Available online at www.sciencedirect.com
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Organizational Behavior and Human Decision Processes 93 (2004) 102–113
ORGANIZATIONAL BEHAVIOR AND HUMAN DECISION PROCESSES
www.elsevier.com/locate/obhdp

When is one head better than two? Interdependent information in group decision making☆

Samuel N. Fraidin*

University of Southern California Law School, USA

Abstract

Research on information exchange in group decision making has frequently assumed that information items have independent meanings. Relaxing this assumption raises new issues and presents new possibilities. In the experiment presented here, dyads worked on hidden profile decision tasks in which pairs of unshared information items had interdependent meanings. Dyad decisions were more likely to be accurate when each pair of interdependent items was allocated to a single member (a "connected" hidden profile) than when each pair of interdependent items was separated between the two members (a "disconnected" hidden profile). These information distributions influenced the degree to which dyads considered unshared information. Cognitive load was manipulated, and it impaired decision makers' ability to identify connections among interdependent information items. The differentiated distribution of information inherent in transactive memory systems moderated the negative effects of cognitive load on dyad decisions.

Keywords: Group processes; Decision making; Time pressure; Hidden profiles; Transactive memory

Introduction

Most research on group decision making, particularly research using hidden profile tasks (Stasser & Titus, 1985), has assumed that information items have relatively independent meanings (Winquist & Larson, 1998; Wittenbaum & Stasser, 1996). Although significant knowledge has been gained from research that has made this simplifying assumption, relaxing it raises new issues and presents new possibilities. How will information exchange be affected if some information items influence the interpretation of other items? How will decision accuracy be affected if these items are allocated to different group members? Will the impact of these items on group decisions be particularly sensitive to cognitive load? Will the division of labor inherent in transactive memory (Wegner, 1987) moderate the effects of cognitive load?

Information items have interdependent meanings if the meaning of one item cannot be accurately evaluated without considering another item (Pennington & Hastie, 1993). The study presented here used hidden profile tasks involving interdependent information items to examine the effects of information distribution and cognitive load on dyad decision making performance. These effects were examined in the context of decision making dyads using transactive memory systems (Stasser, Stewart, & Wittenbaum, 1995; Wegner, Erber, & Raymond, 1991).

Hidden profiles

A hidden profile occurs when the total profile of information available to a group favors one decision alternative, but the pattern of information seen by individual members prior to discussion favors another alternative (Stasser, 1992). This situation occurs when

☆ A Center for Law, Economics, and Organization fellowship at the University of Southern California Law School and a John M. Olin, Jr. fellowship at Columbia Law School supported the author during the writing of this paper. The following people provided helpful comments during the course of this project: Andrea Hollingshead, Pat Laughlin, Greg Northcraft, Peter Carnevale, David Budescu, Terry Connolly, and several anonymous reviewers. Don Choi, Sarah Fraidin, and Renae Franiuk assisted with data collection. Katie Casey, Katie Sullivan, and Denise Colangelo coded the discussion transcripts.

* Present address: Columbia Law School, 435 West 116th Street, New York, NY 10027, USA.

E-mail addresses: sfraid@law.columbia.edu, sfraidin@law.usc.edu.

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doi:10.1016/j.obhdp.2003.12.003

the information supporting the best alternative is divided among group members (unshared information), and all members possess the information supporting the inferior alternatives (shared information).

Group decision accuracy is relatively poor in this situation primarily as a result of two factors: individual members prefer an inferior alternative before discussion begins (Gigone & Hastie, 1993; Hollingshead, 1996; Kelly & Karau, 1999; Winquist & Larson, 1998), and group members discuss more shared than unshared information (Larson, Foster-Fishman, & Keys, 1994; Stasser, Taylor, & Hanna, 1989; Stasser & Titus, 1987). Collective Information Sampling (CIS) theory (Stasser & Titus, 1987; see also Larson et al., 1994; Wittenbaum & Stasser, 1996) accounts for the latter finding by proposing that the likelihood that an item will be mentioned to a group is a function of (1) the number of group members who have seen the item, and (2) a parameter indicating the likelihood that an individual member who has seen the item will mention it to the group. This parameter (which, following Stasser, 1992; I will refer to as an item's salience) depends on a variety of factors, including memory for the item (Stasser et al., 1989; Stasser & Titus, 1987) and decisions to mention the item (Brodbeck, Kerschreiter, Mojzisch, Frey, & Schulz-Hardt, 2002; Stasser, 1992).

Most research on hidden profiles assumes that unshared information is as memorable as shared information (Stasser, 1992; Wittenbaum & Stasser, 1996). When variations in item salience are addressed, they are typically treated as noise and controlled (e.g., Stasser et al., 1989). However, two studies in the hidden profile literature have focused directly on the effects of variations in the salience parameter across items.

Kelly and Karau (1999) evaluated the effect of item diagnosticity on group discussion content. They found that groups "centered their discussions around diagnostic information," mentioning a higher percentage of facts that had positive or negative implications than facts that had neutral implications regarding the decision alternatives. The commonly observed tendency for groups to discuss more shared than unshared information (Wittenbaum & Park, 2001) did not occur in conditions of the experiment in which unshared information was particularly diagnostic (Kelly & Karau, 1999). As the authors suggested, this result can be interpreted as consistent with information sampling models if diagnostic information is assumed to have a higher salience parameter than non-diagnostic information.

