Multiparty Negotiation Support: The Role of Visualization’s Influence on the Development of Shared Mental Models

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ABSTRACT: The study examines a method for supporting multiparty negotiations by means of a Negotiation Support System (NSS). More specifically, this study investigated the effect of visualization support on the development of shared mental models among negotiators who resolved a spatial planning dispute. The objective of this study is to determine how to support the development of shared mental models in order to stimulate more productive negotiations. A further goal is to provide guidelines for the design of NSS. Compared with a control condition, visualization improved three
aspects of negotiations: visualization support aided negotiators’ convergence of perceptions of reality and had positive socio-emotional consequences in terms of increasing cohesiveness and entitativity. As a result, groups with visualization support reached consensus more easily and were more satisfied with the process. In sum, the current study provides support for the idea that presenting negotiators with unambiguous information helps negotiators develop shared mental models.

**KEY WORDS AND PHRASES:** multiparty negotiation, negotiation support systems, pro-social climate, shared mental model, visualization of information.

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**The past decade has seen a rising interest** in what was called the “group mind” at the end of the nineteenth century. Unfortunately, the research in this area of collective sense-making has not yet lead to consensus about the conceptualization of such forms of collective cognition. So, several terms are used to describe the processes by which multiple individuals make collective sense of their surroundings. Social sharedness [45], mental models [40], collective minds [48], shared situation models [35], socially shared cognition [38], and shared mental models [23] are all concepts that refer to how dyads, groups, and larger collectives gain an understanding of phenomena that is not merely grounded in individual cognition but also consensual among group members.

However, there are also commonalities across definitions. All views recognize the existence of knowledge structures at a supra-individual level, for example, relating to aspects of the group’s context or task. In addition, they all stress the potential productivity that such socially shared knowledge structures have for the group. For example, it has been argued that a shared understanding helps group members to coordinate their collaboration [7, 24, 34, 36]. The concept of “shared mental models” is one of the most widely used terms for referring to these socially shared knowledge structures [23, 40]. A mental model is a mental representation of a system that can be used to describe, explain, and predict future system states [40]. Mental models allow individuals to understand phenomena, make inferences, and experience events by proxy [18]. They refer to a general class of cognitive constructs that have been invoked to explain how knowledge and information are presented in the mind [23]. Several sorts of shared mental models may be important for group functioning: models about the group, models about group members, and models about work or the task at hand [24, 34, 36, 43].

In this paper we shall focus especially on the last type of shared mental model: models about the task at hand (in this case a negotiating task). The idea is that a shared mental model of the task serves to organize the beliefs of individuals about the nature of a problem and possible solutions in a given situation [31, 47]. Thus, in the present research we define a shared mental model as the amount of overlap in knowledge among different negotiators about the problem or task they face, and its possible solutions.
Shared Mental Models in Negotiation

We argue that negotiation outcomes are likely to improve to the extent that mental models are more shared. It is often the case within negotiations that different parties see what they expect to see due to different knowledge they possess a priori. Thereby, the motives they have during the negotiation also influence their perceptions. So, it is very likely that negotiators have different conceptualizations of the problem situation, and inconsistencies between their cognitions about both the problem and potential solutions may foster further disagreement during negotiations over and above any other disagreements that may exist between them. If, on the other hand, negotiators have similar knowledge of the problem, understand its nature in similar ways, and agree about the potential solutions, one could envisage there are fewer obstacles that stand in the way of settlement. In addition, parties may recognize the common ground among them, which could form the basis for convergence.

We expect that shared mental models have two consequences in negotiations. In the first place, if mental models are shared, negotiators will interpret any information about the problem from a common viewpoint, and this is likely to stimulate settlement or the achievement of consensus about what are acceptable or less acceptable solutions [20, 43, 45].

Second, we expect that due to the existence of a shared mental model, negotiators will recognize that they and their opponents have similar views on certain issues. The recognition of similarity is generally a good predictor of social attraction and is likely to foster the development of a common identity of some form [16]. Both liking and common identity reflect a pro-social climate [11, 14, 15, 25]. This pro-social climate is a strong precursor to mutually satisfactory negotiation and decision-making [5, 9, 37]. Although we do not attempt to influence the pro-social climate directly in this study, we do think that it could be affected by shared mental models, such that more overlap in cognitions has a positive affective outcome for a group of negotiators.

In sum, we argue that the influence of shared mental models on negotiation outcomes is positive for two reasons. On one hand, a shared mental model influences negotiation outcomes directly by providing common views of the problem at hand and potential solutions, thereby facilitating consensus. On the other hand, we speculate that shared mental models might affect the pro-social climate positively, which in turn should have a positive impact on negotiation outcomes.

