TOWARD A TRULY DYNAMIC THEORY OF PROBLEM-SOLVING GROUP EFFECTIVENESS: COGNITIVE AND EMOTIONAL PROCESSES DURING THE ROOT CAUSE ANALYSIS PERFORMED BY A BUSINESS PROCESS RE-ENGINEERING TEAM

by

Leonid Khaimovich

BS Physics/Education, Vilnius University, 1984

MS Theoretical Physics, Vilnius University, 1985

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Dissertation Committee:

Burkart Holzner, Department of Sociology and University Center for International Studies, University of Pittsburgh

……signature……

Norman Hummon, Department of Sociology, University of Pittsburgh

……signature……

Alan Lesgold, Department of Psychology and Learning Research and Development Center, University of Pittsburgh

……signature……

Herbert Simon, Department of Psychology, Carnegie Mellon University

……signature……

TOWARD A TRULY DYNAMIC THEORY OF PROBLEM-SOLVING GROUP EFFECTIVENESS: COGNITIVE AND EMOTIONAL PROCESSES DURING THE ROOT CAUSE ANALYSIS PERFORMED BY A BUSINESS PROCESS RE-ENGINEERING TEAM

Leonid Khaimovich, Ph.D.

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The study develops a methodology for relating cognitive and emotional processes in a problem-solving group to its effectiveness. The adopted notion of effectiveness consists of 5 components. One describing quality of the causal diagrams generated by a group, and four describing individual characteristics of participants:

- D_U - understanding of solutions and other knowledge generated during the problem solving;
- D_M - willingness to use solutions and other knowledge generated during the problem solving;
- C_U - understanding of roles, goals, abilities, and problem-solving preferences of others;
- C_M - willingness to work with others.

In accord with the recent ideas proposed by McGrath (1997) and Weingart (1997), the study views groups as complex, adaptive, dynamic systems. Yet it also is guided by a theoretical orientation that stems from an attempt to grasp the role of rationality in human affairs and was originated by Weber (1968/1924). The work was motivated by our ultimate interest in developing a theory of a firm as driven by a network of problem-solving processes.

Data for the study were collected during the 1.5-month long consulting engagement in a high-tech company, which was designing a process for resolving software problems reported by customers. The data include: field notes, company communications, interviews, tests of problem-solving and interaction preferences of all workshop participants, 16 hours of videotapes recorded during the workshop, and a post-workshop questionnaire.

Videotapes and supporting contextual materials were used for designing Cognition-Emotion-Motivation-Action (CEMA) coding scheme and diagrams capable of tracing both cognitive and emotional states of each participant. Reliability of coding was estimated and lessons were drawn for improving it. A list of productions governing transitions between the states was generated and the size of a complete production system for the collaborative Root Cause Analysis task was estimated. CEMA diagrams extend Problem Behavior Graph (PBG) technique proposed by Newell and Simon (1972) into the area of collaborative face-to-face problem solving.

Several substantive findings relating group dynamics and effectiveness have been made and are reported. Practical recommendations for effective use of the Root Cause Analysis by groups are formulated.

ACKNOWLEDGMENTS

This study greatly benefited from support and encouragement of several individuals and organizations.

The late Jiri Nehnevajsa—the first Chairman of my dissertation committee—believed that I was doing something important and unique. He was the only person not afraid to convey his belief in my potential to me and probably to others too. Many doors opened to me when he was alive. After his sudden death Burkart Holzner kindly agreed to chair the committee.

Herbert Simon introduced me to cognitive psychology and made sure that there was not much "heresy" in my thesis. Our—monthly first, and weekly toward the conclusion of the project—meetings came closest to an ideal of relentless pursuit of truth that is driven by pure interest to subject matter. This is why I am using "we" throughout the thesis. Sparks of Herb's interest kept me going. Hiring a coder for the reliability study was funded by him, and at one crucial moment my family was financially carried through the summer by the "research support"—this is how it was stated on personal checks from Dorothy and Herbert Simon.

I would like to have more extensive discussions with my other dissertation advisor—Alan Lesgold. Even though the time he was able to spend on supervising my research was short, this was at least partially compensated by his ability to quickly point out the most crucial issues. The office Alan was able to keep for me at the LRDC since 1996 became my "permanent address." Laurie Weingart kindly permitted me to use a video and transcription lab at the Carnegie Mellon University's GSIA.

It's amazing how few researchers working in the same area will take time to look at a graduate student's work and to provide him or her with specific comments. In my case it is easy to mention those precious few. Dick Moreland, Fred Bales, and Bob Putnam read the draft of my dissertation proposal and/or reviewed the videos, and were instrumental in shaping my thinking.

On several occasions when the obstacles in the course of my studies seemed to be insurmountable and nobody else cared, Carol Choma—a graduate secretary—stepped in, found a solution, made it happen, and convinced me to go on. Daniel Regan's help was as crucial as Carol's before he left the department.

The current study benefited immensely from being focused on practically significant issues and working with industrial companies representing the best modern organizational practices. Stephen Mcintosh and PPG, Jennifer Smith and PQ Systems, James Frasier and Motorola, David Little and IDEO, Saulius Sidaras and SITI, Toni Meister and Westinghouse PQC, Pete Malpass and SEI, and the Director of Total Quality and employees of the company where the problem-solving workshop was videotaped, donated their time and attention to the project. The workshop participants, which have to stay anonymous for confidentiality purposes, always will serve me as examples of strong engineering spirit and candid discussion of problems that is possible only on the grounds of sincere mutual respect. My efforts to reciprocate by being useful were definitely not sufficient to match their generosity. I feel quite honored and

relieved that American Society for Quality recognized the study as practically important and awarded it in 1996 with the Research Fellowship Grant.

On a more personal note, I would like to acknowledge my parents, whose criticism is always welcome, because I know that they do care. For years both of my grandfathers served me as role models in the degree I probably have not recognized even by now. For example, in the preface to 1986 volume of Advances in Electronics and Electron Physics (Hawkes and Kazan 1986) the editor wrote about the work of one of them:

> The final article is devoted to two common elements of systems of charged-particle optics that have been neglected in comparison with round lenses, prisms, and multipoles. These elements, mirrors and cathode lenses, have been regarded as difficult to analyze owing to the fact that some of the usual mathematical approximations that are fully justified in lenses and prisms can no longer be employed. Considerable progress with this problem has been made in the group led by V.M. Kelman, co-author of the standard Russian book on electron optics, in the Nuclear Physics Institute in Alma-Ata. (p. vii)

Now I know who is "responsible" for my selection of the "intractable" problem for the dissertation study.

My heartfelt gratitude goes to Angela who created stable, sane and often graceful and jovial lifestyle for our family in the midst of way-below-the-poverty-line chaos we were and are traveling through. Our daughter Irina once confessed being thankful to her mom because she "forced" her to go to nature every weekend. I feel exactly the same. In addition to everything and on the top of it, creating artwork Angela always finds deep harmony in our world, though it seems impossible at times. This is the best encouragement I could receive. Also it always has been and is a pleasure to witness Irina developing into a wholesome, interesting and tactful person.

Dennis Morgan—my "photography boss"—is another major force that keeps me going. He is the only person who has been able and, probably, ever will be able to supervise me for 7 years. How was he able to do that? Just by being "always here", when I might need him. He taught me a lot about those aspects of this country that are not commonly known, but are ones that compensate for shallowness of its market-driven civilization.

Finally, I feel obliged to mention another unwavering source of support; namely, the safety net extended time and again for our family by the Department of Public Welfare, and its tactful employees. It is assuring to know that when our country prospers, funding for basic research starts coming from new government sources. Cheers!

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ACRONYMS

BAC – Best Available Coding;
BPR – Business Process Re-Engineering;
CE – Coding Error;
CEMA – Cognition-Emotion-Motivation-Action [coding scheme];
CPR – Customer Problem Resolution;
CTA – Cognitive Tasks and Actions [coding scheme];
FE – Field Engineering;
GAT – Generate-and Test;
HS – Heuristic Search;
IC – Index of Concordance;
ICR – Inter/Intra-Coder Reliability;
IMT – Interaction Management Task;
IPS – Information Processing System;
KC – Knowledge of Contacts [episode];
LM – Limited Manpower [episode];
LTM – Long-Term Memory;
MTD – Maximum Time Discrepancy;
ND – not demonstrated;
P&L – Profit and Loss [statement];
PM – Project Management;
PSGE – Problem-Solving Group Effectiveness;
PT – Procedural Task;
SE – Strategic Engineering;
ST – Substantive Task;
STM – Short-Term Memory;
WE – Window Error;
WM – Window Match.

1.0 Scope and goals of the study.

An immediate objective of this study was to see how reasoning and emotions are interlaced during the face-to-face collaborative problem solving aimed at rationally designing a business process by those who will participate in it. Because our senses cannot directly register the emotional and cognitive processes that are unfolding in a group, the task involved extensive interpretation. It was necessary to learn how to interpret what was occurring in front of our eyes.

The essence of scientific work--and a Ph.D. thesis falls into this category--is formulating and testing hypotheses (Klahr and Simon 1999). Yet to carry out both tasks, we also have to learn how to describe our phenomena of interest. Furthermore, because of its vast scope, scientific advancement is necessarily a social undertaking. It requires that scientific knowledge be transmitted with appropriate fidelity among peers and generations of researchers. It means that in addition to "seeing", we show others what we see. Thus, the immediate goal of this study is to develop a reliable methodology for describing emotional and cognitive processes in a small co-acting group.

To do so, we, in fact, formulated and tested hypotheses of a particular kind. We recorded what we thought we saw, and then used our current knowledge of cognitive and emotional processes to check whether our account was plausible. As is typical of initial stages of inquiry, the activities of formulating and testing hypotheses were continually alternating, starting from vaguely stated questions that are given only tentative answers by applying incipient theories, and progressing through the sequence of iterative cycles. It would be disadvantageous to spend considerable time attempting to formulate exact questions when only crude tools are available to address them, or to develop refined analytic methods for testing rudimentary hypotheses based on noisy data. It is well known that the fallacy of misplaced precision leads only to trivial statements that are difficult or impossible to elaborate or utilize pragmatically, and to unwieldy methodologies that obscure rather than promote our understanding.

The current study employed the author's experience of informally observing approximately 30 problem-solving groups in 4 companies. All of them were working with the same set of analytic methods--known as Quality Tools (Bassard and Ritter 1994)--for finding problems in business processes and correcting them. All analyses that are reported in this thesis are based on a 16-minute long videotaped episode from a Business Process Re-engineering workshop, where a group of 4 managers and 4 engineers led by a facilitator, was performing Root Cause Analysis (Wilson et al 1993) of difficulties that had been encountered in resolving software problems with equipment installed at customer sites. Videotaped data were complemented by materials collected during 1.5-month long fieldwork performed prior to the workshop and immediately after it.

Our search for an appropriate description of cognitive and emotional group dynamics was further focused by two more considerations. First, we were looking for a computable formalism. In other words, given cognitive and emotional states of all participants at any moment, we would like to be able to compute what will happen next. Second, the formalism was intended to be helpful for developing a truly dynamic

analysis of group effectiveness, in the sense of relating cognitive and emotional processes going on in a problem-solving group to variables describing its effectiveness. Our definition of effectiveness was derived from Hackman's formulation (Hackman 1987) and consists of 5 components: one describing quality of the causal diagrams generated by a group, and four describing individual characteristics of participants.

Individual characteristics of participants relevant to effectiveness can be divided into two classes--direction and coordination--each of which has a motivational and understanding components. Thus there will be 4 individual characteristics in the definition of effectiveness:

- D_U - understanding component of direction, i.e. understanding of solutions and other knowledge generated during the problem solving;
- D_M - motivational component of direction, i.e. willingness to use solutions and other knowledge generated during the problem solving;
- C_U - understanding component of coordination, i.e. understanding of roles, goals, abilities, and problem-solving preferences of others;
- C_M - motivational component of coordination, i.e. willingness to work with others.

Having 4 individual variables and 1 group variable means that $4\times N+1$ values are required for describing effectiveness of a group with N participants. The dimensions are not independent because understanding components of both direction and coordination may have strong influence on the motivational component of the same variable.

The current study was focused on developing a methodology for describing both cognitive and emotional dynamics of a problem-solving group. Working on this task we came up with several descriptions that are of substantive interest, and will be presented and discussed. Presenting these findings within the scope of the current manuscript both demonstrates the utility of our formalism and helps to explain why some features of problem-solving processes were included when others were not.

The work was motivated by our ultimate interest in developing a theory of a firm as a network of problem-solving processes. The next chapter on the significance of the study provides more detail.

2.0 Significance of the study.

The project spanned the worlds of theory building, empirical verification, and practice. We hope that all three worlds have gained something from the undertaking.

First, the study was pursued using a theoretical framework that stems from an attempt to grasp the role of rationality in human affairs and was originated by Weber (1968/1924). To be sure, the intellectual tradition is much longer and can be traced, at least, to the issue of philosopher-kings in Plato's Republic. The project mixed already available ingredients to make one more brick that can be added to the existing theoretical edifice.

Second, we were utilizing a methodology of theory building through simulation, which is rarely applied in the social sciences. Newell and Simon (1972) laid its groundwork while developing their theory of human problem solving. In the course of the study we augmented our knowledge of the strengths and

weaknesses of this approach, which seems especially well suited for initial exploration of complex dynamic phenomena.

Third, although the study was not intended to yield any definitive and readily applicable conclusions or prescriptions, it has provided insights permitting people of practical affairs to consider more alternatives, foresee possible outcomes, and develop adequate language to describe problem-solving processes in groups.

In the rest of this section let us expand on each of these three contributions of the study.

2.1 Location of the study in the existing theoretical framework.

Methodology utilized by Weber in Economy and Society (1968/1924)--the form of methodological individualism--analyzes social phenomena by concentrating on actors of three kinds: particular, average, and ideal-typical. The two first kinds of actors are empirical entities: they actually exist and may be used as objects of descriptive research. Actors of the third kind are abstract concepts that are often helpful in theory building. Weber writes:

> For the purposes of a typological scientific analysis it is convenient to treat all irrational, affectually determined elements of behavior as factors of deviation from a conceptually pure type of rational action. ... The construction of purely rational course of action in such cases serves the sociologist as a type (ideal type) which has the merit of clear understandability and lack of ambiguity. By comparison with this it is possible to understand the ways in which actual action is influenced by irrational factors of all sorts, such as affects and errors, in that they account for the deviation from the line of conduct which would be expected on the hypothesis that the action were purely rational. (p. 6)

Building his theory of rational-legal legitimation of power structures Weber showed how the rationality of modern societies stems from three recent and tightly interwoven developments: democratization of political life, creation of market economies, and development of communication technologies. He concluded that the ideal type of a rational actor had become a good approximation of reality and creates his theory of ideal-type bureaucracy based on this assumption. Consistent with his own methodology, Weber made an effort to determine the origins of his theory's deviation from practice. He came up with two mutually complementary factors: human resistance to the separation of official duties from private life, and uncertainty arising from competition among rival bureaucratic bodies.

Yet from the way Weber described the characteristics of a modern bureaucracy (pp. 956-8), it becomes clear that these two factors are not sufficient to account for discrepancies between theory and reality. Origins of the gap between the two become clearer when we read a section on markets and the subsequent discussion of differences between formal and substantive rationality (pp. 84-5). It seems that Weber did not distinguish between the rationality of researchers, who can explore behavior at leisurely pace, are physically detached from the events they analyze, and are at the leading edge of scientific knowledge, and the rationality of actors, who must act now and here. He also did not account for differences in access to information and information processing abilities among actors.

This is why Administrative Behavior by Simon (1945/57) and Organizations by March and Simon (1958) which introduced the notion of bounded rationality, make a considerable stride in clarifying relationships between decision-making practices and bureaucratic behavior. In the introduction to the second edition of Administrative Behavior Simon emphasized that:

> The central concern of administrative theory is with the boundary between the rational and the non-rational aspects of human social behavior. (p. xxiv)

In Organizations, March and Simon developed ideas from Administrative Behavior in more formal way. As a departure point, they employed a theoretical framework that has its origin in classic theories of economics. These theories assume that actors chose to behave in a certain way on the basis of the following information that is always available to them:

- all possible alternatives for action;
- probability and value of all consequences of each alternative;
- rules of comparison of consequences.

Thus, an actor is able to select the optimal alternative and, in this sense, is rational.

March and Simon argue that this image of an omniscient actor does not correspond to reality. They wrote:

> From a phenomenological viewpoint we can only speak of rationality relative to frames of reference; and this frame of reference will be determined by the limitations of the rational man's knowledge. (138)

For the purposes of organizational analysis they proposed amending the economic rational choice theory with an assumption of "bounded rationality".