The salience of unshared information items was manipulated in a computer simulation study by Stasser (1992). Although the CIS model combines them in one parameter, Stasser (1992) distinguished two aspects of salience: an increased likelihood that group members will recall an information item they see prior to discussion and an increased likelihood that group members will mention an information item they have recalled. Somewhat surprisingly, Stasser found that salience had relatively little impact, except for smaller groups whose members did not advocate for particular outcomes. He also found that implementing salience as increased memory for an item had more impact than implementing it as an increased likelihood of mentioning the item.

Interdependent information items

Stasser (1992) and Kelly and Karau (1999) identified reasons that some pieces of information might be more salient than others. Stasser (1992) suggested that experts will see information in their domain of expertise as more salient. Kelly and Karau (1999) pointed to a feature present in many decision contexts: more diagnostic information will be more salient (see also Gigone, 1996).

Another factor that can influence salience is interdependent meanings. A key feature of interdependence is that items that seem rather unimportant on their own can take on great significance when considered together (Wegner, 1987). The change in meaning that occurs when interdependent items are considered together can result in those items being more likely to be remembered and mentioned to the group.

For example, consider these two pieces of information from a murder mystery (Stasser & Stewart, 1992): (1) suspect E told the police he heard another suspect's car at the crime scene and (2) suspect E is completely deaf. The second fact takes on much greater significance in light of the first fact (and vice versa): together they indicate that suspect E lied to the police. The two items are more likely to be remembered and mentioned in a discussion when they are considered together rather than separately.

This sort of interdependence is probably a common phenomenon. Connections among pieces of information are seen as critical in research on a wide variety of topics, including memory (Bower, Lesgold, & Tieman, 1969; Schul & Burnstein, 1983; Trabasso & Sperry, 1985), impression formation (Sedikides & Anderson, 1994), and problem solving (Pennington & Hastie, 1993). Conversation is influenced in a particularly important way by connections: discussion contributions are expected to be relevant to the topic of discussion (Grice, 1975; Kelly & Karau, 1999); that is, new information is expected to be connected in some way to what has been discussed (Haviland & Clark, 1974; Teigen, 1985).

Interdependence and information distributions

When information items have interdependent meanings, the way they are distributed among group members can affect how they are perceived. Members who are allocated two or more interdependent items (i.e., when the interdependent items are in one head) may perceive the connections among the items prior to discussion. Group members who are allocated one interdependent item without the related items (i.e., when the interdependent items are separated between two heads) cannot perceive the connection among items prior to discussion.

As a result, two types of hidden profiles can be distinguished. In a "connected hidden profile," each group member possesses unshared items whose meanings are dependent on other unshared items held by that group member. For example, one group member would receive the item about suspect E telling police he heard a car, as well as the one about suspect E's hearing problem. This group member could identify the connection, recognize the significance of the items, and mention them to the group.

In contrast, in a "disconnected hidden profile," each group member possesses unshared items whose meanings are dependent on unshared items held by other group members (cf. the aircraft maintenance example in Wegner, 1987). For example, one group member would receive the information about suspect E telling police he heard a car, and a different group member would receive the information that suspect E is deaf. Neither group member would be able to understand the importance of these items prior to discussion, and, as a result, neither member would be likely to mention them.

The connected hidden profile hypothesis:

Part 1. Groups working with a connected hidden profile will be more likely to select the correct decision alternative than will groups working with a disconnected hidden profile.

Part 2. The superior decision accuracy of groups working with connected hidden profile will be mediated by the perceived importance of unshared interdependent information items and by discussion of those items.

Cognitive load and interdependent items

Cognitive load is a function of the amount of information people are required to process and the amount of time allowed for processing it (Hendy, Liao, & Milgram, 1997). Cognitive load can be increased by increasing the amount of information or by reducing the amount of time allowed for processing it. Stasser and Titus (1987) found that increasing cognitive load in groups solving hidden profiles (by increasing the amount of information allocated to each group member) reduced the discussion of unshared items and degraded group decision accuracy.

Cognitive load should have particularly strong effects on the discussion of interdependent items because understanding the meaning of interdependent items is a more complex task than understanding the meaning of independent items (Pollock, Chandler, & Sweller, 2001; Sweller, 1994). If interdependent items are not particularly noteworthy when considered independently, a decision maker who is pressed for time may ignore them instead of exerting the effort required to see the connection (cf. Weenig & Maarleveld, 2002).

Transactive memory can reduce the cognitive load individual group members experience. A transactive memory system is an understanding that (1) each group member is responsible for a certain type of information and (2) all group members are aware of and rely on each others' responsibilities (see Hollingshead, 2001; Moreland & Myaskovsky, 2000; Wegner, 1987). Groups using transactive memory systems allocate information to certain group members (rather than let it be processed by the entire group), and call on those group members to retrieve the information when the group needs to use it (Wegner, 1985). This differentiated distribution of information reduces overlapping efforts. (Groups working on hidden profiles also have a differentiated distribution of information, even though they are typically not aware of its nature.) The reduction in overlapping work allows every member's workload to be reduced without a corresponding reduction in the amount of information the group processes; the work is simply distributed more efficiently (cf. Tindale & Sheffey, 2002). As a result, transactive memory can help groups learn more information (Hollingshead, 1998; Moreland & Myaskovsky, 2000; Wegner et al., 1991) perhaps in a shorter amount of time (cf. Littlepage & Karau, 1997), and process it more thoroughly.