Supporting the Development of Shared Mental Models

Now that we have illustrated the importance of shared mental models for negotiation outcomes, a further question is how one could stimulate the development of shared mental models during negotiations.

The overall idea is that the development of shared mental models could be facilitated by the presentation of information that is available prior to and during the negotiation process. This information should be designed and presented in such a way that it leads to a convergence of perceptions, for example, by aiding negotiators to define
a problem unambiguously. Thus, we argue that controlling the presentation and availability of information is an important tool for aligning the interpretations and perception of the problem, and thus for the development of a shared mental model.

Group information processing models may inform us about how to provide negotiators with information [17]. According to such models of information processing, people process different activities. First, group members perceive the information they are exposed to. After this attention stage, group members encode the information by structuring, evaluating, interpreting, and transforming the information into a mental representation. Hereafter, the information will be stored in memory to be retrieved later in the negotiation process.

Because encoding involves negotiators to structure and interpret the information in order to transform it into knowledge, it functions as a key element in producing cognitions of the problem and possible solutions. Therefore, if negotiators structure and interpret the information in similar ways, knowledge about the problem and possible solutions will also be more shared. On the other hand, if negotiators interpret the situation differently, cognitions are likely to diverge, which may hinder the negotiation process. Thus, the challenge is to stimulate similar encoding processes among negotiators in order to develop shared knowledge toward the problem and possible solutions. Because the encoding phase is preceded and influenced by the attention to available information, we argue that one possibility for stimulating convergence between negotiators could be to intervene within this phase. Therefore, we suggest that presenting them with unambiguous information stimulates similar structuring and representation processes and thereby supports the development of shared mental models.

One possibility to provide information unambiguously is to use visual representation aids, which are known to have a strong impact on the problem perception in groups [3, 31]. These visual representation aids provide ways of presenting and manipulating a problem situation by means of images, charts, maps, and so on [49]. The underlying idea behind the powerful impact of such representational aids on cognitions is that they can be comprehended quite easily and that they tend to minimize the scope for divergent interpretation compared with textual and verbal information exchange [39]. The graphical forms can provide a common framework that is a basis for negotiators in interacting with each other and communicating proposals and preferred solutions [31]. Thereby, graphical representations can also diminish the time it takes negotiators to verbalize their perceptions of the problem. So, attention should be focused on perceiving the visual representation, rather than relying solely on logical inferences based on interpretations of language [26]. The idea is that discussion evoked by the representational aids will lead negotiators to realize which information is absent and important and which is present and unimportant [1].

In sum, by unambiguous visualization of information regarding the problem and possible solutions, negotiators are able to encode the information more similarly. As a result, mental models will be more shared and we propose that this will be associated with other negotiation outcomes.
Summarizing the ideas above in the form of hypotheses to be tested, we expect that visualization support affects four distinct classes of negotiation outcomes. The first outcome is the shared mental model of negotiators. Based on the theoretical analysis above, a main objective of negotiation support could be to foster a common understanding among negotiators about the nature of problem, and possible solutions [31, 43, 45]. This common understanding could be triggered by unambiguous visualization of a problem, thereby providing negotiators with similar perceptions of the problem at hand and of possible solutions. Due to well-designed visual aids, shared mental models should arise more easily.

**H1:** Visualization support fosters the development of a shared mental model among negotiating parties, compared with negotiations without visualization support.

As a result of the like-mindedness created by shared task mental models, commonalities among negotiators will become more salient and this perceived similarity is likely to foster a pro-social climate. To measure the pro-social climate, we distinguished two different variables. One variable related to the pro-social climate is the degree to which negotiating parties are bonded to each other. Negotiation support should increase feelings of attraction for specific group members and for the overarching group itself, and increase the degree to which negotiators coordinate their efforts to achieve common goals. These properties are commonly known as cohesion [8, 12].

**H2a:** Visualization support increases cohesion among negotiating parties compared with negotiations without visualization support.

A second variable closely related to the pro-social climate is the perception of a common identity. In this study, common identity was operationalized with a measure of entitativity [6, 13]. This concept captures the degree of perceived unity among negotiators, such that strong entitativity implies that differences between negotiators are small. As such, entitativity can be seen as a measure of common in-group identity [32]. Parallel to the reasoning for the previous hypothesis, support should increase entitativity.

**H2b:** Visualization support increases entitativity among negotiating parties compared with negotiations without visualization support.

