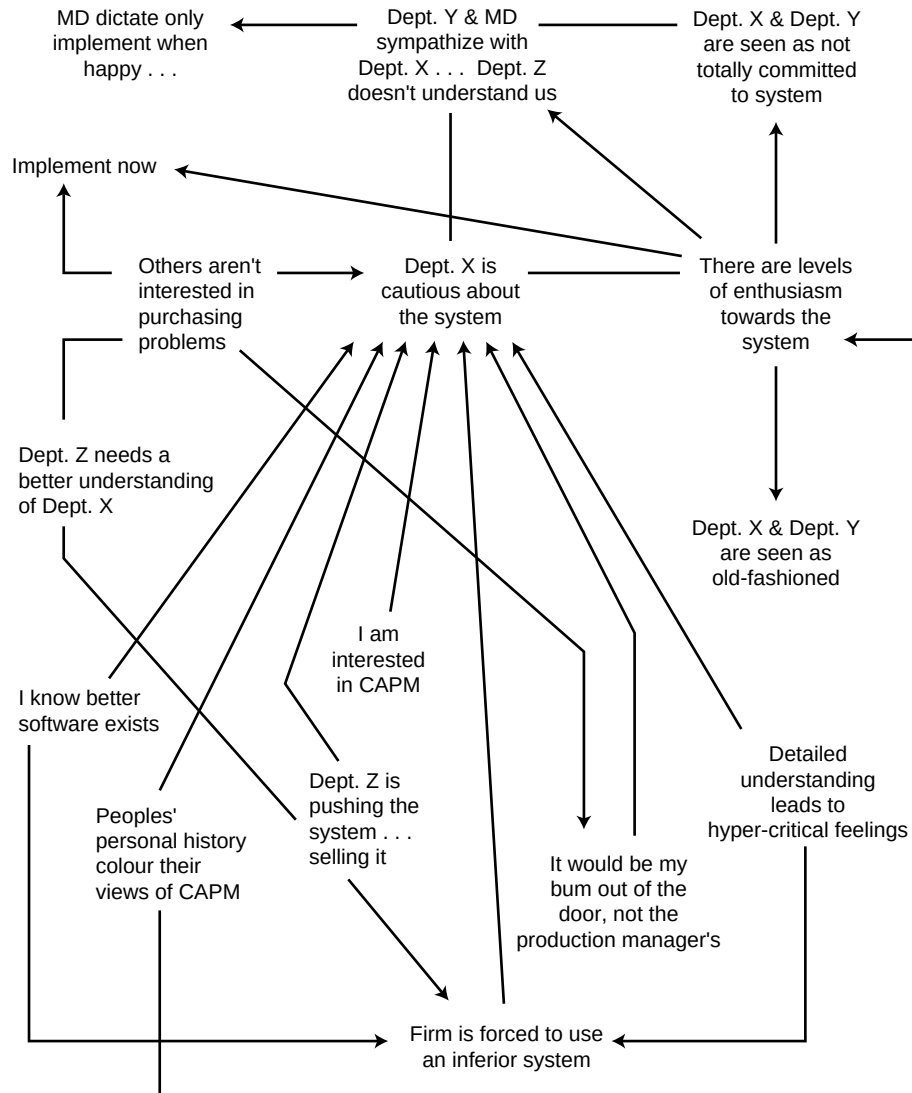


Figure 1. Individual cognitive map for manager Department X

visuospatial layout. The outcome of a mapping technique is usually referred to as a cognitive map although, as will be seen below, this is really a confusion of terms. Figure 1 shows an example of a hypothetical output from a cognitive mapping technique which describes the beliefs that the manager in Department X has about CAPM (adapted from Bessant *et al.*, 1989). This map contains key concepts, or nodes; for example, 'I know that better software exists'. The map also contains relationships among concepts, or links and the arrowheads show the direction of these relationships; for example, 'I know better

software exists' and 'peoples' personal history colour their views of CAPM' lead to the conclusion that 'Dept. X are cautious about adopting the system'.

Mapping techniques

Mapping techniques include, variously:

- content analysis of text to reveal key concepts and themes (Erderner and Dunn, 1990)
- repertory grid techniques and factor analysis to identify dimensions for individuals that

- underlie the concepts they use in problem-solving domains (Kelly, 1955; Reger, 1990)
- systematic coding of causal relationships based on the analysis of documents (Axelrod, 1976; Huff *et al.*, 1990)
 - matrices and matrix-multiplication techniques to examine causal relationships among key concepts (Bougon *et al.*, 1977; Ford and Hegarty, 1984)
 - computer software to produce models of concept meanings and causal relationships of the type shown in Figure 1 (Eden, 1989)
 - interviews in which the participants question themselves in order to expose concepts and relationships (i.e. the 'Self-Q' technique – Bougon, 1983)
 - techniques for mapping arguments used in decision-making (Fletcher and Huff, 1990)
 - semiotic analysis which is a technique borrowed from linguistics that draws out hidden meanings and underlying beliefs from surface manifestations of narrative text (Fiol, 1990).

