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SYNTHETIC INTERACTION AND FOCUSED ACTIVITY IN

SUSTAINMENT OF THE RATIONAL TASK-GROUP

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Abstract

A control of natural interaction (36 groups), a technique of simple synthetic interactivity (*distributed processing* - 36 groups), and a technique of synthetic interactivity which focuses individual contribution through facilitated knowledge elicitation (*braided* - 36 groups) were compared in the collaboration of three-member task-groups facing a complex *discovered problem* (Getzels, 1982). Additional structure tested factors of coactivity (same vs. separate locations) and communication modality (written vs. oral). The task involved management (public policy) of a simulated city facing the onset of a health epidemic (Doerner, Schaub & Badke-Schaub, 1990). Several measures of group performance were obtained both from raw group output and resulting simulation values. Results indicate: 1.) no important differences between communication modalities or coactivity level, 2.) freely collaborating groups (control) performed similarly to randomized baseline trials of the simulation, and 3.) collaborative structure enabled large performance elevation with *braided* groups outperforming *distributed* groups and both techniques outperforming the control.

Synthetic Interaction and Focused Activity in Sustainment of the Rational Task-Group

A wide range of protocol has been proposed for the guidance of synchronous collaborative procedure[1], yet the keys to rational *ad hoc* task-group performance in terms of process and activity remain unclear and unaccepted (Ganster, Williams & Poppler, 1991; Lipshitz & Bar-Ilan, 1996). That the endeavor should hold dim prospects appears to have more to do with measures of ambiguity left in various folds of investigation than with naturally occuring optimalities in typical task-group collaboration (e.g., Katzenstein, 1996). If theoretical account (such as *groupthink* and *process loss*) is vague, difficult to articulate in experimental settings (e.g., Aldag & Fuller, 1994; Park, 1990); nevertheless the literature is dominated with demonstrations of task-group failure and flaw.

Albeit a quite restricted form of task-group activity, one hale exception to this yet deeply entangled phenomena can be found in the well-understood task of idea-generation (see Stroebe & Diehl, 1994), where the non-specific and straightforward concept of *production blocking* has been demonstrated to largely account for performance deficit in the natural, continuously interactive task-group as compared to the collective effort of participants working alone. In a new study Nijstad, Stroebe and Lodewijkx (1999) found that under conditions without time pressure, groups compensate for the productivity loss caused by blocking through a higher task persistence. Being that any broader task-activity involves registration of more than a discrete production which can be sorted and piled together, the utility of this robust finding might appear limited where it is noted that the typical

[1] Methods implemented to guide and frame the work and collaborative processes of a task-group. Elsewhere known as collaborative structure, decision-aids, process intervention, methods of structured debate, and including several variants of group training and conditioning.

collaborative process of a natural group is a complex emergence of group action from the immediate interactivity of its members.

We shall not reach this too hastily, but it is indeed suggested that generalization be warranted for a larger term of *focal blocking*, which includes impedances to production, evaluation and other phases of problem-solving activity. The essential idea is simple enough: participation in the natural task-group (i.e., discussing, explaining, listening) interferes with immediate qualities of individual thinking such as focus, depth and clarity. Task-group participants might thus be required to separately devote their individual energies to obtaining and describing problem-solving perspective if an uncomplicated but effective synthesis allowed these ideas to be periodically shared and worked on in some collective form. As we later discuss, a redirection of attention to the task-activity itself, with heavy emphasis placed on the focus and clarity of individual contribution, allows one to move beyond a discussion of participant effects on each other. It is the interweaving of a "group of concentrated ideas" and whether such a *braided* group is rejected as really no group at all, like the pooled and synthetic groups of the past, it could allow determination of relevant performance boundary properties.

The present concern is to take a most general form of task-group activity and submit it to a pair of conditions which support non-continuously interactive collaboration through stepwise synthetic procedures governing the production and exchange of task-activity between members of a task-group. The first of the techniques, *distributed processing*, is a most general form of the many previous "nominal" arrangements which involve the exchange of individually developed task information between distributed task-group members (e.g., Casey, Gettys, Pliske & Mehle, 1984; Kabanoff & O'Brien, 1979; McGlynn, Tubbs & Holzhausen, 1995). The second technique, referred to here as *procedural moderation* or *PROMOD*, shares the basic structure of *distributed* groups, yet involves a further intensive process of facilitated knowledge elicitation (see for example, Hoffman, Shadbolt, Burton &

Klein, 1995; Scheele & Groeben, 1988). Included in the study are related factors of coactivity and communication modality (oral vs. written); however the central comparison to be made is between three levels of individual focus, as found in the continuously interactive task-group working in the normal format of a round table discussion, the group of distributed processors which periodically share ideas, and the group of distributed processors which are involved in an intensive process of knowldege elicitation.

In light of this interest and the multiple concerns mentioned, we take the opportunity to summarize previous investigation into rational task-group support techniques, tracing out and discussing what has been considered and what appears to be known. We offer consideration of those notions relevant to design of the *PROMOD* technique, as well as a few others which might be considered together as part of a general attempt to sustain the task-group. At last, emphasizing an encompassing picture of task-activity, an appropriate experimental condition is to be provided. One potential is found in the management of complex phenomena as modelled in simulations; the present research utilizes the management of a "microworld", and we describe it in some detail.

TASK-GROUP SUSTAINMENT

Given a host of interested parties, investigation into techniques of *ad hoc* task-group sustainment has been broad, if not broadly integrated. Even at this late stage, due to the somewhat incomplete nature of research traditions which are often based on certain, restricted embodiments of task-group activity; one is only able to offer quite rough estimates about what might work in sustainment of the rational task-group. Our purpose is not to catalog the numerous published techniques with respect to stated rationalizations, but to give an idea of the relevant notions and procedures which have received investigation so as to inform present hypotheses.

Having played a fundamental role in group theorizing, the venerable distinction between normative and informational social influence (Deutsch & Gerard, 1955) may serve to organize the following discussion - as it often has in previous work, (e.g., Kaplan & Miller, 1987). This for the simple fact that conceptualization of *ad hoc* task-group performance is widely based on the axiom of rational collaboration*: ideas which are optimal vis-à-vis the task can be recognized by task-group members should they be given the chance*. It is the belief that even should task-group members not possess proper or correct ideas (signal), they can and do recognize such things when presented them by other members - as long as social/hierarchical imbalances or pressures towards conformity do not get in the way. The notions and procedures of task-group improvement may therefore be viewed as either seeking to augment informational influence by producing improved signal, or reduce normative influence by hindering signal jamming/interference and guarding against premature signal resonance. We first consider this latter set, under three headings: ***distributed processing***, ***anonymous signalling*** and ***signal tempering***.

Distributed processing: task-group activity which is approached separately by distributed participants, but with individual contributions to be circulated among the members as impetus for reconsideration or mutual inspiration. Now the notion that natural face-to-face interaction in the group is marked by inconsistency is one of the central motifs found in modern social psychology, however at first, the idea that the task-group might benefit from restriction of its interaction was actually initiated in response to early claims about the possible positive effects of interaction. This research (e.g., Campbell, 1968; Dunnette, Campbell & Jaastad, 1963; Taylor, Berry & Block, 1958) gave clear demonstration that the pooled output of individual members was often better than that of the face-to-face task-group. In line with this thinking, the earliest task-group techniques made a natural decision to consider new forms of collaboration in which interaction was cut out in part, or for the entire procedure.

The first *distributed processing* technique to receive prolonged attention came with the *delphi* technique (e.g., Dalkey & Helmer, 1963), an arrangement of determining and circulating individual opinion in a larger collection through a series of mailed questionnaires. Although the technique has been abridged for use in more general problem-solving situations, the *delphi* technique was created to merely allow the pooling of a large number of judgments in which participants privately compare and modify their input against that of the collection (Moore, 1987). In any case, *delphi* leaves most of the surrounding task activity to be arranged and determined by the experimental staff and therefore claims (e.g., Linstone & Turoff, 1975) that the technique moderates status effects are limited, from the very outset, to a search and representation of the pattern of perspective in a collection.