Transactive memory systems have been shown to improve group performance on hidden profile tasks (Stasser et al., 1995). However, when Stasser et al. (1995) compared an all-shared control condition (in which all group members were given all task information prior to discussion) to a condition in which members used a transactive memory system to work on the same problem presented as a hidden profile, they found no difference in group decision accuracy (p. 252). Although that finding was not a central focus of that study, it can be taken to imply that, if dividing task information among members will result in a hidden profile, groups in which information is all shared would gain little by dividing their information among members and implementing a transactive memory system.

However, the implication may be different when groups work under cognitive load. In such a situation, the differentiated distribution of information in transactive memory systems may help decision making groups manage cognitive load. If there are interdependent pieces of information, it may also help the members see the connections and make better decisions. This comparison—between groups with all shared information and groups working with a transactive memory system—is typical of transactive memory research (e.g., Hollingshead, 1998; Wegner et al., 1991), and arises in real-world situations when groups decide whether to divide their task information among members.

The cognitive load hypothesis:

Part 1. Increasing cognitive load will impair group decision accuracy more for groups working with all shared information than for groups working with a transactive memory system.

Part 2. The effect of increasing cognitive load on group decision accuracy will be mediated by perceptions of the importance of unshared interdependent information items and by discussion of those items.

Method

Overview of the experiment

The procedure of the experiment followed a typical group decision making paradigm, with individual decisions followed by a group discussions and a group decision. Participants reviewed task information individually and indicated a response preference. Then participants discussed the task with a partner and agreed on a response. Discussions took place through a computer-mediated communication system. Three factors were manipulated: the amount of time individuals were allowed to review the task information prior to discussion, whether individuals rated the importance of each task information item prior to discussion,[1] and the way information was distributed among the dyad members. Transactive memory systems were created in the hidden profile conditions. The primary purpose of the importance ratings was to identify which participants had discovered connections among interdependent items.

Participants

The participants in this study were 413 undergraduates (198 males, 215 females) taking introductory psychology classes at the University of Illinois, Urbana-Champaign. Students participated in the study in partial fulfillment of a course requirement. Participants worked in dyads; there were 184 dyads in the sample analyzed here. Thirteen participants were excluded from individual-level analyses because they were not assigned partners (in experimental sessions consisting of an odd number of participants), or because of computer or software malfunction. Thirty-two additional participants were not included in the dyad-level analyses because of computer or software malfunction that occurred after the individual-level data had been collected.

[1] This factor was manipulated to make sure ratings did not influence discussions. There were no significant effects of the ratings factor on discussion content or decisions.

Design

A $3 \times 2 \times 2$ design was used. The first factor manipulated the distribution of information to dyad members (all shared, connected hidden profile, or disconnected hidden profile). The second factor manipulated cognitive load (low or high). The third factor varied whether pre-discussion importance ratings were made (ratings or no ratings). Dyad members in the hidden profile conditions were assigned specializations to create transactive memory systems.

Materials

Two hidden profile decision tasks were developed for this study, a murder mystery (based on the one used in Stasser & Stewart, 1992), and a hiring task. The tasks were designed (and refined as a result of pilot testing) to have identical characteristics. Each task consisted of 20 information items. There were two response choices in each task, A and B (A was always the correct choice): there were two suspects in the murder mystery, and two job applicants in the hiring task.

The tasks met two requirements of the experimental design. The first was to allow the items to be distributed as a connected or disconnected hidden profile. The second was to allow the items to be distributed in a way that gave each dyad member extra information about a particular topic. To meet these requirements, items varied on four dimensions: their type, the response alternative they described, the response alternative they favored, and the source from which they were derived.

Information item types

There were three types of items in the tasks: (1) interdependent items (there were four pairs, all of which favored the correct choice), such as this pair from the murder mystery task: "In his interview, A said he heard a car drive away at 6:45am, but couldn't see it because he was too far away," and "According to medical records, A has complete hearing loss in both ears"; (2) neutral items (eight items that favored neither choice), such as this item from the mystery task: "In his interview, B said he knew the victim for about five years"; and (3) "countervailing" items (four items that favored the incorrect choice, B), such as, "In an interview, B's wife said B argued angrily with the victim on the phone the morning of the murder."

Half of the items of each type described choice A and half described choice B. Half of the items of each type also indicated that they were derived from police interviews (or job interviews in the hiring task), and half indicated that they derived from police records (or letters of recommendation in the hiring task).

The defining characteristic of the pairs of interdependent items was that both items in each pair were perceived as more important when considered together than apart. The items in each pair were related in this way, but items from different pairs were unrelated. The interdependent items will also be referred to as "critical" items, because they constituted all of the evidence supporting the correct choice, and were therefore critical to the solution of the task.

Hidden profiles

In the two hidden profile conditions, each member was given eight shared items and six unshared items. Each member's shared information consisted of the four countervailing items and four neutral items. Each member's unshared information consisted of four of the interdependent items and two neutral items.

All of the interdependent items were unshared in both hidden profile conditions. The tasks were presented to dyads as connected or disconnected hidden profiles by varying the way these items were distributed. In the connected hidden profile condition, each dyad member received two pairs of interdependent items. In the disconnected hidden profile condition, each dyad member received four items from different pairs of interdependent items. See Table 1.

