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The Use of Cognitive Mapping in Eliciting and Evaluating Group Cognitions

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A holistic method for eliciting and evaluating group cognition was introduced and tested. In the study, 359 undergraduate students were assigned to 72 groups, consisting of 4 to 6 members who worked on research projects lasting for 14 weeks. In order to evaluate the way groups represent the specific knowledge related to their tasks, we used a conceptual mapping technique. Conceptual mapping proved to be a fruitful way to understand the way groups represent their knowledge. The conceptual maps were stable in time and had explanatory power for groups' performance.

In this information age, organizational groups perform more cognitive tasks than any other type of tasks (Hinsz, 1990). As a consequence, several attempts have been made to explore the information-processing mechanisms in groups. Group cognition is now a key area of research in group dynamics (Hinsz, Vollrath, & Tindale, 1997; Hutchins, 1995a; Salas & Fiore, 2004). *Group cognition* refers to the way groups acquire, represent, store, and use knowledge structures (Curşeu, 2006; Hollan, Hutchins, & Kirsch, 2000; Hutchins, 1995a, 1995b; Hutchins & Klausen, 1996). Thus, a distinction is made between knowledge and the representation of knowledge (Graumann, 1989), also known as *knowledge structures*, *cognitions*, or *knowledge representations*. The core theoretical proposition of group cognition theories is that emergent cognitive structures (i.e., group cognition) are the main explanatory factors for group performance (Cannon-Bowers & Salas, 2001).

Group cognition is an emergent phenomenon influenced by the content of individual memories of group members, as well as by the interactions that take place within the group (Cooke, Salas, Kiekel, & Bell, 2004; Curşeu, 2006; Rentsch & Woehr, 2004). Therefore, the methods used to evaluate group cognition should address this construct as a holistic, group-level phenomenon. However, most of studies have focused on aggregation methods to

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elicit and evaluate group cognition, and there has been little to no attempt to investigate holistic elicitation and representation methods for group cognition (Cooke, Salas, Cannon-Bowers, & Stout, 2000; Cooke et al., 2004; Curşeu & Rus, 2005; Curşeu, Schruijer, & Boroş, 2007; Mohammed, Klimoski, & Rentsch, 2000; Rentsch & Woehr, 2004). Methods based on aggregation lack construct validity because they ignore any form of social interaction, while they claim to evaluate a variable that is supposed to emerge from and be influenced by group interactions (Mohammed et al., 2000).

The aim of the present paper is to investigate the suitability of cognitive mapping as an elicitation and evaluation technique for the structure of cognitive representations that are used by groups. We extend existing research in the following ways. First, we combine a card-sorting technique with text-based cognitive mapping to obtain a method suitable for the evaluation of group cognitive representations at the group level. Second, we extend a validation strategy used in cognitive sciences for semantic networks (Collins & Loftus, 1975) to assess the construct validity of the emergent collective cognitive maps. The possibility of accurately assessing group cognition has far-reaching implications, both for theory (it opens new ways to test more accurately key theoretical propositions) and practice (it enables the evaluation of training needs and progress for group training programs).

In this paper, we will first give an overview of the literature on group cognition and cognitive mapping, which argues in favor of a need for holistic methods to assess group cognition. Based on this discussion, we will describe a modified cognitive mapping technique, which satisfies the criteria for group level evaluations (Bar-Tal, 1990). Finally, we will test its validity, stability in time, and explanatory power for group performance in a cognitive task.

Group Cognition as an Emergent Group-Level Phenomenon

A first line of research on group cognition has focused on the shared nature of individual knowledge structures within a group. A core argument of these approaches is that in order to make a group effective, the members must share two types of knowledge representations: task-related and group-work-related knowledge representations (Cannon-Bowers & Salas, 2001; Cannon-Bowers, Salas, & Converse, 1993; Kraiger & Wentzel, 1997; Mohammed et al., 2000; Mohammed & Dumville, 2001; Rouse, Cannon-Bowers, & Salas, 1992). Another key argument is that in order to maximize the likelihood of a certain knowledge structure being remembered and used during group interactions, group members must share as much information as possible (Stasser & Titus, 1985, 1987; Tindale & Shefrey, 2002).

A second stream of research has focused on the distributed nature of cognition in teams (Hollan et al., 2000; Hutchins, 1995a, 1995b; Hutchins & Klausen, 1996; Wegner, 1987; Wegner, Erber, & Raymond, 1991). The main argument is that effective teams combine the variety of skills and knowledge of their members; and in order to perform well, each team member must know who knows what. A team's *transactive memory system* refers to the memory system of the individual team members and their collective awareness concerning the type and location of task-relevant knowledge within the group (Lewis, 2003). A team performs well if team members have enough specialized task-relevant knowledge and they know who knows what about the task.

Shared and distributed cognition approaches have dominated the research on group cognition in recent decades (Hodgkinson & Healey, 2008). However, these approaches have shown little attention to the interaction processes through which collective knowledge representations emerge in groups (Cooke et al., 2000; Rentsch & Woehr, 2004). Group cognition emerges from interpersonal interactions. Group members discuss and negotiate their individual views and opinions; share their knowledge; and use their skills to process the information made available during group debates (Akkerman et al., 2007; Cooke & Gorman, 2006; Rentsch & Woehr, 2004). Therefore, *group cognition* refers to the collective knowledge representations that emerge from social interactions and their transformations during group discussions.

In line with classical symbolic cognitive theories, the present paper makes a distinction between knowledge and the representation of knowledge. This distinction is somewhat blurred in the shared cognition approach. Nevertheless, it is relevant when analyzing a group as a cognitive system (or information-processing system; Graumann, 1989; Posner, 1989).

Each group experiences knowledge in a different way. A group will use its understanding to some extent in all of its future decision-making or problem-solving activities related to a particular subject. The way in which organizational groups experience knowledge will be referred to later as the group's *frame of reference* or *cognitive collective representation* (Curşeu, 2006; Curşeu & Schruijer, 2008). The cognitive collective representation is domain-specific. It emerges in relation to a particular task or in relation to a particular aspect of reality. Groups can use the representations developed for a particular decision domain to deal with decisions that involve similar constraints or knowledge requirements.

Using a complex systems perspective on groups (for details, see Arrow, McGrath, & Berdahl, 2000; Curşeu, 2006; Streufert, 1997; Streufert & Satish, 1997), and based on the previous arguments, we can conclude that group composition as well as group interaction processes are essential for the emergence of group cognition (Curşeu, 2006; Curşeu et al., 2007). Group composition influences the pool of knowledge and expertise of the group, and it influences the representation developed by the group. Group diversity in terms of knowledge and expertise influences the complexity and accuracy of its cognitive collective representations. Finally, these representations are the result of interactions that take place inside the group, a fact that should be taken into account when designing evaluation methods for studying cognitive collective representations.

The concept of cognitive collective representation has received some empirical support in prior studies. Previous research has shown that different groups with access to the same knowledge use different representations, depending on their interaction with the knowledge domain (Curşeu & Schruijer, 2008). This allows us to explain why groups with a similar composition, having access to the same informational content, perform differently on cognitive tasks.