We argue that both variables (shared mental model and a pro-social climate) have positive effects on the negotiation outcome. One key outcome of any negotiation is the reduction of interparty conflict, thereby increasing possibilities for an agreement. Typical for conflict situations is the existence of conflicting interpretations of the problem and especially its solutions. Due to potential effects of both shared mental model and a pro-social climate, we expect that visualization support will have positive effects on this negotiation outcome. The underlying idea is that visualization helps the creation of a shared mental model, which together with a pro-social climate, builds the foundation for a common agreement in the form of interparty consensus.
H3: Visualization support increases consensus among negotiating parties compared with negotiations without visualization support.

To examine a negotiator’s evaluation of the method of visualization support, three different satisfaction variables are measured. Because satisfaction is closely related to people’s appreciation of the quality of negotiations as a social process, we expect that satisfaction will be greater when there is visualization support. We distinguish between satisfaction with the outcome, the process, and the facilitator’s role. These three may be interrelated, but measure conceptually different aspects the support.

H4a: Visualization support increases satisfaction with the outcome of negotiation among negotiating parties compared with negotiations without visualization support.

H4b: Visualization support increases satisfaction with the process of negotiation among negotiating parties compared with negotiations without visualization support.

H4c: Visualization support increases satisfaction with the facilitator who supports negotiation among negotiating parties compared with negotiations without visualization support.

Method

Participants and Design

Participants were recruited from different social science departments in the Netherlands. Fifty-six third year students (33 men and 23 women) participated in the experiment. There were seven groups in every condition, with four persons per group. The average age was 24 years. Participants received no financial reward for their participation. They were given a guided tour through the Virtuality laboratory. Participants were randomly assigned to experimental conditions. Although some group members knew each other, most did not. None of the group members had a past history of working together within their particular group. The experiment had one independent variable, the type of negotiation support: groups were either supported by visualization or they were not. Groups in both conditions performed the same tasks and communicated verbally.

Negotiation Task

Participants performed a negotiation task in which each individual represented a different party with conflicting interests. The purpose of the task was for each party to explore the possibility of reaching a joint agreement that would maximize their returns. The negotiation task was a simulated business game based on the real-life negotiations surrounding environmental planning and water management in the harbor.
of Rotterdam, a negotiation in which several parties with conflicts of interest needed to reach consensus. In the game, four of these parties negotiated whether joint investments should be made in buildings and factories, new roads, or a network of pipelines. Every participant played a different role, and they had to maximize the result for their party. Two participants played representatives of an industrial organization, which we shall call X and Y, both oil refineries. A third participant negotiated on behalf of the Ministry of Transport, Public Works, and Water Management, and the fourth participant represented an environmental protection organization.

All the parties had plans within this area, but settlement depended on the ministry to subsidize (or sometimes to not penalize) these plans. Plans were displayed in the simulation model in terms of their financial and environmental returns. Although both industrial organizations wanted to expand, the nature of their desired expansion differed strongly. For example, the small industrial organization wanted to build new roads because their plant was isolated from the rest of the area. The other industrial organization, a big multinational refinery wanted to expand their buildings and factories. So, interests of industrial organizations conflicted in the sense that they both wanted something else. Further, they differed in their core business as the smaller organization was a shipping company and the latter an oil refinery organization. Although industrial policies would have financial benefits, both had negative environmental consequences. The objective of the small industrial organization was to persuade the ministry to subsidize part of their costs because they did not have sufficient financial means to realize their plans. However, the large industrial party did have enough financial resources, it depended on the ministry because they needed building licenses. The third party involved—an environmental protection organization—had extremely different plans and wanted to realize a network of pipelines for efficient heat and energy reuse. In terms of financial and environmental returns, this plan was environment-friendly, but financially less attractive for the two industrial organizations. The problem for the environmental protection organization was that they had no budget available for the realization of their plans, and were thus dependent on investments of the ministry and of the industrial organizations. Their objective was to persuade them.

The ministry played a different role than the other three actors. The ministry’s main objective was not to stimulate investment in this or that, but to develop a shared policy in the harbor area. This policy should meet two requirements: it should improve the economy of the region, and contribute to a cleaner and healthier environment. The ministry’s representative had no concrete objectives, such as the other three organizations, but had the power to subsidize plans that would improve the situation in the region. Moreover, although the ministry did not have veto power, they could penalize plans that would be harmful to the environment, by imposing the so-called ecotax. This is extra taxation on environmental pollution, and would decrease the financial performance of the industrial organizations. The idea underlying the task that parties with interdependent outcomes negotiated about an issue, but that conflicts of interests hindered the required settlement, and the “best” solution would be a win-win solution, based on the different objectives.
Procedure

At the moment of arrival, participants were asked to join the negotiating table. Each of the participants were asked to read the instructions, explaining in detail their role in the game, giving them the background of their organization, and the objective of their party. Within this background information, participants were given private information about the costs and benefits of negotiation outcomes for them. Also, they were given directives for their negotiation strategy. After reading the instructions, participants were given the full description of the problem at hand, introducing the issue. After that, they filled out a short pretest questionnaire. This took 15 minutes. After the introduction, the facilitator informed negotiators that their objective was to explore the possibilities of a shared policy, and presented three possible scenarios. These three scenarios represented the optimal plans of three of the parties involved: refinery X, refinery Y, and the environmental protection organization. This introduction to the parties’ optimal scenarios took 20 minutes.