Dyad member areas of specialization

To allow transactive memory systems to be constructed, each dyad member was assigned an area of specialization. In the connected hidden profile condition, one member of each dyad was assigned unshared information items describing choice A, and the other member was assigned unshared information items describing choice B. In the disconnected hidden profile condition, one member of each dyad was assigned unshared information items deriving from interviews, and the other was assigned unshared information items derived from police records (in the mystery task) or recommendation letters (in the hiring task).

Participants in the all shared condition each received all 20 information items. Participants in the hidden profile conditions each received 14 information items. Every dyad in the study received all 20 items collectively.

Procedure

The entire experiment took place at computers. Approximately 15–20 participants were run in each 50-min session. The steps in the study were as follows: initial instructions, individual task information review, individual decision, pre-discussion importance ratings, dyad discussion, and dyad decision report.

Initial instructions

Participants were informed that they would function in the role of a police investigator or as a personnel coordinator at a company, and would be presented with information about two murder suspects or about two candidates for a job. They were told that one of the choices was better, and that if they made the right choice individually they would be entered into a lottery for one of five $20 prizes. They were also informed that they would be working with a partner on the task, and that

Table 1
Information distributions used in this study

Item valence	All shared information distribution		
	Dyad member X	Both members	Dyad member Y
Items supporting choice A		A1/A2, A3/A4, B1/B2, B3/B4	
Items supporting choice B		A5, A6, B5, B6	
Neutral items		A7, A8, A9, A10, B7, B8, B9, B10	
	Connected hidden profile information distribution		
	Dyad member X (choice A specialist)	Both members	Dyad member Y (choice B specialist)
Items supporting choice A	A1/A2, A3/A4		B1/B2, B3/B4
Items supporting choice B		A5, A6, B5, B6	
Neutral items	A7, A8	A9, A10, B9, B10	B7, B8
	Disconnected hidden profile information distribution		
	Dyad member X (interviews specialist)	Both members	Dyad member Y (records or recommendation letters specialist)
Items supporting choice A	A1, A3, B1, B3		A2, A4, B2, B4
Items supporting choice B		A5, A6, B5, B6	
Neutral items	A7, B7	A9, A10, B9, B10	A8, B8

Note. Each information item is represented by a letter and a number. The letter indicates which response choice is described by the item (A or B). The numbers (1–10) are used to make each identifier unique. Item A1 is interdependent with A2, A3 is interdependent with A4, B1 is interdependent with B2, and B3 is interdependent with B4. Odd-numbered items present information from interviews; even-numbered items present information from police records or recommendation letters. The column headers indicate to whom each item is given. The dyad members are arbitrarily designated X and Y.

they may not have received exactly the same information as their partner. These instructions appeared on each participant's computer screen and were read aloud. Participants were randomly assigned partners.

In the hidden profile conditions, the initial instructions on each participant's screen also identified the participant's area of specialization, as well as the partner's area of specialization. At the end of the initial instructions, participants were asked to type their initials into the computer.

Individual task information review

After the initial instructions, participants were presented with the task information and given either 40 s (high cognitive load condition) or 3 min (low cognitive load condition) to study it. The amount of time remaining was displayed on the screen. The information items were listed on each participant's computer screen in a random order that differed for each participant.

Individual decision

At the end of the individual task information review, participants were presented with questions regarding which choice they thought was best. Participants were given as much time as they needed to complete these questions.

Pre-discussion importance ratings

Participants in the no ratings condition began their discussions immediately after answering the individual decision questions. In the ratings condition, participants were asked to rate the importance of each information item before discussion began.

An inevitable result of having participants rate the importance of information items was to give them extra time to review the items. In order to maintain experimental control over learning time, the information items were presented one at a time for exactly 9 s each. During that time, the participant was to indicate the item's impact by selecting one of five buttons. The question, "What effect did this item have on your decision or confidence?" appeared at the top of the screen (cf. Harries & Harvey, 2000; Surber, 1985). The leftmost button was labeled "No effect on me" and the rightmost button was labeled "Very large effect on me."

After 9 s, the item disappeared and the next one appeared, regardless of whether the participant had selected an importance rating for that item. Two practice items (with no task-related content) were rated before the real importance ratings were made. Participants made their ratings within 9 s on more than 95% of the real items, and there were no significant differences among the conditions. Only information items presented to the participant during the individual task information review were presented for importance rating.

Dyad discussion

After the importance ratings were made, the discussion began. Participants had been told that they would be working with a partner, but until the discussion began they had no contact with the partner.

Participants were shown the discussion screen and instructed as to how to use it. Messages were exchanged with the partner by typing them into a box and pressing a "send" button. They were told that they would have a maximum of 20 min to agree on a decision with their partner, but they could press a button marked, "We've reached agreement" to end the discussion if they were done sooner. At the start of the discussion, each member received a message listing the initials of the two dyad members and the area of specialized knowledge of each (if any). Participants were told before discussion began that if their dyad agreed on the best choice, they would be entered into a second lottery for one of five $20 prizes.

Dyad decision report

After the discussion was over, participants were asked to indicate the decision agreed on with the partner and provide an explanation of why the dyad made that decision. These questions were answered individually, with no interaction between dyad members.

Content coding

Discussion transcripts were analyzed by trained coders who identified which of the 20 information items were referred to in every speaking turn. The coders were blind to experimental condition and the hypotheses. Over 90% of the transcripts were coded by two coders. The average intercoder agreement over all transcripts was 91.4%. Disagreements were resolved by a third coder.