A second technique based largely on *distributed processing*, but more in line with assisting collaborative synchronous activity, is the *nominal group technique* (e.g., Van de Ven & Delbecq, 1971). Here participants meet together and are led by the experimenter(s) through four essential steps, three of which are characterized by *distributed processing*: 1.) silent generation of ideas in writing, 2.) round robin recording of ideas, 3.) interactive discussion of ideas and 4.) round robin recording of vote. In a quite similar way to the privately pooled judgments of the *delphi*, the *nominal group technique* uses a controlled form of interactivity in a task-group to protect the task-group situation from status and verbal dominance effects (e.g., as with participants subordinate to or not well familiar with others). Though the *nominal group technique* has a primary concern for the unfettered generation and statement of a wide range of ideas, it has often received emprical scrutiny as a technique for decision making as in the rank-order survival tasks (e.g., Herbert & Yost, 1979) and judgment schemes (e.g., Gustafson, Shukla, Delbecq & Walster, 1973; Rohrbaugh, 1979, 1981). Similar to reports of several field studies, most evidence suggests that the *nominal group technique* accounts for increases in task performance (Delbecq, Van de Ven & Gustafson, 1975); however, it remains unknown as to whether this occurs due to specific changes in process or simply through its novelty on restricted forms of task activity (Moore, 1987).

A further method involving *distributed processing* in the task-group has been recently proposed in the *stepladder* technique (Rogelberg, Barnes-Farrell & Lowe, 1992). The *stepladder* technique calls, at first, for the collaboration of a core group of two participants, to which are added one at a time, the separately developed thoughts and perspectives of future participants. Once a member has presented her/his initial findings to the current group, the previous group solution is revealed and the now enlarged group seeks to reach a new consensus. Thus both the *nominal* and *stepladder* techniques provide for production and communication of individual input which is somewhat free from normative pressure (participants in the *stepladder* group have no idea of other opinion at first, participants in the *nominal* group may have more or less information given their place in the round robin format), thereby allowing for the full range of present signal. As in many task-group studies, the *stepladder* technique was tested with a rank-ordering task where it produced significant increments in that task-activity (Rogelberg, *et al*., 1992). Bearing a further similarity to many such studies, this has not been yet tied to any aspect of the process outside of self-report data which indicate that normative forces are perceived to be reduced in the *stepladder* groups.

Thus we have early claims about the usefulness of *distributed processing* with regard to removing normative pressures, but little demonstration in the actual process as to how it might prove beneficial to the task-group. We are indeed set to discuss the main work of Rohrbaugh at a later point (see *decomposition*), yet his two articles (1979, 1981) are of further interest here as they involve the beginnings of a certain perspective that needs review. In his investigation of the *delphi* and *nominal* techniques as compared to naturally interactive groups, Rohrbaugh reports that the *distributed processing* techniques exhibited difficulties with respect to reducing disagreement and developing group consensus (see also Harmon &

Rohrbaugh, 1990). To be frank, however, the "discovery" that such techniques result in a persistence of opinion difference amounts to no more than a positive manipulation check of the *distributed processing* feature, where the independent creation and complete transmission of present perspective is sought in such a way so that task information is the source of opinion change, and not conformity effects and what not.

At this point, conclusive evidence either supporting or refuting the claim that *distributed processing* supports group accomplishment through reduction of status and other normative forces, remains to be collected. Given some of the positive encouragement, and within the tenable perspective of focal blocking, we form a general experimental hypothesis, $\boldsymbol{H_1}$ **:** *distributed processing* permits greater levels of achievement in rational task-groups.

Anonymous signalling: the rich cues involved in face-to-face communication are partially or completely eliminated through various modalities which enable some form of distal interaction (e.g., tele-conferencing, network messaging, etc.). *Anonymous signalling* refers to a logistical arrangement which permits isolated participants to be connected into an interactive task-group. As the previous notion of *distributed processing* may also involve the physical separation of participants, it may be observed that the distinction between the two is a fine one, based on the fact that most studies of *anonymous signalling* utilize continuously interactive communication (i.e., differing from the natural group only in degrees to which the participants can see or hear each other). The notion of *anonymous signalling* therefore concerns two essential aspects; one in which the participants are physically separated and one in which a shift is made from oral to written communication. In all, the psychological motivation stems, much like the research on *distributed processing*, from a desire to relieve the various social pressures found in the natural group.

Although some early studies have considered distal oral communication (e.g., Williams, 1977), a strong trend exists toward operation in the written context with the predominance of research devoted to the idea of network messaging (i.e., so-called computer-mediated communication). For one, most of the research on network messaging reports an effect of fostering more equal participation (e.g., Siegel, Dubrovsky, Kiesler & McGuire, 1986). Though this be a robust finding in comparison to face-to-face groups, it must not be forgotten that individuals still dominate interaction in both settings (Strauss, 1996). A second and frequent finding related to separation, but surely also dependent on modality, involves a tendency for extreme, uninhibited expression and non-productive interaction (e.g., Kiesler & Sproull, 1992).

In terms of the written modality alone, differentiation from typical face-to-face interaction has been well documented. Distal, written collaboration permits fewer, smaller, less complex and less novel arguments; and as might be expected, makes laborious the reaching of a group consensus (e.g., Siegel, *et al*., 1986; McGuire, Kiesler & Siegel, 1987; Strauss, 1996). In sum, *anonymous signalling* (at least in the written form) clearly permits the avoidance of certain status and other social pressures in task-group collaboration; but it would appear this comes at a cost of information degradation, even taking into account a more balanced participation[2]. Kiesler & Sproull (1992, p118) suggest that: “face-to-face decision making probably is best when a decision requires complex thinking and subtle multiparty negotiations, and when problems are ill-defined”. One of the dimensions in the present investigation offers just that sort of situation in which to examine whether the reduction incurred from a written modality plays out in this fashion with a complex and extended task-activity. We therefore fix a second hypothesis, $\boldsymbol{H_2}$ **:** task-group interactivity in the written form (as opposed to oral) will hamper rational task-group performance.

[2] It is noteworthy, however, that several studies of various task-group activities find little or no reduction in the overall quality of task performance due to the written modality (e.g., Strauss & McGrath, 1994; Weisband, 1992).

Signal tempering: participants are either directed or encouraged to challenge and to accept stated ideas only after they have been opposed in debate. Some accounts of the notion of *signal tempering* or intellectual conflict harken back to the concept of the Hegelian dialectic in which thesis meets antithesis in a clash permitting synthesis. While it is in general possible to interpret the notion of *tempering* as involving the development of ideas (i.e., where it is believed that emphatic evaluation and analysis of assumptions produces the "fittest" idea), we include it as normative technique in that it is an attempt to reduce the strain to convergence through direction of participant collaboration, regardless of individual opinion. *Tempering* has received a great deal of attention in methods of structured debate, *dialectical inquiry* (e.g., Mason, 1969) and *devil's advocacy* (e.g., Cosier, 1978). With the exception of field studies, investigation of the debate methods has largely taken place in restricted decision making settings where selection is to be made of pre-formulated ideas (decisions or plans) on the table for implementation (Katzenstein, 1996). Ambiguities in the operationalization of the methods and various schemes of the decision making has resulted in little agreement on a best approach; indeed, at one point it has been disputed as to whether either approach could be said to offer improvement to task-group activity (Schweiger & Finger, 1984). Later research (Schweiger, Sandberg & Ragan, 1986); however, has accomplished a thorough improvement of the situation through clear definition of the techniques, implemented in realistic settings of unstructured problem-solving tasks (e.g., case studies). Though the results remain somewhat equivocal as to pronounced differences between either approach, we are confident in the demonstration that some characteristic(s) of the structure in either debate method raises task-group performance both in terms of analysis and decision making. As this research involved one further technique involving the notion of *tempering,* we pause in this discussion for its introduction.

Whereas the debate methods arrange for the creation and direction of particular conflict so as to avoid premature convergence, the communication training technique introduced by Hall & Watson (1971) - referred to as consensual conflict resolution or the *consensus* technique - entails an effort to protect naturally occuring conflict and hence involves a less specific avoidance of buckling due to pressures of conformity. To this end, the *consensus* technique offers a list of instructions which asks participants to "avoid changing your mind only to avoid conflict and to reach agreement and harmony", "avoid conflict-reducing techniques such as majority voting, averaging, bargaining, coin flipping and the like" and "view differences of opinion as both natural and helpful rather than as a hindrance in decison making".