It is amazing how many social phenomena can be quite plausibly described after replacing "economic man" by another ideal-type actor--"administrative man"--who is "intendendly rational, but only limitedly so" (Simon 1945/57: xxiv). Peters and Waterman (1982:101-102) wrote about Organizations that it "constitutes a full management theory. Arguably, there has been no true organizing theory written since then." The work is so rich in detail that it can be used as a handbook. The book also constitutes a significant contribution to social theory. It provided "the muscle and flesh for the Weberian skeleton, giving it more substance, complexity, and believability without reducing organizational theory to propositions about individual behavior" as Perrow put it (1972:146).

Yet at the time when Organizations was published, Simon was leaving the field of organizational behavior. He worked with Newell on "describing in detail a decision-making mechanism capable of exhibiting certain complex human problem-solving behavior--specifically, the discovery of proofs for theorems in logic" (March and Simon 1945/57: xxvi). The goal was to verify the main features of a model of "bounded rationality." Since then, Newell and Simon have developed a theory of human intelligence and applied it to problem solving in cryptarithmetic, logic, and chess. This work is summarized in their Human Problem Solving (1972). The theory elaborated in the book also was used to model many kinds of complex technical reasoning involved in solving ill-defined problems; for example, analysis of accounting

documents (Bouwman 1978), architectural design (Akin 1991), troubleshooting of nuclear power plant, (Roth et al, 1992), and medical diagnosing (Evans and Miller 1987). All these applications focused on individual problem-solving tasks.

The project utilizes a theory developed by Newell and Simon for modeling how groups use systematic methods for finding a way to improve their products or processes. This is an attempt to bring the "administrative man", who almost has forgotten his origins in organizational behavior and thinks about himself as representing fields of artificial intelligence or cognitive science, back into organization where his idea was conceived.

An adequate description of group problem solving requires an "administrative man" who possesses two features that he now lacks: emotions, and a switching mechanism that would allocate attention between technical problems and interactions with other group members. Some advances in this direction were made by Simon (1987, 1994), Kaplan and Simon (1990), and Kim et al (1994).

Another theoretical advance was also necessary for completing the proposed project, namely the unification of two lines of research. One of them evolves from work of Newell and Simon. As mentioned earlier, they treat problem solving as a cognitive process driven by the goal provided in the problem statement. A group working on a task will interpret that statement and try to achieve consensus about the best way to reach the goal. Another line of research is represented by the work of Goffman (1959), who treated any collective behavior, including collective problem solving, as negotiation about the issue “who will decide” conducted according to internalized norms of exchange. Goffman wrote (1959:9-10):

> We do not mean that there will be the kind of consensus that arises when each individual present candidly expresses what he really feels and honestly agrees with the expressed feelings of the others present. This kind of harmony is an optimistic ideal and in any case not necessary for the smooth working of society. Rather, each participant is expected to suppress his immediate heartfelt feelings, conveying a view of the situation which he feels the others will be able to find at least temporarily acceptable. ... Together the participants contribute to a single over-all definition of the situation which involves not so much a real agreement as to what exists but rather a real agreement as to whose claims concerning what issues will be temporarily honored. Real agreement will also exist concerning the desirability of avoiding an open conflict of definitions of the situation.

Goffman called the latter kind of consensus "working consensus", argued that it is much more widespread than "ideal consensus", and devoted his efforts mostly to analysis of it. Most of the Bales' work lays in the same vein. Although he considered (Bales 1951:8-10) “Adaptive-Instrumental” and “Integrative-Expressive” modes of interaction as equally important aspects of problem solving, he did not account for the influence of task content on interaction processes. And in his later work (Bales 1970; Bales and Cohen 1979), Bales devoted attention mostly to the personalities of participants. A life-long effort by Argyris to move organizational decision-making toward " ideal consensus" resulted in a detailed picture of the many dynamics that lead to "working consensus" and originate from it (Argyris 1990). A concept of "frame of reference," developed by Holzner and Marx(1979: 99) to explain the social construction of reality, will be utilized in the proposed study to analyze how an attempt to reach "ideal consensus" may lead to a search of

"working consensus" because of disagreements about taken-for-granted assumptions, preferences for symbol systems, analytical devices, and "reality or truth tests by which both the basic beginning points of the experiential base and the knowledge outcomes are validated" (p. 100). The processes of establishing "working consensus" and of alternating or combining both kinds of consensus during the same problem-solving session do not contradict but complement the theory developed in Organizations. In a considerable degree they can be described within Newell and Simon's framework of human information processing.

2.2 Relevance of the proposed study to practice.

The study evolved from a single practical question: how to implement cooperative data-based decision making? For anybody in the field of organizational change--be it under the banner of Total Quality Management, Process Re-engineering, or Agile Manufacturing--importance of this question does not require an explanation. Yet let us try to make obvious things explicit by addressing two issues; first, how this question relates to present and future efforts to increase effectiveness of business enterprise; and second, what is still not clear in this question, why it needs an investigation.

To explore the first issue, it is enough to look at the results from the International Quality Study performed by Ernst & Young LLP and the American Quality Foundation.

Table 1. Percentage of organizations with more than half the work force participating on natural work teams (department improvement teams).

	Manufacturing	Service
Past	22%	3%
Present	30%	8%
Future	53%	33%

The data were collected in 1990-1991from the automotive, banking, computer, and health care industries within four countries--Canada, Germany, Japan, and the United States. Trend data were collected showing what organizations did three years ago, do now, and what are their plans for doing three years in the future. Not including data for Canada "since it is similar to the US," and combining data from automotive and computer industries into the "manufacturing" category, and from banking and health care into "service," Harrington (1995) reports the results that are presented in Table 1.

If we make a plausible assumption that the popularity of teams is directly related to demands for collaborative decision-making, then it follows that the topic of the proposed research is relevant to efforts of a considerable and increasing part of work-force in industrialized nations. Harrington's results also provide an idea of how often data-based methods are used for decision making. Although the numbers depend on the kind of methods--such as brainstorming, statistical process control, cause and effect analysis, and Pareto charting--the average percentage of manufacturing employees who regularly use at

least one of these methods varies approximately from 10 % to 20% in Germany, from 50% to 70% in Japan, and from 20% to 40% in the United States.

Although a huge effort is being applied to learning and using data-based collaborative decision making, most of the trainers and industrial engineers involved could testify that things rarely go smoothly. More often than not, the training is not utilized properly, wasting many man-hours and leaving a long-lasting disappointment with "science". There is a host of possible reasons for negative outcomes of the attempts to approach problems rationally: allocation of insufficient time, poor preparation of trainers, quick turnover, and so on. Yet many of these problems stem from planning without realizing what it really takes to implement collaborative decision making.

It is commonly accepted that an adequate preparation for collaborative problem solving consists of two parts. First, participants need to master the "soft" skills of “smooth interaction” that help to achieve "working consensus." Second, they have to learn the "hard" stuff that includes measurement techniques and methods of data analysis and is necessary for building "ideal consensus." Although most of the people working in this field agree that both parts are necessary for the successful implementation of collaborative data-based decision making, in practice most organizations select either one or another approach. At best, employees are given "a dose of soft and a dose of hard skills." How to combine the two is never taught; employees or a facilitator are supposed to fill in breaches. Yet how to maintain team solidarity and at the same time candidly address technical problems is not a trivial matter. It begs for analysis.

How complex is the problem of combining “soft” and “hard” skills can be seen from a range of relevant issues sketched in The New Economics by Dr. Edwards Deming (1993). The book summarizes over 40 years of his experience as a worldwide consultant in statistics and management. As a part of the Marshall Plan, Deming started to work in Japan on improving the quality of their manufacturing products through applications of statistical methods. He quickly realized that this task could not be accomplished without changes in the whole management style. Given a rare opportunity to check his ideas against practice, over the course of many years Deming came up with, in his own terms, a "system of profound knowledge" that seemed necessary to complete the transformation. Aside from statistical reasoning, the system consists of three more interrelated parts (Deming 1993: 96): appreciation for a system, theory of knowledge, and psychology.

Appreciation for a system includes understanding of an organization and its environment as a system of interdependent parts that need to be coordinated. The obligation of every component is to "contribute its best to the system," even if it requires a competitive disadvantage of the component. Negotiations should be based on "optimization for everyone concerned."

A theory of knowledge includes an issue of theory’s role in making predictions from data, an issue of true value addressed from the vantagepoint of adequate operational definition, and an issue of social construction of reality.

Writing about psychology, Deming pointed out that "people learn in different ways, and at different speeds." He warned against ranking people, because of its impact on motivation and the

difficulties involved in accounting for a host of factors that are beyond control of an individual. Deming also emphasized the importance of understanding the interplay between extrinsic and intrinsic motivation.

The topic of motivation brings us to another important practical issue that is located on the boundary with ethics--the issue of some human beings manipulating others.

In Functions of the Executive, Barnard introduced a notion of "zone of indifference" within which an individual accepts orders "without conscious questioning of their authority" (1938/1968: 167). He also described how to create and expand these zones using reward systems. March and Simon (1958), preferring to talk about "zones of acceptance," explained how they can be affected in an influence model that is grounded in the decision-making paradigm:

> The influence model asserts that an individual may be influenced by (a) changing the values associated with given states of affairs, (b) changing the perceived consequences of an alternative of action, and (c) changing the set of states of affairs that are evoked (either by changing cues or by changing connections between cues and evoked sets). (52)

Together Barnard, March, and Simon enriched our knowledge about the workings of rational-legal legitimation of authority discovered by Weber (1968/1924). Unfortunately, this knowledge created a potential for manipulation. That potential was realized, according to Mitchell and Scott (1988), who wrote:

> Thus, what Barnard and Simon genuinely saw as a possibility of reaching the Promised Land of "mutuality of interests" has resulted in a somewhat different orthodoxy. The manipulative notions without adherence to substantive content and ethically acceptable standards for all may have left us with many of the worst aspects of the Barnard-Simon legacy without the positive aspects. ... We are left with a doctrine of manipulation without substance, value or higher purpose. (365-366)

Barnard and Simon saw this possibility and were concerned about it. Yet they believed in different safeguards. Because a "cooperative system," where organizational and individual goals coincide seemed possible to Barnard (1938/68), he invested his hope in the ethical standards of a leader (p. 322):

> when there are involved instructions, persuasion, and leadership, which we think call for the highest manifestations of mind in all fields, the test of character is the final test of intellect as well as morals.

Simon saw the needs of organizations and of individuals as only partly overlapping (March and Simon 1958). For this reason, he put his faith in a different mechanism, described in his article on altruism (1990). Here Simon showed that docile people, who "tend to learn and believe what they perceive others in the society want them to learn and believe" may be evolutionary better fitted than those who lack docility.

Barnard and Simon reached their conclusions at a very general level of analysis. They are cited here only to show that an issue of manipulation was taken seriously by both of them. The study touched upon this issue on a much more specific level. More precisely, the study described how and when a rational approach arouses suspicion, how and in which extent docility of the same person varies depending on discussed issues and present people, what is the role of rituals in stimulating the creation of valid knowledge and its utilization, and how and when problem-solving methods turn into ceremonial rituals preventing any advance of understanding. As far as we see it now, all these processes are related to the

mechanisms of creation and utilization of trust, which go hand in hand with the creation and utilization of knowledge, but can be influenced only epiphenomenally (Lindbloom and Cohen 1979:57-8).

Returning back from ethical issues to the issues of effective performance, let us mention those for which the proposed study is directly relevant:

- determining appropriateness of individual vs. team problem solving;
- selection of compatible team members and assigning responsibilities;
- testing of skills and knowledge needed for successful problem solving;
- creating friendly organizational environment for collaborative data-based problem solving.

All these issues are becoming of key importance for managerial practice because, according to Drucker (1993:42), we are living through the time of

> irreversible change: *knowledge is now being applied to knowledge*. This is the third and perhaps the ultimate step in the transformation of knowledge. Supplying knowledge to find out how existing knowledge can best be applied to produce results is, in effect, what we mean by management. ... This third change in the dynamics of knowledge can be called the "Management Revolution." Like its two predecessors--knowledge applied to tools, processes, and products, and knowledge applied to human work--the Management Revolution has swept the earth.

This sounds grandiose, even frightening. So, let us get into the detail of group problem solving, simultaneously trying not to forget Saint-Exupery's call "to strive toward a synthesis that satisfies not just one of our needs--such as order or technical development--but all our needs."

2.3 General methodological remarks.

The utilized methodology attempts to combine an emphasis on meaning, characteristic of qualitative studies, with the accuracy characteristic of quantitative research, and still produce a theory rather than a one-shot case study. For this purpose, generalizations will be made in two steps. First, process models of specific problem-solving sessions are built. The main concern is for accuracy of description as evaluated by possibility to make practically useful predictions. After a sufficient number of accurate models are built, generalizations will be drawn from them, if it makes sense from the point of view of systematization or of making inductive inferences, and if generalizations are possible.

Detailed information about specific models is necessary for checking possibilities for generalization. When we say detailed, we mean that the studied phenomena are treated not as black boxes, but as systems of processes that are described together with input and output measures. This approach will allow us to generalize from models with the same underlying processes and avoid "lumping" together cases governed by different mechanisms. For example, if we want to make some conclusions about the quality of decisions by measuring how many alternatives people consider when looking for an optimal size of batches and frequency of ordering raw materials, it would be meaningless to combine in one "representative" sample cases where trial-and-error and an equation are used. Different processes for solving the problem make meaningful generalization impossible. Another example would involve issues of group facilitation. Given an interest in the impact of games on learning in groups, it is worthwhile to distinguish between

natural work teams--like departments where people have been working together for long periods of time--and cross-functional teams, whose members were brought together for a particular task. This can be readily seen, if one considers interpersonal familiarity as a mediating variable in a process that links use of games to outcomes of learning.

In abstract terms, if one wants to use X as a predictor of Y, the usual procedure is to measure (X,Y) pairs, plug them in a linear regression model[1], get coefficients A and B, and then use the resulting expression--Y=AX+B--for prediction. Yet the prediction may be considerably improved, if analysis of underlying processes reveals "physical" or "social" meaning of the coefficients and permits sorting all cases into several groups with theoretically different values of A and B. Furthermore, process analysis usually permits making conclusions about shapes of relations among variables. For example, prediction will improve, if it is discovered that for some class of cases Y is proportional to the second degree of X, and in other cases X and Y are exponentially related.

Issues of prediction and generalization are traditionally linked by the concept of a representative sample (Campbell and Stanley 1966). Usually, when an appropriate representative sample is selected, researchers take into account only its size and randomness of choice of cases. Yet analysis of underlying processes, which determine the shapes of relations among variables and result in principal differences among values of parameters, brings another dimension into the notion of representativeness. Namely, a sample with underlying processes representative of the population should be selected. This may be impossible to do, if our population is not homogeneous with respect to underlying processes.

The task of modeling dynamic processes requires methods different from statistically checking hypotheses based on assumptions of linearity or log-linearity. Although natural sciences demonstrate a range of possible ideas and approaches (Bar-Yam 1997), it may be too cumbersome to use them for analysis of social phenomena that are, arguably, more complex than the unanimated world. Two factors provide some hope.

First developed from the needs of exact sciences, mathematical apparatus took life on its own. Most of mathematical theory is intrinsically consistent and logical in the sense that it is possible to learn it independently of any applications. That is, we are in an advantageous position compared to exact sciences because we can separate two tasks--learning mathematical methods and designing operational definitions that permit checking the theory empirically. Actually, we also can learn how to design usable operational definitions by practicing on simpler and already solved problems from exact sciences. Finally, there are still largely unexplored prospects of collaboration between social scientists and mathematicians.

Second, even outside economics there are examples of insightful and realistic studies based on analyses of underlying social processes. Mathematical Thinking in the Social Sciences edited by Lazarsfeld

[1] Speaking about linear regression model, we also have in mind multiple regressions, path analysis (Blalock 1982), and structural equation models (Hayduk 1987). In one word, we juxtapose two kinds of analytical methods: those that derive existence and shape of relationship between variables from technical

(1954) and An Introduction to Models in the Social Sciences by Lave and March (1975) provide many examples.

Yet the most visible achievement which, by the way, does not use any advanced mathematics, is a theory of human problem solving developed by Newell and Simon (1972) using a two-stage methodology: first, creating accurate models of specific phenomena; second, deriving general theory from these models. If we view each model as an experimental point, the second stage can be seen as interpolation and/or extrapolation from these points. Newell and Simon report in their book about the outcome of completing both stages. The study was limited only to the first stage. After a sufficient number of realistic models addressing the same practical question (how to implement cooperative data-based decision making?) are created, we will be ready to enter the second stage--creating a general theory of collaborative data-based problem solving. Completion of the task will heavily depend on how explicit are the available models, on the interest of other researchers, and on our ability to follow along the path of "validity-enhancing collective belief change" envisioned by Campbell (1988:Ch. 19). The study has made several steps along this path.