It is important to note that the collective representation developed by the group is different from the sum of individual representations, in the same way that a group cannot be reduced to the sum of its members (Ashby, 2004; Streufert, 1997). The individual representations change during the interactions among group members. In a group, each member behaves according to the representations he or she has about the other group members and himself or herself in comparison to them, about the group's task and the context in which the group interacts. Individual behaviors trigger changes in individual cognitions. Hence, a dynamic process of structuring and restructuring the collective representation takes place up to the moment that the group members reach consensus. Then, the collective representation reaches stability. The collective representation thus formed will be stored in the group's long-term memory and used later in the group's further actions to make decisions or solve problems (Curşeu, 2006).

Conceptual Networks and Cognitive Mapping

One possibility to represent groups' declarative knowledge is conceptual schemas. Conceptual schemas capture relations, which hold between concepts or arguments that are not interchangeable (Coronges, Stacy, & Valente, 2007; Posner, 1989; Stillings et al., 1995). Therefore, two main elements are central to any cognitive map: concepts and relations. Concepts are used to represent aspects of social reality (i.e., people objects, events, facts). The number of concepts used in a cognitive map varies, with scholars reaching no agreement on the optimal number of concepts to be used in a map.

Several types of relations can link concepts. Gómez, Moreno, Pazos, and Sierra-Alonso (2000) distinguished among several possible types of relations between concepts in a conceptual map (e.g., causal, association, equivalence, topological, structural, chronological). Graphical representations of these concepts and of the relations between them result in different types of cognitive maps or conceptual networks (Bitonti, 1993; Bougon, 1992; Fiol & Huff, 1992; Mohammed et al., 2000). In summary, a conceptual map is a knowledge representation in a cognitive system (i.e., individual or group).

In the present paper, a *cognitive map* is the spatial location of elements (i.e., concepts) in a network and is relevant for the interpretation of relationships between concepts (Coronges et al., 2007; Huff, 1990). In a conceptual map, *nodes* represent the concepts in the knowledge domain, and the *strings* represent the links between these concepts. The concepts of the knowledge domain are extracted from interviews or from other post hoc analyses of formal documents (Carley, 1993, 1997; Hodgkinson & Clarkson, 2005; Mohammed et al., 2000).

There have been few holistic attempts to evaluate group cognition at the group level. So far, increasingly sophisticated metrics, which aggregate individual mental models into team mental models have been advanced to evaluate shared mental models in groups (Cooke et al., 2000, 2004; Lagan-Fox, Code, & Langfield-Smith, 2000). Questionnaires have been used to evaluate transactive memory systems (Lewis, 2003), and little attention has been given to developing methods that evaluate group cognition as an emergent phenomenon at the group level (Cooke & Gorman, 2006; Cooke et al., 2004; Hodgkinson & Healey, 2008; Rentsch & Woehr, 2004).

Group cognition is a group-level phenomenon. Therefore, valid evaluation methods should address this level of analysis. Similar concerns have been raised in the group processes literature (Cooke et al., 2004; Kirkman, Tesluk, & Rosen, 2001). Methods used to evaluate group-level variables should satisfy four criteria. First, they should address the group as a whole. Second, group members should agree with regard to the construct, and the method should reflect this agreement. Third, the construct must discriminate across groups and, finally, the origin of the construct must reflect group interaction processes (Bar-Tal, 1990). Using the so-called consensus method to evaluate group processes, Kirkman et al. (2001) showed that this method satisfies all of the aforementioned requirements and is a better predictor of group outcomes than is the aggregation technique.

A variety of disciplines (e.g., psychology, sociology, organization studies, management) use cognitive mapping as a method to get access into complex information processing in a variety of cognitive systems. As a result, several methods have been developed. However, there is substantial inconsistency in the way cognitive mapping is used in empirical settings.

In a comprehensive review, Hodgkinson and Clarkson (2005) argued that the process of cognitive mapping consists of four steps: (a) knowledge elicitation; (b) construction; (c) analysis; and (d) aggregation or comparison. In the knowledge-elicitation stage, the authors distinguished between ideographic and nomothetic approaches. In the ideographic approach, the researcher collects the concepts that are used by the individual or the group to describe a particular task or the way in which a particular task is (to be) performed. In nomothetic elicitation, the researcher provides predefined concepts based on theoretical models or own hypotheses. Nomothetic methods are often criticized because the set of concepts used by the researcher might prove meaningless for participants; thus, the emerging conceptual structure is actually an artifact. In the present study, we use an ideographic elicitation method to select the 20 most relevant concepts used by groups in relation to a task domain. We have limited the number of concepts to a manageable number and use this as a standard in order to compare across groups.

Concerning the construction of cognitive maps, either the researcher organizes the concepts (if the procedure is based on written documents), or the individual/group is asked to organize the given set of concepts. As a representation technique, we use here a card-sorting technique and ask the groups to organize the concepts so we can be sure that what we are using is actually the representation developed by the group as a whole. A card-sorting technique is suitable in this respect because it allows for interaction; thus, the final product captures the interaction processes. It is an emergent group product, as argued in the conceptualization of team cognition as an emergent group-level phenomenon. Relevant concepts are written on independent cards, and then the group members are instructed to organize them in a way that makes sense for the group as a whole. This simple method allows for exploration of the conceptual networks developed by groups at the group level of analysis. The method meets Bar-Tal's (1990) four requirements for holistic evaluation methods.

In the analysis stage, we use a set of predefined possible relations described by Gómez et al. (2000) to evaluate the nature of a particular connection between two concepts. In order to compute the complexity of the cognitive maps and to be able to compare across groups, we use algorithms described by Curşeu and colleagues (Curşeu, 2008; Curşeu & Rus, 2005; Curşeu et al., 2007).

Hypotheses

Our general claim is that formal groups represent as conceptual maps their conceptual knowledge with respect to a specific cognitive task they must perform. If the conceptual map is a plausible way for groups to represent their knowledge, then the resulting conceptual map is valid and stable in time, and has explanatory power for group performance. As mentioned previously, knowledge representation emerges from a complex pattern of interactions among group members. Therefore, any holistic evaluation method for group cognition is valid if (a) it reflects the group as a whole; and (b) it provides a mnemonic framework by which the group processes task-relevant information.

In cognitive psychology, several methods have been advanced to test the validity of knowledge structures (i.e., propositional units of knowledge schemas). One way to test the integrity of schemas is to show that activating a part of it leads to the activation of the whole structure, and the degree of activation (reflected in the reaction time of the respondent) is higher for the central elements of the schema and lower for the peripheral ones (Collins & Loftus, 1975). In other words, individuals react more quickly to decide on the similarity (i.e., connectedness) of two proximal concepts and more slowly to decide on two distal ones (Posner, 1989; Wilkes, 1997).

We extrapolate and adapt this strategy to test the validity of the conceptual schemas developed by groups. Once the conceptual schema of the group is elicited and represented, we can induce the activation of a certain conceptual cluster of the schema or the activation of the whole knowledge structure; and we can explore the impact of these two types of activation on the group's behavior. If two proximal concepts are selected from the map and the group is being asked to discuss the relationship between them, it is very likely that only a small conceptual cluster of the whole map will be activated in the group's memory; thus, the group will perform the task rather quickly. However, if two distal concepts are selected, and the group has the same task, it is very likely that at least two different conceptual clusters, or the whole knowledge structure, will be activated; thus, the group will need more time to sort out the conceptual linkages and to agree on a particular relationship among the two selected concepts.