The participants were then asked by the facilitator to comment on these scenarios. Subsequently, they negotiated and explored the possibilities for a shared policy. The maximum time they could use for the negotiations was one hour. After 60 minutes of negotiating, participants were asked if they wanted to make a decision now, or continue with the negotiations in the future (one of the groups in the unsupported condition didn’t want to continue future negotiations at all). The negotiations were then terminated, and participants were asked to fill in a posttest questionnaire. The facilitator was present at all times to structure the meeting and, if necessary, as an instigator of the discussion.

Independent Variable: Type of Negotiation Support

Negotiators were supported with a visualization system, the Virtual Business System (VBS), developed by the Virtuality Group at the Netherlands Organization for Applied Scientific Research (TNO). The system uses simulation models that synchronize with the visualization model. So, negotiators could say exactly where and to what extent they wanted to penalize their plans. For example, the big industrial organization was able to visually demonstrate his plans within the area of discussion. Therefore, he could draw new factories on a big screen, whereas environmental and financial profits were rendered immediately. All parties involved could see these effects, and were able to comment on the scenarios in a structured way. Participants were able to form their own representations before discussing the problem altogether within the group (see also [31] for a similar procedure). In the second place, interpersonal interaction in both experimental conditions went via face-to-face discussion, accounting for a “rich” communication climate, required for negotiation support [29]. The visualization could be in a two-dimensional, three-dimensional, or four-dimensional (three-dimensional graphics with modifications over time) format.

The manipulation of visualization support consisted of letting negotiators use the VBS in the support condition, or not in the control condition. Practically, this meant
that although all information was presented on one screen (visible to all) in the support condition, multiple sources of information were used in the control condition.

Players in the visualization support condition were supported by projections on a big semicircular, 150-degree screen with presentations depicting the environment, alterations made to it, and the economic and environmental consequences. They sat with each other around a table, facing the screen, and were supported by an independent facilitator, a whiteboard, and flip-over (see Figure 1). Participants in the no-support control condition met each other without any automated aids for visualization support, and sat around a big table, also supported by the independent facilitator, a whiteboard, and flip-over. In this configuration, an overhead projector was present. On the wall, behind the facilitator, a two-dimensional map of the whole area was present. The participants also had a little map on their desks, with a two-dimensional view of the harbor area.

A further difference between conditions was that players in the support condition could interact with the VBS system. Their proposals for alterations (such as building roads or investments made) were passed to the system by the facilitator, and immediately visualized on the three-dimensional map of the environment (Figure 2).

Another section of the screen was reserved for simulations. When participants decided to invest, for example in new buildings, financial and environmental effects could be visualized in this display (Figure 2). In contrast, in the control condition, participants were not able to make the adjustments to the shared display. Instead, each negotiator had a small-copied map on which they could make notes. In addition, an overhead display and flip-over were available to share the information about various simulations of economic and environmental effects.

In sum, in the support condition, all relevant information was displayed on one screen, and players had the opportunity to visualize their proposals and gain some insight into the consequences of various settlements. In contrast, although in the control condition the exact same information was provided, the displays were static, all two-dimensional, and different types of information were displayed on different sources.
Figure 2. Visualization and Negotiation Support: Three-dimensional visualization of the harbor area (top) and corresponding financial/environmental consequences (bottom) of a certain investment.
Dependent Measures

We distinguish between four types of dependent measures: three types of negotiation outcomes, and some additional outcome variables. The wording of questions of the scales are presented in the Appendix. All responses were recorded on five-point Likert-type scales ranging from 1 (very negative/strongly disagree) to 5 (very positive/strongly agree), unless indicated otherwise. Scale means were computed by averaging across items. The variables and their Cronbach’s alpha are displayed in Table 1, reliabilities were acceptable.

The measure of shared mental models was included in both pretest and posttest. This measure captured the amount of overlap in cognition about the issue at hand as reflected in participants’ assessment of the importance of a shared policy and shared objectives for themselves, the environment, and for the economic development of the region [24]. So, these were all questions regarding an individual’s knowledge of the problem at hand and its possible solutions. It should be pointed out that, to our knowledge, this operationalization of shared mental models is a novel method in negotiation support research.