Details of how to carry out these techniques can be found elsewhere (e.g. Huff, 1990). The purpose here is not to repeat these details but to evaluate the general usefulness and limitations of cognitive mapping techniques as management research tools. It should be noted that the emphasis here is on techniques for eliciting maps from managers directly, rather than on techniques based on the analysis of organizational documents, such as Axelrod's 'digraphs', although some of the issues raised may also apply to these.

Mapping techniques that have been used for management research vary in terms of the nature of the subjective beliefs they intend to describe. Some techniques, such as content analysis of interview scripts and documents, focus on describing the concepts that are held to be important by the interviewee. These have been used for example, to investigate top managers' understandings about which companies feature as important in their competitive environment (Calori *et al.*, 1992). Content analysis may be used to identify the perceived importance of themes and shift in the importance of concepts by looking at how often certain words are used, how they are juxtaposed and how their usage changes over time. These techniques can be carried out quite easily – maps can be constructed from interview or archival data with the help of word-processing packages to

count words – and can be useful in labelling concepts. A problem is that frequency of word usage may not be a very good reflection of the importance of the concept. For example, strongly embedded cultural values may not be articulated.

Other techniques, such as repertory grid techniques, have been used in management research to identify salient concepts as well as the underlying cognitive dimensions that individuals use to categorize and relate these concepts (see Easterby-Smith *et al.*, 1991). Repertory grid techniques were derived from Kelly's (1955) personal construct theory, which assumed that individuals construct their worlds along a unique set of dimensions (see Fransella and Bannister, 1977). Reger (1990) used repertory grid techniques to identify salient cognitive dimensions used by strategic managers to understand their competitive positioning in the banking market. For example, one strategist saw 'degree of asset-based lending' as a salient dimension that distinguished competitors in the market place and this was seen as part of the broader superordinate cluster – 'target lending market'. Reger then compared the repertory grids of individual managers from different firms in the same competitive environment and found relatively low levels of agreement on what constituted key strategic dimensions. This suggested that strategic decision-makers had their own idiosyncratic perceptions of key problem dimensions. Reger also compared the repertory grids for the entire group of managers and found that the salient dimensions identified in this group did not match those that strategic researchers have identified as important, indicating that strategists and researchers may be operating under different frames of reference in solving strategic problems.

A disadvantage of the repertory grid is that it is fairly time consuming and therefore requires good access to decision-makers. Further, proponents of personal construct theory might argue that comparisons of individuals and groups using this technique are meaningless because individuals' cognitions are unique, even to the extent that they may attribute different meanings to the same words (see Kelly, 1955). Adopting a strong idiographic stance negates the usefulness of measuring and comparing individuals across common dimensions. A further disadvantage of repertory grid techniques is that they focus only on the adjectives that individuals use to describe the content and structure of cognitive constructs. Thus repertory

grids present only part of the picture. They do not address, for example, the more processual aspects of the individual's belief system but, as discussed earlier, these are equally important for understanding organizational decision-making.

Causal mapping methodologies have been the most commonly used by researchers investigating cognitions of decision-makers in organizations (e.g. Ford and Hegarty, 1984; Eden, 1989; Bougon *et al.*, 1977). These expose both salient concepts in a belief system and the cause-effect relationships that exist among concepts. Links among concepts in causal maps can be either positive (A causes B), or negative (A causes the opposite of B). There are several reasons why causal maps are targeted by researchers of managerial cognition. First, manual and software tools have been developed that make causal relationships more amenable to research (Eden, 1989; Bougon, *et al.*, 1977). Second, the assumption has been that peoples' beliefs about the causes and effects of past events create expectations about the likely outcomes of future events and therefore guide their decision-making processes.

Cognitive mapping techniques have been described as operating on a continuum of different levels of analysis from those that describe the manifest content of cognitions (e.g. content analysis) to those that describe deeper underlying structures, processes and relationships (e.g. causal mapping, Huff, 1990). This is a convenient description but it may be overly simplistic (Swan, 1995). Research in psychology suggests for example, that words are themselves a reflection of deeper abstract concepts and that it is these abstractions that are encoded in memory and guide decision-making (e.g. Bartlett, 1932; Bransford and Franks, 1971). For example, when an individual uses the word 'computer' overtly, this is a reflection of an abstract mental representation comprising all the prototypical features of computers (physical characteristics, uses, times and places where computers are found and so on). In other words, there is nothing very 'superficial' about content analysis based on word usage. The manifest content-to-underlying-structure continuum also tends to confuse outputs of cognitive mapping techniques with implicit cognitive maps because it implies that particular mapping techniques can actually capture underlying mental structures and processes. As will be seen below, this is oversimplifying the case. Thus, whilst this continuum is convenient,

it might be more useful to distinguish mapping techniques just in terms of the types of subjective beliefs they intend to describe – some mapping techniques describe salient concepts, while others describe cause-effect relationships – without alluding to the idea that some of these beliefs are cognitively 'deeper' than others. In this way, depth of *analysis* is possible with any of the techniques depending on the extent to which the maps that are produced provide a more or less meaningful and accurate description of the subjective beliefs they claim to reveal.