In other words, we argue that a group's cognitive map is valid if the spatial relations established between concepts are reflected in actual group behavior (e.g., reaction time to discuss the relations among the concepts). Formulated in spatial terms, the degree of proximity between two concepts in a conceptual network should reflect the length of time needed by the group to discuss the relation between the two concepts. If two concepts are proximal, activation of the conceptual schema is punctual, and the time needed to agree is low. However, if two concepts are distal, activation of the conceptual schema is generalized, and the time needed to clarify all possible conceptual associations is longer. Therefore, we propose the following:

> *Hypothesis 1* (validity). The time needed for the group to establish the relation between two proximal concepts selected from the conceptual map will be significantly shorter than the time needed to establish the relation between two distal concepts of the same conceptual map.

Each cognitive representation has a certain degree of stability. As mentioned previously, groups can develop, store, and use cognitive representations. If, indeed, the group stores propositional representations, it means that when the group organizes the same concepts a second time after a certain period, the resulting conceptual map must be similar to the initial one. We propose the following:

> *Hypothesis 2* (time stability). The conceptual maps developed by groups will be stable over time.

The cognitive map reflects the way in which groups represent their conceptual knowledge, and it emerges from group interactions (Curşeu, 2006). On the one hand, group characteristics (e.g., group composition) influence group processes and the quality of interactions among group members. On the other hand, if, indeed, our thesis that cognitive representations influence group performance is correct, then cognitive map complexity should be a good predictor for group effectiveness. A more complex representation will give the group a competitive advantage. The group will ultimately translate complex representations (i.e., cognitive map) into better decisions and solutions (Iederan, Curşeu, & Vermeulen, 2009). Therefore, complex knowledge representations will have a positive impact on group performance (Calori, Johnson, & Sarnin, 1994; Hinsz et al., 1997), because the group will be able to consider a higher number of relations between relevant events and a higher number of alternative courses of action.

The concept of group cognitive complexity (Curşeu et al., 2007) reflects the degree of elaboration of task-relevant information (Hinsz et al., 1997; van Knippenberg, de Dreu, & Homan, 2004). Group diversity is the most important factor that influences the elaboration of task-relevant knowledge. Group diversity received considerable interest during recent decades as a crucial antecedent of group effectiveness (Harrison & Klein, 2007; Pate, Watson, & Johnson, 1998; Williams & O'Reilly, 1998). However, the results are mixed, with some studies providing empirical support for a positive effect of group diversity on group performance, and others for a negative effect of diversity on performance (for comprehensive reviews, see Milliken & Martins, 1996; Williams & O'Reilly, 1998).

In several attempts to explain the mixed results of the effects of group diversity on group performance, researchers (e.g., Swann, Polzer, Seyle, &

Ko, 2004; van Knippenberg et al., 2004; Williams & O'Reilly, 1998) identified two coexisting mechanisms (i.e., social categorization processes, knowledge elaboration processes) through which group diversity affects group performance. A stronger elaboration of task-relevant information in heterogeneous groups might be endangered by intergroup biases (via the tendency to trust the in-group more than the out-group; for comprehensive reviews, see Swann et al., 2004; Williams & O'Reilly, 1998).

Harrison and Klein (2007) attempted to clarify the differentiated effects of group diversity on performance. They distinguished between three types of diversity: separation, disparity, and variety. *Separation* refers to differences in opinion between group members. It most likely leads to conflict and interpersonal friction and, therefore, negatively influences group outcomes. *Disparity* refers to differences in assets or resources (including cognitive resources) of group members and most likely lowers group performance. *Variety* refers to differences in types of knowledge or experience of group members and is most likely associated with a strong elaboration of task-relevant information. This is the only diversity type that is positively associated with group performance (Harrison & Klein, 2007).

An example of the difference between variety and disparity is the distinction between diversity with respect to the type and level of expertise of group members. One can consider both attributes (i.e., type of expertise, level of expertise) to define group diversity. However, diversity with respect to type of expertise is a form of variety. It eventually strengthens the elaboration of task-relevant information through a greater pool of knowledge (i.e., different types of knowledge linked with the types of expertise will be discussed in groups), while diversity in level of expertise is a form of disparity and will most likely hinder the elaboration of task-relevant information (since only a few members have a high level of expertise).

In the present study, we consider the level of expertise of group members concerning the task or the problem addressed by the group. If the group members have different levels of expertise, it is likely that their contributions to task accomplishment will be different. The higher the diversity in terms of individual level of expertise, the lower will be the complexity of the emerging collective representation. In order to test the relation between level of expertise and contribution to the group, another diversity variable will be used; namely, diversity in group members' contribution to the group (referred to hereafter as *group contribution diversity*). The specific prediction is that group contribution diversity will have a negative effect on the complexity of the representation developed by the group and that it will ultimately lower group performance.

Finally, illustrative for group variety, we consider the group's demographic diversity. In this study, gender is the only variable used. Mixed-gender

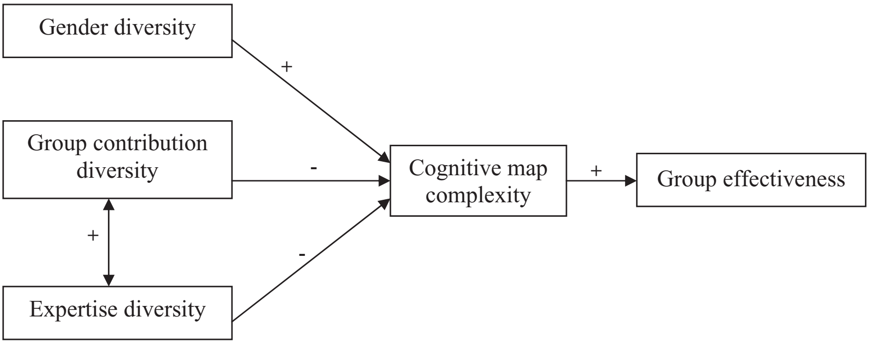

Figure 1. Overall model for mediation role of cognitive map complexity (explanatory power).

groups will most likely benefit from the different perspectives, ideas, and experiences of their members (Baugh & Graen, 1997). In a previous study, Curşeu et al. (2007) showed that gender diversity (conceptualized as variety) is beneficial for the cognitive complexity of groups, while cognitive disparity is detrimental for the complexity of the maps developed by groups. In addition, heterogeneous groups with respect to gender discuss a greater number of alternative ideas, compared with homogeneous groups (Schruijer & Mostert, 1997). Based on the previous arguments, it is not unreasonable to assume that gender diversity will strengthen the elaboration of task-relevant knowledge through a greater pool of cognitive resources (i.e., ideas, experiences, perspectives). Therefore, we hypothesize that gender diversity will have a positive effect on cognitive map complexity.

The conceptual model presented in Figure 1 summarizes the hypothesized relations between group composition and cognitive map complexity on the one hand, and between cognitive map complexity and group performance on the other hand. We propose the following hypothesis:

> *Hypothesis 3* (explanatory power). Cognitive map complexity will mediate the relation between group composition and group performance.