In most cases, the *consensus* technique has been tested on the NASA Moon rank-order task (e.g., Hall & Watson, 1971) in which the intervention produces significant performance improvement. Although early studies (e.g., Nemiroff & King, 1975; Nemiroff, Pasmore & Ford, 1976) exerted no great effort to reveal how the technique altered group process, it was recognized that groups which had received the training less often resorted to opinion averaging through "majority votes, averaging of rankings and trading" (as requested in the various instructions) than control groups having no instruction as how to reach a "group decision". Although later studies by Bottger & Yetton (1988) and Innami (1994) included a more careful analysis of group process in the verbal behavior, both utilized a similar coarse dichotomy in classifying activity as either helpful informational reasoning or hindering opinionation so that the results provide little basis for interpretation. Both papers offer the reasonable conclusion that support of informational reasoning and the curtailing of opinionation are vital to group performance, however the mechanism proposed to account for this (individual recognition of the best informational resource) could not be based solely on these studies in which the response format plays an enormous role in the task-group process (i.e., in which each group member possesses a list of rankings from which a group solution is to be determined, and where it could be expected that much of the activity would involve large amounts of some sort of consensual bartering being prohibited by the consensual treatment)[3]. As mentioned just above, Schweiger and colleagues (1986, 1988) performed comparisons of the two debate methods together with the *consensus* technique for tasks of quite general complex problem solving (e.g., case analysis). That is, the support for the debate methods mentioned above was derived, in fact, by comparison to *consensus* groups rather than control groups with no specified procedure. Although these authors admit that "very little is known about how groups should actually use either approach (of debate) to arrive at decisions", they conclude that the results support the mechanism of a "more critical evaluation of personal assumptions". Given a perspective of focal blocking, we might point out that the debate methods as arranged by Schweiger and colleagues involved the splitting up of groups into dyads for large portions of the task, and hence played an important role in the comparison to the full sized consensus groups - especially as would be experienced in a process of focused self-analysis. It is further interesting to note, although task-groups using the debate techniques outperformed consensus group along several indices, debate engendered less acceptance of the group decision.

Thus far, we have considered the major notions in support of the task group through the functional reduction and elimination of various forms of normative influence. As suggested by the signal metaphor, the complement to an avoidance of non-informational suppression and bias would consist of more constructive notions which look to nurture the content of consideration in the task group. Following a distinction between the management and regimentation of mental activity, we discuss two headings: *formatting* and *decomposition*. The former involves instructional methods which highlight various strategies with regard to important functions or phases in the problem solving, the latter consists of more fundamental

[3] See also Schweiger, *et al*. (1986), footnote 1.

schemes by which a complex problem is broken down into questions of a more restricted nature.

Formatting: participants are provided a general format describing a particular optimal problem-solving strategy. Underlying the general concept of *formatting* is a fundamental statement relating problem-solving process and performance which originated with Dewey (1910) and was further developed by Bales and Strodtbeck (1951). Referred to today as a rational or phase model, it holds that problem-solving involves certain phases, and that the occurence of these phases in particular patterns accounts for problem-solving performance[4]. To date, several such rational models have been proposed and tested with individuals and groups, however, the location of key phases and key arrangements of phases has proven difficult to establish in the face of equifinality[5]. (e.g., Hirokawa, 1983; Smith, 1989; Witte, 1972). Being that task-group activity often exaggerates biases found for individual rational thinking (e.g., Frey, Schultz-Hardt & Stahlberg, 1996), difficulty in locating optimal patterns is perhaps neither too surprising nor discomforting. However, even if it is clear that no best general problem-solving format exists, a number of researchers assert that bringing attention and direction to specific problem-solving functions in the task-group can arrange for a reliable improvement in performance (Bottger & Yetton, 1987; Hirokawa, 1987; Schultz, Ketrow & Urban, 1995). In view of the difficulty with formulation of best phase orders, such attempts instead provide participants with a format which decribes defective phase patterns or "things not to do."

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[4] The extension of this individual based model to that of a group often entails a curious assignment of precedence to communicational facilities as opposed to reflective thinking qualities. Since task-group participants are thinking and talking together, with analysis often focused on the latter, it is common to find the perspective that how group members "talk about the problems, options, and consequences facing the group influences the way they think about those problems, options and consequences..." (Hirokawa & Rost, 1992, p. 269). The reverse statement, in which individual thinking is viewed as antecedent to the group discussion, would seem at least as reasonable a proposition.

[5] Markedly different phase patterns with similar performance.

In each of the above cited studies, Janis and Mann's (1977) list of defective decision-making processes (i.e., not considering enough alternatives, not discussing problems in depth, not confronting nonsupported information, etc.). serves as the basis for development of a set of instructions which describe common flaws to be avoided in task-group problem-solving activity. Although most of the evidence obtained from task-groups under such error avoidance or *vigilance* formats would suggest it to be a reasonable intervention, some strong doubts have been voiced in a replication (Ganster, *et al.*, 1991) of the flawed Bottger & Yetton (1987) study. Finding no assistance from a vigilance format in their study, Ganster and colleagues (1991, p. 482) assert that: “teaching subjects to be better users of their task knowledge does not achieve the same result as actually increasing their technical task knowledge”. One might further add, where an intervention is based on the premise that left to their own devices participants in a task-group will make a variety of errors for whatever reason(s), it remains to be seen how they could be much better at the corrective administration of their own work. To some extent, this prediction has been born out by reports of success for an extended method in which hidden task-group monitors call attention to lapses in vigilance where participants are familiar with that concept (Schultz *et al.*, 1995).

Decomposition: dividing an overall task into a set of more focused subtasks so as to deal with basic dimensions of a complex situation in a straightforward way. The procedure of decomposing complex problems for more direct analysis has been around for some time, as for example in Benjamin Franklin's advice to list the benefits and detractions of a given plan and then make a comparison of the overall sums. *Decomposition* therefore treats participant knowledge not as a given input for introduction into task-group collaboration, but rather as an object with basic qualities to be unearthed and described so as to permit a global consideration and combination of these qualities into a summary decision. As such, *decomposition* is not an attempt to increase (or teach) task knowledge, rather it seeks to clarify as best as possible what is known[6]. The concept may be described as obtaining and refining subjective theories which deal with knowledge and perspective lying just beyond what one knows in an explicit sense (Scheele & Groeben, 1988).

The several studies which have made use of the *decomposition* procedure in task-groups have provided subjects both with a general problem, the particular dimensions to be used for analysis and in some cases the specific rules on how to combine or weight the various results[7]. At least two separate task-group procedures have had a sustained following in the literature, multiattribute utility analysis and social judgment analysis.

The first of these methods, multiattribute utility analysis (or *maua*), is a decision aid designed to improve an intuitive process in the evaluation (i.e., selection or rank-ordering) of a fixed collection (for example, the career opportunities available to John Doe). To this end, *maua* first arranges for judgments of the collection along simple attributes or dimensions (e.g., salary, benefits, prospects for advancement, etc.,) then calls for the attributes themselves to be given weights, thereby enabling the experimenter to calculate (from a specified algorithm) the *utility* of each member of the collection (von Winterfeldt & Fischer, 1975). The comparison of *maua* to controls and objective measures both in the individual (von Winterfeldt & Edwards, 1986) and the interacting task-group (Eils & John, 1980; Timmermans & Vlek, 1996) has provided strong evidence that it well sustains performance through an increase of the number of attributes used and the depth of analysis.

Basing his work on that of Hammond and Brehmer (e.g., 1973), Rohrbaugh (1979, 1981) introduced to task-groups a similar *decomposition* method referred to as social

[6] The quite expansive summary article on expert knowledge elicitation by Hoffman and colleagues (1995) contains access to many useful ideas surrounding "the question of what makes for useful methodology for the general purpose of revealing, representing, preserving and disseminating expert knowledge", however fails to provide discussion of a host of relevant task-group studies.