Outcomes, uses and limitations of cognitive mapping

There is a danger in moving from the psychological use of the term 'cognitive map' as an internal mental representation to its use as a term to describe a set of research techniques. This is because what you end up with as a result of using a cognitive mapping technique is not a cognitive map, in the psychological sense. In other words, the outcome of a cognitive mapping technique is not the same as the internally represented mental model but rather a reconstruction of subjective beliefs that have been revealed to the researcher (Eden, 1992). A distinction, therefore, needs to be made then between the output of a cognitive mapping technique and a cognitive map. There are several reasons for this and these are discussed next.

The outputs produced by cognitive mapping techniques are, like any other research techniques, shaped by the method used to elicit the map, although mapping techniques are bound by the methodology in different ways. Many mapping techniques used in management research address only cause-effect relations among concepts (these are called causal maps) but a causal map will be only part of the individual's total belief system. In fact, one limitation with the existing empirical literature is that there are very few studies of other types of relationships among concepts that may be important in decision-makers' belief systems. Causal mapping techniques do not capture other relationships among concepts such as proximity or similarity, and yet research has suggested that these are also important for understanding the ways in which decisions are made in organizations (e.g. Tversky and

Khaneman, 1974). For example, decisions about the design of CAPM have been made through a process of analogies with other firms (i.e. this works for them so it will work for us), sometimes with disastrous results (Swan and Clark, 1992). Analogies entail some notion of similarity between the features of one situation and the features of another that would not necessarily be revealed in a causal map.

Goldberg (1994) makes a useful distinction in cognitive mapping between the method used for data collection and the method used for data analysis, and suggests that the output of a mapping technique (i.e. the revealed map) may be bound by the method used at either of these stages. The ways in which a mapping technique constrains the revealed output can be seen by considering the example of a causal mapping technique developed by Bougon, Weick and Binkhorst (1977). This technique was used to map beliefs about the causes and effects of quality of performance among members of the Utrecht Jazz Orchestra. These authors developed a two-dimensional 'grid' comprised of a list of elements (i.e. concepts) along the rows, which were repeated in the columns. These elements (e.g. practise of musical pieces) had been extracted following interviews with orchestra members where they had been mentioned as things that might affect the quality of playing performance. Members of the orchestra were then asked to go through the grid and to indicate for each cell whether a change in the row variable would directly cause a change in the column variable, and whether this change would be in a positive or negative direction (e.g. more practise causes better quality performance). The maps produced for individuals were then combined into a group map that represented cause-effect beliefs that were shared by most of the members of the orchestra about which factors they felt to be important for improving the quality of their playing performance.

Swan and Newell (1993) adapted this 'grid' technique in order to investigate production managers' beliefs about the factors that caused or resulted from technological innovation in the production control area. Again, a group map was constructed which showed the most commonly shared cause-effect beliefs about what made innovation more likely in production control. For example more than half believed that having more professional staff in their organization made

innovation in production control more likely. They also believed that changes in the technology were likely to cause changes in the infrastructure of their firms.

This 'grid' mapping technique is useful in revealing and describing, in a systematic and understandable way, subjective beliefs of individuals in a particular problem domain, and for portraying those beliefs that are commonly shared. However, the output of this mapping technique is constrained by the method of data collection in several important respects. First, the individuals were asked only to indicate causal relationships and were only asked to reveal these in an 'all or none' fashion – there was no opportunity to suggest that a causal relationship was likely only some or most of the time. Second, the concepts that the individuals were asked to consider were limited to those that the researchers listed in the grid. Some individuals may have felt other concepts to be important that were not listed. The Swan and Newell (1993) study was more 'method-bound' in this respect than the Bougon *et al.* (1977) study because in the former the researchers derived the list of concepts from the literature on innovation, whereas in the latter the concepts were derived from initial interviews with the participants themselves. It is likely then, that in the Swan and Newell study, some concepts that the production managers held to be important did not appear in managers' maps because they were not asked about them. Although managers were given the opportunity to add concepts to the grid, most of them did not, which may have been an artefact of the technique rather than an indication that all of the important elements were captured.

A further limitation of the 'grid' approach is that it assumes that the meaning attached to the labels used in the grid are the same for each individual. This may have been alleviated to some extent in the Swan and Newell (1993) study because individuals were given common definitions of the labels. Scheper and Faber (1994) refer to this as a problem of specificity of meaning. Initially when people use labels (verbal tags) they may appear to agree on the meaning of the labels. However, as the specific properties of labels becomes more specific (for example through discourse), agreement disappears. Conversely, individuals may attach different labels to the same underlying meanings. This can be particularly problematic when combining maps from individuals

using the grid technique into one aggregate (sum-mated) map because the aggregate assumes individuals attach a common set of meanings to the concepts in the grid (Scheper and Faber, 1994). This does not negate the usefulness of the grid technique as a research tool, but suggests that there should be some additional mechanism built in to assess what the labels actually mean for the individuals concerned. Similarly, a group map could prove to be a useful device for understanding and facilitating decision-making even if people do not attach the same meaning to the labels used in the map. Depending on how the group map was subsequently used, it could help to reveal important differences in individuals' understandings of what were assumed to be common terms and therefore encourage negotiation of shared meanings (Eden, 1992).