Method

Sample

Participants were 359 students (220 women, 139 men) who were enrolled in psychology classes at a Romanian university (Babeş-Bolyai University

Cluj-Napoca).[2] Participants ranged in age from 19 to 29 years (*Mdn* age = 22.5). Most of the participants reported prior group experiences, either outside of the university setting (10% of the participants work in different organizational settings, where group work is required), or at school where they completed some group work for different research papers (95%). Because the purpose of this project is to analyze the way groups represent and process information, it was important to locate participants with experience in work groups.

Procedure

Participants were randomly assigned to 72 small groups consisting of 4 to 6 members each. Of the groups, 35 were homogenous with respect to gender (all women), and 37 were heterogeneous (both sexes). All of the groups had the task of writing a research paper on a topic of their choice. The group project could be an academic paper exploring in depth one or more concepts discussed during classes or selected from the reading materials available for each course, or an applied study in which concepts and theories discussed in each course were used as a theoretical background. The final written project was graded, and the grade covered 30% of their individual grades.

Groups met inside and outside of the classes; the number of meetings varied from 3 to 25. The meetings lasted from 30 to 300 min. The average duration of one meeting was 150.5 min ($SD = 95.6$). Total time spent together by group members ranged from 120 to 6000 min (*Mdn* time = 975 min). Of the groups, 3 (15 participants) were excluded from the study because some problems occurred during the semester in these groups (e.g., one or two members left the group; one group split because of internal conflicts).

Over the course of one semester (14 weeks), the students worked on the research projects. They participated in a videotaped cognitive mapping meeting after they delivered the written project. After presenting the written projects, participants received their group and individual grades.

In order to test the validity of the conceptual maps, we used the following strategy: Two pairs of highly similar concepts (each situated in the other's immediate proximity) and two loosely related concepts (situated within a larger distance from each other) were selected for each network, derived from the group debates. Two weeks after the conceptual map was created, each group was required to complete a follow-up task. They were presented with

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[2] Of the students, 277 were enrolled in Social Psychology, 54 in Organizational Diagnosis, and 28 in Knowledge Management classes.

four pairs of concepts, one after the other, and asked to specify the exact relationship between the two concepts of each pair. The final answer had to reflect the group's consensus. We computed the average time needed to discuss the relation between two proximal, respectively two distal concepts. The 2-week interval was used in order to provide a more pure measure of differences between the length of time needed for processing proximal versus distal concepts from the map.

To test the stability of conceptual maps, we asked the groups to reorganize the same 20 concepts, using the same procedure as for the first task, but after a 6-month period (only 10 groups were still available for the second evaluation). The groups included in this part of the study were selected based on their willingness to participate in a follow-up session. Furthermore, we made sure that the selected groups did not continue to work as a group or discuss the conceptual domain in the meantime. We did this to exclude the possibility that the previously formed conceptual map did change as a result of the groups' interaction with the conceptual domain.

We used four indicators in the analyses: surface structure of the map (i.e., the extent to which the concepts were located at the same topographical position on the page), deep conceptual structure of the map (i.e., the extent to which the concepts remained in the same conceptual cluster), map connectivity, and map diversity. Surface structure of the map was computed as the number of concepts that changed their locations on the A3 (11.7 in. × 16.5 in., or 29.7 cm × 42.0 cm) page (i.e., exact comparison of the surface structure of the map). Deep conceptual structure of the map was computed by counting the number of concepts that changed their locations (i.e., membership) in a conceptual cluster.

To test the explanatory power of cognitive map complexity, a path analysis model was performed. The model used gender diversity, group contribution diversity, and expertise level diversity as independent variables; cognitive map complexity as a mediator variable; and group effectiveness as a dependent variable.

After the final stage of the study, participants were asked if they could identify the study's hypotheses. No one mentioned the actual hypotheses, and most participants thought that the aim of the study was to evaluate the way students understood a set of concepts. After that, the participants were debriefed, and the actual aim of the study was explained.

Group Effectiveness

We used three indicators from Hackman's (1983) model of group effectiveness in this study: group performance, group viability, and group members' satisfaction with the group. *Group performance* refers to the quality or measurable quantity of group outcomes (Hackman, 1983). In the present study, we used an expert-based method to evaluate the performance of groups.

The first author and a colleague, independent of one another, rated the groups' performance on a 10-point Likert-type scale ranging from 1 (*unacceptable performance*) to 10 (*excellent performance*). Raters were instructed to use an assessment form similar to the one proposed by Kniveton (1996) for essay evaluation. They evaluated the quality of the research paper, and each gave an independent grade. All of the papers for which evaluations made by the two experts differed by more than 1 point were discussed, and the disagreements were resolved, resulting in a correlation coefficient of .83 between the two evaluations for the entire sample.

An intraclass correlation coefficient was computed to adjust actual agreement levels for agreement by chance. The resulting value was .84 (when using an absolute agreement definition and average measurement, since the two evaluations were averaged afterward), which indicates good between-raters agreement. Therefore, as a general indicator of group performance, we used the mean of the two evaluations made by these experts.

Group viability refers to the group's ability to perform effectively in the future (Hackman, 1983). The concept of group viability was reframed as *collective group efficacy* (Gibson, 1990) or *group potency* (Guzzo, Yost, Campbell, & Shea, 1993). Both concepts refer to the shared belief among group members that the group can perform effectively in the future.

Guzzo et al. (1993) introduced a scale for evaluating group potency, a scale that has a unitary factor structure and good validity in evaluating group members' beliefs in the group's viability (Gibson, Randel, & Earley, 2000; Guzzo et al., 1993). In order to fit with the definition of group viability, we used four items of this scale that strongly emphasize the ability of the group to perform effectively in the future (e.g., "This group feels it can solve any problems it encounters," "This team believes that it can be very productive"). The answers were evaluated on a 5-point Likert scale ranging from 1 (*completely agree*) to 5 (*completely disagree*). Each team answered the four items by consensus. The consensus method proved to yield more predictive results for group performance, as compared to the classical aggregation method (Gibson et al., 2000). Cronbach's alpha for this scale was .71.

Group satisfaction refers to the degree to which group members were satisfied with group processes, emotional support provided by the other group members, and group outcomes. Group satisfaction was evaluated using four items (e.g., "How satisfied are you with the group processes?") that were rated on a 5-point scale ranging from 1 (*very unsatisfied*) to 5 (*very satisfied*). Each member of the group was asked to complete the scale, and then the individual scores were aggregated into group scores by computing the group average. Cronbach's alpha for this scale was .79.

Group Diversity

The diversity index for gender was computed using a formula proposed by Teachman (1980) and widely used in the group-diversity literature (Williams & Meân, 2004). The formula is

$$H = -\sum_{i=1}^{s} P_i(\ln P_i)$$

where i represents a particular category, s is the total number of categories, and P_i is the proportion of members belonging to the i category. If a group can consist of members belonging to s categories, and P_i is the probability assigned to a given category, then the H index is a measure of group heterogeneity (i.e., structural diversity). A high value indicates high group diversity. The theoretical maximum for H depends on the total number of categories (s; Williams & Meân, 2004).