[7] For this, the actual tasks must be characterized as somewhat restricted (i.e., forecasting and judgment).

judgment analysis (or *sja*). *Sja* is a forecasting procedure which uses the values from a round of basic (or holistic) judgments made on some set of exemplars (e.g., handicapping a number of dog races) to obtain a judgment pattern which relates how basic attributes about the dog and its past performances are factoring into the prediction scheme. Rather than weighting these attributes for a summary combination as in *maua*, the participants are confronted with their pattern of judgments (feedback in the form of a graph) and allowed to reconsider and modify this "policy". Last, a task-group is formed and discussion centers on the various policies in order to locate a best policy.

Given that the role of *feedback* in *sja* is quite specific, providing the basis both for the individual and task-group activity, the first consideration of *sja* (Rohrbaugh, 1979, 1981) involved comparison of the sja procedure in task-groups with natural interaction and those with various techniques of *distributed processing* governing the end group phase. In terms of the forecasting, no differences were found; but as was earlier mentioned, difficulty was reported in obtaining consensus in the *distributed* groups. In a follow-up study, Harmon and Rohrbaugh (1990) compared the *sja* task in groups of participants who did not receive the feedback, and in groups which were either permitted or not, to share the feedback describing individual policies in the group phase of the task. In addition, after groups had agreed on a best policy, the participants were asked again to provide a best individual policy. It is not clear why, but little is made of the repeated finding that no differences were found either between groups with or without feedback, or between groups which shared or did not share feedback. Furthermore, the authors offer a questionable interpretation of the fact that groups which could share (and hence discuss in particular) the various graphs of individual policies had more similar post-discussion policies. This was reported as evidence that *sja* promoted individual learning.

A specification of these results is important, where we consider the recent test of an *sja* variant (Reagan-Cirincione, 1994) which includes a second round of holistic judgments and policy reconciliation by the task-group together, and in addition provides a facilitator to govern the process and promote a balanced discussion of the differences among participant judgments and policies. This study was reported in the recent review of accuracy in group judgment (Gigone & Hastie. 1997) to be the single instance in which a so-called process gain was experienced (i.e., where group judgments are more accurate than the mean individual judgment). Although Reagan-Cirincione (1994) offers a persuasive argument that the impressive results were obtained not due to Stroop's "canceling out error variance", she assigns as critical factor the process of group interaction, "since individuals working alone repeatedly failed to demonstrate any improvement" and cites the Harmon & Rohrbaugh paper. But this opinion, related to the perspective that changes to interaction are undesirable (e.g., Argote & McGrath, 1993; Henry, 1995), must look elsewhere for support. Moreover, it is not clear how to assimilate reports to the contrary, where for example in a recent study of judgments, the combination of estimates from individuals working alone (*distributed processing*) were better calibrated (i.e., not demonstrating overconfidence) than interactive groups (Plous, 1993).

In the end, whether the endeavor of synthetic interaction is motivated to better the typical face-to-face situation or a goal in and of itself; the challenge remains to find an optimal arrangement of individuals working alone but sharing and developing their thoughts with concurrently active participants.

Braided Task-Groups

THROUGH PROCEDURAL MODERATION (PROMOD)

The notions and procedures addressed here are concerned with the sustainment of the rational task-group, with an emphasis on bringing a high level of quality consideration to bear on a non-trivial situation. Certain to be of great importance but ignored here are aspects such as improvement of the acceptance of a group decision (e.g., Castore & Murnighan, 1978) or feelings of well being in the group (e.g., Heath & Jourden, 1997). Rather, we would appreciate the dominant underlying theme (whether made explicit or not) as the question of rational collaboration and therefore consider the issue here as restricted to such. Much of the experimental evidence discussed so far would suggest some modest potential of rational sustainment from the procedure of synthetic interaction. If this is at least theoretically amenable to the idea of focal blocking as first mentioned, we would now take the argument a step further.

The collaboration of a task-group is primarily viewed under a fundamental axiom of rationality which we have described as the acceptance of quality signal in the task-group, thus we may pose an extended axiom of rationality which further describes signal and its transmission in the task-group. ***The quality of an individual's signal, both in relation to the task and for transmission to others, increases with its preciseness and clarity***. Acceptance of this statement of course does not mean that we can expect that increasing an individual's signal clarity must represent an actual improvement in light of the task. It is precisely here we must remember that this be the ultimate justification of the use of a task-group, it is for all purposes a situation in which no expert (or group of experts) can articulate a theory in which to pronounce absolutes. Nevertheless, those particular qualities in an individual's signal should pay additional dividends as it is communicated to others who may recognize it "for what it is."

One way to satisfy this extended requirement that an individual's knowledge and perspective should be applied and described in a most clear and precise manner, is to provide *formatting* to the participants which details a reasonable schema of the phases necessary to the task or decomposition. As was argued, the method as found in previous attempts leaves perhaps too much in the hands of participants. One possibility is to keep a given format in mind and simply design a system of *decomposition* which arranges for a regimentation of particular activity within that framework of problem-solving. Thus the idea is to produce the desired phases of activity in an environment which necessitates the "doing" without the additional baggage of describing what is to be done and the reasons underlying these phases. For this, the method used in this study (for both groups of synthetic interaction) accomplishes this by first taking into account the cognitive psychological finding that most general problem-solving lacks a concentrated phase of diagnosis (Doerner, 1979; Lipshitz & Bar-Ilan, 1996). Rather than advising participants to diagnose problems, we use a simple *decomposition* method which achieves the production of a basic format by requiring them to determine in four separate steps: 1.) the dimensions of the present current state, 2.) the dimensions of the desired future state, 3.) interventions which might assist a transformation of the current state into the desired state, and 4.) the apparent relationships at play in the consideration so far.

At this point, the process of individual activity within such a framework should be more devoted to obtaining a clear picture of particular knowledge and perspective, for uninterrupted transmission to others concerned with the task. However, before braiding the strands of our simile into an interaction of sorts, it is wished to reinforce or recheck the individual contribution. Instead of a redundant request that a participant think over and make more clear her/his work so far, an appropriate stimulus may be used to encourage renewed and perhaps deeper reflection. As informed by the work of Scheele and Groeben (1988) on dialogue and facilitated knowledge elicitation, initial participant output of problem decomposition is to be provided an external prompt of general and obvious questions which are aimed at encouraging completeness of thought and clarity of syntax.

For this, each member of a *braided* group is provided a facilitator who intermittently checks on the individual current state of contribution and poses non-content-specific questions which are aimed at enhancing the explicitness of the various accounts described so far in the individual's work. Of course, with such a method it is of highest importance that such an intervention does not introduce what was not already present. We have taken care to assure that such facilitation does not involve particular directions or guidance to the individual[8], so for example the questions are restricted to the following sort: "Are these all the important connections you can think of?", "Could you explain this relationship more precisely because I as a lay-person do not understand your ideas?", "Does your plan have any side-effects?", etc.

After an intensive process of focused activity, the strands of individual input may finally be brought together - the individual ideas exchanged - so that the multiplicity of perspective and attitude of the task-group is made known. Again for this process, the members direct critique and comments to each other's plans as they work alone. The process (which we have referred to as procedural moderation or PROMOD) may be repeated for one or more steps. In the end, a body of plans which were developed along the same format of decomposition and diagnosis should be amenable to a simple form of selection (such as majority vote) for implementation. In closing, we offer a third general hypothesis with regards the PROMOD technique, ***H_3* :** braided task-group activity fosters improvements in focus and performance over activity within the simple *distributed processing* framework.

METHOD

Subjects

[8] Discussion of concerns regarding unwanted benefits which facilitators might unknowingly provide led to consultation with Badke-Schaub, a developer of the simulation. Here, we have been assured that limited contact with the simulation itself, as in the case of our facilitators, could not in general constitute a basis for "figuring

The subjects were 131 male and 193 female students (median age = 27) from the Social Sciences and Economics departments of three northern German universities. Subjects received both course credit and a payment of around $25 dollars in exchange for participation in a 3-member task-group which was convened for two equal length meetings (separated by a week) for a total of five hours.