With regard to the changes in structure of the pro-social climate over the course of the negotiation, measures of cohesion [27] were included in the pretest and posttest. Entitativity was only measured in the posttest [41] (see Table 1 for details).

The level of consensus was measured with a measure of differentiation within the group, proposed by Linville et al. [30]. This measure of differentiation can range from 0 (total agreement) to 1 (maximum disagreement), and is less susceptible to the influence of “lone deviants” than other measures of variance. The degree of differentiation between parties was computed for the responses to items of the shared mental model scale, and then averaged. Thus, it was a measure of consensus about the problem at hand.
Further, subjective assessment of typical group research variables were recorded with scales of satisfaction with the outcome, satisfaction of the process, and satisfaction with the facilitation [4].

Analytic Strategy

Because of the interdependence among negotiators, the group was the level of analysis. Although we had seven groups within each condition, analyses of variance (ANOVA) were conducted to test for between-condition differences. Some dependent variables were collected both prior to and after the negotiation. These variables were analyzed in a repeated-measures ANOVA with experimental condition as a between-participants variable, and time as a within-participants variable. This analysis yields three types of effects (Table 2). One is the between-groups main effect of support condition. This indicates whether support across pre- and posttest has any effect on the dependent variables. The second is the pre-post difference main effect. This indicates whether there are any changes from pre- to posttest across support conditions. Finally, there is the pre-post times support condition interaction. This indicates whether changes from pre- to posttest are different for the support versus no support condition. Since we predict that support should yield better outcomes than no support, we predict that this interaction should be significant. In sum, hypotheses were tested by looking at the differences between pre- and posttest for each condition.

Results

Shared Mental Model

Regarding shared mental models, there was no difference between the support condition \((M = 3.97; SD = 0.22)\) and the control condition \((M = 3.92; SD = 0.33)\) in the pretest, \(F(1,12), \text{n.s.} \) (not significant). In the posttest however, the supported condition developed more shared mental models \((M = 4.43; SD = 0.20)\) than the control condition \((M = 4.04; SD = 0.49)\). Changes over time differed reliably between conditions, \(F(1,12) = 7.20, p < 0.05\). This provides support for our hypothesis that visualization support develops shared mental models (H1).

Pro-Social Climate

At the pretest, the level of cohesion in the support condition \((M = 3.02; SD = 0.29)\) was similar to the control condition \((M = 3.00; SD = 0.57)\). However, at the posttest, supported groups were more cohesive \((M = 3.42; SD = 0.50)\) than control groups \((M = 2.71; SD = 0.42)\). The significant interaction effect between the two conditions over time, \(F(1,12) = 7.52, p < 0.05\), supports our hypothesis that visualization support increases cohesion (H2a).
Table 2. Means per Condition (Standard Deviations Between Brackets) and Analysis of Variance

<table>
<thead>
<tr>
<th></th>
<th>Pretest Support</th>
<th>Pretest No support</th>
<th>Posttest Support</th>
<th>Posttest No support</th>
<th>Support F (1,12)</th>
<th>Pre-post F (1,12)</th>
<th>Interaction F (1,12)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shared mental model</td>
<td>3.97a (0.22)</td>
<td>3.92a (0.33)</td>
<td>4.43bc (0.20)</td>
<td>4.04ac (0.49)</td>
<td>1.82</td>
<td>21.51***</td>
<td>7.20*</td>
</tr>
<tr>
<td>Cohesion</td>
<td>3.02a (0.29)</td>
<td>3.00a (0.57)</td>
<td>3.42b (0.50)</td>
<td>2.71a (0.42)</td>
<td>2.99</td>
<td>0.21</td>
<td>7.52*</td>
</tr>
<tr>
<td>Entitativity</td>
<td>—</td>
<td>—</td>
<td>3.70a (0.35)</td>
<td>3.03b (0.39)</td>
<td>10.86**</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Consensus</td>
<td>0.72a (0.07)</td>
<td>0.66a (0.12)</td>
<td>0.52b (0.12)</td>
<td>0.66a (0.11)</td>
<td>0.97</td>
<td>7.87*</td>
<td>7.66*</td>
</tr>
<tr>
<td>Satisfaction with process</td>
<td>—</td>
<td>—</td>
<td>4.04a (0.29)</td>
<td>3.36b (0.34)</td>
<td>16.40**</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Satisfaction with outcome</td>
<td>—</td>
<td>—</td>
<td>3.62a (0.38)</td>
<td>3.30a (0.56)</td>
<td>1.61</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>Satisfaction with facilitation</td>
<td>—</td>
<td>—</td>
<td>4.26a (0.40)</td>
<td>3.82b (0.21)</td>
<td>6.70*</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Notes: Means in a row with a different letter (a, b, or c) differ reliably at $p < 0.05$; dashes indicate that the effect cannot be computed because measures were only completed at the posttest; * $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$. 
Predictions were also confirmed for entitativity. Although the control condition scored neutrally ($M = 3.03; SD = 0.39$), groups in the support condition ($M = 3.70; SD = 0.35$) scored significantly higher on entitativity after negotiations, $F (1,12) = 10.86, p < 0.01$. Groups with visualization support are thus more entitative than nonsupported groups, which supports our hypothesis H2b.