Newell and Simon's (1972) methodology and the resulting shape of theory are still unusual in the social sciences. Let us briefly summarize their ideas with the same purpose as Newell and Simon did 26 years ago: "to help the reader assimilate the development of the theory ... without being too surprised at the emergence of certain features and the (otherwise curious) absence of others."

The authors mention 7 features of their theory. The first--emphasis on processes--was sufficiently discussed above. The second one--deriving a theory of human information processing from models of individuals--corresponds to the proposal of two-stage theory development when generalizations are made not from data directly, but from models that describe specific case studies.

The third feature--content orientation--logically follows from what is now commonly accepted as a requirement for conducting a case study (Yin 1989). Newell and Simon make here an interesting comment; namely that paying attention to the content of the cognitive task (i.e. to the task environment) "removes a barrier toward extension of the theory." Further in the book they elaborate this statement and conclude:

> Just as scissors cannot cut paper without two blades, a theory of thinking and problem solving cannot predict behavior unless it encompasses both an analysis of the structure of task environments and an analysis of the limits of rational adaptation to task requirements. We shall attempt such a two-bladed theory here (p. 55)

This citation pinpoints the junction of psychology and sociology necessary for describing social behavior. Norms and rules of interaction that constitute an embedding social culture are indispensable parts of the task environment in any group effort.

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treatment of collected data, and those that start from observation of processes and use data to check hypotheses about functional relationships derived from theoretical analysis of underlying mechanisms.

The fourth feature--dynamic orientation--enables us to go beyond description and to explain behavior and reasoning in the sense of "characterizing each new act as a function of the immediately preceding state of the organism and of its environment." The authors note that limitations of mathematical technique kept most of their analyses informal and closely tied to empirical evidence, but they express the belief that further formalization is possible (cf. Hummon and Fararo 1994).

The fifth feature--being empirical, but not experimental--means heavy reliance on rich longitudinal data, or what now would be called "thick description" (Geertz 1973) instead of using control groups. As mentioned earlier, an appropriate selection of control groups may be difficult until one understands the underlying processes.

The sixth feature--limited use of statistics--is related to reluctance to use control groups prematurely and to the difficulty of trying "to test theories of dynamic, history-dependent systems." The difficulty may be not so daunting now as it was 20 years ago. Progress in the analysis of non-linear dynamic systems (Prigogine and Stengers 1984) has led to an elaboration of three concepts--deterministic chaos, catastrophe, and the "slaving principle"--and enabled description of discreet and chaotic processes that previously were considered amenable only for probabilistic treatment. These developments originated in physical chemistry, and quickly moved into population ecology, neuroscience, and applied areas like traffic control. Their promise for analyzing richly detailed historical data in sociology was discussed by Khaimovich (1992).

The last, seventh feature--sufficiency analysis--means concentrating first on "discovering and describing systems of mechanisms that are sufficient to perform the cognitive task under study." In my case it will be a group problem-solving task and the criteria of sufficiency will be the opinion of trainers and team facilitators that the model is realistic. To pursue sufficiency in a specific case, before matching modeled behavior quantitatively in a wide range of cases, seems natural for research that is concerned first with the shape of relationships and, second, with finding parameter values. Newell and Simon write:

To take sufficiency as a first requirement of a theory is simply to adopt a particular approximating sequence in science's progress (a choice not without consequences, however).

The consequences and rationale for this choice may be seen from a suggestion by Cook and Campbell (1979:83) that investigators with theoretical interests will consider construct validity as more important than external validity. For applied researchers, the order is usually reversed.

One more recent advance in understanding of modeling complex systems is directly relevant to the goals of the current study. In his popular book on plectics Gell-Mann (1994) introduces the notions of crude and effective complexity. He defines the former as “the length of the shortest message that will describe a system, at a given level of coarse graining, to someone at a distance, employing language, knowledge, and understanding that both parties share (and know they share) beforehand” (p.34). In contrast, effective complexity “can be roughly characterized as the length of a concise description of the regularities of that system” (p. 50).

The distinction is important for envisioning how to proceed while developing two kinds of models necessary for relating a problem-solving process to effectiveness: one - of the process itself, and another one - of the links between the events and/or variables of the process and indicators of effectiveness. A task of developing a model of the process itself is close to figuring out crude complexity of a problem-solving group. Regularities of group behavior are important, because knowing them will enable us to formulate rules making the description shorter. Yet not shorter than necessary for capturing dynamics of the problem-solving process in the sense of characterizing each new act as a function of the immediately preceding cognitive and emotional states of all participants. Because participants have to deal and are dealing with developments in group behavior they cannot predict, it becomes important to model such unpredictable--and in this sense random--events.

Discovering links between the events, sequences of events, variables of the process and indicators of effectiveness is a very different task from creating "artificial life" that simulates problem-solving behavior. Effectiveness is a conceptual construct and we are interested only in modeling regularities that relate it to group processes. In this case we try to figure out the effective complexity. Although this task is different from accounting for randomness of group dynamics, it is not necessarily simpler. Newell and Simon (1972: 301) noticed long time ago that when we have large combinatorial behavior spaces--as in the case of group problem-solving behaviors--small instantaneous changes can bring about great divergence further down the behavior paths. Impact of events can accumulate or they can cause radical changes in behavior at fluctuation points. Also events can combine in many ways compensating, increasing or canceling impact of each other on effectiveness. Thus it becomes rarely possible to speak about impact of any isolated event on effectiveness.

The tasks of creating models of the process itself and of the links between the events and/or variables of the process and indicators of effectiveness are different but difficult to separate at the initial stages of inquiry. Moving back and forward between the two was crucial for staying focused and checking for mistakes.

3.0 Literature review and conceptualization of cognitive and emotional dynamics of a problem-solving group.

On the basis of preliminary observations and a literature review, the model shown in Figure 1 was selected as a departure point for the current study.

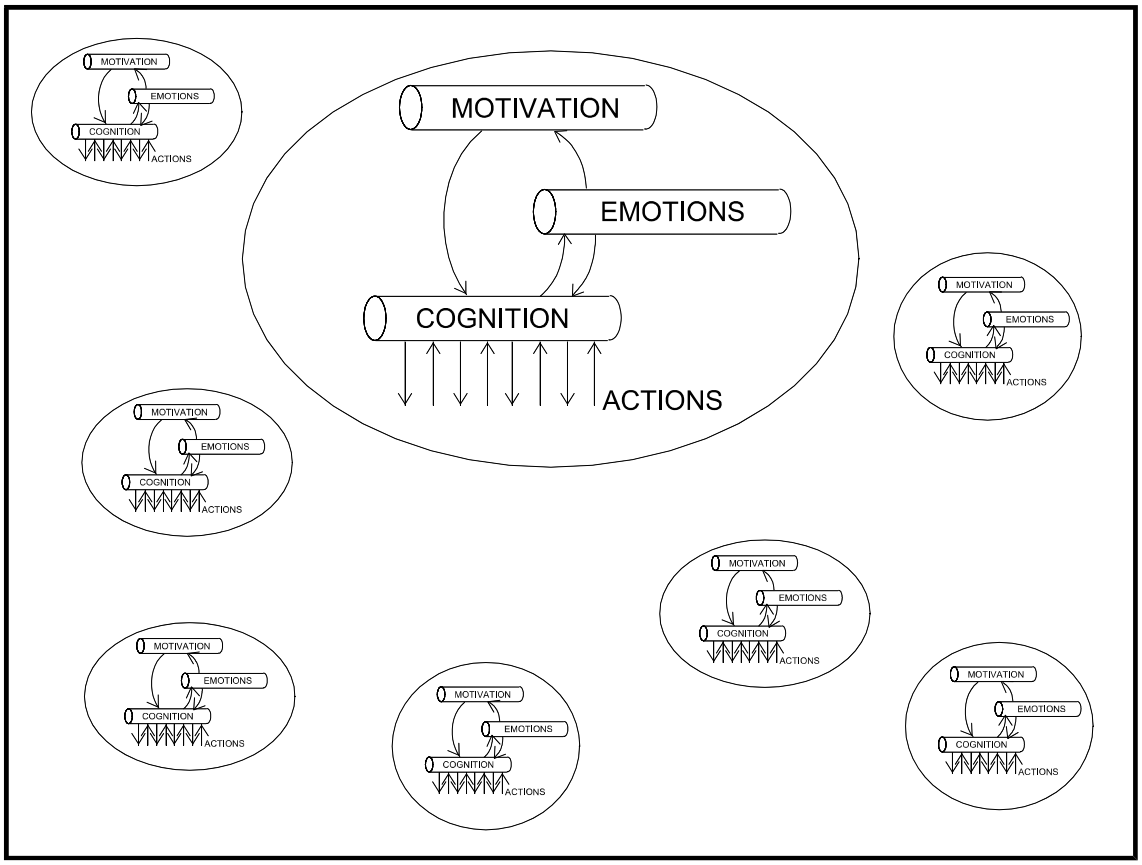

Figure 1. A model of group problem solving.

According to this diagram, the process of group problem solving can be represented as parallel problem-solving activities of individual actors interacting with each other and their environment. Each actor can be described at any time point by his or her cognitive, emotional, and motivational state. A problem statement initiates changes in the cognitive state when the problem is interpreted and expectations about what is desirable and possible are formed. This affects emotions, which in turn influence further information processing directly and/or through the motivation to solve the problem or do something else.

Interpretation may lead to actions, which are interpreted by other group members and produce actions on their part. These actions are, in turn, interpreted and evaluated by participants according to their expectations at that moment and consequently generate changes in emotional and motivational states that influence information processing and may result in more actions.

Actions may be not aimed directly at other group members, but be manipulations of objects. Recording in a notebook or on a flip-chart, or moving closer to the table are examples of actions directed on objects in the group's environment. Also actions do not need to originate from group members. Burning out a bulb in an overhead projector may considerably influence the flow of problem solving, for example. Surely, the proposed model cannot foresee all possible features of the group's environment. However, it

will take into consideration the robustness of problem-solving process to accidental and unrelated disturbances.

The model will account for individual differences in several ways. First, initial cognitive, emotional, and motivational states of participants may differ. Second, information-processing mechanisms, as well as mechanisms linking cognition, emotions and motivation, are not necessarily the same among individuals. Third, actions will be divided into several categories according to generating mechanisms and according to their impact on cognitive and emotional states of participants. Now we will present some initial ideas that are described in the literature and/or come from preliminary observations. They will be organized according to elements of the model shown in Figure 1.

3.1 Cognitive processes.

To model the cognitive processes of actors, we will use a theory of human information processing developed by Newell and Simon (1972). They postulate that "the human operates as an information processing system (**IPS**)" (p. 19) presented in Figure 2.

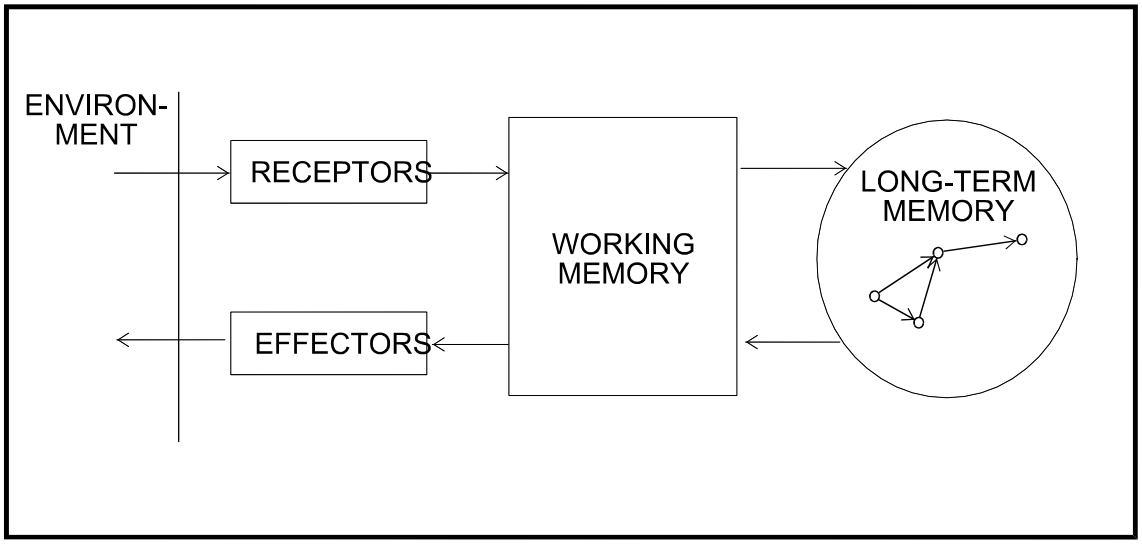

Figure 2. General structure of an information processing system.

Division into working memory **(WM)** and long-term memory **(LTM)** is crucial for understanding of human information processing. LTM contains all knowledge that an individual has learned during her lifetime and retained. It may be huge, but he or she is not able to attend to all of it simultaneously. To use this knowledge and/or to modify it, the individual needs to retrieve a small part of it into WM. WM consists of:

1. a (fixed) set of elementary information processes (eip's);
2. a short-term memory (**STM**) that holds input and output system structures of the eip's;
3. an interpreter that determines the sequence of eip's to be executed by the IPS as a function of the symbol structures in STM.

Recent models of IPS's elaborate mechanisms of WM by making STM size adjustable within some limits (Just and Carpenter 1992), dividing it into separate parts responsible for the processing of audio and visual inputs (Richman et al 1995).

Models of LTM become more and more complex too (Richman et al 1995). For purposes of this study, it is important that symbols in LTM can be linked into structures of several kinds differing in speed of information retrieval and whether retrieval sequences are conscious or subconscious, that is whether they are accessible from verbal reports or not.

Additionally to basic set of control commands of the interpreter that is a part of WM, LTM stores much larger and expanding system of "if-then" structures that control application of operators. These structures are called productions. Although production systems change while individuals learn to perform a task, these changes are slow. Newell and Simon's work (1972) demonstrates that it is possible to infer limited sets of productions used by individuals to solve a problem during an exercise lasting an hour or two. Because production systems determine sequences of actions individuals perform while working on a task, their analysis will constitute an important part of this study.

The limited size of WM and its organization of knowledge into structures connected by associative links leads to distinctive two stages in most problem-solving processes. First, information from the LTM that seems relevant to the problem is selected. In other words, a problem space is chosen. And second, an individual tries to solve the problem within this space. For example, after discovering that keys are locked in her car, an individual may see this as a problem of calling police or a problem of finding a wire suitable for "breaking in" the car. Allocation of attention and information-processing flow will be quite different in these two problem spaces.

Working in the same problem space does not guarantee that group members will proceed in the same or even similar direction when solving the problem. Analyzing data collected from a variety of problems and individuals, Newell and Simon (1972:94-105) came up with three general kinds of problem-solving approaches: recognition, generate-and-test, and heuristic method.

A problem is solved by recognition when the answer "was already in memory and was simply evoked by the act of understanding the question". In the case of pure recognition, understanding does not require any transformation of the information contained in the problem statement. Using discrimination nets the statement is matched to a symbolic structure that already exists in memory and has a direct link to another one representing the solution. Questions about the telephone number, or "Which is your cat?" are answered by recognition. More complex problems from mathematics and logic also can be solved by a sequence of recognition acts, if a person is familiar with the problem and can find the solution applying a standard routine. Recognition is fast and individuals are usually not conscious of the matching procedures that are involved.

The generate-and-test method can be used when a problem is stated in the state-predicate formulation. That is, information contained in the problem formulation allows to generate a set of possible

solutions--U--and then test them according to some criteria of the solution set--G. The method can be presented as the following algorithm:

1. generate a new element from U; if no elements, stop and report "no solution."
2. test if element is in G;
3. if true, stop and report solution;
4. if not true, go to 1.

Selecting only black balls from a box containing balls of different colors would be a pure example of generate-and-test method. Limits on what can be considered as generate-and-test method are similar to the case of recognition method: generate-and-test does not require any deliberate processing of information contained in the problem statement. It means that the test of belonging to G is performed by recognition. Generate-and-test differs from the two-stage recognition methods by the systematic way in which elements of set U are generated, which ensures testing all of them.

Heuristic search is different from recognition and generate-and-test because it includes selection and application of operators to transform existing states of knowledge into new states that look promising for clarifying what to do next. Selection is guided by already available information and starts from the problem statement. Yet the consequent steps are not "hardwired" in the initial statement; they are selected on the basis of more or less rigorous rules that are called heuristics. Compared with generate-and-test method, heuristics utilize newly created knowledge, and help to avoid searching in subsets of U that cannot contain solutions at all or are not plausible. Heuristics can also steer the search in direction of less effort and/or, if solutions differ according to their desirability, in the direction of more desirable ones.