We evaluated differences in the level of expertise with a multiple-choice knowledge test, which evaluated students' knowledge related to the conceptual domain of the course. As an indicator of expertise diversity, we used the coefficient of variation, computed by dividing the standard deviation of the scores within each group by the mean score of the group. The coefficient of variation was introduced by Alison (1978) and is the most frequently used formula to compute within-group diversity for continuous variables (Sørensen, 2002; Williams & Meân, 2004). A high score indicates large within-group differences in level of expertise (i.e., one group member scores very high on the knowledge test, while the others score low; for details, see Harrison & Klein, 2007).

To compute the diversity indicator of individual contributions to the group, we used a peer-evaluation method that was proposed by Goldfinch and Raeside (1990). Each member of the group had to evaluate the other members using four criteria (i.e., contribution to data collection, theoretical analyses, editing of the paper, contribution of new and creative ideas) on a scale from 1 (*very poor contribution*) to 5 (*excellent contribution*). The next step was to compute the group score by summing all of the results of the peer evaluations. The sum of each individual peer assessment score gave an individual total, which was divided by the mean peer assessment mark for the group (Goldfinch & Raeside, 1990). The score obtained from this peer assessment method reflects the way in which the group members perceived their individual contributions to the group outcome. As an index of diversity with respect to the individual contribution to the group outcome, we used the standard deviation of the individual scores within each group (since the mean for every group is 1, it makes no sense to compute the coefficient of variation).

Conceptual Mapping Technique

After a thorough analysis of each research project, we extracted key concepts from each project (the same two experts who initially graded the papers also selected the concepts). For the purpose of comparability, we made sure that the 20 most important concepts were selected from each research paper and printed on different cards. The groups received an envelope with the 20 concepts, an A3 blank sheet of paper, and glue. Their task was to distribute the concepts on the sheet of paper in such a manner that their spatial proximity reflected the extent to which they relate to each other. Afterward, the groups received the instruction to specify the nature of the relations between concepts. The standardized instruction received by each group was as follows:

> You will receive an envelope containing 20 cards on which the main concepts of your research paper are written. On each card, you have a single concept. Please organize these concepts on the A3 sheet of paper in such a way that they reflect the way you, as a group, understand the relation between these concepts. When you all agree upon the final chart, glue the cards to the paper, and draw lines between related concepts. On the lines linking the concepts, specify the exact relation existing between them.

The debate needed for finishing the conceptual map was timed.

The method satisfies all four criteria for a holistic method as stated by Bar-Tal (1990). First, the method allowed for actual assessment of collective performance, since every member of the group could contribute at every moment during the task execution. Therefore, the task was representative for the group as a whole, rather than individuals as separate units. Second, the structure of the map reflected the agreement of group members. Third, map connectivity, map diversity, and map complexity were dimensions evaluated for each map so that the structure of the map discriminated between groups (a detailed description of each dimension will follow). Fourth, the final structure of the map reflected the processes of interaction that occurred within each group.

It was possible that some members contributed less to group discussions and had little influence on the final structure of the map, but this is the very essence of group work. The group as a system is different from the sum of its parts; therefore, a method used to evaluate this system should consider this characteristic. During task execution, the group kept an image of all the concepts and their interrelations; thus, we have certainty that this technique allowed for actual assessment of groups' cognitive complexity.

We considered two aspects for analysis of the groups' cognitive maps, both related to the configuration of the map. First, we analyzed the map diversity as the number of distinct relations established between the 20 concepts of the map. Starting from the taxonomy proposed by Gómez et al. (2000), we considered seven distinct types of relations between concepts: causal (CA), association (ASO), equivalence (EQ), topological (TOP), structural (STR), chronological (CHR), and hierarchical (HIE; see the Appendix for a detailed description of these types). Map diversity was computed by adding the number of different relations identified in the map (e.g., a map in which CA, STR, HIE, and ASO types of relations could be identified has a diversity of 4).

Next, we analyzed map connectivity as the total number of connections established between concepts. Cognitive map connectivity is one of the most frequently cited ways of approaching cognitive map analysis (Bougon, 1992; Calori, Johnson & Sarnin, 1994; Eden, Ackerman, & Cropper, 1992).

Map diversity and map connectivity are both indicators of map complexity. The larger the number of distinct relations and connections established between the concepts, the higher will be the map complexity. Conceptual map complexity (CMCo) was computed using the formula that was used by Curşeu and Rus (2005),

$$CMCo = \frac{CMC \times CMD}{NoC}$$

where *NoC* is the total number of concepts used in the map. This formula for computing cognitive complexity was derived from the definition provided by Calori et al. (1994): "the complexity of an individual conceptual system is determined by two interdependent aspects: the number of parts or dimensions of the system, and the nature and the extent of rules for integrating these parts" (p. 439). The formula that was used reflects the richness of the cognitive map, and it is in line with the conceptualization of integrative complexity (for details, see Satish, 1997; Streufert & Satish, 1997; Suedfeld, 1985).

Results

Table 1 presents the descriptive statistics and correlations between the variables considered in the present study (all variables are group level). Further, the results will be presented for every hypothesis, starting with the

Table 1

Descriptive Statistics and Correlations for Variables at the Group Level of Analysis

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10
1. Group size	5.34	0.90	—									
2. Gender diversity	0.39	0.30	.04	—								
3. Group contribution diversity	0.11	0.09	.31**	−.20	—							
4. Expertise diversity	0.16	0.08	.10	−.23	.37**	—						
5. TDPC (in seconds)	108.06	64.46	.16	−.07	−.01	.12	—					
6. TDDC (in seconds)	225.47	100.37	.15	−.04	−.01	−.05	.70**	—				
7. TGIT (in seconds)	1503.54	1376.36	−.02	.18	−.22	−.17	.11	.06	—			
8. Cognitive map complexity	3.91	1.95	.08	.31**	−.30**	−.36**	−.13	−.03	.42**	—		
9. Group performance	7.66	1.01	.12	.08	−.31**	−.24*	−.17	−.07	.24*	.51**	—	
10. Group viability	4.71	0.68	−.12	.10	−.44**	−.15	.04	.03	.31**	.36**	.46**	—
11. Satisfaction	4.69	0.70	−.31**	.12	−.30**	.07	−.15	−.07	.30*	.11	.27*	.20

Note. TDPC = time needed to reach agreement on the relation between two proximal concepts; TDDC = time needed to reach agreement on the relation between two distal concepts; TGIT = total group interaction time (i.e., total time spent together by group members).
*$p < .05$. **$p < .01$.

validity of the conceptual map (Hypothesis 1), stability in time (Hypothesis 2), and explanatory power (Hypothesis 3).

Validity

In order to test Hypothesis 1, a four-way mixed ANOVA was conducted. The following were the independent variables: topographical position of the concepts (within-subjects: proximal vs. distal concepts), group size (between-subjects: 4-member, 5-member, or 6-member groups), group composition (between-subjects: homogeneous vs. heterogeneous groups with respect to gender), and total interaction time (between-subjects; a median split was used to define two groups with < 975 min vs. > 975 min interaction time). The dependent variable is the time needed to reach consensus concerning the relationship between two concepts.

The analysis of within-subjects effects shows a statistically significant effect of the within-subjects variable (topographical position of concepts), $F(1, 60) = 192.55, p < .0001$. This means that the time needed for establishing the relation between two proximal concepts was significantly shorter ($M = 113.1$ s, $SD = 64.5$) than was the time needed for two distal ones ($M = 229.6$ s, $SD = 100.4$; see Table 2). Therefore, we can conclude that Hypothesis 1 was fully supported.