Task-Activity

As far as can be told, the actual complexities underlying most real-life problems arise where an *eigendynamic* (or idiosyncratic dynamism) is experienced among a host of connected variables (Funke, 1992). Of course, the complexity experienced working on such a task is often greatly increased to the extent the variables remain unknown or ambiguous. Creativity researchers (Getzels, 1982) refer to a task which includes such ambiguity as a *discovered problem*, in order to highlight the important role participants play in both the determination of a problem as well as the search for a solution. Computer simulations provide a natural means to provide such discovered problems for use in task-group studies, where one models a singular reality (i.e. a world of variables with fixed relationships) which may be addressed (accessed and treated) by participants in a multitude of ways (Frensch & Funke, 1995).

The present research involves the simulated management (strategic planning) of a city called Simad which is facing the outbreak of an unknown epidemic in 1983 - one that will be later known as AIDS. Committees of three members are given the rough goal of "as few infected, ill and dead as possible" over the coming eighteen years, so that the task-activity involves both determining a variety of problems and then providing interventions which address those problems. As described later, the task-activity is split into four rounds of work

out" how the simulation works. This possibility remaining alone with the simulation interface, an experimenter who had no contact with subjects whatsoever.

so as to introduce interventions into the simulation and allow system feedback, which, is largely determined by the committee itself. The essential scheme of activity is: 1.) receive feedback concerning the previous round (*standard feedback*: which of the previous interventions could be implemented and those which could not, and whether an intervention could be run only in a modified way and how it was run, and *requested feedback*: responses to the previous state queries posed by the task-group with regards the state of Simad and previously implemented interventions), 2.) consider the present situation, 3.) generate interventions and questions (state queries) about the simulated city, 4.) decide which to submit to the Simad "bureaucracy" for implementation (the experimenter/interface to the simulation), and 5.) take a small break until the next round.

The simulation program, Vaids, was developed by Doerner and colleagues (Doerner, Schaub & Badke-Schaub, 1990) using the demographics of a large german city to derive initial conditions and relationships among a multitude of factors (i.e., subpopulation sizes, fluctuations within subpopulations over time, promiscuity rates, mortality rates - in subpopulations depending on age, special risk factors, stage of the AIDS-infection, and many others). There is, of course, a near unbounded number of potential parameters and interventions possible in such a simulation. In this, we must say that the developers of the simulation Vaids have gone to great length with the specification of an extensive categorization scheme including and differentiating more that 1,000 kinds of interventions.

Vaids is so constructed to distinguish between similar interventions (e.g., informing the public through school announcements, in newspapers, on TV in languages of foreign minorities, etc.) and the committee may address the various subpopulations in a host of different ways. For further examples, the committee might seek to provide hospitals with specially trained staff, and they might fund medical research. As mentioned above, the committee must request a variety of information, such as the number of infected or dead citizens, medical research-reports or public opinion-surveys (e.g., "Is intervention X well received or at least understood by the public?"). At last, although we found no examples in the current study, violation of civil liberties is not permitted in the simulation, with the one exception of internment of infected citizens.

General and Role-Specific Instructions

At first, a general introduction conveys the situation that confronts the Simad city management committee as well as discussing the process of submitting interventions and state queries to the Simad "bureaucracy". Subjects are informed that: 1.) Only interventions and state queries that address the current work round will be processed, 2.) All information about the state of the city and intervention must be requested from the bureaucracy, 3.) Only concretely formulated suggestions can be translated into action as the bureaucracy would make no guesses as to what a suggestions should mean, but rather skip badly formulated ones. At this point, the formulation " WHO shall do WHAT ACTION upon WHOM at WHICH TIME?" is presented as a guideline. To insure clarity, one example of a well formulated and ill formulated intervention is given (from an unrelated situation). Each group is then informed that certain further ground rules must be strictly followed: 1). each round has a strict time length of one hour, 2). any request for information must be directed at the Simad bureaucracy, and 3). Facilitators would offer no guidance with respect to the task at hand.

Procedure

Each committee met on two work dates within a one-week-interval, each work date lasting for 2 ½ hours, including one break of 15 minutes. Each meeting consisted of 2 rounds, each of which accounted for either 4 or 5 years in the simulation (for a total of 18 simulation years). The proceedings of Meeting 1 (e.g, feedback, questions, interventions and any notes) are recorded and handed out again at "Meeting 2". Table 1 contains specifics.

TABLE 1. Time table for simulation planning periods and real work times.

	Round No.	**Real Time Span**	**Simulation Period**
Meeting I	1	65 min.	1983—1986
	break	*(15 min.)*	
	2	70 min.	1987-1991
Meeting II	3	70 min.	1992-1996
	break	(15 min.)	
	4	65 min.	1997-2000

Experimenter and Facilitator Roles

The experimenter coded the committees' intervention lists into Vaids commands, gave each proposed intervention an explicitness rating of 1,2 or 3 (which is designed to give the simulation further sensitivity to the proposed inputs), ran the simulation, and then collected feedback to be given to the groups. The experimenter was seated in a remote location, with contact between groups and experimenter conducted by facilitators who were charged with courier services. With one exception, only female psychology (aged 25-35 years) students were recruited and trained for the task of facilitating.

Experimental Design

Subjects were randomly assigned to one of 108 groups (9 groups per cell) in a 2 × 2 × 3 factorial design with factors: coactivity (same vs. separate locations), communication modality (oral vs. written), and collaborative procedure (control, *distributed* and *braided* techniques). Table 2 contains abbreviations to be used for throughout for reference to the individual conditions.

TABLE 2. The Experimental Conditions.

	Control (C)		***Distributed (D)***		***Braided (B)***	
	Oral (O)	***Written (W)***	***Oral (O)***	***Written (W)***	***Oral (O)***	***Written (W)***
Coactive	***CO***	***CW***	***DO***	***DW***	***BO***	***BW***
Separated	***C_O***	***C_W***	***D_O***	***D_W***	***B_O***	***B_W***

The first factor (coactivity) varies whether group members will work in the same room or not; the second (communication modality) is the basic manipulation dictating whether communication will be carried out in either oral or written form. Where called for in the separated, oral conditions (C_O, and D_O), portable phones were used. The Control cells (CO, C_O, CW and C_W) were given no direction as to how they would organize aspects of their work, including the resolution of group decisions. For purposes of balance within our design, a facilitator is present at all times in these four conditions, but keeps a low profile.

Cells DO, D_O, DW, and D_W received a most general technique of *distributed processing*. Here, the groups are guided by a single facilitator through the stepwise approach discussed in the text: individual consideration in intervention/state query generation, round robin declaration of interventions and state queries, and voting by secret ballots as to which would be submitted. Similar to the many previous *nominal group technique*, after the round robin declarations a period of restricted interaction takes place in which subjects are directed to only ask questions of others which would lead to the clarification of an idea, intervention or potential state query.

The remaining cells, BO, B_O, BW, and B_W are those groups which received the procedural moderation technique as introduced in the previous section. As described, members of the B experimental groups were not permitted to speak at all with each other during the task-activity. For each of the four rounds of task-activity, subjects are directed to first think out and put down their ideas with respect to the four steps mentioned (current and desired states, interventions, and proposed relationships) on index cards which are arranged together on a large piece of flip-chart paper (solution map). (Subject has created a "map" modelling their subjective theories of the problem and of their suggested means of solving it (therefore: structure-laying technique; Scheele & Groeben, 1988)). As these cards are being prepared, a facilitator makes an occasional (approx. every 5 minutes) check of the subject's writings and poses general questions designed to increase the amount and clarity of the formulations. After this period of facilitated reworking, solution maps are rotated in the group to allow for the informational exchange as well as critique and comments of the solution maps. The subjects then "optimize" their own maps, the maps exchanged once more, and a vote by secret ballot is taken on the optimized suggestions (as in the *distributed processing* condition).

Performance Measures

We consider task-group performance along four levels, beginning with the raw interventions and state queries which were selected by the task-group for implementation and paring them down in a progression of steps moving from the quantitative to the qualitative. Given the nature of the four rounds of task-activity, it is possible to further include time as a factor in the following analyses; however, as all indices reported here experienced a strong level of linear dependence over the four rounds ($.64 \geq r \geq .85$), it was decided to revert to one sum - an averaged total score.