Heuristic search can proceed from the problem statement toward solution. If possible solutions are known, search may start from them and proceed toward the problem statement (Hastie and Pennington 1991). Yet most real problems are not stated clearly and comprehensively at the onset and are ill defined, in the sense that there are no clear criteria for the best solution. In these cases, heuristic search proceeds as a sequence of iterations. First, an initial solution is generated on the basis of crude heuristics or even by recognition. Then, while testing if this solution is correct or desirable, new information is produced that adds to the initial problem statement and helps to find a better solution. Individuals will differ with respect to the number of times they are willing to repeat this cycle until reaching an acceptable solution, and in their criteria of what is acceptable.

As mentioned earlier, tasks can considerably constrain the flow of problem solving. The problem statement has strong impact on the choice of the problem space and, consequently on the selection of problem-solving approach. Furthermore, Newell and Simon have shown that within broad limits of intelligence, all individuals working within the same problem space will pass the same episodes--"small self-contained phase[s] of highly organized activity" (Newell and Simon 1972: 287). Existence of episodes is determined by two factors. First, for all people above some level of intelligence and familiarity with the task, there is at least one sequence of steps that will seem obvious. Second, for all people below some level of intelligence and familiarity with the task, this will be the only imaginable way to approach the task. That is, it will be the necessary way. For example, if the task is to find the area of a quadrangle and a ruler is

provided, most people who graduated from elementary school will measure the sides of the figure and multiply the results.

The contents of participants' LTM also impose limits on the possible flow of cognition. To solve a problem, individuals first create a problem space combining selected information from the problem statement and relevant knowledge retrieved from LTM. Similarly, to interpret any single action, it must be 'embedded' into more or less coherent structure that is remembered from before and consists of other actions and events organized according to the inferred goals of the actor, or according to other associative links: for example, proximity in time and space (Hewstone 1989: 106). These so called “knowledge structures” (Abelson and Black 1986) not only provide meaning to separate actions by relating them to goals, but also allow people to fill in any gaps in the information necessary for forming a response.

Behavioral norms and stereotypes are instances of knowledge structures that allow direct interpretation of actions. According to Argyris (1990), these basic knowledge structures can be and are interpreted themselves, using theories that relate norms to fundamental cultural values: caring, respect for others, honesty, strength, and integrity (Argyris 1990: 19-20). Argyris distinguishes only two such theories and calls them Model I and Model II. He argues that Model I is much more widespread now, but “productive reasoning goes along with Model II”. Argyris compares two models in Table 2 .

Table 2. Comparison of normative actions in Model I and Model II (Argyris 1990: 106-7).

Model I Social Virtues	Model II Social Virtues
HELP AND SUPPORT	
Give approval and praise others. Tell others what you believe will make them feel good about themselves. Reduce their feelings of hurt by telling them how much you care, and, if possible, agree with them that the others acted improperly.	Increase the others' capacity to confront their own ideas, to create a window into their own mind, and to face their unsurfaced assumptions, biases, and fears by acting in these ways toward other people.
RESPECT FOR OTHERS	
Defer to other people and do not confront their reasoning or actions.	Attribute to other people a high capacity for self-reflection and self-examination without becoming so upset that they lose their effectiveness and their sense of self-responsibility and choice. Keep testing this attribution opening.
STRENGTH	
Advocate your position in order to win. Hold your own position in the face of advocacy. Feeling vulnerable is a sign of weakness.	Advocate your position and combine it with inquiry and self-reflection. Feeling vulnerable while encouraging inquiry is a sign of strength.
HONESTY	
Tell other people no lies or tell others all you think and feel.	Encourage other people to say what they know yet fear to say. Minimize what would otherwise be subject to distortion and cover-up of the distortion.
INTEGRITY	
Stick to your principles, values, and beliefs.	Advocate your principles, values, and beliefs in a way that invites inquiry into them and encourages other people to do the same.

As we see it, the fundamental difference between the two models is in underlying beliefs about the character of conflict. Model I produces norms adequate for dealing with situations in which the victory of one party is inevitably a loss for the other. The aim here is to prepare for a new conflict because one of the parties remains dissatisfied. Making a loss as painless as possible serves this purpose in the most civilized way. Model II is appropriate when exploration of the conflict allows people to find outcomes satisfying both parties. In this case, the main aim is to promote focused and clear search of alternatives. Model II is also self-reflective; its normative actions help to create conditions facilitating a switch from Model I to Model II.

3.1 Influence of cognition on emotions.

Emotions will be viewed in the present study as a signal that an organism gives to itself when it prepares to act after interpreting a situation (cf. Frijda 1986). Collins (1975: 92) calls emotions "a meeting ground of mind and body." Because people share many physiological processes with higher mammals, emotions stemming from unpleasant stimuli and preparing an organism to deal with them by fighting, flying, or freezing, as well as emotions aroused by pleasant physical stimuli should be common for people and animals. These emotions--fear, anger, deference and happiness--involve a minimal amount of cognitive processing and are similar to sensory inputs. For example, feeling heat leads to an instant muscular contraction meant to remove the body from the source of heat. It is even more difficult to say where the boundary is between the ways bodies signal about states that do not require an immediate action--like hunger or saturation--and these primitive emotions.

With development of mind, which goes hand in hand with increasing complexity of human society (Durkheim 1912/1965), humans acquired emotions that require more extensive information processing. Many of them are related to religious experience--like shame, quilt, pity and contempt, pride and arrogance. These emotions are especially relevant for the study of social interaction. As shown by Weiner (1986), their arousal involves essential cognitive processes that attribute effort, ability, friendliness, and so on to other group members (cf. Ortony et al 1988).

Cognition also influences emotions by interpreting events and actions according to two dimensions: desirable vs. undesirable, and expected vs. unexpected. We expect that the position of an event along these two dimensions will determine whether emotion is negative or positive and to what extent (cf. Stephan and Stephan 1993: 123).

It is also important to keep in mind that some events have a ritual character. That is, their primary aim is management of emotions. Even verbal technical statements may have ritual elements in them. Collins (1975: 97) argued that:

> The language differences between humans and other animals are not so great. We only elaborate more on the arbitrary part of dance built up around innate gestures. Our language is based on cries, pleas, snarls, demands, coos, and so forth, and talk is an effort to convey one's mood to someone else.

On page 101 Collins summarizes his views on the place of cognition in verbal interaction by saying:

> Man is a social animal with a distinctively human capacity for symbolization of unseen, amplified through internalization of social language. But underlying this are the same kinds of emotional bonds found among animals: sexual, paternal, and related familistic responses; responses related to fighting, including mutual alarm signals, mutual support in attack and defense, as well as intragroup signals of threat and submission; and playing responses consisting especially of toned-down versions of fighting and struggling.

Indeed, while observing problem-solving groups, the author saw how statements intended to collect more information--for example, a seemingly neutral question "Why do you think so?"--or statements introducing additional information--like "There is another possibility."--were often interpreted as indicating aggressive attitudes. Interpretation depends on particular organizational norms and can vary during the same problem-solving session, depending on whether attention is allocation to technical vs.

interpersonal issues. In the extreme case, even turn-taking in a conversation may be perceived as a potential threat.

Information processing flow, or more exactly, how smooth and successful a cognitive search is, should also have influence on emotions. The search is fueled by cognitive dissonance (Festinger 1954) associated with emotional state. Similarly, an ability to answer posed questions should give rise to emotions that may vary from excitement and/or pride of "Aha!"-experience to anxiety and shame when reasoning does not bring desired results. It is possible that emotional pressures to find an answer can build so high that critical mental abilities will be suppressed, leading to superficial solutions (Simon 1987: 62). This phenomenon is especially likely when a situation is perceived as threatening and it becomes unbearable to endure so much uncertainty. This is an instance of emotional influence on cognition leading to so-called "wishful thinking." It will be discussed in more detail in the following section.

3.3 Influence of emotions on cognition.

In general, "wishful thinking" can be defined as a cognitive process directed on managing the emotional states of a person. Long-term goals are abandoned and replaced by an urgent goal to achieve some immediate emotional comfort. Krau (1991: 156), who calls this phenomenon "emotional thinking," says that it is marked by unwarranted generalizations that are "made on all-or-none basis, and no exceptions, partial accounts or probability statements are tolerated." These conditions create a fertile setting for the emergence and use of stereotypes. Emotions associated with these stereotypes may reinforce uneasiness and anxiety, starting a self-amplifying cycle that renders any productive reasoning impossible. In extreme cases, the cycle leads to verbal or physical aggression, or, more often, to the break-up of communication and subsequent isolation of participants.

If communication continues, strong emotions may increase the pace of interaction, leaving less time for reasoning. Furthermore, under these circumstances, reasoning may focus on the rationalization of felt emotions rather than on substantive issues related to the problem statement (Campbell 1967).

Krau (1991: 179) mentions another, more peaceful, influence of wishful thinking on problem solving, namely the rejection of undesired information and weakening of critical analytical attitudes with a purpose to maintain a benevolent image of reality. Wishful thinking may also serve as an escape, at least a temporary one, from making unpleasant choices. The phenomenon constitutes a core of "cover-up" activities, which are carefully maintained by all of the participants in a group that "hits" an issue that endangers self-esteem of individuals (Argyris 1990).

It is possible that symbols representing emotions are parts of human memory. We have names for emotions, just as we name events, objects, and classes of events or objects. Emotions can be aroused by sequences of black signs on white background, that is by written words. Therefore, if we model memory structures as nodes connected by associative links, than some of these nodes can stand for emotions. Consequently, reasoning can relate events that have nothing else in common but an emotion

If our model is valid and emotions are treated as information, then cognition will be directly influenced by the location and kind of emotional nodes within symbolic structures stored in memory. Assuming that corresponding feelings are aroused when cognitive processes activate an emotional node, we have another mechanism for cognition's impact on emotions. If we assume that emotional nodes can be linked with each other, we need to accept that the emotional state of a person can evolve on itself, and so it is possible to represent emotions and cognition as interconnected parallel systems (cf. Stephen and Stephen 1993). Although, because a number of emotions, even considering gradations in their intensity, seems to be much smaller than a number of events or objects that are distinctively different, variety of possible developments purely within the emotional state should be quite limited.

3.4 Impact of emotions on motivation.

The term "motivation" is used here to denote willingness to initiate or continue a specific activity. It can be a cognitive or behavioral activity, but now we are interested more in how people maintain continuity and direction of their thoughts.

Motivation can be generated in several ways. First of them may have nothing to do with emotions: people become motivated by cognitively relating an action's or reasoning's direct aim to another desired goal. But why do some goals become desired when others do not? Why are some goals sought for more intensively than others? We assume that motivation to engage in an activity is related to the history of positive and negative emotions associated with that activity, and is mediated by expectations that the same pattern of emotional reinforcement will persist in the future.

Motivation can gradually decrease with every negative feeling associated with the goal and increase with any positive feelings. A model describing this kind of changes in motivation when performing a task that requires constant effort declining with practice, for example when studying foreign language, is described by Simon (1954 in Lazarsfeld).

Negative emotions associated with an activity do not always lead to diminishing motivation and positive emotions do not necessarily increase it. Motivation can be aroused by negative feelings or emotions, as in a case of unsatisfied needs. Positive feelings stemming from satisfaction of needs may decrease motivation, but not necessarily. People may strive to maintain and increase pleasant stimuli. We assume that strong needs usually lead to a strong motivation to satisfy these needs. This happens at the expense of other needs. Yet sometimes, if satisfaction of strong needs is blocked, accumulated motivation can be transferred to other needs. This mechanism accounts for the rare cases of pursuing higher Maslovian needs even when lower and stronger needs are unmet.

Motivation also can change abruptly and increase in face of difficulties. This relationship between emotions and motivation is found in volitional acts performed by people with a strong will. A term "will" is used here in the sense developed by Vygotsky (1987/1932), who introduced several distinctions that facilitate understanding of dynamics of volitional acts. Referring to the early work of Kurt Lewin, Vygotsky argued that persistence in achieving goals even when facing difficulties can also result from

instincts or habit. Volitional acts are different because they start from conscious intentions. Next, will locks these intentions in putting people with strong wills in control of themselves in the sense that they behave according to their intentions, not according to circumstances. Their resolution does not diminish gradually because of negative stimuli. If it changes, this happens abruptly because their intentions are abandoned or revised. Existence of intentions, and not a long history of strong positive reinforcement, is the necessary condition for a will to be activated. Anyway, emotions still may play an important role in decisions to stop trying: after some attempts, people may change their opinions about the difficulty of the task and decide that the aim is not worth the necessary sacrifice. Also, after encountering unforeseen obstacles, people may deliberately "pump up" their determination to proceed toward the goal. Obstacles may cause emotions like anger, which increase the motivation to overcome. In extreme cases, motivation to win may make people to forget their initial goals.

We assume that stronger motivation leads to allocating more resources to the task. This often happens on the expense of activities directed to other goals. In the present model, we consider that the amount of available resources, especially of cognitive resources, is linked to another characteristic of person's state: vigor. In contrast with motivation, vigor is not related to any specific activity. It shows how fresh and free of stress a person is. People who are low on vigor feel tired and have a smaller capability to maintain goal-directed search in face of difficulties. Their behavior becomes more expressive rather than instrumental and their cognitive processes are driven by immediately available stimuli and contents of LTM. That is, their information processing approaches the state of dreaming. I assume that negative feelings and emotions drain off vigor and that positive feelings and emotions replenish it. Vigor also diminishes with invested effort and increases after rest.

3.5 Impact of motivation and vigor on cognition.

Motivation and vigor play major roles in allocating cognitive resources. In turn they lead to changes in attention control and associated switches between problem-solving methods and between problem spaces. They also influence the ability to discriminate between similar phenomena and to handle complex and large symbolic structures.

We assume that people are able to pursue several cognitive tasks simultaneously. This ability differs from person to person: Napoleon, for example, was able to discuss a dozen of different issues with different people simultaneously, although we do not think that everybody was talking at the same time. Most people are able to deal with one or two problems that require concentrated effort, and can only scan the environment in search of phenomena related to a couple of more tasks. Possibly, the ability to explore several tasks in depth simultaneously can be learned, but this requires much more time than is available during a problem-solving session. It is possible that some cognitive tasks are performed almost constantly and in parallel to any other tasks. Recognition of large, bright, quickly moving objects, that seems to be inborn, is one example.

Also, we assume that cognitive resources allocated to a task are directly but not necessary linearly related to the strength of corresponding motivation. And the capability of the WM as a whole is positively related to vigor. Finally, we assume that filtering stimuli from receptors through discrimination nets in search for relevant information requires fewer cognitive resources than modifying these nets or working through the associative networks. Therefore, when resources allocated to a task wither away, scanning will cease last before complete extinction of the task-related activities from the WM.

So, what happens when a task's resources change with changes in vigor? We will describe a case of increasing capabilities. The opposite case will reverse all of these processes. When vigor increases people run more tests and consequently discriminate better between similar stimuli. They do more scanning and consequently notice more relevant stimuli. They also run more tests when checking "if" part of productions and consequently make fewer mistakes applying productions. Finally, they are able to work on more problems simultaneously.

When motivation increases the resources allocated to particular tasks, the quality and quantity of testing will increase in a similar manner, yet only for these tasks. If vigor is not increasing the capabilities of WM as a whole quickly enough, the resources will be reallocated between tasks. This makes it less plausible that a search in other problem spaces, or the use of other methods, will dig out a new seemingly promising approach increasing the associated motivation. This is an instance of a self-reinforcing cycle that would lead to extinction of all tasks but one. Two possible processes can prevent this outcome: a decreasing motivation in the case of not reaching the desired outcome, and tracking of attention by associative links stored in LTM.

Speaking about attention, one needs to distinguish two commonly used meanings of this word in psychology. One describes a locus of conscious cognitive processes like in the sentence: "Her attention switched to finding the largest number on the list." Another meaning relates to the ability to notice and retain information, even when this happens subconsciously and is revealed only by later utilization. Attention, in the former meaning of the word, will tend to jump between two tasks, if a person is similarly motivated to work on both of them, or when attention is deliberately directed to a task with lower motivation.

3.6 Group-level processes of collaborative problem solving.

Analysis of interaction at the group level comes much more naturally than on individual level. During group discussions involving several people, time is not sufficient to analyze what happens within the head of each participant. Participants rather concentrate on the proposed course of actions and how it suits their interests. This means that group members adjust not only to each other but also to what they perceive as the group's course of action. For this reason, it is useful to have a group-level image of interaction. How do individual participants create a shared understanding of "the proposed course of action" at any particular moment? Is this understanding really shared by all participants? And how does participation in the shared effort, or isolation from it, influence individual members? All these questions

will be addressed using individual-level model. Yet some ideas about the direction of collaborative problem solving can be derived from group-level analysis.