Results

Verification of task properties and manipulation checks

As expected, differences between the mystery task and the hiring task were small and most were not significant. Except as otherwise noted, the data were combined for all analyses.

Hidden profiles

To verify that the tasks were hidden profiles, individual decisions were analyzed in a 2×2 log-linear analysis, with the presence of a hidden profile (hidden profile vs. all shared) and task (hiring or mystery task) as the factors. The only significant effect was from the presence of a hidden profile ($\chi^2(1) = 40.17$, $p < .001$), reflecting greater decision accuracy for individuals receiving all the information (103/144 or 71.5%) than for individuals receiving a hidden profile (100/256 or 39.1%). There was a best (or "correct") response when all the information was known: the proportion of individuals in the all shared condition who selected the choice designated as correct was significantly greater than .5 ($z = 3.74$, $p < .001$).

Variation in the perceived importance of interdependent items

A second assumption about the task materials was that the interdependent items would be seen as more important when considered in pairs than when considered separately. In a one-way ANOVA with average individual pre-discussion importance ratings of the interdependent items (on a 0–4 scale) as the dependent variable and information distribution as the factor, there was a significant main effect of information distribution ($F(2, 220) = 10.70$, $p < .001$ $\eta^2 = .09$). This effect reflected higher mean importance ratings in the all shared and connected hidden profile conditions ($M_{\text{all shared}} = 2.79$, $M_{\text{connected}} = 2.96$) than in the disconnected hidden profile condition ($M_{\text{disconnected}} = 2.29$). A planned contrast indicated that the difference was significant ($t(220) = 4.53$, $p < .001$).

Item types

The four pairs of interdependent items were assumed to play a critical role in the discovery of the correct answer, and the data indicate they did so. Importance ratings of the interdependent items were significantly higher for individuals who selected the correct response than the incorrect response ($M_{\text{correct}} = 3.06$, $M_{\text{incorrect}} = 2.29$, $F(1, 221) = 47.00$, $p < .001$, $\eta^2 = .18$).

Eight items in each task were intended to be neutral. The average importance rating of these items was 1.46. Participants saw the neutral items as less important than the interdependent items ($M = 2.70$, $F(1, 222) = 286.90$, $p < .001$, $\eta^2 = .56$) and the items supporting the incorrect choice ($M = 2.57$, $F(1, 222) = 261.12$, $p < .001$, $\eta^2 = .54$).

Transactive memory systems

Participants paid more attention to items in their area of assigned specialization than outside that area. In the transactive memory conditions, each dyad member had as many shared neutral items in his or her area of specialization (two) as outside it, but, on average, mentioned a larger proportion of the items in the area of specialization ($M_{\text{in}} = .27$, $M_{\text{out}} = .20$, $F(1, 115) = 6.78$, $p = .01$, $\eta^2 = .06$).[2] The interaction with information distribution condition (connected vs. disconnected hidden profile) was not significant ($F(1, 115) = .71$, ns).[3]

Overall analyses

The dyad decision results were initially subjected to a $3 \times 2 \times 2$ log-linear analysis, with information distribution, cognitive load, and pre-discussion ratings (made or not made) as the factors. The only significant effects were for information distribution ($\chi^2(2) = 12.52$, $p < .002$) and cognitive load ($\chi^2(1) = 16.14$, $p < .001$). These effects are examined in more detail in connection with the hypothesis tests. The average number of items mentioned was 5.54 (not including repeats), the average number of messages exchanged was 28.23, and the average discussion length was 321.83 s.

The connected hidden profile hypothesis

Part 1 of the connected hidden profile hypothesis says that groups working with a connected hidden profile information distribution will be more likely to make correct decisions than groups working with a disconnected hidden profile information distribution. To test this hypothesis, dyad decision accuracy was subjected to a log-linear analysis, with information distribution (connected or disconnected hidden profile) and cognitive load (low or high) as the factors. The predicted effect of information distribution was significant ($\chi^2(1) = 7.60$, $p < .01$), and the interaction of information distribution and cognitive load was not significant ($\chi^2(1) = .03$, ns). More dyads in the connected hidden profile condition selected the correct response (45/64 or 70.3%) than in the disconnected hidden profile condition (25/55 or 45.5%).

Part 2 of the connected hidden profile hypothesis concerns the mediating variables for the finding that dyads in the connected hidden profile condition were more likely to make correct decisions than dyads in the disconnected hidden profile condition. Perceived importance of the interdependent items and discussion of the interdependent items were expected to mediate

[2] A transformation of $2\arcsin(\sqrt{p})$ was applied to these and all other proportions in this paper when the difference between them was tested. See Neter, Kutner, Nachtsheim, and Wasserman (1996). The means in the text are untransformed, but the test results are based on the transformed values.

[3] Following Stasser, Vaughan, and Stewart (2000), an "in-role" index was computed by dividing the number of shared neutral items the dyad members mentioned from their respective specializations by the total number of shared neutral items the dyad members mentioned. A value of 1 would indicate that dyad members mentioned shared neutral items only from within their specializations; a value of .5 would indicate that dyad members were equally likely to mention shared neutral items from inside and outside their specializations. The average value of the in-role index was .58, which is significantly different from .5 ($t(79) = 2.08$, $p < .05$), suggesting that dyad members focused on information in their area of specializations and avoided information outside it. Although this is not a particularly powerful effect, it is different from the one obtained by Stasser et al. (2000), perhaps because the analysis here was restricted to neutral items and theirs was not.

the effect of information distribution. Because one mediating variable here is the perceived pre-discussion importance of the interdependent items, the analyses were conducted on only the dyads that completed pre-discussion importance ratings.