The output of the grid mapping technique is also constrained by the way in which the data is analysed. In the Swan and Newell (1993) study for example, the data from each individual was combined into a group map by representing in that map only those beliefs that were shared by more than half of the sample. This aggregating of the data had the advantage of producing an interpretable description of shared beliefs – assuming the people attached similar meanings to the definitions of the labels. This is important because it is claimed that those beliefs that are shared are more likely to influence organizational decisions (Schwenk, 1988; Lyles and Schwenk, 1992; Jelinek and Litterer, 1994). Therefore, a shared map may be a better predictor of the ways in which organizational decisions are made and their likely outcomes (Weick and Bougon, 1986). On the other hand, this way of combining data precluded from the output beliefs that were held by particular individuals. It may be equally important to capture these rather idiosyncratic beliefs because particular individuals with formal or informal power may have considerable influence on the outcomes of the organizational decision. For example, our case studies with CAPM suggested that implementation problems occurred when particular individuals lower down the organizational hierarchy, but with informal power, held firmly entrenched beliefs that CAPM was an inappropriate solution for their problems. These beliefs were not necessarily shared by others at the top of the hierarchy who had made the decision to adopt CAPM, but were none the less important when it came to implementing the CAPM solution

(Swan and Clark, 1992). If individual differences are considered in the socio-political context of the organization, then cognitive mapping techniques could be a powerful research tool for understanding who in the organization was influential in shaping the outcomes of organizational decisions.

It would in any case be impossible for any cognitive mapping technique to reveal a person's entire complement of implicitly held beliefs even for a particular problem domain, regardless of how sophisticated the technique is. In other words cognitive mapping techniques could not reveal cognitive maps in the psychological sense because an individual could never fully reveal all that they know. An analogy can be made here to the problem encountered by researchers in artificial intelligence, where it is argued that there can never be such a thing as a computer model of the brain because the computer would have to be more knowledgeable than the human brain in order to be able to reproduce it. But, since humans programme computers, this is impossible. Thus some researchers in this area prefer to label what they do as computer simulation, rather than artificial intelligence (Cohen, 1988). A similar confusion arises in cognitive mapping because the output of a cognitive mapping technique is commonly referred to as a 'cognitive map' but it is not a mental model (Eden, 1992). The term 'cognitive mapping' is perhaps something of a misnomer. It may be more useful to refer to 'content mapping', 'causal mapping' or 'argument mapping' to describe cognitive mapping techniques, depending on the nature of the relationships between concepts analysed by using the particular technique.

Researchers should be concerned with the validity of any mapping methodology, ensuring that it reveals concepts and relations that are in fact important to the interviewee and not just artefacts of the particular approach taken. The very process of eliciting the revealed map (e.g. by face-to-face interviews) may alter its composition because the interaction between the researcher and the interviewee involves articulation which can change the cognitions of both researcher and interviewee. Thus the interviewee cognitively reconstructs their own vision of the world and then the mapping process reveals a second-order construction of this. Any cognitive mapping technique involves some process of reflecting on what has gone before and this reflection may alter present and future beliefs (Eden, 1992).

Eden (1992) argues that this is only problematic if cognitive maps are seen as models of cognition that allow description and prediction of thinking. The problem does not arise if a somewhat weaker view of cognitive mapping is taken: that the revealed maps represent subjective data in a meaningful way. Weick (1990b) suggests that maps are reflections of the words people use to describe events, and not the events themselves, which he refers to as 'territory'. Although maps are not the same as the territory they are none the less useful in management research because the distinction between maps and territories sometimes becomes blurred or disappears. This is because much of managerial life is socially constructed in talk, symbols, expectations, memories and so on (Weick, 1985):

'In a socially constructed world, the map creates the territory, labels to territory, prefigures self-confirming perception and action.' (Weick, 1990b, p. 128)

Maps, even crude maps, allow managers to impose some meaning on the territory which then triggers action and allows new meaning to be constructed in the map. Weick appears to be talking about implicit maps. However, it follows that if maps revealed through cognitive mapping are meaningful representations (however crude) of these subjective beliefs, then they may be useful tools for triggering action and for facilitating negotiation and decision-making within organizations. With this approach it matters less that the process of revealing a map can itself change the way people think. Indeed, it is because of this artefact that the revealed map can be useful as a tool for organizational intervention (Eden, 1992).