Several authors describe group problem solving as a sequence of phases organized according to distinctive tasks or as a mechanism that accounts for selection of these tasks. Bales (1951) used both kinds of description in his analysis of interaction process. First he introduced "the simplest way to conceive an idealized problem-solving sequence" (p. 8) as a sequence of three phases: questions, attempted answers, and then positive or negative reactions to the answers. He also proposed six larger phases of successful problem solving and wrote:

> the order of events might follow something like this order: The first phase of the meeting might be devoted largely to getting an initial factual or cognitive orientation to the problem as the group faces it. This might be followed by a phase of analyzing and diagnosing the situation in the light of values, needs, and desires of the members of the group, and the formulation of a general common goal. The next phase might be devoted to finding ways and means of controlling the factors in the situation, including the activities of the members, in order to bring about the desired state of affairs which is the goal. On nearing completion of this sub-phase of actual decision or crystallization of intent might then appear, with further last-minute articulation of the earlier steps. Then a period of laughing and joking might appear as a penultimate phase, releasing and dissipating the various tensions created in the process up to this point. Finally, a short phase of reward, praise, and encouragement of the members by each other would knit the group together again and bring the meeting to close. (p. 11)

Also Bales described interaction process "as one of alternating emphasis on the two types of problems" and proposed the following mechanism of alternation:

> When attention is given to the task, strains are created in the social and emotional relations of the members of the group, and attention then turns to the solution of these problems. So long as the group devotes its activity simply to social-emotional activity, however, the task is not getting done, and attention would be expected to turn again to the task area. (p. 8)

Bales developed a system of 12 categories that allows researchers to classify all interaction instances with a direct goal to see how well his models reflect reality and in attempt to derive information about the personalities of participants, as well as about the social culture and structure of the group.

Fisher (1980) modified Bales' categories to avoid problems caused by the need to classify every act as either contributing to performing the task or influencing the social-emotional aspects of interaction. Also Fisher distinguished between acts of interpretation--"a simple value judgement without evidence, reasons, or explanation"--and acts of substantiation that "include supporting evidence or reasons to enhance the believability of the expressed value judgement" (p. 324). Using this system, Fisher described decision making as a sequence of 4 phases: orientation, conflict, emergence, and reinforcement (p. 144-9).

Several other authors (Bennis and Shepard 1961; Dunphy 1964; Tuckman 1965) divided decision-making or problem-solving process into four phases that are highly similar to Fisher's model. All of them point to processes of familiarization with the task and of initial adjustment of the participants to each other, that are rarely settled without relatively confrontational period. If the group is able to manage tensions

(Bormann 1969) and work out acceptable norms of interaction, then it concentrates its efforts on substantive tasks. Fisher (1980: 142) goes one step further and accepts the "spiral model" developed by Scheidel and Crowell (1964). In this model decisions are not really made or discovered after passing through a linear sequence of stages, but rather they emerge in a gradual and cumulative manner. After an idea is proposed, it is tentatively accepted and "reach-tested" to check how useful and consistent it is. Then the idea is accepted and forms an "anchor point" for further reach-testing, or it is rejected and participants return to the previous anchor point. Newell and Simon (1972: 172) used the Problem Behavior Graph to describe the similar kind of behavior in the case of individual problem-solving. Mintzberg, Raisinghani, and Theoret (1976) also mention the similar cyclical pattern discovered in his study of strategic decision making. Fisher argues that group problem solving proceeds in cycles throughout each of the four phases. Yet the number of new ideas introduced by group members and the extent of reach-testing differ from phase to phase. Although Fisher viewed problem solving primarily as a search for ideas, directed by the problem statement, he emphasized importance of social conflicts for decision modification (p. 154).

Collins and Guetzkow (1964) started their exploration of decision-making effectiveness of groups from what they call "a simple working model of decision-making groups" (p.81) shown in Figure 3. They saw decision making as a process originating from obstacles that constitute a source of problem, and driven by rewards that are considered to be "the source of power for individual group members and for the group as a whole" (p. 120). A flexible link between outputs and rewards creates leeway for the emergence of power structures that, in turn, modify this link. Citing Blau and Scott's (1962) ideas about the debilitating impact of formally established hierarchies on group performance (p. 84), Collins and Guetzkow demonstrated that while the existence of rules and norms of interaction may be a necessary condition for productive problem solving, the relation between the two is not of "the more, the more" kind.

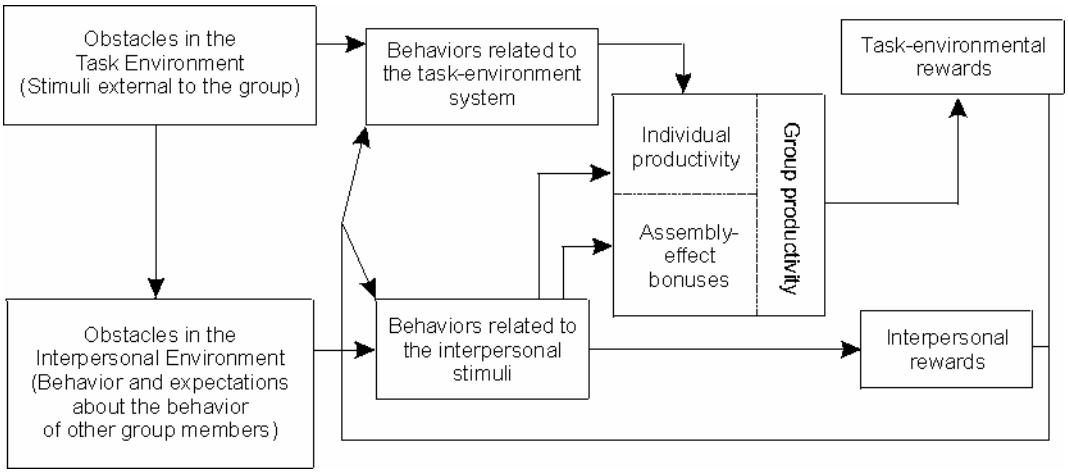

Figure 3. A simple working model of decision-making groups.

Turner's (1988) extensive and focused literature review again shows how difficult the topic of structuring is. Emergence of norms and roles has attracted the best minds by the promise of revealing a link between micro and macro social processes and yet still it looms large. Turner explained the situation as follows:

> when addressing the topic of structure, theorists become too macro and emphasize large-scale and long-term interactive patterns; yet, curiously, when they try to connect these macro dimensions of structure to individuals, they typically become too micro and delve into properties of human consciousness and cognition. The result is conceptual flip-plopping between the majesty of the macro structural order and the inner workings of individual mental constructions. (p. 149)

Turner argued that this oscillation between macro and micro is a consequence of insufficient understanding of both levels of analysis. Encountering difficulties on one level, researchers quickly switch to another one instead of investing more effort in clarifying whatever blocked their approach. Turner claimed that it was possible to understand structuring starting from both micro and macro levels. Departing from the macro level, he introduced six "general conceptual rubrics for understanding how structuring operates" and labels them: (1) categorization, (2) regionalization, (3) normatization, (4) ritualization, (5) routinization, and (6) stabilization of resource transfers (p. 150). Although it is not clear how it is possible to generate a detailed, dynamic description of these six processes without entering the field of cognitive psychology, Turner's approach helps by marking group-level processes that need to be derived from individual-level phenomena, if one wants to account for impact of structuring on problem-solving. Turner's abstract and general discussion of the dynamics of interaction between motivation, communication, and structuring (pp. 176-213) helps to shape the individual-level model described in the previous section.

Probably structuring cannot be described completely within a group-level model: emergence of norms and roles stems not only from activities in which all, or even the dominant majority, of members participate. A private interaction between two group members, which passes unnoticed by the rest, can have a decisive impact on their relative position within the group structure. Also, ignoring proposals and suggestions that are made in passing can be hardly considered as the group's actions, yet it establishes important norms of interaction that are closely related to problem-solving effectiveness of the group.

3.7 Problem-solving group's effectiveness (PSGE).

Group effectiveness research has been producing a strong continual stream of publications. Two extensive reviews (Bettenhausen 1991; Cohen and Bailey 1996) cover hundreds of the studies conducted during the last decade. To the best of our knowledge, none of them relates group dynamics and effectiveness. The authors who claim to analyze impact of internal group processes merely examine statistical relationships between effectiveness and occurrences of events like conflict, collaboration, or particular negotiation techniques. We were not able to find any trace of endeavors to discover how the time course of problem solving leads to higher or lower effectiveness. The situation is not surprising. Even if we

consider only the conceptual level, there are several reasons for it. Problems with developing operational definitions are also possible but we are not at the stage yet to encounter them.

First, to relate a problem-solving process to effectiveness one needs to build not one but at least two models: one - of the process itself, and another one - of the links between the events and/or variables of the process and indicators of effectiveness.

Second, it only makes sense to speak about effectiveness of behavior after some period of time required for completing a task and implement solutions. Yet direction and, especially, coordination of participants probably will continue influencing collaboration of participants even after solutions are implemented. For this reason a question of time-span for estimating effectiveness has to be explicitly resolved.

Third, if one accepts direction and coordination of participants as important dimensions of effectiveness, there emerges a question of how individual characteristics combine in the notion of group effectiveness. For any practical purpose of predicting performance of the group under specific circumstances, averaging or arithmetically adding measures of individual direction and coordination is meaningless. In order to speak about group effectiveness we may need to know how results of problem solving will be used. In the sense we need to build one more model--a model of utilization of outcomes of problem solving.

By now we have outlined what is currently known about cognitive and emotional dynamics in problem-solving groups and how this is related to their effectiveness. The next chapter starts presenting specific data collected during the project and used for analyses.

4.0 History, culture, and organizational structure of the company that served as a research site.

Many interpretations made in the course of analyzing videotaped group behavior--the central part of this thesis--would be impossible without knowing the culture and organizational structure of the company that served as a research site and will be called The Company hereafter.

Cultural values determine, in a large degree, what motivates employees. Corporate rituals are usually adhered to automatically and without questioning. The swift and severe reaction to breaking cultural norms and rules is usually impossible to explain without taking into consideration the processes of symbolic management described by Deal and Kennedy (1982). These authors define strong culture as “a system of informal rules that spells out how people are to behave most of the time.” In our case, many behaviors can be explained by a derivative of strong culture; namely, by the state of cultural transition from a formerly strong and uniform set of corporate values that was adhered to for almost a century to a new one. For this reason, it is important to outline history of The Company during its recent transformation as well as during the formative years of its old culture.

In this chapter we will first describe the corporate history, and, second, we will add more detail about the events and organizational arrangements of one of its division’s headquarters, where the study

took place. Most materials for the first part of this chapter come from numerous articles and interviews published in periodicals after The Company officially ceased to exist about a year ago. The second part of the chapter is based on our own interviews, observations made during the field work, and internal documents--like business performance improvement plan and messages to and from management--circulated in the division.

4.1 Corporate history.

The Company was created by a world-wide famous inventor who was one of the "born leaders"--the category defined by Deal and Kennedy (1982: 43) as "the people whose influence lasts for generations. ... The entrepreneurial spirit of the country fostered them, and they in turn became symbols of that spirit." In mid-80s The Company celebrated its Centennial. A block of stamps issued on this occasion by the U.S. Postal Service mentions 38 "the first" and "the most" in the field of electric and electronic engineering. At its peak in mid-70s The Company employed approximately 200,000 people working in more than 150 divisions all over the globe.

From its inception the company was run by scientists and engineers. Its research laboratory was a perennial leader in patents and home to one of the largest population of Ph.D.'s in the world. All of The Company's Chairmen had engineering backgrounds and many of them were promoted because of their brilliance in this field. Until the early 1980s they were corporate heroes, admired throughout the company for their technical ingenuity, their deeds that proved time and again that technology can be a tool for positive social change, as well as for their "mystical" abilities like solving a Rubik's cube in no time.

In 1997 The Company officially ceased to exist. It did not go bankrupt, but all its units, but one that was in completely different business, were piecemeal sold. The company's name was changed. Its stockholders did not lose. Its employees are now probably in more secure environments then they were before. Just the system which took over the century to create and which was capable for engineering excellence has disintegrated.

The Company's demise followed a path common at that time. Increased competition and uncritical acceptance of market economy ideas throughout the society in the 1960s led to diversification of the country's businesses. To run their companies CEO's had to be investment bankers. Even when producing goods and providing services in many relatively independent markets, winning short-term financial battles became a necessary condition for corporate survival. Adjusting to new fiscal realities required a large cultural shift in upper echelons of management. The nationwide change in the rules of doing business only aggravated financial problems and led to numerous and prolonged legal battles. In many cases the old cadre of executives did not have enough time and clout for selecting and preparing their successors. Selfish people who were quick to adjust to new market pressures because of not being burdened by comprehensive and sophisticated moral values emerged at the helm. This development only further aggravated financial and legal problems that were usually pushed under the tablecloth and emerged when the next generation of leadership came to power. To compensate for uncertainty in corporate performance, executives created a

system of large perks for themselves, and stopped hesitating to carry out massive and regular layoffs. Corporate loyalty and morale started to whither away and were replaced by an insular culture of resistance. Change became obstructed, rendering a decisive reversal of fiscal downward motion very difficult or impossible. Often the situation was aggravated by difficulties in communication between top executives that had purely financial background and lower levels of management with topical expertise in their areas of production or service.

During the last 14 years of its existence the company saw a succession of 4 Chairmen. According to the former manager, the first of them, who came to power after a period of extensive and intensive intrigues among top executives behind the back of the CEO who was completely absorbed by a 4-year long series of litigations, maintained that "you had to treat the company as if it were the raider or it wouldn't survive." The second one led The Company for only 2.5 years before retiring. Being focused on short-term fiscal indicators, he achieved a considerable increase in The Company's stock price, but left a time bomb for his successor. When it exploded," The Company lost several billions of dollars and went through 5 "dig-out" years before showing a positive net income. The last Chairman inherited a company with management paralyzed by fear. According to him, the prevalent motto was: "Stay put and shut up. Don't make waves." This corresponds with my impression formed during the fieldwork.

Many other companies followed a similar downward path for shorter or longer period of time, yet they managed to survive. Why? First of all, because competition's outcome is determined by relative fiscal performance. There always are businesses that are doing better than others are, and they survive. Yet what does differentiate the companies that are able to adjust to a new market economy from the rest? In our case, among the major culprits is the fact that good engineers rarely become good managers when they are bogged down in meeting quarterly fiscal performance goals.

First, pressures of short-term survival lead to such obvious sub-optimization, and psychological factors of competition weigh so much more than technological excellence, that engineers trained to seek technical solutions optimizing the whole system, should feel acute dissatisfaction with a current state of affairs and helplessness to change it by means they are familiar with. The Company's Chairman, who served from mid-60s to mid-70s and was the last one who was able "to do well by doing good," said in a recent interview: "The thing I liked best is I provided good jobs for many thousands of people, and I did that while, most of the time, also making money. After I retired, everybody got this craze--what are we doing for stockholders?" More than 20 years later, the group we videotaped came up during the workshop with the following problem: "People have an inherent desire to solve a customer's problem, but financial considerations get in the way."

Second, engineers' confidence in quantitative predictions is often misplaced when applied to strategic management. Also they often do not pay enough attention to psychological and social phenomena. The Company's history provides abundant examples. For example, a gigantic contract was signed with customers based on a raw material price calculated according to its availability and costs of extraction and transportation. But a cartel formed by competing companies artificially raised prices to the level that was

approximately 8 times higher than had been predicted. To change the contract The Company had to go through the lengthy litigation that distracted its financial and management resources at a time its competitors were gaining pace. Large up-front investments that ignored changing public opinion on environmental issues, political situation in the world, or fluctuating consumption fads led to vast losses over and over again. It is indicative that in the 1980s, strategic planning for the whole corporation was entrusted to a "dispassionate" computer program with a name formed by directly abbreviating the 4-word sequence describing the essence of what the program did. Unfortunately, the name would better suit a monstrous villain from Disney animation. As far as we know, no obvious mistakes were made by decision-makers using the program.

At the time of fieldwork--in the summer of 1996--The Company went through two more transformations that captivated attention of all its employees. First, a decision was announced to split it into two parts: fast-growth and slow-growth. The latter would consist of all industrial divisions. Analysts expected that the stock of the slow-growth fraction would fall 3 to 4 times in price. Second, the defense division that served as a source of innovation and a testing ground for the whole company was sold. Without it The Company could not stay the leader in technology. The future was perceived as uncertain, at best.