Testing mediation involves three steps (Baron & Kenny, 1986). The effect of information distribution (connected or disconnected) on dyad decision accuracy (yes or no) was significant in a logistic regression ($B = 1.24$, $SE = .55$, Wald $= 5.17$, $p < .03$), and information distribution had a significant effect on the mediating variable, perceived importance of the interdependent items ($F(1, 58) = 12.72$, $p = .001$, $\eta^2 = .18$). The effect of the mediating variable (perceived importance) on the outcome variable (dyad decision accuracy) was significant ($B = 1.03$, $SE = .43$, Wald $= 5.70$, $p < .02$) when controlling for the effect of the initial variable (information distribution), which no longer had a significant effect ($B = .71$, $SE = .60$, Wald $= 1.40$, $p > .23$). This means that the effect of information distribution was completely mediated by perceived importance.

This part of the connected hidden profile hypothesis also says that discussion content mediates the effect of information distribution on group decision accuracy. To test this assertion, the number of interdependent items mentioned by each dyad was included in a logistic regression along with information distribution and perceived importance ratings of the interdependent items. The effects of information distribution ($B = .43$, $SE = .71$, Wald $= .36$, $p > .54$), and perceived importance ($B = .29$, $SE = .54$, Wald $= .30$, $p > .58$) were not significant. The effect of the number of interdependent items mentioned was significant, however ($B = .56$, $SE = .16$, Wald $= 12.28$, $p < .001$), indicating that it mediated the effect of information distribution on decision accuracy. Including the number of initially correct dyad members (0, 1 or 2) in the regression equations did not significantly change the results of any of the analyses involving discussion content.

The effect of perceived importance of the interdependent items on the number of interdependent items mentioned was significant (standardized $B = .56$, $t = 5.10$, $p < .001$). Groups mentioned more of their shared information than their unshared information in the disconnected hidden profile condition ($M_{\text{shared}} = .43$, $M_{\text{unshared}} = .28$, $F(1, 54) = 31.98$, $p < .001$, $\eta^2 = .37$), but not in the connected hidden profile condition ($M_{\text{shared}} = .38$, $M_{\text{unshared}} = .40$, $F(1, 63) = .10$, $p > .75$).

The cognitive load hypothesis

The first part of the cognitive load hypothesis states that increasing cognitive load will impair group decision accuracy more for groups working with all shared information than for groups working with a transactive memory system.

Effect of cognitive load on dyad decision accuracy

To test this part of the hypothesis, a log-linear analysis was conducted with information distribution (all shared or hidden profile) and cognitive load (low or high) as the factors. The two hidden profile conditions (both of which involved transactive memory systems as well as hidden profiles) were combined into a single "transactive memory" condition and compared to the all shared condition. There was a main effect of cognitive load on decision accuracy ($\chi^2(1) = 15.99$, $p < .001$) and, as predicted, the interaction of cognitive load and transactive memory was significant ($\chi^2(1) = 5.20$, $p < .03$).

The main effect of cognitive load reflects greater decision accuracy with low cognitive load (75/96 or 78.1%) than high cognitive load (46/91 or 50.5%). The interaction of cognitive load and transactive memory reflects a larger effect of cognitive load on dyads in the all shared condition than in the groups with transactive memory. In the all shared condition, 33/35 (94.3%) dyads were correct in the low cognitive load condition, and 17/32 (53.1%) dyads were correct in the high cognitive load condition ($z = 3.87$, $p < .001$). In dyads with transactive memory, the effect of cognitive load was significant but smaller: 42/61 correct (68.9%) with low cognitive load and 29/59 correct (49.2%) with high cognitive load ($z = 2.19$, $p < .03$).

An additional analysis revealed that the effect of cognitive load was not significant in the connected hidden profile condition: 26 out of 33 dyads (78.8%) were correct with low cognitive load, and 20/32 (62.5%) were correct with high cognitive load ($z = 1.44$, $p > .14$). Nor was it significant in the disconnected hidden profile condition (16/28 (57.1%) correct with low cognitive load vs. 9/27 (33.3%) correct with high cognitive load; $z = 1.77$, $p > .07$).

Mediating role of perceived importance

Mediation analyses were conducted to test the second part of the cognitive load hypothesis, that the effect of cognitive load on dyad decision accuracy would be mediated by perceptions of the importance of the interdependent items and by discussion content. Since importance ratings were a mediating variable in this analysis, only dyads in the ratings condition were included. Cognitive load had a significant effect on dyad decision accuracy ($B = 1.27$, $SE = .46$, Wald $= 7.67$, $p < .01$), and cognitive load had a significant effect on the perceived importance of the interdependent items ($M_{\text{low}} = 3.07$, $M_{\text{high}} = 2.27$, $F(1, 94) = 35.89$, $p < .001$, $\eta^2 = .28$). The effect of perceived importance on decision accuracy was significant ($B = 1.42$, $SE = .42$, Wald $= 11.65$, $p = .001$), controlling for the effect of cognitive load ($B = .30$, $SE = .56$, Wald $= .28$, $p > .59$), indicating that the effect of cognitive load on dyad decision accuracy was completely mediated by the perceived importance of the interdependent items.