Mapping techniques differ in the extent to which the revealed map is subject to the researcher's own interpretations. Content analyses, causal maps and argument maps that are produced from accounts where the researcher has elicited the concepts by asking the interviewee direct questions (e.g. what do you think affects the quality of your performance?) are more prone to researcher-led interpretation. In contrast, repertory grids and the Self-Q technique transfer most of the eliciting of concepts and relationships to the interviewee and are probably less susceptible. For example, the Self-Q technique gets respondents to ask themselves questions about the problem domain

and then to validate their own concepts (Bougon, 1983). This frees the researcher from initiating and steering the interview and, because the interviewee is instructed that they do not have to answer their own questions, the technique also frees the interviewee from the feeling that they must offer some *post-hoc*, rationalized explanation of events just because the researcher is asking about them.

Most existing research produces maps for what are thought to be key decision-makers in organizations. These may be corporate-level managers (Ginsberg, 1989); political elites (Axelrod, 1976); company executives (Narayanan and Fahey, 1990), or any top manager involved in major decisions. The reasoning behind this interest in the mental maps of top managers is the assumption that knowledge and cognitions of top managers crucially determine organizational decisions and performance outcomes (e.g. Narayanan and Fahey, 1990). Hence a better understanding of top managers' cognitions will lead to a better understanding of organizational performance. However, it is probably simplistic to assume that cognitions of certain individual top managers directly affect strategies and outcomes at the organizational level. The relationship between individual decision-makers' cognitions and organizational outcomes is mediated by other factors, especially intra-firm politics (Swan and Clark, 1992). In decisions about CAPM for example, middle managers not involved in decisions during early decision episodes could, none the less, exert considerable influence over the outcomes of implementation. So, whilst some understanding of organizational-level outcomes might be gained from looking at cognitions of key individuals, this might prove to be limited.

The validity of some mapping techniques (e.g. repertory grids) is well established, whereas with others there is still a need to address issues of validity to ensure that they reveal beliefs that are salient to the individual concerned and not just artefacts of the particular methodology. There are still relatively few empirical studies that include an assessment of the validity of different mapping techniques (though for an exception see Daniels *et al.*, 1994). In particular, it might be useful to use cognitive mapping in conjunction with process-oriented research in order to validate the often-assumed links between subjective beliefs and behavioural outcomes. In decisions about technological innovation, for example, there are many

other contextual factors (e.g. intra-organizational politics) that could mediate the link between beliefs of particular individuals or groups and decision outcomes (Swan and Clark, 1992). Mapping techniques could be used at different points in the decision process and for different units of analysis (e.g. groups and individuals) to examine the links between revealed subjective beliefs and decision outcomes *over time*.

Group and organizational maps

Some authors have suggested that mapping techniques could be used to identify and describe subjective beliefs at the level of the organization (e.g. Weick and Bougon, 1986). Cognitive maps then, can be explored for different units of analysis from the micro individual to the more macro, group or organizational level. Group or organizational mapping techniques usually begin with individual cognitive mapping and then combine the data into a group representation, although they are sometimes produced directly from group debate (e.g. Eden, 1993). Collective or organizational maps can be produced by:

- averaging the individual maps so that only the beliefs that are most often shared by the group of individuals are shown
- assembling the maps from the views expressed by the dominant elite (e.g. Axelrod, 1976)
- merging the individual maps into composite maps so that the common features are highlighted but idiosyncratic beliefs of individuals still figure in the map (Scheper and Faber, 1994).

Thus the resultant organizational map describes the subjective beliefs that are shared by individuals plus, in some cases, any additional idiosyncratic beliefs that are held by particular individuals (though see Scheper and Faber, 1994 for a critique of the meaningfulness of collective maps). This is useful because shared beliefs may be more directly related to strategy and decision-making outcomes at the organizational level (Schwenk, 1988; Jelinek and Litterer, 1994).

The matrix technique developed by Bougon *et al.* (1983, described above) produces group maps that are relatively easy to interpret by aggregating individual maps, showing only beliefs that are commonly shared (e.g. Swan and Newell, 1993).

However, this technique loses information about differences among individuals' cognitions which may be crucial. In our CAPM cases, for example, differences among beliefs of key actors in different functional areas of firms trying to adopt CAPM were at the root of political infighting, delays and interruptions in implementation. Decisions about information technology often have consequences for people across different functional areas who would have had different access to knowledge bases and diverse types of experience, so differences in cognitions relating to information technologies are likely to be quite significant.

An alternative is strategic options development and analysis (SODA) which has been designed to facilitate operations research consultants and their clients in working out messy problems (Eden, 1989). The merged map overlays individual maps so that common concepts and links appear once, but unique features are also maintained and these can be discussed by the group. The resulting maps can be employed as a facilitative device that promotes psychological negotiation among the members of the group so that they can come to a consensus on the definition of the problem, key concepts relating to the problem, relationships among these concepts and areas of strategic intervention (Ackerman and Belton, 1994). The technique could, therefore, be used as an action research tool or a consultancy tool. The technique itself produces very large and complex maps like that shown in Figure 1 which contain bipolar concepts (e.g. 'I know better software exists' versus 'there is no better software') and causal relationships among concepts (e.g. 'I know better software exists' therefore 'Dept. X is cautious about adopting the system'). The complexity of the mapping process is reduced by computer software called COPE that enables these maps to be constructed and analysed. This type of mapping is useful because it maintains individual differences in beliefs that may be crucial, particularly for negotiating decisions about the design of integrating information technologies like CAPM. However, individual differences are maintained at the cost of complexity – a merged map might contain several hundred concepts – and the usefulness of this approach relies heavily on the interpretative skills of the researcher or the consultant in analysing the causal maps, and also on their interviewing skills, which are crucial for generating the maps in the first place (Eden, 1992).