Group size and gender composition also had a significant effect on the time needed to establish the relation between concepts, in the sense that larger groups and heterogeneous groups need more time to discuss the relationships between concepts (see Tables 2 and 3). The interaction between gender composition and the topographical position of the concepts was almost significant. We found no statistically significant interaction between group size and topographical position of the concepts. Interaction effects appear in Figure 2.

To establish the relation between two distal concepts, the activation of a larger volume of knowledge was needed. This is illustrated by the fact that during the debate, 68 groups (94.4%) mentioned concepts that were situated in between the given distal pair in the conceptual map. Thus, activation of cognitive representations regarding the task in the group's working memory was related to the structure of the conceptual map.

Stability

In order to test Hypothesis 2, we compared the changes in the structure of cognitive maps after 6 months, using a paired-sample *t* test. As dependent variables, we used the surface structure of the map and the deep conceptual

Table 2

Means and Standard Errors for Groups in Four-Way Mixed ANOVA

Variable and condition	*M*	*SE*
Topographical position of concepts		
Proximal	113.11	6.98
Distal	229.58	10.68
Total interaction time		
< 975 min	177.65	11.36
> 975 min	165.03	11.25
Group size		
4 members	141.57	13.77
5 members	161.33	13.73
6 members	211.13	14.03
Gender composition		
Homogeneous	153.60	11.49
Heterogeneous	189.08	11.11

Note. Dependent variable was the time needed to reach consensus concerning the relationship between the concepts.

structure of the map. Regarding the surface structure, after 6 months, an average of 14.6 concepts changed their positions on the map, while only 5.4 remained in the same position. Regarding the conceptual structure, after 6 months, an average of 3.7 concepts changed positions in the conceptual cluster, whereas an average of 16.3 concepts remained in the same cluster (for details, see Table 4).

Based on the entries presented in Table 4, we can conclude that there was no significant difference attributable to time lapse in map diversity and connectivity. In other words, there was no difference between the number of relations and number of connections established between the concepts in the first phase, compared to the number of relations and number of connections established between the concepts in the second phase. Therefore, Hypothesis 2 stating that the structure of the cognitive map is stable in time was supported.

Explanatory Power

To test Hypothesis 3, we performed a path analysis with cognitive map complexity as a mediator variable between group diversity (composition) and

Table 3

Results of Four-Way Mixed ANOVA

Independent variable	F	p
Topographical position of concepts (within-group: proximal vs. distal concepts)	192.55	.000
Total group interaction time (between-group: < 975 min vs. > 975 min)	0.62	.433
Group size (between-group: 4-member, 5-member, or 6-member groups)	6.62	.003
Gender composition (between-group: homogeneous vs. heterogeneous groups)	4.92	.030
Interaction of topographical position of concepts by total interaction time	0.18	.67
Interaction of topographical position of concepts by group size	1.54	.22
Interaction of topographical position of concepts by gender composition	3.03	.08

Note. Dependent variable was the time needed to reach consensus concerning the relationship between the concepts.

group effectiveness. Analyses were conducted using AMOS structural equation modeling software Version 5. We tested the path model using the maximum likelihood procedure. Descriptive statistics and correlations were computed for all variables, prior to running the path analyses (see Table 1). The path diagram with the results of the path analysis appears in Figure 3.

The fit indexes reflect a good fit of the theoretical model with the data. The chi-square value was not significant, $\chi^2(3, N = 72) = 5.91, p < .11$. Therefore, we can conclude that the variances and covariances implied in the theoretical model match the observed variances and covariances in the data. This absolute fit index is very sensitive to sample size (Hoyle & Panter, 1995), and several other fit indexes will be discussed here.

The minimum discrepancy index computed as the chi-square value divided by degrees of freedom was 1.97 (< 5.00; Marsh & Hocevar, 1985), and shows a significant fit of the model with the data. Root mean square error mean of approximation (RMSEA) was .078. The guidelines for this particular index are debated little in the literature. A value lower than .05 illustrates a well-fitting model, while a value below .08 indicates a reasonable-fitting model (Browne & Cudeck, 1993). This index, however, tends to favor models

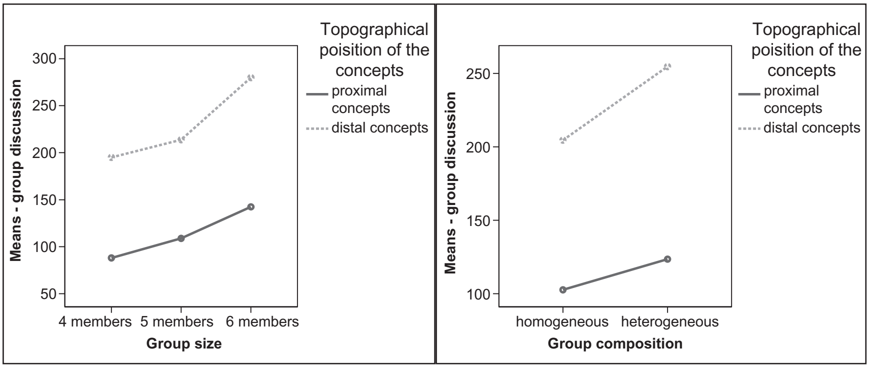

Figure 2. Overall effects of interaction between topographical position of concepts and group size (left) and group composition (right) on group discussion time.

Table 4

Results of Time Stability Test for Cognitive Maps

Variable and condition	*M*	*SD*
Surface structure of map		
Number of concepts not changed	5.40	2.27
Number of concepts changed	14.60	2.27
Deep conceptual structure of map		
Number of concepts not changed	16.30	3.05
Number of concepts changed	3.70	3.05
Cognitive map connectivity		
Connectivity 1st evaluation	20.50	3.83
Connectivity 2nd evaluation	20.00	4.85
Cognitive map diversity		
Diversity 1st evaluation	4.70	1.05
Diversity 2nd evaluation	4.60	0.96
Cognitive map complexity		
Complexity 1st evaluation	4.92	1.79
Complexity 2nd evaluation	4.72	1.78

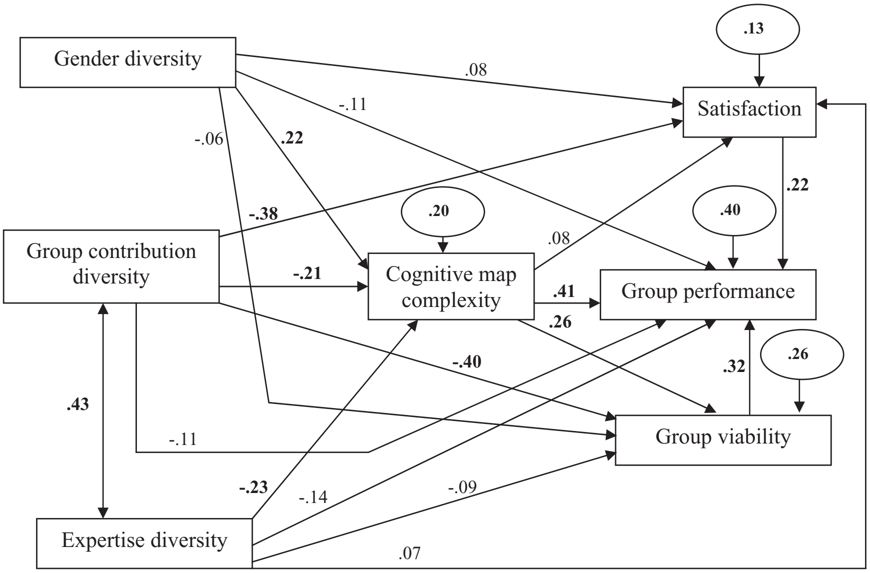

Figure 3. Path diagram for testing the explanatory power of cognitive map complexity, $\chi^2(3, N = 72) = 5.91$, $p < .11$; TLI = .96; CFI = .97; NFI = .94; RMSEA = .078.

with a higher number of parameters; and since the tested model was rather simple and the value of RMSEA was acceptable, we can conclude that this index supports the fit between the model and the data.