**Negotiation Outcome**

Results for consensus indicated that at the pretest, there was no reliable difference between the support condition ($M = 0.72; SD = 0.07$) and the control condition ($M = 0.66; SD = 0.12$), $F (1,12) = 1.12, n.s.$ Over time, however, the level of consensus increased in the support condition ($M = 0.52; SD = 0.12$), but it did not increase in the control condition ($M = 0.66; SD = 0.11$), $F (1,12) = 7.66, p < 0.05$. Thus, H3 was confirmed: visualization support increases the level of consensus among negotiators.

**Outcome-Related Variables**

Results for satisfaction with the outcome show that groups in the support condition ($M = 3.62; SD = 0.38$) were also somewhat more satisfied on this dimension of the negotiation than in the control condition ($M = 3.30; SD = 0.56$). This difference was not significant, however, $F (1,12) = 1.61, n.s.$ This leads us to reject our hypothesis that VBS exposure leads to more satisfaction with the negotiation outcome (H4a).

After negotiation, supported groups were more satisfied with the process ($M = 4.04; SD = 0.29$) than control groups ($M = 3.36; SD = 0.34$), $F (1,12) = 16.40, p < 0.01$. Visualization support thus leads to more satisfaction with the negotiation process, in support of our hypothesis (H4b).

For satisfaction with the facilitation, a reliable difference between the support condition ($M = 4.26; SD = 0.40$) and the control condition ($M = 3.82; SD = 0.21$) was found, $F (1,12) = 6.70, p < 0.05$. This leads us to accept our hypothesis that groups with visualization support are more satisfied with the facilitation (H4c).

**Discussion**

RESULTS SHOWED A NUMBER OF RELIABLE DIFFERENCES in negotiation outcomes when comparing negotiations with visualization support with unsupported negotiations. The pretest did not show reliable differences between conditions, which implies that changes were caused by experimental treatments. In particular, visualization support improves the outcomes of negotiations on a number of central negotiation variables, in comparison with a control condition. Most important, sharedness of the mental model increases significantly in the support condition, as opposed to the control condition. Thus, the prediction was confirmed that visualization support may aid the focusing of groups in such a way that shared mental models emerge. In view of this finding, it is not surprising that groups with visualization support reached consensus more easily than control groups did.
Visualization support also improves the pro-social climate. Supported groups were significantly more cohesive when compared with unsupported groups. The results also confirmed our predictions for negotiating groups’ entitativity: once more, supported groups were more entitative, indicating that the perceived unity was greater. Thus, the results on socio-emotional variables tend to support the prediction that visualization support fosters a positive climate among negotiating parties.

No significant effects were found for satisfaction with the outcome. Because supported groups reached significantly more consensus, this result could be seen as somewhat surprising. A likely explanation is that only two out of seven supported groups reached a final agreement, against zero in the control groups. This means that most of the groups did not have a concrete “outcome”: they had converged, but still did not agree completely yet. However, the results do confirm that visualization support leads to significantly more satisfaction with the negotiation process, in support of our hypothesis. Finally, although groups in both conditions seemed satisfied with the facilitation of the meeting, groups with visualization support were more satisfied, in support of our hypothesis.

In sum, visualization appears to improve three aspects of negotiations: (1) visualization support aids negotiators’ convergence of perceptions of reality, (2) it has positive socio-emotional consequences in terms of increasing cohesiveness and entitativity, and (3) it stimulates consensus formation (and hence diminishes conflict). In the study, then, visualization appeared to have contributed positively to the negotiation process, and functioned as a strong cue for cognitions about the problem [2, 46]. We therefore conclude that negotiations about a spatial planning issue are successfully supported by means of visual representation aids.

Establishing that visualization has three different effects raises the question in what way these effects are related to each other. As mentioned briefly in the introduction, we were working on the a priori assumption that shared mental models are the mediator, and that positive climate and consensus are the outcomes. However, it is also possible that a positive pro-social climate is the mediator, or even that consensus is the fundamental process driving the other effects. It is hard if not impossible to make any definite claims about causation on the basis of the present data: ideally, one would manipulate each of the three variables involved experimentally in order to establish their impact on the others. However, we did conduct a post hoc analysis of our theoretical assumption by means of a structural equation model. This explorative analysis provided tentative support for our assumption that shared mental models mediate the other effects. Nonetheless, in order to overcome the problems of inferring causation from correlation—especially with samples of this size—future research should be devoted to assessing the central role of shared mental models and the processes involved.