Summary and conclusions

This review has suggested that cognitive mapping techniques are potentially useful tools for management research, though researchers using these techniques need to be clear about their uses and limitations and, in particular, about what is revealed as a result of the particular technique employed. Cognitive mapping methodologies could be used to identify and describe decision-makers' subjective beliefs so that they are accessible for analysis and reflection.

A variety of mapping methodologies have been outlined. However, the paper has argued that the maps produced using these methodologies do not mirror individuals' mental models in the psychological sense because the information contained in the map that is revealed will be constrained by the methodology. Further, it is difficult to relate what is revealed by cognitive mapping to organizational behaviour and outcomes. However, cognitive mapping is not really any different in this respect from other social science methodologies (Goldberg, 1994). For example, similar debates surround the use of interviewing techniques, where the type of interview technique used can influence the content of what is revealed and where what is revealed may not be very closely related to what actually happens in the organization. The question is then, whether cognitive mapping methodologies offer additional useful insights for management research, over and above traditional research techniques.

This paper contends that cognitions have, until recently, been under emphasized in the literature on technological innovation and that cognitive mapping does provide a potentially useful set of alternative methodologies for investigating and explaining their impact further. Given that technology is equivocal, the subjective beliefs of different individuals and groups within an organization can have a very real impact on the outcomes of decisions about innovation design. Innovation with integrating technologies like CAPM has been found to be particularly problematic because it has consequences for individuals and groups across functional areas of the firm who may have quite diverse beliefs about the technology. Cognitive mapping techniques could provide an insight into these alternative perspectives. They may also make decision-makers more aware of their own or others' subjective beliefs and in doing so alter and/or

facilitate the decision-making process. Cognitive mapping could therefore promote decision-makers' understandings of potential problems and design choices and encourage negotiation in the innovation decision process. Subsequent examination of the outputs of the mapping process could also allow the managers involved to engage in a dialogue with the researcher in a novel way and this could help to develop and refine research problems. Of course the extent to which this is possible in practice will depend on the purposes for which the mapping process is used and the political context in which this takes place.

The conclusion here is that, provided their validity is established, mapping methodologies are potentially useful in informing management research because they enable researchers to examine in more detail the subjective beliefs that managers hold about specific problem domains and to portray these data in a meaningful way. With respect to research on innovation, cognitive mapping could be a useful addition to the existing repertoire of management research tools, especially if used to complement process-oriented research (for example, longitudinal case studies). Process research would help to contextualize the 'snapshots' traditionally revealed through mapping techniques and would better locate the role of cognitions in the process of innovation. This route might be worth pursuing if it leads to a better understanding of how individual cognitions shape or are shaped by organizational outcomes of the innovation decision process.

References

- Ackerman, F. and V. Belton (1994). 'Managing Corporate Knowledge Experiences with SODA and V.I.S.A.', *British Journal of Management*, **5**, pp. 163–176.
- Axelrod, R. (1976). *Structure of Decision: the Cognitive Maps of Political Elites*. Princeton University Press, Princeton, NJ.
- Bartlett, F. C. (1932). *Remembering*. Cambridge University Press, Cambridge.
- Bateson, G. (1979). *Mind and Nature: A Necessary Unity*. Fontana, London.
- Berniker, E. (1987). 'Understanding Technical Systems', *Symposium of Management Training Programmes: Implications of New Technologies*. Geneva.
- Bessant, J., J. Buckingham and R. Lamming (1989). 'Organisational Learning for Effective Implementation of Computer-aided Production Management', *Report for ACME, Science and Engineering Research Council*. EPSRC, Swindon, UK.