The industrial part of The Company now consisted of 5 business units with separate P&L statements. Each business unit contained from one to several divisions that were financially independent too. Each division had its own headquarters, where engineering, marketing, sales, and human resources were located, and several production facilities. The division where the study was carried out will be called hereafter BASE.

4.2 Division where the study took place and its headquarters.

BASE is producing large electronic systems for industrial customers. It takes from a year to several years to develop and install one system. Its price varies from one to tens of millions of dollars. In the U.S. BASE has only one serious competitor, though a second one has emerged recently. In 1996 sales of BASE totaled $170M at the profit level of 8%.

BASE's headquarters are located in the suburbs of a large metropolitan city in the northeastern U.S. They occupy two 2-storey buildings connected by a skywalk. The main building hosts a production facility on the first floor; and marketing, sales, human resources, engineering, offices of the General Manager, managers of BASE Asia and BASE Europe, and of Total Quality manager--on the second. The adjacent building has a large training facility and hosts more engineering. The division has offices in 5 more U.S. cities, in Poland and Singapore, and a plant producing electronic components in Puerto Rico.

Organizationally BASE consists of three parts: domestic, BASE Europe, and BASE Asia. General Manager is directly in charge of domestic projects, yet managers of Asian and European branches report to her too. International offices of BASE have the same set of services as domestic, excluding human resources, strategic engineering, production, and Total Quality.

Domestic engineering is divided in three departments: strategic engineering (SE)--developing new systems; project management (PM)--designing and updating systems according to customer requirements; and field engineering (FE)--installing and serving systems at customer sites. A staff manager reporting to the General Manager heads each of the three groups. There are three levels of stratification below staff managers: managers, lead engineers, and engineers.

Managers have offices; engineers and lead engineers are working in the cubicles. Staff managers are in their late-50s or early-60s. They have worked with each other for decades. Because hiring was almost frozen for the last 10 years preceding the study, the average age of engineers is probably in low-40s. Majority of them worked for The Company for more than 10 years. Because of re-organizations accompanying layoffs, many of engineers worked for other departments. It looks like new hires often start in FE and later move to other departments where work is not so stressful and requires less travel. Altogether, informal cooperation in domestic engineering is ubiquitous and it is in sharp conflict with the recently introduced cross-charging policies.

Around 1993 BASE made an attempt to replace functional organization by one organized according to customer groups. Yet they kept old functional managers creating a matrix organization. Having two bosses instead of one in the environment of continuing downsizing and other cost-cutting measures led to chaos and was quickly abandoned. Yet the groups serving 4 or 5 largest customers survived partially because these customers were given preferential treatment.

Accelerating government deregulation of utilities that are accounting for more than 50% of BASE's sales caused another major cultural shift. If earlier utilities wanted the best and the largest systems, now they are requiring the least expensive ones. Trying to save on training and troubleshooting cost, utilities are also looking for simple, transparent systems. As a result, at the time of fieldwork SE was finishing development of a new system that was considerably different from the previous one. First of all, a new system can be built from standard components manufactured by other companies. This is a radical deviation from the earlier approach when most of the hardware equipment was specially designed and produced by the BASE. Organizational balance between hardware and software designers was affected. Furthermore, the whole division's identity was starting to change from electric and electronic engineering toward software development. Second, unwieldy UNIX interface of operator workstations was replaced with simple graphic displays. Third, safety and documentation requirements that previously were driven by nuclear and defense customers were considerably reduced.

The 1996 Business Performance Improvement Plan reflects the current situation. Additionally to emphasis on professional development of employees--which are provided, by the way, with an average of 26 hours of training per year--the plan calls to look for new target markets, to expand internationally, and to decrease product costs.

Statements made during interviews by corporate leadership, content of training programs, and action items in business plans--all demonstrate that there is a feeling at the top that employees are not really concerned about costs. Yet our interviews in the division, and several discussions during the workshop we

videotaped show that middle managers and engineers are very much cost conscious, but they feel that it is impossible to continue doing a good job under the current fiscal restrictions. Strict inter-departmental accountability leads to frank and vehement arguments about, so-called, commercial issues among managers. It is noteworthy that because of mutual respect forged over the years of work on joint projects, these confrontations do not cause sore feelings that could be expected. Yet they are not resolved either. Or in other cases, financial burden is shifted on external customers. Making employees buy the company's stock intensifies the pressure for fiscal performance.

For these reasons, relationships with external customers are becoming more antagonistic. For example, the workshop videotaped for this study was dedicated to customer problem resolution. It clearly showed that all its participants--managers and engineers of BASE--were resistant to inviting customers to co-develop customer service system or to make it more transparent. The participants maintained that if customers see that BASE operates in crisis mode, they would use it.

The antagonism between BASE and its customers is growing hand in hand with strengthening initiatives to seek customer satisfaction. The division has a quarterly customer satisfaction survey administered by a third party. All field engineers are required to leave their performance evaluation cards with their clients, who are requested to mail them directly to the engineers' supervisors. A philosophy of Total Quality Management, which had been embraced by the whole corporation for more than a decade, insists that sustainable customer satisfaction is tantamount to high quality and constitutes the main source of long-term profitability. This kind of indoctrination, that also sounds quite reasonable, completes the circle and leaves no escape from the dilemma of maximizing profitability by two mutually contradictory means--cost cutting and customer satisfaction.

At the time of the fieldwork staff managers knew and everybody else in the division was ready for a new wave of downsizing that had to trim 10% of manpower in engineering. Yet BASE had achieved its profitability targets for two years in the row, and a common feeling was: "the future is bright for those who will survive." Layoffs were a recurring reality for the last decade and employees learned how to live with them. Furthermore, they had learned to figure out who would be gone. People were busy with their everyday tasks, and impending cuts did not seem to cause major disturbance.

5.0 The project timeline and data collection procedures.

For purposes of systematic data collection and analysis, we adopted a classification model of team interaction and performance developed by McGrath (1984). According to this model, the essence of a team lies in the interaction of its members (p. 12). To understand the processes of interaction, one needs to consider several categories of variables:

- individual properties of team members;
- characteristics of group structure, i.e. more or less stable relationships between team members;
- properties of the task;
- properties of the embedding environment.

To learn about each of these categories, we observed a team charged with a specific quality improvement task. Using McGrath's categories of groups, one can say that the study's object was a "task force" with a characteristically limited time and activity scope (McGrath 1984: 44).

It is difficult to say when data collection began. In the summer of 1992 the author decided to prepare a dissertation on rationality of quality control in business organizations. At that time he was introduced to the RCA as one of the problem-solving methods in the battery of Quality Tools, and started to accumulate information about the properties of the task. In the spring of 1994 the author spent one month observing training of manufacturing employees at the BASE. So, when the actual project started in May of 1996, he was familiar with the division, though he never met the future workshop participants before that.

5.1 The project's timeline.

After an introduction by our common friend at the beginning of May 1996, the author approached a Director of Total Quality at BASE with a request for help with videotaping a group applying Quality Tools to solve an important business problem.

The Director just had received the last results from a quarterly survey of customer satisfaction and determined that resolution of problems the division's customers experienced with equipment installed at their sites presented the largest improvement potential. He convened several focus groups and discovered that the longest delays and mistakes in handling customer requests occurred when software problems required collaboration of three departments: Field Engineering, which worked directly with customers; Strategic Engineering, which developed the software modules; and Project Management, which combined software and hardware into customized systems.

At this time the Director of Total Quality with an advise from the *ad hoc* Advisory Team, which was formed from staff and line managers, decided to have a workshop where a cross-functional team would design a seamless customer resolution process cutting through the organizational boundaries. The only problem was to find a person who could organize and prepare the workshop. The author was at the right place at the right time to be chosen. His task was: in collaboration with the Advisory Team to clarify expectations of customers and staff management, to determine the scope of a new process, to select team members, and to plan the workshop. The Director of Total Quality, who is a kind of person who always is looking for opportunities to learn, promised the author to create conditions for videotaping and testing problem-solving and interaction preferences of participants, if all of them and the Advisory Team agrees.

It took a month and a half to prepare the workshop. During this period, with an exception of one week, the author was working like other people in engineering. It means, he was coming at 8am and leaving between 4pm and 8pm from Monday to Friday. Occasionally he had to put in some time on weekends. At the end of each day he spent from 15 minutes to an hour reflecting on recent events and writing notes. Most of this time was spent examining existing problem-resolution procedures. Working on this issue with future workshop participants was valuable for learning about their personalities and

relations with each other. Experience and knowledge of the researcher were utilized for selecting team members, clarifying specific training needs, and providing feedback to participants. This practical involvement legitimized the researcher's presence in the eyes of team members. They felt more like partners rather than experimental subjects. There was no problem when the author asked about permission to test problem-solving and interaction preferences of participants, and to videotape the workshop.

At the end of June four line managers and four engineers representing Field and Strategic Engineering, and both domestic and international sections of Project Management participated in a 2.5-day long off-site meeting. It was facilitated by a professional external facilitator with many years of experience and the background in engineering. All participants, with an exception of one of the engineers who came from a regional FE office, had been working at the division's headquarters for at least several years. All four managers had worked together on previous occasions and were familiar with each other. Interesting that all participating engineers started their employment with the division in the FE.

The workshop's map is shown in Figure 4. During the first day participants learned about their task of designing a cross-functional Customer Problem Resolution (CPR) process for software products, brainstormed problems with existing practices, pinpointed the critical ones, conducted the RCA, and generated a list of possible solutions. During the second day they drafted a new process, compared alternatives, and drew a map of a new process. Then participants devised process measures and targets to monitor effectiveness of the proposed process, formulated requirements for implementing and running the new process, discussed responsibilities of the key players, and planned the implementation phase. On the morning of the third day participants presented their proposal to staff management, and it was approved with some minor suggestions. The post-workshop questionnaire was administered at this time. Five out of eight participants answered that "the workshop turned to be better than they expected. The other three participants said that it was "the same as they expected." Because the suggestion to hire 3 to 6 people for forming a CPR support group went against the prolonged downsizing of the division, and because staff management accepted this suggestion, participants considered the workshop to be very successful.

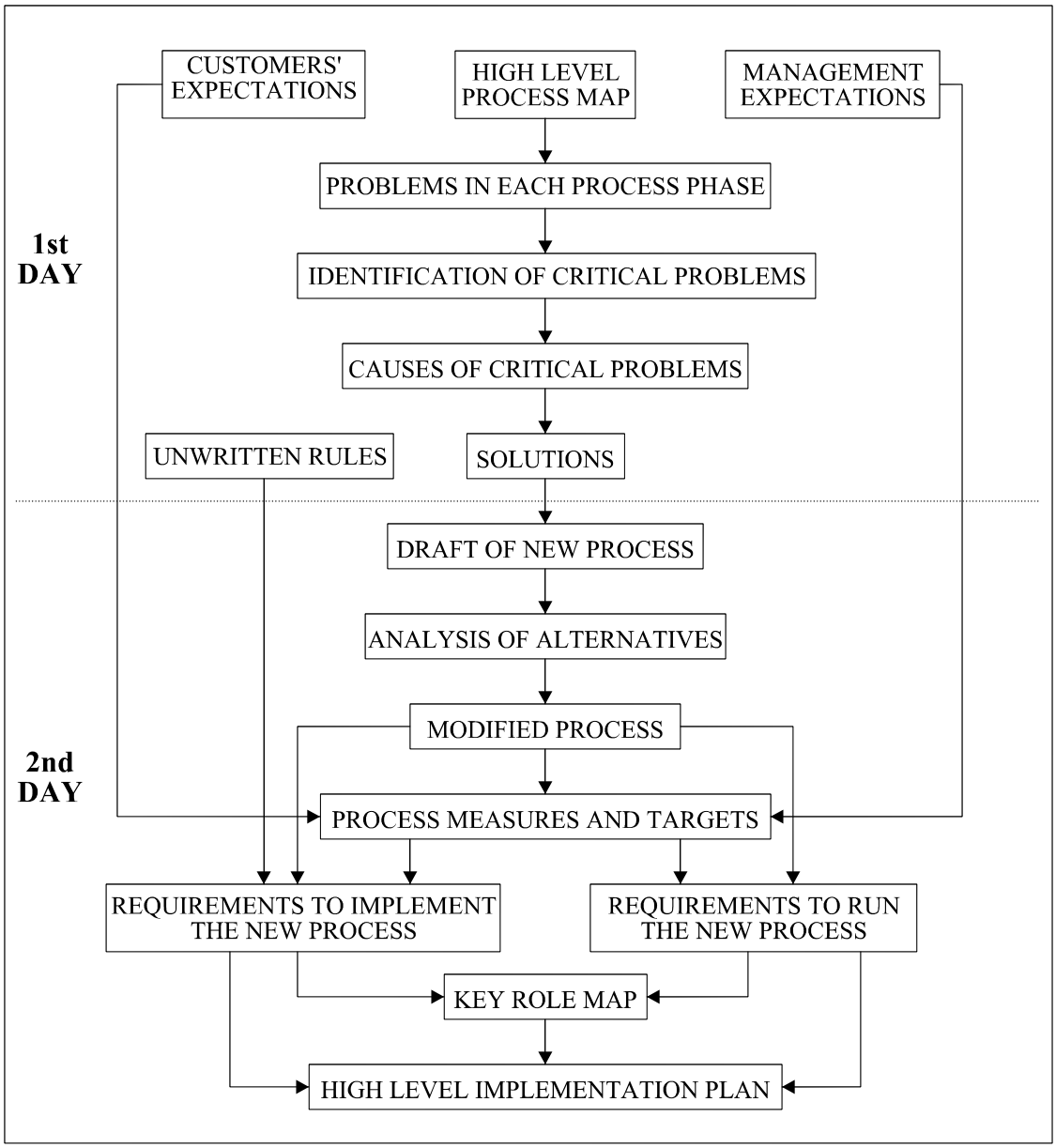

Figure 4. A flow-chart of the BPR workshop.

Two days after the workshop was over, the author went abroad and returned in September to learn that the Director of Total Quality had taken a voluntarily separation package. The CPR support group that had to report to him was being formed under FE staff manager, who had quite different ideas about how it should be organized. Another one, who also participated in the workshop, but was rejected as a candidate for this role, replaced the workshop participant that was recommended during the workshop to lead the group. As revenge, the new group leader manifestly ignored the workshop's suggestions. There was a general feeling shared by the participants, that their efforts were wasted. Nevertheless, since then we have

had several meetings with the participants to clarify events on the videotapes and to learn about implementation of the workshop's solutions. They were always cooperative.

5.2 Learning about individual properties of team members.

Individual properties of team members were studied in several ways to provide sufficiently rich data for cross-checking.

Individual problem-solving sessions conducted when forming teams were the main source of information about reasoning styles. Prospective team members were given a two-page description, which is enclosed in Appendix A, of manufacturing defects, of related production processes, and of outcomes of previous unsuccessful attempts to eliminate these defects. Then they were asked to propose their solution to the problem and to explain it to the researcher. Some participants were asked additional questions in order to solicit specific information after they completed their explanations. The answers were audio-recorded. The whole problem-solving session took between 20 and 40 minutes. It provided data on:

- tendency to concentrate attention on people versus things;
- tendency to trust management's findings:
- number of considered alternative causes, solutions, and ways to implement solutions;
- amount and purpose of explanations;
- employed reasoning type (recognition, generate-and-test, heuristic search);
- preferences for depth-first or breadth-first search strategies;
- tendency to concentrate attention on pictures, text, and numbers.

Prospective team members also were shown a 5-minute long video of a problem-solving session with 4 participants and then were asked to tell what they had seen in the tape. The answers were audio-recorded too. The test provided information about:

- aspects of interaction that attract subject's attention;
- preferred interaction style;
- opinions about proper norms of interaction and about breaking these norms;
- amount and purpose of explanations.

Working with future team members while preparing the workshop served as another source of information about their personalities. Priory to the workshop the author spent at least 20 hours in individual and group meetings with Greg; more than 10 hours with Tom, and Judy; and at least 3 hours with other team participants except Mike. Mike's participation was arranged by Rick only a couple of days before the workshop.

Videotapes provide us with an opportunity "to spend" 2.5 days more with team participants and to repeat this experience again and again. We could use this material for making inferences about their personalities using the approach developed by Bales (1970). Yet so far, we do not feel that this will provide us with new information.

5.3 Learning about group structure.

A group structure reveals itself through interaction and is described in terms of communicative acts like asking for opinion or expressing support. In our case, team members had a long history of

interaction priory to the workshop and had already established affectual or authority relationships, which were transplanted into the team's activities. Though, in principle, interaction may lead to transformation of the already established social structure, this was not our case. Thus, differential functional roles and significance of participants observed while preparing the workshop constitute the main source of information about the authority structure of the team. With regard to affective structure of the group, the data from the post-workshop questionnaire enclosed in Appendix B--especially items 11-13--complemented with knowledge of interpersonal relationships, provide the best indicators.