As we say, the first level of measures is comprised of the simple number of ***interventions*** (***I***) and ***state queries*** (***Q***). We count up all interventions which fit one of the more than thousand entries accounted for in the program Vaids, and which were deemed acceptable by the program given the current state of the simulation when submitted. For example, an intervention involving the screening of plasma would be dependent on the development/obtainment of medical knowledge by which the virus in question can be identified. Taking the percentage of interventions which meet this criterion, we obtain the second level of measures - ***implementable interventions*** (***IMP***).

The third level of performance measures is as well an important step in the process of simulation. As the experimenter has ascertained that a peculiar intervention can be coded for Vaids, its level of explicitness must be taken into account of in one of three levels (e.g., "low"=1,"fair"=2 or "high"=3). For example, an intervention like "Inform the public about the dangers of sexually transmitted diseases" is less thought-out (and less effective in Vaids) than "Run television ads in which popular entertainers inform youth about "Safe Sex". This evaluation was carried out by the experimenter and then fed into the computer simulation. ***Explicitness*** (***EXP***) is the ratio of all thought-out interventions (interventions judged as being either fair (2) to highly (3) explicit) by the number of implementable interventions (***IMP***) taken at all.

As the rated interventions have been fed into the simulation and run, Vaids returns values to a handful parameters which describe the state of the epidemic and make up the fourth and last level of performance measures, the ***simulation performance*** (***SIM***). To form one overall ***SIM*** measure, we took the three Vaids raw values (cumulative AIDS-dead, AIDS-sick, and AIDS-infected at the time of simulation termination), transformed each to a z-value and formed the sum. Being a sum of z-values, however, ***SIM*** is itself not a z-value.

RESULTS[9]

[9] All measures are inspected on aggregated level. According to Cohen (1977), for a requested large effect size of f = 0.40, given $\alpha = \beta = 0.05$, a number of 33 groups for each collaboration modality is required (i.e., a total of 99 groups). Given a 12-cell ANOVA

Taking into account potential losses of test power ex ante, we choose $\alpha = 0.05$ as level of statistical significance for both hypotheses testing and in the event of post-hoc-tests where we preferred the more restrictive Scheffé multiple range-test over the Duncan test. With several tests of significance on one sample, and thus several non-orthogonal comparisons, one is supposed to adjust any single α-level. We avoid this here by calculating effect sizes and underventing power analyses following Cohen (1977, 1992) and Witte (1980).

Data analyses reported here were carried out by means of simple ANOVAs. We began with the mere global 2×2×3-factor design level (coactivity, communication modality, and collaborative procedure). Results were such that the further individual comparison of the 12 working conditions (i.e., the 12 cells of Table 2) allowed us to explain larger amounts of the variability. Thus, in this article we focus on direct comparisons between these 12 working conditions and neglect coactivity and communication mode—except for the results of overall group performances that are of main interest, of course.

The variables sex, age and major were incidental and randomly distributed over the twelve cells of the design. Analyses also revealed that neither averaged group age (ANOVA) nor combination of the sexes within the groups (Chi-Square) had any significant influence on the measures.

Interventions (***I***) *and State-Queries* (***Q***)

The simple ANOVAs for the first level of measures ***I*** and ***Q*** can be found in Table 3. The number of interventions returned with a highly significant measure and with effect sizes of $eta^2 = .75$ on cell level and $eta^2 = .67$ on level of collaboration procedure.

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design (2×2×3-factors), 36 groups for each collaboration modality (or 9 groups for either 12 cell) were recruited, making a total of 108 groups or 324 Subjects.

TABLE 3

Numbers of interventions (I) and state queries (Q) as seen in separate simple ANOVAs comparing the twelve of the working conditions, as well as the three collaboration procedures.

		F	df	p	power	eta^2
Interventions	12 conditions	26.39	11	.00	1.00	.75
	3 collaboration forms	108.94	2	.00	1.00	.67
State Queries	12 conditions	4.89	11	.00	1.00	.36
	3 collaboration forms	13.50	2	.00	.99	.20

Note: each analysis made on $N = 12 \times 9$, respectively $N = 3 \times 36 = 108$ frequencies.

Scheffé-tests revealed that all of the *braided* groups had significantly more raw interventions than any control group, as well as the oral *distributed* groups (DO and D_O) and the DW group. Interestingly, the separated *braided* group B_O and B_W generated, in addition, more raw interventions than the remaining *distributed* groups (D_W). The means (with respective standard deviations in parentheses) were: controls = 40.64 (13.02), *distributed* groups = 57.25 (25.02), and *braided* groups = 108.69 (21.28).

As can be further witnessed in Table 3, the effect sizes for subjects' information seeking (state queries) are smaller, however significant. As compared to Interventions, effect sizes for Queries decrease to $eta^2 = .36$ (cell level) or .20 (collaboration level), yet the mean numbers of state queries do follow the general form found with interventions: controls = 9.97 (8.02), *distributed* groups = 13.58 (8.11), and *braided* groups = 19.44 (7.25). Although *post-hoc* Scheffé-tests did not reveal single significant differences, the global pattern found with the ANOVA indicates strong differences between conditions of collaboration. In sum, the first level of rough quantitative measures offer support for the first and third hypotheses

(***H_1*** and ***H_3***) in which task-group performance should be enhanced through a form of *distributed* processing and the additional features as incorporated in the *braiding* technique. In addition, and as mentioned above, no results for the coactivity and communication modality were found to encourage more exacting analyses, suggesting no comment as yet for the second hypothesis (***H_2***).

*Implementable Interventions (**IMP**)*

Table 4 contains the ANOVA results obtained on the second level of task-group performance measurement. Effect sizes of $eta^2 = .35$ on cell level or $eta^2 = .14$ on level of collaboration procedure were found for the measure of ***IMP***[110]**.** Scheffé multiple range-tests revealed that only the control group C_W and the *braided* groups outperformed the control group CW. In the case of the less stringent Duncan test, all *braided* groups and the control group C_W were better than remaining controls (CO, C_O, CW) and the *distributed* group DO. The three collaboration modalities had the following means and standard deviations for ***IMP***: controls = .72 (.21), *distributed* = .78 (.12), and *braided* groups = .86 (.06). This measure of a more qualitative level reveals less of a difference between the types of groups. At this stage, although elevated, the performance of braided groups would not appear drastic.

*Intervention Explicitness (**EXP**)*

TABLE 4

1

[10] ***IMP*** failed to be normally distributed, with the Kolmogorov-Smirnov-test resulting ($Z = 1.76$, p = .00). Square root ($Z = 1.96$, p = .00) as well as natural logarithmic transformations ($Z = 2.13$, p = .00), did not, however, improve approximation to normal distributiveness. Hence, ***IMP*** is used here unmodified.

A simple ANOVA on ***IMP*** comparing the twelve working conditions, as well as the three collaboration main forms.

		F	df	p	power	eta²
Adequacy	12 conditions	4.69	11	.00	1.00	.35
	3 collaboration forms	8.66	2	.00	.96	.14

Note: each analysis made on $N = 12 \times 9$, respectively $N = 3 \times 36 = 108$ frequencies.

In a progression towards capturing the quality of task-group performance, we formed the measure ***EXP*** by taking the ratio of those interventions which were fair to highly explicit to all interventions (***IMP***). Thus the ***EXP*** measure is a simple percentage which describes how much of the task-group output could be said to be clearly formulated. ***EXP***, although being a measure of percentage, is normally distributed (Z = 1.30, p = .07, Kolmogorov-Smirnov-test). As the reader may find in Table 5, results of a simple ANOVA (3×2×2-factors design) demonstrate no statistical significance for the collaboration modality. Communication modality, however, has an effect size of eta² = .11 - giving an indication of significant effect.