Theoretical Implications

There are several theoretical implications of this study. First, it sheds light on the operationalization of shared mental models. To our best knowledge, the method to measure the shared mental models we developed is a novel one, although it does not
cover all aspects that such models comprise. Future research could extend these measures to also cover shared knowledge of procedures and credibility [34, 36]. In any case, the information processing perspective proved to be helpful in determining when and how information should be provided in order to increase the sharedness of mental models. We inferred that providing unambiguous information (in this case by visualization) in the encoding stage is essential in attaining shared mental models. Indeed, it appeared that discrepancies in knowledge and perceptual distortions among the negotiators were reduced by the use of visualization support [28, 44]. This is also illustrated by participants’ comments such as “visualization made the whole issue less complex and more transparent” and “I was able to see causalities on an abstract level, which I would not have seen without the visualization tool.” An interesting question for future research could be to examine what types of information support the development of shared mental models in negotiation contexts other than spatial planning conflict.

Furthermore, this study has implications for Negotiation Support Systems (NSS) theory. Much of the research that has been conducted to examine the utility of NSSs has been based on Lim and Benbasat’s [29] theory of NSS. This theory recognizes the separate but important roles played by two components of NSS—decision support systems and electronic communication support. As the authors propose, the decision support systems component of NSSs should provide negotiators with an increased capacity for information processing. In the current study, one might argue that we provided the decision support component by presenting negotiators with unambiguous information, which stimulated similar encoding processes among negotiators and led to the development of shared mental models.

In this regard, our findings support the theoretical proposition by Lim and Benbasat [29]. However, our results also show that the provision of visual information had an effect on the pro-social climate. That is, groups with negotiation support developed a more pro-social climate than those who were unsupported. Although ultimately an empirical question requiring further attention in future research, the present findings do suggest that the social climate may be an important factor involved in negotiations [9]. This suggests that future theorizing about NSS development should also consider when and how NSSs can foster a pro-social climate.

Moreover, designing NSSs with an electronic communication component might have effects that are detrimental to a pro-social climate: Lim and Benbasat [29], for example, argue this elicits task-oriented behavior [see also 33]. More generally, much research on NSS has focused on how, when, or why to deliver the right information with certain NSSs, but these studies tend to de-emphasize the relational demands that negotiations place on the communication environment [21, 22, 42, 50]. We argue that NSSs should cater for a pro-social climate, since this factor has been shown to be a good predictor of negotiation settlement with and without the use of computer-mediated communication techniques [9, 19]. Thus, we argue that one prerequisite of NSSs is that the communication support they provide allows for “rich” interaction [5]. In the current study, we did so by providing both conditions the possibility to negotiate face-to-face.
In sum, although we found support for existing theories of negotiation support and the design of NSS, our results also suggest that prior research tends to underestimate the importance of the relational aspects within negotiation.

Limitations

What is remarkable about the present study, is that the control condition provided essentially similar information to negotiators, but via different channels. Thus, participants in the control condition also received maps, charts, and all the relevant background information. Three aspects were different, however. First, the relevant information in the VBS was displayed simultaneously and in one location (on a large semicircular screen), which forced negotiators to focus on the same objects throughout their negotiations. Second, the VBS offered the possibility to make interactive changes to the display, which heightened participants’ awareness of the impact of future scenario’s while focusing them on similar outcomes. Third, the VBS environment presented an impressive display of technology, and forced participants to focus on the displays, which were colorful, dynamic, and entertaining. We believe that these three aspects mutually caused the differences between conditions, and that they can account for the emergence of shared mental models and consensus. Future research could attempt to isolate the respective influence of each of these three aspects of the NSS used in this study.

Although the results support the conclusion that visualization in negotiations can be productive, the use of the experimental sample (student groups) may limit the study’s ecological validity [10]. To some extent, this limitation is reduced by the fact that NSS used in this study is also successful in “real-world” negotiations, when negotiators are actual organizations and companies. For example, the VBS recently played a significant role during a negotiation in which stakes were quite high for those involved, and where managers and policy-makers from different parties (government, oil industries, and interest groups) discussed water management in the Dutch mainport of Rotterdam. Although a final agreement was not reached during the initial negotiations when the VBS was used, negotiators had high expectations of future success, and post-negotiation interviews showed that they gained considerable insight into each other’s interests, problems, and in the possible solutions they could reach. The development of a shared policy in this area is momentarily advancing rapidly. Thus, case studies tend to confirm that visualization may be beneficial for real-world negotiation support.