The effect of cognitive load on decision accuracy does not appear to have been mediated by perceptions of the importance of other types of items. Increasing cognitive load did not cause a significant change in the perceived importance of the countervailing items ($M_{high} = 2.77$, $M_{low} = 2.55$, $F(1, 94) = 2.02$, $p > .15$). The effect of the cognitive load manipulation on perceived importance of the neutral items also was not significant ($M_{high} = 1.40$, $M_{low} = 1.47$, $F(1, 94) = .31$, ns).

Mediating role of discussion content

Cognitive load had a significant effect on decision accuracy (see the log-linear analysis above) and on the number of interdependent items mentioned ($M_{high} = 1.90$, $M_{low} = 4.06$, $F(1, 181) = 37.73$, $p < .001$, $\eta^2 = .17$). In a logistic regression with cognitive load and the number of interdependent items mentioned as the predictors, and decision accuracy as the outcome variable, the effect of cognitive load on decision accuracy was no longer significant ($B = .69$, $SE = .36$, Wald $= 3.64$, $p = .057$), but the effect of the number of interdependent items mentioned was significant ($B = .40$, $SE = .08$, Wald $= 22.89$, $p < .001$). This means that discussion of the interdependent items completely mediated the effects of cognitive load.

The effect of discussion content remained significant ($B = .52$, $SE = .11$, Wald $= 21.00$, $p < .001$) when the number of initially correct group members (0, 1 or 2) was added to the regression equation. The effect of the number of initially correct members was also significant ($B = 2.35$, $SE = .38$, Wald $= 38.78$, $p < .001$).

Discussion of the countervailing items did not mediate the effects of cognitive load. A smaller proportion of the countervailing items was discussed in the high cognitive load condition ($M = .30$) than in the low cognitive load condition ($M = .39$; $F(1, 181) = 3.90$, $p = .05$, $\eta^2 = .02$). In a logistic regression with cognitive load (low or high) and the number of countervailing items mentioned as predictors and dyad decision accuracy as the outcome variable, the effect of discussion of the countervailing items was not significant ($B = -.53$, $SE = .49$, Wald $= 1.17$, $p = .28$).

A larger proportion of the dyad's unshared information was discussed by dyads working with low cognitive load ($M = .48$) than with high cognitive load ($M = .20$; $F(1, 117) = 28.41$, $p < .001$, $\eta^2 = .20$). Moreover, dyads in the low cognitive load condition mentioned as much of their unshared information as their shared ($M_{unshared} = .48$, $M_{shared} = .51$; $t(60) = 1.07$, $p > .29$), whereas dyads in the high cognitive load condition exhibited the familiar bias towards mentioning a larger proportion of their shared than unshared items ($M_{shared} = .29$, $M_{unshared} = .20$; $t(57) = 3.16$, $p < .004$).

Discussion

The experiment presented here used interdependent pieces of task information to make two contributions to our understanding of group decision making. The first builds on a point made by information sampling models (e.g., Larson et al., 1994; Stasser et al., 1989; Stasser & Titus, 1987), that the salience of information items—the likelihood that they will be remembered and discussed—has far-reaching effects on group decisions. The study presented here suggests that information distributions can affect the salience of information items by influencing the ability of group members to identify connections among the items. When interdependent information items are present, different hidden profiles can lead to differences in the likelihood that groups will consider unshared information.

Second, this study builds on research that has shown that cognitive load affects group decision making performance (e.g., Stasser & Titus, 1987). In the experiment presented here, the effect of cognitive load on decision accuracy was mediated by participants' ability to identify connections between interdependent pieces of information. Cognitive load impaired the decisions of dyads in which both members were given all the task information, but had a smaller effect on dyads in which the task information was divided between the members, probably because dividing the information meant that each member had a smaller amount of information to learn in the limited amount of time allowed. Dividing task information helped groups manage cognitive load.

The experiment presented here extends existing transactive memory research by suggesting that a differentiated distribution of information (such as occurs in hidden profiles and transactive memory systems) not only can increase the amount of information groups can learn (Hollingshead, 1998; Tindale & Sheffey, 2002; Wegner, 1987), but can also increase the rate at which groups learn information.[4] Applications of this result are straightforward—groups gathering information under time pressure can gather more information if they use a transactive memory system than if all group members attempt to learn all of the information.

The finding that the salience of information items can depend on how they are distributed has complex and important implications for transactive memory and group decision making. Group members are more likely to remember information if it seems important, or if it is related to other pieces of information (Trabasso & Sperry, 1985), so the degree to which a group's plan for allocating information causes interdependent items to be separated

[4] It is certainly possible that the benefits of transactive memory identified in this study could exist in groups using a differentiated distribution of information without a shared system of assigned responsibilities (e.g., a typical hidden profile situation).

among members can affect group performance. For example, a hiring committee deciding if job applications should be divided among its members must consider the possibility that a division of labor will cause group members to miss connections among the information in the applications. The group must weigh the costs of missing these connections (as well as the possibility that the division of labor might inadvertently create a hidden profile) against the increase in the amount of information a group can learn when information is divided among group members. In many situations, it may not be clear that the increase in the amount of information a group can learn when information responsibilities are divided will outweigh the potential for missed connections among interdependent facts.