The means (and standard deviations) for ***EXP*** along the factors of oral communication M = .32 (.15), written communication M = .44 (.21) would suggest that any collaboration form seems to have benefited from written communication. For this, the controls and *distributed* groups would not appear to be clearly worse than the *braided* groups: controls = .38 (.26), *distributed* = .34 (.15), and *braided* groups = .42 (.11). This would appear to cast further doubt on the second hypothesis (**H_2**). Qualitative measures, contrary to the prediction from the literature review, show an improvement of written task-group interaction on a complex problem with a robust main effect across all other independent variables. Written interaction can increase the quality of task-group performance.

We pause here to note that unlike much of the brainstorming vs. summed individual research, the measures ***I*** and ***EXP*** experienced almost no correlation (r = .06). That is to say, the quality of ***EXP*** is largely independent from the quantity ***I***. This is strong support for use of a *discovered* problem as a tool for task-group measurement, where a tightly controlled experiment can sample the near boundless creativity of a task-group without trivializing results in which no distinction can be drawn between the number of responses and kind of responses.

TABLE 5

Three factor ANOVA results (”3×2×2”-factor design without repeated measures) for ***EXP*** in a discovered problem-task.

	F	df	p	power	eta^2
Collaboration main forms	2.01	2	.14	.41	.04
Communication	11.57	1	.05	.95	.11
Coactivity	4.59	1	.05	.74	.05
Collaboration × Communication	2.40	2	.10	.47	.05

Collaboration × Coactivity	1.02	2	.37	.22	.02
Coactivity × Communication	.08	1	.78	.05	.00
Collaboration × Coactivity × Communication	.56	2	.57	.14	.01

Note: analysis made on *N* = 108 groups.

*Simulation Measures (**SIM**)*

One last refinement to the idea of quality task-group performance is now considered in the last level of measurements. The simulation measures offer a deterministic description of the task-group/simulation interaction. As described earlier, ***SIM*** is the sum of the z-score outputs from Vaids which describe the populations of AIDS-sick, infected and dead which have accumulated during the simulated time span. As can be seen from Table 6, the only factor a significant effect ($eta^2 = .42$) is the type of collaboration. None of the other factors explain any amount of variance that could be of additional relevance. Multiple range-testing by Scheffé confirms that *braided* groups outperform both control and *distributed* groups. For ***SIM*** we observed the following means of collaboration form: control = –2.37 (2.78), *distributed* = –.80 (3.13), and *braided* groups = 3.18 (2.72).

Table 7 shows that the amount of variance explained on the more differentiated cell level ($eta^2 = .44$) is about as large as on global level. Post hoc comparisons (Scheffé test) reveal that *braided* groups B_W are the best in toto, and significantly better than the *distributed* group D_O, and the controls C_O and CW. (See also Figure 1).

TABLE 6

Three factor ANOVA results (”3×2×2”-factor design without repeated measures) for ***SIM*** in a discovered problem-task.

	F	df	p	power	eta²
Collaboration main forms	34.51	2	.00	1.00	.42
Communication	2.75	1	.10	.38	.03
Coactivity	.20	1	.65	.05	.00
Collaboration × Communication	.79	2	.46	.18	.02
Collaboration × Coactivity	.81	2	.45	.18	.02
Coactivity × Communication	.21	1	.65	.05	.00
Collaboration × Coactivity × Communication	.03	2	.65	.06	.00

Note: analysis made on $N = 12 \times 9 = 108$ groups.

TABLE 7

Simple ANOVA results without repeated measures for ***SIM*** in a discovered problem-task. Twelve empirical groups.

	F	df	p	power	eta²
Collaboration Form	6.86	11	.00	1.0	.44

Note: analysis made on $N = 12 \times 9 = 108$ groups.

The correlations between qualitative and quantitative measures are of some interest, as they again allow for a cross-check of the results of the divergent thinking paradigm. All coefficients reported here are significant at the level of p = .01. Numbers of interventions (***I***) and ***SIM*** give r = .65 which makes sense in a discovered problem-task, as inventiveness helps to attack the problem from a variety of perspectives. ***Q*** and ***SIM*** experience a relatively low r = .28, but some connection between active information gathering and achievement is indicated. ***IMP*** and ***SIM*** correlate r = .42, and ***EXP*** and ***SIM*** have r = .18 (p = .03); both of which indicate that quality goes along with better achievement, and that the Simad-task is a non-trivial problem where clarity, focus and steadiness is more effective than unorganized activism. Furthermore, it is also evident that a few high quality interventions alone is not the best strategy for solving this complex problem. What has to be found is a balance between quality and quantity under the condition of time pressure.

Finally, we compare the 12 different work group conditions and one condition "randomly chosen interventions", in other words, the outcomes of 12 empirical group types and one "simulated group". In the latter, nine random program runs (for 9 groups in each design cell) were performed. The random program runs may serve to mark a baseline to better evaluate the performance qualities of the empirical groups.

A comparison between the 12 empirical cells and the random results reveals that all *braided* groups and the written *distributed* groups (DW and D_W) were better than the random results (see Figure 2 and Table 8). Perhaps somewhat dismaying is the fact that all of the control groups and the orally communicating *distributed* groups obtain a level of performance which is, in principle, no better than that of Vaids runs with randomly chosen interventions. In a complex *discovered problem* type task, a task-group without a rational strategy would appear to be lost.

TABLE 8

Simple ANOVA results without repeated measures for steering achievement in a discovered problem-task. Twelve empirical groups in relation to random simulation runs.

	F	df	p	power	eta^2
Group types	6.89	12	.00	1.0	.40

Note: analysis made on $N = 13 \times 9 = 117$ groups.

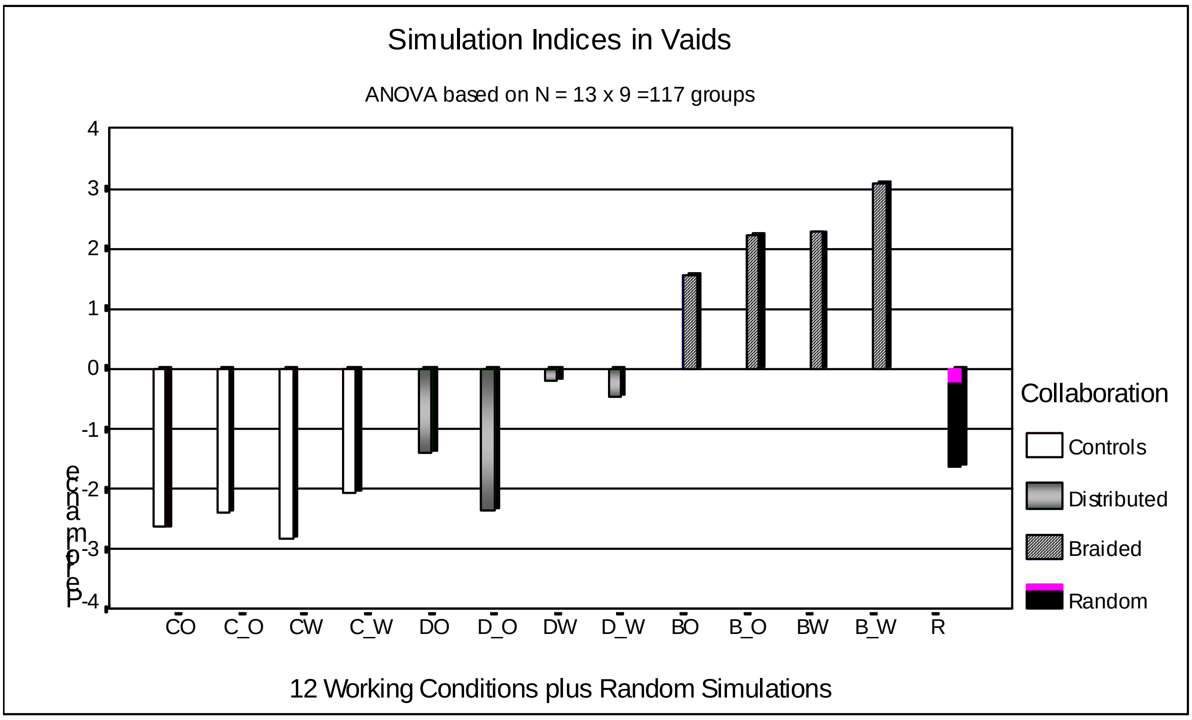

FIGURE 1: Simulation Measures in a the SIMAD discovered problem-task. Results of a simple ANOVA over thirteen cells without repeated measures. Twelve empirical groups in relation to random simulation runs. Note: Larger scores indicate better performances (i.e., reduced cumulative numbers of sick, dead, etc.). Analysis made on $N = 13 \times 9 = 117$ frequencies.