- Bougon, M. (1983). 'Uncovering Cognitive Maps: the Self-Q Technique'. In: G. Morgan (ed.), *Beyond Method: Strategies for Social Research*. Sage, Beverly Hills, CA.
- Bougon, M., K. Weick and D. Binkhorst (1977). 'Cognition in Organizations: An Analysis of the Utrecht Jazz Orchestra', *Administrative Science Quarterly*, **22**, pp. 606–639.
- Bransford, J. D. and J. J. Franks (1971). 'The Abstraction of Linguistic Ideas', *Cognitive Psychology*, **2**, pp. 331–350.
- Calori, R., G. Johnson and P. Sarnin (1992). 'French and British Managers' Understanding of the Structure and the Dynamics of their Industries: A Cognitive Analysis and Comparison', *British Journal of Management*, **3**, pp. 61–78.
- Clark, P. A. (1987). *Anglo-American Innovation*. De Gruyter, New York.
- Clark, P. A. and N. Staunton (1989). *Innovation in Technology and Organization*. Routledge, London.
- Cohen, C. (1988). *The Psychology of Cognition*. Academic Press, London.
- Corke, D. (1985). *A Guide to CAPM*. Institute of Production Engineers, London.
- Daniels, K., G. Johnson and L. de Chernatony (1994). 'Differences in Managerial Cognitions of Competition', *British Journal of Management*, **5**, pp. S21–S30.
- Easterby-Smith, M., R. Thorpe and A. Lowe (1991). *Management Research – An Introduction*. Sage, London.
- Eden, C. (1989). 'Using Cognitive Mapping for Strategic Options Development and Analysis (SODA)'. In: J. Rosenhead (ed.), *Rational Analysis for a Problematic World*, pp. 21–42. Wiley, Chichester.
- Eden, C. (1992). 'On the Nature of Cognitive Maps', *Journal of Management Studies*, **29**, pp. 261–265.
- Eden, C. (1993). 'Strategy Development and Implementation – Cognitive Mapping for Group Support'. In: J. Hendry and G. Johnson (eds), *Strategic Thinking: Leadership and the Management of Change*. Wiley, New York.
- Erdener, C. B. and C. P. Dunn (1990). 'Content Analysis'. In: A. Huff (ed.), *Mapping Strategic Thought*. Wiley, Chichester.
- Fiol, C. M. (1990). 'Narrative Semiotics: Theory, Procedure and Illustration'. In: A. Huff (ed.), *Mapping Strategic Thought*. Wiley, Chichester.
- Fiol, C. M. and A. S. Huff (1992). 'Maps for Managers: Where are We? Where Do We Go From Here?', *Journal of Management Studies*, **29**, pp. 267–285.
- Fiske, S. T. and S. E. Taylor (1984). *Social Cognition*. Addison, Reading, MA.
- Fletcher, K. E. and A. Huff (1990). 'Argument Mapping'. In: A. Huff (ed.), *Mapping Strategic Thought*. Wiley, Chichester.
- Ford, J. D. and W. H. Hegarty (1984). 'About the Causes and Effects of Structure: An Exploratory Study', *Academy of Management Journal*, **27**, pp. 271–291.
- Fransella, F. and D. Bannister (1977). *A Manual for Repertory Grid Technique*. Academic Press, New York.
- Gardner, H. (1994). *Frames of Mind*. Fontana, London.
- Gerwin, D. (1988). 'A Theory of Innovation Processes for Computer-aided Manufacturing', *IEEE Transactions on Engineering Management*, **35**, pp. 90–100.
- Giddens, A. (1984). *The Constitution of Society. Outline of the Theory of Structuration*. Polity Press, Cambridge.
- Ginsberg, A. (1989). 'Construing the Business Portfolio: a Cognitive Model of Diversification', *Journal of Management Studies*, **26**, pp. 417–438.
- Goldberg, J. (1994). 'Cause Mapping: An Outsider's View', paper presented at *ELASM 2nd Workshop on Managerial and Organisational Cognition*, Brussels, May.
- Huff, A. (1990). *Mapping Strategic Thought*. Wiley, Chichester.
- Huff, A., V. Narapareddy and K. E. Fletcher (1990). 'Coding the Causal Association of Concepts'. In: A. Huff (ed.), *Mapping Strategic Thought*. Wiley, Chichester.
- Jelinek, M. and J. Litterer (1994). 'Toward a Cognitive Theory of Organizations'. In: C. Stubbart, J. R. Meindl and J. F. Porac (eds), *Advances in Managerial Cognition and Organizational Information Processing*, **5**, pp. 3–41.
- Kelly, G. A. (1955). *The Psychology of Personal Constructs*. Norton, New York.
- Koopman, P. L. and J. Pool (1994). 'Decision Making in Organizations'. In: C. L. Cooper and I. T. Robertson (eds), *Key Reviews in Managerial Psychology*, pp. 189–236. Wiley, Chichester.
- Lowstedt, J. (1985). 'Contingencies or Cognitions? Two Paths for Research on Organization and Technology', *Scandinavian Journal of Management Studies*, **1**, pp. 207–225.
- Lyles, M. and C. R. Schwenk (1992). 'Top Management Strategy and Organizational Knowledge Structures', *Journal of Management Studies*, **29**, pp. 155–174.
- March, J. and H. Simon (1958). *Organizations*. Wiley, New York.
- Minsky, M. (1975). 'A Framework for Representing Knowledge'. In: P. H. Winston (ed.), *The Psychology of Computer Vision*. McGraw-Hill, New York.
- Narayanan, V. and L. Fahey (1990). 'Evolution of Revealed Causal Maps during Decline: A Case Study of Admiral'. In: A. Huff (ed.), *Mapping Strategic Thought*. Wiley, Chichester.
- Porac, J. F. and H. Thomas (1989). 'Managerial Thinking in Business Environments', *Journal of Management Studies*, **26**.
- Reger, R. K. (1990). 'Managerial Thought, Structures and Competitive Positioning'. In: A. Huff (ed.), *Mapping Strategic Thought*. Chichester, Wiley.
- Robertson, M., J. A. Swan and S. Newell (1996). 'The Role of Networks in Technology Diffusion', *Journal of Management Studies*, **33**, pp. 335–361.
- Rogers, E. M. (1983). *Diffusion of Innovations* (3rd edn). Free Press, New York.
- Rosenbloom, R. S. and M. A. Cusamano (1987). 'Technological Pioneering and Competitive Advantage: The Birth of the VCR Industry', *California Management Review*, **29**, pp. 51–76.
- Rummelhart, D. E. and A. Ortony (1977). 'The Representation of Knowledge in Memory'. In: R. C. Anderson, R. J. Spiro and W. E. Montague (eds), *Schooling and the Acquisition of Knowledge*. Erlbaum, Hillsdale, NJ.
- Scarbrough, H. and J. M. Corbett (1992). *Technology and Organization: Power, Meaning and Design*. Routledge, London.
- Schank, R. C. and R. P. Abelson (1977). *Scripts, Plans, Goals, and Understanding*. Erlbaum, Hillsdale, NJ.
- Scheper, W. J. and J. Faber (1994). 'Do Cognitive Maps Make Sense?'. In: C. Stubbart, J. R. Meindl and J. F. Porac (eds), *Advances in Managerial Cognition and Organizational Information Processing*, **5**, pp. 165–185.
- Schwenk, C. (1988). 'The Cognitive Perspective on Strategic Decision-making', *Journal of Management Studies*, **25**, pp. 41–55.