5.4 Learning about properties of the task.

The third class of variables influencing interaction describes properties of the task. Because the same goal often can be pursued in several ways, a task is defined here as a combination of a goal statement and the corresponding method to reach that goal.

Problem-solving methods used in industrial teams are usually divided into sequences of steps: each step constituting a separate sub-task requiring a distinctive method to carry it out. Some of the sub-tasks are less explicit then others. In order to understand the necessary sub-tasks and their sequences, as well as the skills and knowledge required to carry out these tasks (Landa 1974; Greeno 1978), we employed help from experts who teach problem-solving methods. Accuracy and comprehensiveness of the cognitive task analysis was verified while analyzing videotaped material.

5.5 Learning about the properties of the embedding environment.

Embedding environment is the last of the four factors influencing group interaction. It consists of four parts itself: observer and observational devices, physical environment, atmosphere created by recent events, and organizational culture.

5.51 "In vivo" videotaping.

The presence of an observer and the consequences of recording on interaction are at the core of methodological questions related to the field study of group performance. If the members of a group behave differently when they are aware that they are being watched, then that difference has to be accounted for purposes of adequate understanding of undisturbed behavior. Research bearing on this issue (Herrold et al 1953; Barker and Wright 1955; Sherif and Sherif 1964:10) is summarized by Fisher (1980: 318-9). He writes that group interaction participants take it for granted that other group members observe them. So, being watched is not something peculiar to an observer's presence. For this reason, if the observer is not participating in a group task, s/he will be treated simply as a completely passive group member. That is, after an initial period of learning that the observer is going to be passive, his or her impact on group behavior is not significant.

On the basis of his own research experience, Fisher concluded that unobtrusive tape recorder or cameras cause even fewer disturbances than an observer does. He reports that surveys conducted after audio taping classroom groups indicate that "they soon forget that the tape recorder is there at all."

Analyzing the language they use and subjects they choose to discuss, Fisher concludes that classroom groups demonstrate "almost total lack of inhibition" due to the presence of tape recorders and that, in general, "after the members have alleviated their primary tension, the impact of an observer or observational device will be minimized."

Video camera has become a commonly used research tool during the last decade. Jordan and Henderson (1995) discuss impact of its presence in their recent article. Using instances of direct looking on camera, as well as more subtle indicators, such as eye blinks or turn transitions, they tried to infer whether people are aware of cameras or not. Their conclusion for a variety of observed groups was that

> people habituate to the camera surprisingly quickly, especially if there is no operator behind it. Where people are intensely involved in what they are doing, the presence of camera is likely to fade out of awareness quite rapidly. (p. 55)

Jordan and Henderson report that researchers using videotaping to study classroom interactions (Roschelle et al 1991), patient-physician interactions (Heath 1986), and police work (Linde 1988) came to a similar conclusion about the impact of cameras.

Our study lends similar results. After videotaping a 2.5-day long Business Process Re-engineering workshop where 8 managers and engineers were designing how to improve resolving problems their customers experienced with software, the author administered a questionnaire. Replying to an item “Videotaping (was /was a little / was not) disturbing me.” in the post-workshop questionnaire, five out of eight participants marked “was not,” and other three participants marked “was a little.”

We would say that being observed is not so important for team members as two other factors. First, training and problem solving are perceived as services provided to participants. Being selected for a problem-solving team is usually considered as an honor. Videotaping may change the whole definition of the situation, putting participants in the role of "guinea pigs" in a scientific experiment. To eliminate this impact is possible, if videotaping is a constituent part of training as in the case when recorded episodes are used for individual feedback on interaction styles of participants.

Second, participants may be sensitive to videotaping because it creates a record of their performance that can be used by superiors for performance evaluation. This kind of influence can be diminished, if participants are promised by somebody they trust, that tapes will not be seen by anybody who is not present during videotaping.

5.52 Physical environment.

A physical environment can be new or familiar to some or all team members. It may make some participants feel like guests and others feel like hosts. It can be perceived as friendly and facilitating or as depressing. Both actual physical characteristics--lighting, noise level, temperature and ventilation--as well as the link between employees’ statuses and locations and settings of their offices may influence this perception.

The workshop took place off site--in a conference room of a yacht club. Arriving participants made plenty of comments. More information about the physical environment was drawn from notes taken during the workshop and item #14 in the post-workshop questionnaire.

5.53 Atmosphere created by recent events.

Recent events--like layoffs or generous bonuses or celebrations of achievements--have impact on employees' concerns and their willingness to participate in a novel activity such as systematic problem solving. Any visible and widely known events both within the company and in its environment--like opening of a cafeteria, or victory or defeat of a home sport team--evoke or activate memories of participants attracting their attention to some aspects of the problem to be solved rather than to others. Shared significant recent experiences also have impact on creating and maintaining group solidarity. The last part of sections 4.1 describes the author's best knowledge of recent important events that took place priory to the workshop.

5.54 Organizational culture.

Organizational culture plays an important role in forming individual features of employees. That is, it can be used for cross-checking results of observing individual properties of team members. Here one needs to bear in mind that subcultures of functional departments tend to differ according to the four categories of production processes delineated by Deal and Kennedy (1982). The distinction is based on a two-dimensional classification: fast vs. slow feedback and high vs. low risk associated with decisions. The existence or absence of a strong overarching culture should be related to the effort needed for team members coming from different parts of the company in order to overcome gaps between subcultures. The less familiar team members are with each other, the larger should be the role of shared norms and values.

Organizational culture also tends to influence behavior directly and immediately in at least two ways. First, according to Deal and Kennedy: "[m]anagers and others throughout the organizations give extraordinary attention to whatever matters are stressed in the corporate value system" (p. 33). This means that besides the efforts to solve technical problems and maintain group solidarity, team members will try to uphold and live up to organizational values. For example, if the use of a particular rational problem-solving method becomes institutionalized and acquires a ritual function of legitimizing solutions, the employment of other problem-solving methods may be inhibited. Second, it is expected that all participants are aware of the company's cultural norms and agree with them. That is, actions that lie within these norms will not be explained or corroborated and will often be taken for granted. Deviations from the norms will be considered as a purposeful action rather than as stemming from a lack of knowledge.

To learn about organizational culture, observations of activities in the division and analysis of printed materials were combined with information from interviews with both BASE employees and its customers. Although, interviews focused on specific processes of customer problem resolution,

respondents mentioned many aspects of organizational culture in order to explain why things were done the way they were. Chapter 4.0 presents a summary of findings.

5.6 Learning about problem-solving group effectiveness.

Additionally to understanding problem-solving group interaction in the sense of creating a computable description of group dynamics, the study also has a goal of clarifying how problem-solving processes influence quality of resulting solutions and two characteristics of participants that seem crucial for the implementation of solutions: direction, and coordination.

As described in section 5.1, the workshop's recommendations were not implemented. For this reason the research agenda related to effectiveness issues was folded. We do not have much material to assess direction and coordination of participants. To learn about motivational component of both direction and coordination, we had to rely solely on self-reports from the post-workshop questionnaire that is enclosed in Appendix B.

As can be seen from the questionnaire's design, we expect that motivation is related to commitment to the task, which can stem from two origins. First, the commitment may result from the desire to see the idea implemented. This part of commitment depends strongly on being directed, that is, on an understanding of technical goals and their implementation methods. Another origin of commitment is identification with the team and a desire to succeed with whatever the team has decided to do (Moreland and Levin 1982). These two kinds of commitment may clash and level of coordination of individual efforts will determine the outcomes of such conflict.

Quality of resulting solutions for the RCA episode was assessed by comparing causal diagrams generated during the workshop with the version updated by the author after reviewing videotapes. Several reasons make it plausible that the latter can serve as a benchmark for the former.

First, the final product of the teamwork served as a starting point for the author's analysis. Second, the author had considerably more time to spend on the task when participants had only 2.5 days to carry out the whole challenging workshop agenda. Third, the author was able to listen to the same discussion repeatedly on the videotapes. Fourth, while analyzing causal relations, the author was little concerned about hurting feelings of participants or about his feelings being hurt. Fifth, the author was free from the task of generating causes and focused on checking relations among only those of them which were mentioned by participants. Sixth, the author was free to consider relations between any mentioned phenomena when the RCA procedure confined attention of participants to one focal problem at a time. Finally, section 6.74 provides an explanation how each of invalid causal relations was recorded.

5.7 Summary of data collection procedures.

The following list summarizes data collection procedures in the order they were performed.

1. Interviews with BASE employees involved in customer problem resolution **(CPR)**;
2. Telephone interviews with representatives of 6 regional FE offices;
3. Observations of Advisory Team meetings;

4. Observations of focus groups from SE and manufacturing, that were devoted to CPR issues;
5. Review of BASE's yearly plans, communications from the company's headquarters to management, documentation of CPR-related processes, quarterly customer satisfaction surveys;
6. BASE customers' survey;
7. Interviews with staff management to learn about their expectations to CPR and the workshop;
8. Recruiting workshop participants;
9. Testing preferred reasoning styles of workshop participants;
10. Testing preferred interaction styles of workshop participants;
11. Hiring a facilitator and designing with him the workshop;
12. Observing and videotaping the workshop;
13. Administering post-workshop questionnaire to all participants including the facilitator;
14. Reviewing flip-charts records;
15. Meetings with participants in order to learn about the workshop's recommendations implementation progress;
16. Reviewing videotapes with participants in order to clarify complicated episodes.

Some of the above items sound like job activities rather than data collection procedures. Yet in the tradition of action research, all of them were used to learn about different facets of McGrath's model and effectiveness indicators. To show what kind of information was extracted from each of the 16 data collection procedures, we use a matrix shown in Table 3.

Table 3. Data collection procedures (rows) used for learning about elements (columns) of McGrath model and dimensions of group effectiveness.

	A	B	C	D	E	F	G	H	I
1.	+	+		+			+		+
2.				+					+
3.	+	+		+			+	+	+
4.	+	+	+	+	+	+			+
5.				+					+
6.				+					+
7.				+					+
8.	+	+					+	+	
9.	+								
10.	+								
11.	+		+						
12.	+	+	+		+	+	+	+	+
13.		+		+	+		+	+	
14.			+			+			+
15.	+	+			+	+	+	+	
16.	+				+	+	+	+	+

The columns contain 4 categories of variables from McGrath's model, as well as 4 individual and 1 group measure of problem solving effectiveness. The following list of elements defines the columns.

A. Individual properties of team members;
B. Characteristics of group structure;
C. Properties of the RCA task;

D. Properties of the embedding environment;
E. Motivational component of direction - D_M;
F. Understanding component of direction - D_U;
G. Motivational component of coordination - C_M;
H. Understanding component of coordination - C_U;
I. Quality of solutions (causal diagrams).

Rows in Table 3 are numbered according to the list of procedures, and letters denoting columns correspond to items in the list of elements. A "+" sign on the intersection of a column and a row indicates that this row's procedure was used to learn about the column's element. Multiple sources of data for each element of McGrath model and effectiveness indicator enable introduction of several operational definitions for the same element and permit cross-checking of findings.

6.0 Data analyses and their results.

The employed data collection procedures generated a variety of data. Consequently, they were analyzed in different ways described at the beginning of each section in this chapter. Because, first of all, we are interested in emotional and cognitive dynamics observed during the group's interaction, the corresponding section 6.6 is most rigorous methodologically and includes a formal study of coding reliability. Inferences about the components of McGrath models, that define the context of interaction and are reported in sections 6.1 – 6.5, were made in a systematic way but their reliability was not formally estimated. The same can be said about the concluding section 6.7, which attempts to relate group dynamics and indicators of problem-solving group's effectiveness **(PSGE)**. The section 6.3 points to a summary of individual properties of workshop participants and their positions in the social structure.

6.1 Individual properties of team members.

Information about individual properties of team members comes from a number of sources listed in Table 3. In this section we will present outcomes of interpreting data from only one of them—tests of problem-solving and interaction style preferences, which are described in the section 5.2. Information from other sources was not collected or analyzed systematically and serves as a background for inferences made below.

Audiotapes with participants' responses were analyzed by listening to them and filling out, first, the forms with 11 items for problem-solving preferences and, second, 9 items for interaction style. The items were designed prior to reviewing audiotapes. After both forms were filled out for one participant, the responses of another one were examined. The completed forms are contained in Appendices C and D. The item "Flow of the Answer" was included to eliminate listening audio-tapes each time we need a reminder what was said by a participant and in which order. "Comments" capture everything we found to be noteworthy but not belonging to other items.

6.11 Preferred problem-solving approaches of participants.

In order to compare the participants' problem-solving preferences, we compiled a summary of findings contained in Appendix C. It is shown in Table 4.

The 1st column in the table indicates how extensively the participants explicated their reasons for stating causes of defects and proposing particular solutions. The 2nd column provides a number of stated causes and whether use of lotion—marked with "L"—and the most logical cause of used up lotion on effectiveness line—marked with "W"—was among them. The 3rd column provides a number of relevant facts that were mentioned while explaining why particular causes or solutions were proposed. The 4th column provides a number of solutions proposed by each participant. "o" in this column indicates that these were organizational solutions, "t" – that these were technical solutions. When solutions of both kinds were suggested, we used notations "o+t" or "t+o." A first letter corresponds to the predominant kind of solutions. The 5th column demonstrates that all participants were providing more or less clarifications about the ways to implement solutions they suggested. Some of the participants paid more attention to finding defects—marked with "f"—others focused on how to correct them—marked with "c"—and still others considered both procedures. The 6th column shows whether a participant demonstrated sensitivity to feelings of employees working at Spring Breeze, and took a human factor in consideration, when proposing solutions and ways to implement them. The 7th column describes in which tone a participant made his or her recommendations. The 8th column indicates a participant's attitude toward reliability of Spring Breeze management findings, described in the handout. The 9th column describes what kind of reasoning—HS=heuristic search; GAT= generate-and-test; recog=recognition—was predominantly utilized by a participant. **ND** here and in other columns means "not demonstrated." The 10th column shows the major motivation of a participant for performing the test. "request" means that a person was driven mostly by my request. "help" means that a person tried to help me to understand how they solved the problem. "image" denotes that a respondent was trying to look like a competent person. "puzzle" means that a respondent was fascinated by the challenge of the task. "improv" means that a person was seriously trying to improve the described business process as it were real. Columns 11 and 12 indicate use of numeric information and diagrams provided in the handout.

Table 4. A summary of results from problem-solving preference tests.

Partici-pant	(1) Explan-ations	(2) Causes	(3) Facts	(4) Solu-tions	(5) Proce-dures	(6) Human factor	(7) Tone	(8) Accept-ance	(9) Reaso-ning	(10) Motiv-ation	(11) Num-bers	(12) Dia-gram
Tom	few	1,L	0	2,o	c	yes	neutral	full	ND	request	no	little
Judy	many	3,L,W	3	6,o+t	c	yes	tentat	doubt	HS	help	ND	ND
Craig	few	1,L	0	8[2],o+t	c	yes	bold	full	GAT	image	ND	ND
Dave	many	6,L	5	2,o+t	c+f	no	natural	doubt	HS	puzzle	yes	ND
Rick	averg.	5,L	4[3]	3,o	f+c	no	polite	full[4]	recogn	request	some	ND
Mike	many	4	4	2,o	c+f	yes	natural	doubt	HS	puzzle	yes	yes
Sam	few	1,L	0	2,o	c	yes	thghtf	doubt	recog	request	no	yes
Greg	many	3,W	6	3,t+o	f+c	no	bold	full	HS	improv	yes	yes
Andrew	few	1,L	5	0	f	no	bold	doubt	ND	image	yes	yes

The results presented in Table 4 are not sufficient for making any prudent inferences how participants will behave in other problem-solving situations. For example, during his collaboration with Tom while preparing the workshop, the author formed a quite different impression about Tom's aptitude to and for detailed analysis of problems. It seems us, that for the whole duration of the test Tom remained confused by the goals of testing. Probably figuring them out captivated his attention. As a prospective team leader, he felt like being tested for this role. Consequently he was tense and carried out no thorough analysis of the task he was asked to do. It even is difficult to determine what kind of reasoning he employed.

Five participants—Judy, Dave, Rick, Mike, and Greg—explained at length how they discovered the causes and substantiated them by facts. Though, 2 out of 5 causes mentioned by Rick were based on his assumptions, which were grounded, probably, in his experience rather than in the description of Spring Breeze production process. This is an interesting trait by itself.

All participants explicitly discussed procedural issues of implementing solutions. Dave, Rick, Mike, and Greg paid attention to diagnosing the defective process.