Remedies

When a group's information load is low or if it has a large amount of time, the group can simply refrain from dividing its work among the members. However, this is probably not a typical situation in the real world. For example, lawyers have found that there is simply too much information and too much time pressure for any individual lawyer to be knowledgeable about every aspect of the law (Galanter & Palay, 1991). Instead, lawyers work in groups of specialists (Kronman, 1993), and every lawyer is exposed to no more than a portion of the information about a client's legal problem. Groups of lawyers routinely risk missing connections among the parts of a legal matter (Kronman, 1993).

The ideal solution to the dual problems of cognitive load and interdependent information items is to divide the group's information among group members without separating interdependent pieces of information, as exemplified by the connected hidden profile condition in this experiment. In that condition, dyad members were able to learn information relatively rapidly because of the differentiated distribution of information, but they were nevertheless able to perceive the connections between interdependent items.

This is not an easy goal to accomplish outside the laboratory, however. If a group decides to split up its work among members (or if it is forced to do so by time pressure or by an overabundance of information), it must attempt to identify the division of labor that best matches the pattern of interconnections among the information items the group will learn (cf. Hollenbeck et al., 2002). For example, a hiring committee must ask itself if interdependencies are more likely to exist within each applicant's materials or across the materials of different applicants. If the former is the case, allocating several complete applications to each committee member might best preserve the connections. If the latter is the case, it might be best to assign each member of the hiring committee one component of each of the applications (e.g., one member reads all the recommendation letters, another member reads the applicants' publications, etc.; see Stasser & Titus, 1987). It seems unlikely that general rules could be established to guide these judgments. In practice, decisions about how information should be divided among group members probably require detailed knowledge of the task environment.

It may be possible to improve an assignment of responsibilities through trial and error. For example, if performance feedback is available, a group that makes a series of similar decisions (e.g., Gigone & Hastie, 1993) could vary the way responsibilities are divided and determine which division works best. At the very least, it could be beneficial for groups to imagine alternative ways of dividing responsibilities (cf. De Dreu, 2002; Moreland & McMinn, 2002; West, 1996). It may be dangerous to settle on one division of responsibilities without considering other possibilities (cf. Hackman & Morris, 1975).

A significant point suggested by the study presented here is that conversational norms impair a group's ability to overcome the separation of interdependent items among group members. If each item appears relatively unimportant on its own (as was the case in the disconnected hidden profile condition), the conversational maxim to mention only relevant information (Grice, 1975) reduces the likelihood that the interdependency will be discovered. In other words, communication is unlikely to remedy the problem because people generally talk about information they believe is important and relevant.

One potential intervention to solve the problems caused by disconnected hidden profiles could involve attempting to introduce randomness into group members' selection of which pieces of information to contribute. Instead of a devil's advocate (a person who mentions relevant information that supports a minority view), what appears to be needed might be characterized as a fool's advocate: a person who mentions irrelevant, unimportant information. Group members might discover connections between their unshared information and the seemingly unimportant information contributed by the group's "fool."

Other potential interventions might attempt to reduce adherence to conversational norms. This may be more feasible in computer-mediated communication than in face-to-face interactions. For example, the system used by Valacich, Dennis, and Connolly (1994) encourages group members to ignore messages sent by others when it is convenient to do so, and to send messages without waiting for others to stop sending messages. These behaviors would violate social norms if they occurred in a face-to-face setting. Inducing group members to violate the norm of relevance might be more difficult, however. It might be necessary to have members type notes into the computer prior to group discussion and have the system interject randomly selected excerpts from the notes into the discussion at intervals (cf. Selman, Kautz, & Cohen, 1994).

Limitations

This study has a number of limitations. One is the fact that dyads were used, rather than groups of three or more people. Theory and data indicate that hidden profiles are easier for smaller groups to solve (Stasser, 1992; Stasser et al., 1989), and this may have boosted the performance of the hidden profile groups in this study. The relatively small number of information items in the task (20 items) probably compounded this effect. This issue is significant because one point made in this paper is that dividing task information among group members can have benefits even if it results in a hidden profile. The problems posed by hidden profiles might have been more evident in larger groups (although the benefits of division of labor would have been more evident as well).

The use of newly formed groups is a common problem in laboratory experiments, and it was present here. Transactive memory systems can become more effective as group members gain experience working together (Moreland, 1999; but cf. Moreland & Myaskovsky, 2000); unlike in ongoing groups, the participants in this study had little opportunity to develop expertise in their assigned areas. Group member familiarity can interact with hidden profiles (Kim, 1997), so caution must be exercised if the results presented here are applied to long-standing groups. In addition, the dyad discussions were computer-mediated, so generalization to face-to-face groups may not be straightforward, particularly because computer-mediated communication may lead to behavior particularly consistent with the norm of conversational relevance (Reid, Malinek, Stott, Evans et al., 1996).

An issue that raises interesting questions worthy of future research is the possible types of interdependent items. In the experimental materials used here, the interdependent items had a number of characteristics that undoubtedly influenced the results: they were critical for solution of the decision problems, they increased in importance when the connection between them was seen, and each item was related to only one other item. It is certainly possible for interdependent items to have different characteristics: they could seem less important when connected, they could be irrelevant to the solution of a task, and they could each be related to several other items. Theoretical work is needed to understand the effects of varying these characteristics (cf. Pennington & Hastie, 1993), and the situations in which the different types of connections might occur.

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Received 21 October 2003