In relation to the null model, the incremental fit indexes (Tucker–Lewis Index [TLI] = .96; comparative fit index [CFI] = .97; normed fit index [NFI] = .94) had values higher than .90, thus showing that the model cannot be improved significantly. These fit indexes reflect a significant increment in fit over that of a null model (for more technical details, see Widman & Thomson, 2003). Because the expertise diversity is expected to induce an unequal contribution of group members to group activities, the expertise diversity index and group contribution diversity were allowed to covary in the model.

Hypothesis 3 was fully supported: the indirect effects (mediated by cognitive map complexity) of group composition on group performance were stronger than the direct effects. Similar results were obtained for group viability (the second indicator of group effectiveness). With the exception of group contribution diversity, the indirect effects of group composition on group viability were stronger than the direct effects. However, this was not the case for the third indicator of group effectiveness, because the influence of cognitive map complexity on satisfaction was only marginal (.08).

Discussion

The aim of the present study was to test the validity of a holistic evaluation method for group cognition. In order to evaluate the cognitive complexity of groups, we used a modified variant of the card-sorting task for conceptual mapping. We adapted this technique for analysis at the group level.

The conceptual map we obtained is the result of an interaction process of the group members. Because it was based on consensus reached by the group members, it is illustrative for the manner in which the group as an entity (or system) represents conceptual knowledge. If this type of knowledge representation is valid, then the relations established among the concepts reflect the collective behavior of the groups. We tested this by asking the groups to discuss the relation between two proximal concepts on the map, as well as between the two distal ones. The results show that the necessary time for the group to agree on the relation between the two proximal concepts was significantly shorter than the time for the two distal ones.

Further, if the propositional representations indeed represent the conceptual knowledge of the group, the conceptual map should be relatively stable in time. By evaluating the cognitive maps after a 6-month period, we showed that the conceptual structure of the cognitive map (i.e., position of the concepts in a conceptual cluster; number of relations and number of connections established by the group between the map concepts) remains approximately the same over time. The number of concepts remaining in the same conceptual cluster supports the hypothesis that the deep conceptual structure of the cognitive map remained the same. Only the surface structure of the cognitive map—that is, the topographical position of the concepts on the map—changed over time (two thirds of the concepts changed their topographical position on the map). The results support the hypothesis that the profound structure of the conceptual map was stable over time.

Finally, if conceptual maps accurately represent the group's conceptual knowledge, they must have explanatory value for the group's general performance. Cognitive complexity mediates the relation between group composition and group effectiveness. Three indicators of group composition were used in the present study: gender diversity, level of expertise diversity, and group contribution diversity.

Gender diversity had a positive effect on group performance and viability only to the extent to which it increased cognitive map complexity. The direct effect of gender diversity on group viability was small and negative (–.06). Baugh and Graen (1997) reported similar results in a study using organizational teams and similar indicators for team effectiveness. In general, members of groups with high gender diversity perceived their groups as being less able to perform effectively than members of groups with low gender diversity (Baugh & Graen, 1997).

The direct effect of gender diversity on satisfaction was small and positive (.08). Members of groups with high gender diversity were more satisfied with and committed to their group, as compared to members of groups with low gender diversity. The direct effect of gender diversity on group performance was small and negative (–.09), and consistent with the results reported by other studies using similar samples, group tasks, and performance indicators (e.g., Watson, Johnson, & Merritt, 1998).

The positive effect of gender diversity on cognitive map complexity was consistent with the observation that mixed-gender groups generate a higher number of ideas and alternatives than do gender-homogeneous groups (Curşeu et al., 2007; Schruijer & Mostert, 1997). The number and types of connections identified by group members will be higher if the number of ideas generated in the group is higher. One cannot argue that cognitive mapping is a stereotypically masculine or feminine task. We can conclude, though, that the cognitive mapping procedure (at least the way it was used in our study) is a task that is sensitive to the gender composition of the group. In other words, gender is an attribute of diversity that is relevant for this particular task.

Concerning the relation between group contribution diversity and group effectiveness, cognitive map complexity acted as a mediator for group performance. The direct effects of group contribution diversity on group viability and satisfaction were stronger than the indirect effects mediated by cognitive map complexity. These results illustrate that group contribution diversity influences group effectiveness not only through cognitive mechanisms (i.e., cognitive map complexity), but also through affective processes. When the contribution to group activities is unequal, the probability of conflict is high. This can lead to less satisfaction and less strong beliefs in the ability of the group to perform effectively in the future.

Group diversity in level of expertise had a moderate effect, mediated by cognitive map complexity on both group performance and group viability, and no significant effect (direct or indirect) on group members' satisfaction. Cognitive maps made by groups whose members have different levels of expertise were less complex than were maps made by groups with a homogeneous distribution of level of expertise. The results for the effects of group diversity on the complexity of cognitive maps were consistent with the conceptualization of diversity introduced by Harrison and Klein (2007). Group variety is beneficial for the complexity of a group's cognitive map, while group disparity has a negative impact on the collective cognitive representation developed by the group.

The mediator role of cognitive map complexity in the relation between group composition and group effectiveness was fully supported for group performance, marginally supported for group viability, but not supported for group satisfaction. One explanation for the lack of effect of cognitive map complexity on satisfaction could be that satisfaction is driven mainly by non-cognitive factors. Factors such as relationship conflict (Jehn, 1994) could be more important for satisfaction than a pure cognitive factor, such as the complexity of the collective cognitive representation of the group.

Theoretical Implications

The assessment of the cognitive representation developed by the group is an important step in understanding group performance in cognitive tasks. In several instances (Cooke et al., 2000, 2004; Mohammed et al., 2000), it has been acknowledged that the aggregation methods used in most studies on shared cognition do not capture the group interactions that are essential to theorize on group cognition. Several studies have argued that group cognition is more than a collection of individual cognitions, because it emerges from group interactions (Cooke et al., 2004). However, classic elicitation and representation methods start from the implicit assumption that group members are equal in their contributions to group actions. Therefore, the need for improving aggregation methods is a crucial development in the field of group cognition (Cooke et al., 2004). The present study illustrates a way of using conceptual mapping as a holistic method to elicit and evaluate group cognition.