It should be pointed out that the generalizability of this study is potentially limited to spatial planning issues only. Visualization is especially appropriate to this type of negotiation issue. Indeed, we believe it is highly likely that the appropriateness of visualization as a support instrument varies across different negotiation issues. However, this caveat does not affect the more general conclusion that we tentatively draw from our findings, namely that the provision of unambiguous information aids negotiation settlement through the development of a shared mental model and a positive negotiation climate.
Conclusion

On theoretical grounds, we proposed that during multiparty negotiations, shared mental models are likely to be a crucial variable that NSSs should seek to maximize. The results showed that in a spatial planning dispute, visualization is an effective means of improving the shared mental model of a group of negotiators, fostering a pro-social climate among negotiating parties, and thereby stimulating high levels of consensus. Thus, visualization supported the attainment of shared mental models, which could be the nucleus of shared solutions despite existing conflicts of interest. Results also suggest that negotiation support could seek to improve the pro-social climate.

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NOTES

1. Nevertheless, within-negotiation variance is strongly related to differentiation: in the present study, their correlation was $r (14) = 0.77, p < 0.01$.

2. A model tested the theoretical assumption that visualization impacts on shared mental models. Shared mental models were subsequently hypothesized to influence both pro-social climate and consensus. The model finally specified that pro-social climate would have a positive effect on consensus. The model was tested with the structural equations program EQS [3], allowing tests of the significance of hypothesized paths from the covariance matrix, as well as the degree of fit of the whole model. The fit of the model as tested was good, $\chi^2(7) = 7.91, p = 0.34$, n.s., CFI = 0.99, NFI = 0.90. Moreover, the hypothesized paths were all highly reliable.

REFERENCES


Appendix

Constructs and Measurements

<table>
<thead>
<tr>
<th>Scale</th>
<th>Questions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shared mental model</td>
<td>A shared policy within the harbor area is positive for your organization</td>
</tr>
<tr>
<td></td>
<td>A shared policy within the harbor area is positive for the environment</td>
</tr>
<tr>
<td></td>
<td>The placement of pipelines is positive for your organization</td>
</tr>
<tr>
<td></td>
<td>The placement of pipelines is positive for the environment</td>
</tr>
<tr>
<td></td>
<td>In the long term, investments in pipelines have positive economical consequences</td>
</tr>
<tr>
<td></td>
<td>In the long term, investments in pipelines have positive environmental consequences</td>
</tr>
<tr>
<td>Cohesion</td>
<td>The cooperation in the group was efficient</td>
</tr>
<tr>
<td></td>
<td>There is a sense of unity in this group</td>
</tr>
<tr>
<td></td>
<td>The members of this group form a unity</td>
</tr>
<tr>
<td></td>
<td>Despite the differences between the members, the group develops its own identity</td>
</tr>
<tr>
<td>Entitativity</td>
<td>Select which of the figures below fits your idea of the group best</td>
</tr>
<tr>
<td>Satisfaction with the process</td>
<td>I am very satisfied with the method that has been used during the meeting.</td>
</tr>
<tr>
<td>------------------------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td></td>
<td>My overall judgment of the method that has been used during the meeting is positive/negative.</td>
</tr>
<tr>
<td></td>
<td>The influence of the method that has been used during the meeting on the decision-making process was positive/negative.</td>
</tr>
<tr>
<td></td>
<td>The influence of the method that has been used during the meeting on the quality of the deliberation in the group was positive/negative.</td>
</tr>
<tr>
<td></td>
<td>The influence of the method that has been used during the meeting on the atmosphere in the group was positive/negative.</td>
</tr>
<tr>
<td></td>
<td>I rate the quality of the method that has been used during the meeting with the number 1–10.</td>
</tr>
<tr>
<td>Satisfaction with the outcome</td>
<td>I accept the outcome of this meeting.</td>
</tr>
<tr>
<td></td>
<td>The decision that has been made during this meeting is the right one.</td>
</tr>
<tr>
<td></td>
<td>I am satisfied with the results of this meeting.</td>
</tr>
<tr>
<td></td>
<td>I rate the result of this negotiation with the number 1–10.</td>
</tr>
<tr>
<td>Satisfaction with the facilitation</td>
<td>The facilitator's knowledge was sufficient to guide the content of the process.</td>
</tr>
<tr>
<td></td>
<td>The process of the meeting has been guided effectively.</td>
</tr>
<tr>
<td></td>
<td>The facilitator's influence on the process of the meeting was positive/negative.</td>
</tr>
</tbody>
</table>