- Simon, H. A. (1991). 'Bounded Rationality and Organizational Learning'. *Organizational Science*, **4**, pp. 125–133.
- Smith, M. and B. J. M. Stewart (1977). 'Repertory Grids: A Flexible Tool for Establishing the Content and Structure of a Manager's Thoughts'. In: D. Ashton (ed.), *Management Bibliographies and Reviews*. MCB Press, Bradford.
- Solso, J. B. (1993). *Cognitive Psychology* (5th edn). West Publishing, St. Paul.
- Stubbart, C. I. (1989). 'Managerial Cognition: A Missing Link in Strategic Management Research', *Journal of Management Studies*, **26**, pp. 325–347.
- Swan, J. A. (1995). 'Exploring Knowledge and Cognitions in Decisions about Technological Innovation: Mapping Managerial Cognitions', *Human Relations*, **48**, pp. 1241–1270.
- Swan, J. A. and P. A. Clark (1992). 'Organisational Decision-making in the Diffusion and Appropriation of Technological Innovation: Cognitive and Political Dimensions', *European Work and Organizational Psychologist*, **2**, pp. 103–127.
- Swan, J. A. and S. Newell (1993). 'Managers' Beliefs about Factors Affecting the Adoption of Technological Innovation: A Study using Cognitive Maps', *Journals of Managerial Psychology*, **9**, pp. 3–11.
- Tolman, E. (1948). 'Cognitive Maps in Rats and Men'. *Psychological Review*, **55**, pp. 189–208.
- Tversky, A. and D. Kahneman (1974). 'Judgement under Uncertainty: Heuristics and Biases', *Science*, **185**, pp. 1124–1131.
- Walsh, J. (1995). 'Managerial and Organizational Cognition: Notes from a Trip Down Memory Lane'. *Organization Science*, **6**, pp. 280–321.
- Waterlow, G. and J. Monniot (1986). 'A Study of the State of the Art in Computer-aided Production Management', *Report for Science and Engineering Research Council*. SERC, Swindon.
- Weick, K. E. (1979). *The Social Psychology of Organizing*. Addison and Wesley, Reading, MA.
- Weick, K. E. (1985). 'Sources of Order in Underorganized Systems: Themes in Recent Organizational Theory'. In: Y. S. Lincoln (ed.), *Organization Theory and Inquiry*, pp. 106–136. Sage, Beverly Hills, CA.
- Weick, K. E. (1990a). 'Technology as an Equivoque: Sensemaking in New Technologies. In: P. Goodman and L. Sproull, *Technology and Organizations*. Josey-Bass, San Francisco.
- Weick, K. E. (1990b). 'Cartographic Myths in Organizations'. In: A. Huff (ed.), *Mapping Strategic Thought*. Wiley, Chichester.
- Weick, K. E. (1995). *Sensemaking in Organizations*. Sage Publications, Thousand Oaks, CA.
- Weick, K. E. and M. G. Bougon (1986). 'Organizations as Cognitive Maps: Charting Ways to Success and Failure'. In: Sims and Gioia (eds), *The Thinking Organization: Dynamics of Organizational Social Cognition*. Josey-Bass, San Francisco.
- Wilson, F., J. Desmond and H. Roberts (1994). 'Success and Failure of MRP II Implementation', *British Journal of Management*, **5**, pp. 221–240.