Previous theoretical approaches to group cognition have stated that knowledge representations mediate between group characteristics and group performance (Cooke et al., 2004; van Knippenberg et al., 2004; Lagan-Fox et al., 2000), yet little interest has been shown in providing empirical support for this theoretical statement. We tested the theoretical statement, and we provided empirical support for the mediating role of group cognition. Moreover, we addressed another theoretical proposition that group cognitive complexity (i.e., complexity of cognitive representations formed and used by the group) is a good predictor of group performance (Calori et al., 1994). Our study shows that cognitive map complexity is, indeed, an accurate predictor for group performance in knowledge creation tasks.

The results of our study add to the conceptualization of group diversity as disparity, variety, and separation. Our results support the taxonomy introduced by Harrison and Klein (2007) in the sense that only group variety seems to contribute positively to the higher pool of knowledge within groups, while disparity has the opposite effect. Linking this taxonomy to the concept of collective cognitive representation offers the possibility of pointing out the mechanisms that explain the differentiated effects of the three group diversity types on group performance. Further exploration is needed, however, to clarify this explanation. How does group disparity in individual cognitive complexity influence the group's cognitive complexity? What role (if any) do group processes play in this relation?

Practical Implications

Full understanding of information processing within groups is crucial for group design, as well as for group training and development (Hinsz et al., 1997). A technique that is easy to use in real-life situations is conceptual mapping. The manner in which we have modified the technique allows for evaluation of the conceptual map developed at the group level. As shown in the present study, this technique is a good diagnostic tool for evaluating formal groups' collective representation.

The results obtained from the conceptual mapping technique can be used to develop effective group training strategies. In several instances, it has been stated that group cognition can be "trained" in order to increase group performance (Lagan-Fox et al., 2000; Rouse et al., 1992). In order to implement cognitive changes however, one must be able to understand the structure to be changed. By providing the background for the identification and evaluation of group cognition, the proposed method becomes a powerful diagnostic tool.

Another possible application of cognitive mapping during training is to help group members to reach consensus and to diagnose and manage disagreements (Mohamed et al., 2000). In particular, the method we proposed accurately captures situations in which a group member is persuasive, but wrong in his or her statements. An aggregation method will level out this aspect, while the holistic method proposed here is very sensitive, assuming that the same processes take place during actual task performance. In training situations, this aspect is particularly useful, helping group members to acknowledge the problem and to find effective ways of dealing with the disagreements.

As our results show, group composition had a strong influence on cognitive map complexity. In diversity awareness training, the cognitive mapping technique can illustrate the benefits of diverse groups. For example, it will be easy to illustrate that a diverse group will develop more complex maps than a homogeneous one. By using a process-tracking method, it will also be possible to identify the major factors that influence the knowledge pool within groups.

In diagnosing and assessing group training needs, cognitive mapping can be used as an effective tool (e.g., Smith-Jentsch, Campbell, Milanovich, &

Reynolds, 2001). As a result of high group member involvement, ease of use, and the constant overview of all the relevant concepts in a particular area, the holistic approach we have described can be especially useful in evaluating training needs, but also in evaluating training effectiveness. The method can be applied before and after the training, and the differences in the two cognitive maps can be used to evaluate the effectiveness of the training.

Finally, cognitive maps can be used as *exograms*, or external memories for the group (for details about exograms and the cognitive life of things, see Sutton, 2006). A group that develops a cognitive map can use this representation as an external memory that encapsulates understanding of a particular matter at a particular moment in time. This may serve as a reference point for the development of group cognition, as well as for the learning effectiveness of the group. In this way, the cognitive map as a representation can play an important role in the future performance of the group as an artifact, external memory, or exogram.

Limitations and Future Research Directions

A first set of limitations relates to the very assumptions on which the cognitive mapping method is based. First, the method assumes that groups experience the same group processes during cognitive mapping as during actual task performance. However, the instructions to reach consensus concerning the content of the map may induce process behaviors different from actual task-related processes. Second, the method assumes that the elicited concepts are the most central concepts in group cognition. In the present study, 20 concepts were used, which is a manageable number of concepts (Mohammed et al., 2000). However, the research projects differed in complexity, and fixing the number of concepts to 20 may have excluded some relevant concepts for the cognitive representation. However, when applied in more ecological settings, the number of concepts used in the method can easily be changed.

Our conclusions are based on a structural analysis of cognitive maps, and do not go into the conceptual analysis of the map. For a deeper understanding of group cognition, other map characteristics, such as concept (or node) centrality and concept connectivity should be considered (for details. see Coronges et al., 2007; Eden et al., 1992). In addition, a deeper analysis of the conceptual schema (defined as the cluster of a general proposition attached to a concept node) and the conceptual clusters reflected by the map could be performed. A proper qualitative analysis of the type of relations established between concepts could also be appropriate. Such a complex qualitative analysis would provide deeper insight into the structure of the conceptual map.

Another limitation of the present study is the student sample. Student groups satisfy the definitional criteria for groups, but they can be substantially different from groups in actual organizational contexts. Therefore, in order to safely generalize the results of this study to a larger, more diverse population, a replication in an different organizational setting would be useful (e.g., application in management groups). Finally, since the emphasis of this paper is on a holistic cognitive mapping method, and it argues that it is a more valid and reliable method for eliciting and representing group cognition, a direct comparison with an aggregation method would have been appropriate to judge its benefits fully.

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Appendix

Taxonomy of Types of Relations Identified in Cognitive Maps

Gómez, Moreno, Pazos, and Sierra-Alonso (2000) discussed the process of conceptualization as a critical element in every problem-solving activity. The authors presented a framework for conceptual modeling in which they described several types of possible relations between concepts (*relations* are interconnections between concepts in a conceptual network). For the case of cognitive maps (for a detailed discussion, see Gómez et al., 2000), seven types of connections are particularly relevant:

1. *Causal relations* (CA) describe how a given action or phenomenon induces (determines) another state, action, or event (e.g., A is the cause of B; A needs B; A fires B; if A than B); or describe the conditions or actions that are followed by consequences or reactions (e.g., A enables B; A needs B).
2. *Association* (ASO) describes how two or more concepts are correlated (e.g., A is related or associated to B; A is connected to B; A is in contact with B); or describes a combination of concepts (e.g., A and B are combined to . . .).
3. *Equivalence* (EQ) establishes the equality between two or more apparently different concepts, including similarity (i.e., establishes which concepts are similar or analogous and to what extent; e.g., $A = B + C$; A is similar to B).
4. *Topological* (TOP) relations describe the spatial distribution of concepts representing physical items (e.g., A is above B; A is to the right of B; A is inside B).
5. *Structural* (STR) relations describe how a concept or a group of concepts can be decomposed into parts (inclusion–exclusion relations; A is a part of B; A and B are parts of C); or describe how several concepts share a common trait or are united by a common element (A, B, and C share common elements).
6. *Chronological* (CHR) relations describe the way two or more concepts are related in a time sequence (e.g., A occurs before B; A and B occur simultaneously; A occurs during B; A starts before B ends).
7. *Hierarchical* (HIE) relations describe the categorical relation between concepts (one or several elements are subordinated to one or several others; e.g., A is subordinated to B; A, B, and C are subordinated to D); or describe taxonomic relations (e.g., A can be classified as B, C, and D).