With regards our hypotheses; we reject the general prediction (**H_2**) that the written modality hampers task-group performance. Further, distribution alone (**H_1**) can help to improve group performance - with further effectiveness to be found in a technique like procedural moderation which refines the raw inputs through a process of cognitive formatting for introduction into the task-group activity (**H_3**).

Discussion

Participation in a natural task-group means discussing, explaining, listening. This attitude interferes with qualities of individual thinking, such as focus, depth. Such impedance to group-efficiency is called *focal blocking* with reference to the blocking-effect reported by brainstorming research (Stroebe & Diehl, 1994).

Considering task-groups as ‚tools of individual task approaches‘, the overall aim of this project was to facilitate knowledge elicitation and to ultimately arrive at an efficient synthesis of ideas.

In view of certain criticism with regard to former research on group problem solving, we attached great importance to the following criteria of our experimental setting:

(1) The group-members of our experimental groups *feel involved* in the cover story, as it is of present relevance.

(2) The *high complexity* of the task is similar to the complexity of many real life problems. The experimental situation serves as a baseline-model regarding the quality of the process of problem treatment in groups. This computer-simulation considers aspects of cognitive psychology research.

(3) The *time* for each group-experiment amounted to 5 hours which exceeds the time for usual investigations in experimental small group research by far.

(4) The belief, that a task-group of *unfamiliar* group members do not meet daily life reality, is to be rejected in view of the everyday necessity of building short-term teams like project teams, committees, task force groups, cockpit crews, etc.

The aforementioned aspects stand for a face validity of our experimental conditions which allows a reasonable transformation out of the lab into a daily life condition.

Experimental researchers in small groups know about the problems concerning the quality of naturally interacting groups. It has been the aim of various moderation techniques to increase task-group performance up to a high level on which a group *in abstracto* should be able to operate. There are several ways to go.

One approach was proposed with the focus on creating a pleasant group atmosphere, increasing the group‘s coherence and the well-being of all group members (Mullen & Copper, 1996). Indeed results of conforming group-performances do not support this approach. Vice versa the technique of vigilance (Ganster *et al.* 1991) is based on the notion that task-group performances might benefit from restriction of interaction by reducing status and verbal dominance effects and other normative forces. Participants in discussions are instructed to avoid changing their minds only to avoid conflict, to reach harmony and to view differences of opinion which are helpful in decision making. Only with the implementation of group-techniques clearly increasing the informational and decreasing normative influence, significant increment of task activity shows promising results. However, these techniques, e.g.. Delphi-Technique, Nominal Group Technique, Stepladder Technique, lack optimization of individual knowledge elicitation and efficient concatenation of the individual knowledge production, necessary to arrive at a group decision of optimum quality. This was our starting point when developing the *braiding* condition by the *procedural moderation technique PROMOD.*

The quality of an individual’s signal, both in relation to the task and for transmission to others, increases with its *preciseness* and *clarity.* This is our extended axiom of a high performance in group-task performance. A braided group builds on the methods of *distributed processing* in which all individual contributions and improvements are channeled among participants (hypotheses H_1). Additionally, an integrated and externally implemented type of cognitive *formatting* provides a structure to the task-activity process allowing for a *decomposition* of the overall task into subtasks which can be closely addressed. Finally, clarification of any inputs into group collaboration is achieved without the 'tug and pull' of group interactivity so that the clearest form of the message can be judged for what it is. All of these characteristics reduce complexity and enhance clarity and the focus of individuals working on a 'group of concentrated ideas'. Within such a *framework* individual activities should be more devoted to obtaining a clear picture of particular knowledge and perspective, for uninterrupted transmission to others concerned with the task (hypothesis H_3). Additionally an appropriate *stimulus* may be used by the moderator to encourage individual renewed and perhaps deeper reflection and it motivates the subjects by asking for explanations and for more ideas. After an intensive process of focused activity, exchange of individual ideas – so that the multiplicity of perspective and attitude of the task-group is made known – the 'strands' of individual input may finally be brought together and should be amenable to a simple form of selection for implementation.

Empirical results of the present study show that the PROMOD technique strongly increases the number of interventions (**I**) generated by braided groups compared to any other naturally interacting control-group (**C**) as well as in comparison to the distributed groups (**D**). At first glance, correlation analysis tend to support typical findings from brainstorming research with the simulation performance measure (**SIM**) and the number of interventions (**I**) related at r = .65. However, there is no correlation between the quality (**EXP**) and the quantity (**I**) of the interventions themselves. The quality of interventions (**EXP**) is independent on the quantity of signals (**I**), although the number of interventions (**I**) positively influence the quality of the group performance (**SIM**), as inventiveness seems to attack the problem from a variety of perspectives. But we make a point here that it is not the natural interacting groups (**C**) that generated the largest amount of ideas for interventions, it is the braided groups, those working under restricted interaction conditions. However, differences do not appear drastic, braided groups outperformed any of the two other groups in generating interventions that meet the criteria to be implemented in the program Vaids. The number of implementable interventions (**IMP**) and the simulation performance (**SIM**) are related at r = .42.

The control and distributed groups do not appear to be clearly worse than the braided groups concerning the quality of the task-group output (**EXP**). Under the condition of the procedural moderation technique PROMOD the braided groups do not show significantly more output of high quality; this leaves some questions open. However there is a strong difference concerning the communication form: The results suggest that any collaboration form seems to have benefited from written communication (falsification hypothesis H_2). Measures show a robust main effect across all other independent variables. Direct oral communication increases normative influence, develops personal bonds and therewith hampers the quality of group performance. On the other hand written exchange of information leads to elaboration of ideas and interventions (**EXP**). Quality goes along with better achievement.

Considering the last level of simulation measures (**SIM**) it is confirmed that braided groups outperform both control and distributed groups. The only factor of high relevance explaining the amount of variance is the type of collaboration: normally interacting groups, distributed groups or braided groups.

Compared to a random computer simulation run, all of the control groups as well as the orally communicating distributed groups are even worse than the random result. The fact that complex social problems can only be solved in groups of experts, gives evidence of the urgency in developing efficient group moderation techniques.

As we have seen, it is not the distribution or the written condition alone which enhances the braided groups, the combination of the many elements together produces this strong effect. Neither the quality nor the quantity of interventions alone helps to solve a complex problem. What is needed is a balance in face of time pressure and urgency. This can restore the focus, balance and steadiness of task-group activity (Nijstad *et al.*, 1999). This is achieved to some extent in the distributed groups, but to a much greater extent by the additional technique of PROMOD. Individual task-concentration and the construction of subjective theories, exchanging written graphs and combining individual positions by a voting procedure optimizes the clarity of the signals. Group-members are seen as 'tools of ideas' of which the individual 'strands of interventions' are to be braided together. This procedure focuses on the task-achievement by eliminating group-interaction. In this context socio-emotional influences within the group are reduced to a minimum, however, emotional and motivational influences are exercised by the moderator, totally separated from informational influences, increasing personal efforts regarding the task-performance. In this way, normative influences evoking interpersonal conflicts due to conformity processes, resulting in disturbances on the informational side, can be restrained. Consequently, group members can concentrate on the task with the constant support of the moderator, both emotionally and motivationally.

Given strong effects found for the further development of the distributed and cognitive formatting techniques, it remains of utmost importance to extend these findings into the wide domain of possible group-task activities, which we know plays the fundamental role in any statements about task-groups. Further study is planned to address the relative importance of distribution, formatting and moderation in task-groups facing the much simplified and accepted rank-ordering tasks (e.g. desert survival task, NASA moon task, etc.). Of course, in this case formatting can be expected to play less of a role given a task which already carries implications for how to approach the task as a group (Hollingshead, 1996).

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