The main purpose of testing problem-solving approach preferences of participants was to learn about their individual cognitive processes. Yet, the handout describing production problems at Spring Breeze includes social issues as well. For this reason, some participants paid more attention to psychological aspects of finding origins of defects and of implementing solutions than others. Also, through the interaction with the author who administered the tests, the participants revealed some features of their interaction style, which are captured in columns 6,7, and 10 of the Table 4.

Similarities observed in columns 9, 11, and 12 provide at least some tentative indication about commonality of cognitive styles and information representation means. We can presume that they will influence choice of partners for collaboration during the workshop.

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[2] Two of the solutions were just a joke.
[3] 3 out of 4 facts were assumed by Rick, but not mentioned in the handout.
[4] Is aware that other causes are possible too.

6.12 Preferred interaction styles of participants.

To learn about inclinations of participants for particular tactics while interacting in a group, right after the problem-solving preferences test we showed them a 5-minute long episode where 4 people—let us call them S, H, D, and C—were solving the Spring Breeze problem together. S was a female; H, D, and C were males. The episode started from an emotional explosion of C against H's suggestion to involve foremen in collecting more date about defects. C had stayed mostly silent for the whole duration of problem-solving—about one hour—prior to his exclamation "I completely disagree with this!" Explaining his position, C also proposed to involve foremen, like this were his idea opposite to what was said by H. The argument between C and H continued as a sequence of making essentially the same statement, but starting it from "no." C was speaking in a loud, excited voice, when H stayed calm and extensively substantiated his opinions. S and D attempted to interfere and stop this unproductive exchange, but they were not assertive enough.

At the end of the episode, the author invited contributions by asking each participant the same open-ended question: "What was happening here." We were interested what they would say, assuming that their first words would reflect their focus of attention, and probably, their unsatisfied needs related to group interaction. The assumption is based on another one; namely, unsatisfied needs are directing a person's attention in addition to shown material. Then participants were asked more questions. To learn about their preferences for selecting partners, we asked with whom a participant would like and would not like to be on the team. And to learn about the ways they would consider appropriate for dealing with interpersonal collisions, we asked each participant how she or he would resolve the conflict. The results of interpreting audiotapes are presented in Appendix D. Below we summarize our findings.

Responding to an open-ended question, Tom, Judy, Craig, Rick and Andrew said that the group was stuck in an unproductive exchange. Tom and Rick also added that there was no leader to stop it. Dave looked on the situation from the cognitive viewpoint, noting inability of H and C to understand that they were arguing the same point. Mike requested additional information about the roles performed by people on the videotape, and given an answer that this was a fictitious company and no roles were assigned, he found it impossible to answer the question. Sam and Greg made remarks about the content of the argument rather than interaction. Sam spoke about a dilemma of being a manager—"making money"—and caring about people. Greg continued to elaborate his thought that in order to eliminate defects, the concentration of washing solution has to be adjusted.

Responses of Tom, Judy, Craig, Rick, and Andrew follow from the nature of the task they were asked to perform. Reactions of other 4 participants reveal their idiosyncratic features; namely, Dave's inclination to pay attention to cognitive processes of other participants, Sam's preoccupation with his dilemma of "a human manager," Mike's slow and prudent reasoning requiring complete information for making inferences, and Greg's tendency to be carried away by his own train of thought to the point of

disregarding his interlocutors. As we will see later, these observations are consistent with interaction videotaped during the workshop.

Answers of the participants to the questions: "With whom would/wouldn't you like to be on a team?" are summarized in Table 5.

Table 5. A summary of the participants' choices of teammates (item 3 from Appendix D).

Participant	would like				would NOT like				ambiguous			
Tom		H	C					D				
Judy	S					H						
Craig	S										C	D
Dave	S			D		H	C					
Rick	S	H					C					
Mike		H						D				
Sam	S	H	C	D			C					
Greg	S[5]	H										
Andrew	S	H					C					

It is clear that the workshop participants liked S and H and did not like C. In this light, it is interesting that Judy clearly disliked H because he was "unwilling to go on and leave the issue alone." She did not accuse C in the same transgression. It is possible, that here we observe an idiosyncratic reaction, based on H's similarity to somebody familiar to Judy and disliked by her. Both Tom and Mike explained their negative reactions to D by lack of his substantive contribution: he barely said several words during the episode. Sam's dislike of C and Greg's sympathy to H are underlined to show that they were explained in terms of reception or rejection of what people said, rather than their behavior in the group.

The participants' explanations of their likes and dislikes, which are presented in Appendix D, shed additional light on personalities. Craig values knowledge of "real world" and does not mind working in the intensive social atmosphere, if it is friendly. Dave again comes through as a person who is especially sensitive to conditions for cognitive information processing. He distinguishes between those who are listening well, and those who are only talking. Mike evaluates team members first of all from the viewpoint of providing him with input for reasoning.

Listening to Tom's explanation, the author realized that Tom looked at the test as an examination of his ability to perform team leader's duties. In this case, he saw in the conflict between H and C an opportunity for a leader's intervention.

The participants' answers to the question: "What promotes/hinders effectiveness of the problem-solving team like this?" are definitely shaped by the events of the episode. The responses, which are presented in item 4 of Appendix D, refer to a need for a good leader or facilitator, absence of clear objective, and fear to lose in front of one's colleagues. A remark by Mike—who was the only BASE employee tested after the workshop, and probably reflected on it too in his comments—is noteworthy here.

Among the obstacles to group effectiveness he mentioned an outside facilitator, who does not know where are sensitive issues.

Greg's response helps to understand his persistency in proposing his ideas during the workshop. He knows that he has a reputation of a close-minded person. So, he is not afraid to create it. Yet among the features that promote group effectiveness he mentions "an ability, to be allowed, to say what you want to say, instead of being ridiculed."

6.2 Social structure of the problem-solving team.

For a systematic analysis of group structure we employed a theoretical framework proposed by Bales (1951). He distinguished four "most general or universal kinds of differentiation which exist or develop between persons as units in small groups." They are based on differential degree of:

- access to resources;
- control over persons;
- status in a stratified scale of importance or prestige;
- solidarity or identification with the group as a whole.

During the differentiation processes these degrees influence development of each other. Yet none of them completely determines another one.

Interaction may lead to changes in a group's structure. In our case, an anticipated formation of a support group under Judy's supervision has increased her prestige at the end of the workshop. Her identification with the group has grown too. In contrast, after Greg had failed in convincing the workshop's participants that the support group had to be formed in FE department, both his prestige and solidarity went down. Yet these changes were not dramatic. All active participants—Judy, Dave, Sam, and Greg--had known each other for a long time priory to the workshop and went through many similar decisions. The workshop's suggestion to form a new group and to promote Judy still had to be implemented and confirmed by staff management. Also, the suggestion was formulated only at the end of the second day. For this reason, we can consider that the structure of the observed group during the Root Cause Analysis, which took place in the middle of the first day, is stable enough to be described and is similar to one at the beginning of the workshop.

6.21 Differential degree of access to resources and control over other participants.

These two components of social structure are closely related to each other and to formal position of participants in organizational hierarchy. Tom, Rick, Sam, and Greg are line managers in engineering. They represent 4 independent groups and report to different staff managers. They are formally financially independent, but often have to negotiate a variety of issues. Tom is a manager of software validation in SE. Rick is a project manager in BASE Asia. Sam is a project manager in domestic group. Greg is a manager of headquarters' office of FE.

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[5] Greg's liking of S was stated in item 4 in Appendix D.

Judy, Craig, Dave, and Mike are engineers. Judy reports to Tom, Dave to Rick, and Mike works in PM group of BASE Europe. Craig works in one of the domestic regional offices of FE. At the time of data collection he worked with Judy at the BASE headquarters studying new software products, and temporarily reported to Greg.

With respect to differential access to knowledge of the business process that was re-engineered, the group was arranged to have representatives from each part of BASE that was involved in customer problem resolution problem. Yet it turned out that the parts of the process performed, first of all, by Judy and, second, by Greg's group—FE—required substantial changes and became the focus of attention for the most of the workshop's time. Working in FE and studying with Judy, Craig also was in a privileged position from the viewpoint of possession of relevant knowledge.

As a facilitator, Andrew had formal right to control the workshop's flow by formulating questions to particular participants or the group as a whole. His right to interrupt other participants was never challenged too. Tom, though officially he was appointed to be a team leader—a person who controls selection of substantive issues to be addressed by the group—almost completely yielded this duty to Andrew.

6.22 Differential degree of status in a stratified scale of importance or prestige.

Bales (1951) wrote about this component of social structure as not completely derived from superiority of access to resources or from formal authority, due to the tendency toward "generalization." It means, that people remember former instances of manifestation of power, or lack of it, by others and "generalize" them across situations. In this way, expectations of are formed, which may be more or less valid under new circumstances. In our case, from the very beginning of the workshop Dave seemed to have reputation of a tactful person capable to resolve interpersonal conflicts. On the opposite, priory to the workshop the proposal to appoint Greg as a team leader was rejected by the Advisory Team on the grounds that he "is considered not very bright."

6.23 Differential degree of solidarity or identification with the group as a whole.

As was mentioned earlier, willingness to participate in a group's effort can originate from expectations of a variety of benefits and pleasures derived from the affiliation. Still Durkheim (1912/1965) has distinguished between mechanic and organic solidarity, which approximately map correspondingly onto the motivational components of coordination—C_M—and direction--D_M. Because solutions proposed by the workshop were formulated after the Root Cause Analysis, and during the episode analyzed in a current study it was even not clear in which direction problem solving would proceed, identification with technical solutions was not possible. Yet solidarity based on previous associations could be observed in a sitting pattern shown in Figure 6.

Without any deliberate arrangement, participants sat at the table according to their preferences. Unfortunately it was not videotaped, how and in which order the seats were chosen, and now we cannot

obtain additional confirmation from observing the sequence in which they were filled. Anyway, Tom and Judy clearly formed an “SE block.” Craig sat next to Judy because they worked closely together, and he was not well familiar with other participants. Dave, probably, tried to sit close to Judy too. Deciding from Dave’s strongly negative reaction when at the stage of recruiting workshop participants he learned that both Judy and Rick are put on the team, he cares about Judy more than just about a colleague. If Dave did not tell the author that Judy and Rick had been recently divorced and were going through quite bitter lawsuit “dividing” their son, we probably would never learn about this “negative identification” serving as an important background for interaction. Without this knowledge, we could not interpret Rick’s outburst directed on Judy in his post-workshop questionnaire, where he claimed that she dominated the workshop and singled out Greg as the most useful participant.

Dave, Rick, Mike, and Sam formed a “PM block.” Greg’s sitting may be determined by another negative affiliation: as far as possible from Judy, and having only one neighbor in the group he was prepared to wrestle with from the very beginning. Yet we are not sure that this was the only reason.

Identifications that existed priory to the workshop seemed to be much stronger than solidarity of the team as a whole even at the end of the workshop, which dared to recommend hiring new people and managed to obtain agreement of staff management on this issue.

6.3 A summary of individual properties of the workshop’s participants and their positions in the group structure.

Presentation of materials in the sections 6.1 and 6.2 is organized according to the properties that were discussed. This permits easy comparison among the participants and economical referrals to data sources. Yet it makes difficult to create a full image of each participant. In the Appendix E we compensate for this disadvantage by drawing succinct portraits of all workshop participants using essentially the same information about individual properties of workshop participants and their positions in the social structure as already has been provided in the two previous chapters.

6.4 Properties of the Root Cause Analysis task.

6.41 What RCA is for.

Root Cause Analysis **(RCA)** is a problem-solving technique used for getting away from symptoms of problems and discovering real or, so-called, "root" causes. It can be used both individually and in a group. Group approach includes methods to ensure complete and balanced participation of all members additionally to techniques for structuring cognitive processes. Usually RCA follows a brainstorming session, which generates a list of concerns that are on the top of problem-solvers' heads. Due to the nature of attention, most of these concerns mention phenomena leading to acute stress and dissatisfaction. Often than not the concerns will reveal locations in business processes where problems are detected but not where they are created. The RCA is designed to surface phenomena, which may be far

removed from the hot places, but are causing problems mentioned in brainstorming sessions. Root causes are causes which pass one or several of the following usually related criteria:

- changing root causes leads to long-lasting effects. It means that there are no strong forces which will continue to exist trying to bring the whole system back into the old state;
- changing root causes will prevent problems from happening;
- changing root causes will solve several problems at once;
- changing root causes is expedient: i.e. it has low cost/benefit ratio, leads to possibly minimal distress, and is within the authority of supporters of the change initiative.

The first three of these criteria reveal an essential function of causal search: its goal is prediction. In other words, while searching for causal relations we attempt to discover characteristics of the system which will allow us to change it in desired ways.

All four criteria are not easy to apply, but the last of them is especially "soft" because it is bound by specific situation and depends on attribution of supportive attitude to key role players. It would be difficult to use the above definition for determining whether something is a root cause or not. But it is not intended to serve this purpose.

6.42 Generation and verification phases of the RCA.

The aforementioned criteria[6], or more precisely, the description of characteristics of root causes is used for explaining the RCA participants to what they should pay attention when generating causes. Selection of root causes usually constitutes the second part of the RCA. The first part consists from following cause-effect relations to find as many causes of the problem at hand as possible. Participants' attention is directed to relevant information by using "why"-operator which can be written down in its general form like:

$$\text{why } \{\text{event.n}\} \Rightarrow \text{event.(n+1)}$$

This is an operator acting on one knowledge-state and producing a new knowledge-state which is used, in turn, for guiding the next move in the problem space. Because each outcome of applying "why"-operator results in a new solution to the problem of generating causes, the procedure looks like the generate-and-test method (Newell and Simon 1972: 95-100) But the fact of utilizing knowledge, produced during the previous step, for directing the search shows that "why"-operator exemplifies the heuristic search method, which also is described by Newell and Simon (pp. 101-105).

Often only the first part of the RCA is performed in a structured way. After causes are recorded, a facilitator leads a group through the list asking if there is a "good" solution for each of the recorded causes. In this way, selection of solutions for implementation is performed on the set of generated solutions. The

[6] A notion of root cause is very similar to a notion of leverage in systems thinking (Senge 1990). Senge writes about leverage as □seeing where actions and changes in structures can lead to significant, enduring improvements.□ He continues, □Often leverage, follows the principle of economy of means: where the best results come not from large-scale efforts but from small well-focused actions.□(p.114)

task of detecting root causes is eliminated at all. This kind of abridged approach was employed in the studied case.

Versions of the RCA differ according to the ways they generate causes. Probably, the most widespread method is called a Fishbone Diagram. It was invented by Ishikawa (1986) and also is called an Ishikawa diagram. During the observed problem-solving workshop the facilitator was using another RCA technique. It is called "5 Whys." According to this method, a facilitator first elicits causes of the investigated problem X by repeatedly asking, "Why X happens?" These are the so-called "1st tier" causes. The procedure of asking "why" is repeated taking each of them as a focal problem and generating a list of 2nd tier causes. As the name of the technique suggests, it is recommended to continue until the 5th tier is filled out. In practice, rarely when the search extends beyond the 3rd tier. It is recommended to write same tier's causes for each focal problem on a separate flip chart. The recommendation was not followed in our case. Also the facilitator often proceeded with asking "whys" of subsequent tiers before completing the one he was working on.

In general, the facilitator tried to carry out the following sequence of steps:

1. select focal problem; if this is the last problem of the fifth tier, stop;
2. ask why this problem happens. If no contributions provided, go to 1;
3. interpret and fit the contribution to the focal problem;
4. record contribution;
5. check if the group agrees with what was recorded; if not, go to 3;
6. go to 2.

Selecting next focal problem usually was not an issue: the facilitator went down the list of Nth tier until it was exhausted. There are many ways to ask "why". A decision which one to use depends on sensitivity of the topic and distribution of status and expertise within the group. In our case, participants volunteered causes by speaking up. It is recommended to record contributions in terms as close as possible to participants'. How to check the group's agreement with the recorded statement and what to do in the case of disagreement depends very much on the context too. In our case, the facilitator read what he just had written aloud and asked if it was correct addressing the whole group or the person whose contribution was recorded.

6.43 Cognitive tasks inherent to the RCA.

As we will see in the example below, during the RCA a facilitator is under constant strain while attempting to pursue 2 goals in parallel: to interpret contributions in order to record valid causal relations and to ensure a productive environment for eliciting causes. The issue of facilitating contributions of participants has at least 3 aspects too. First, they have to understand the logic and purpose of the exercise. Second, they have to follow the evolving chain leading from one cause to another. And, third, they have to be willing to reveal problems with their work processes and to be given an opportunity to contribute when they are ready.

Understanding the logic and purpose of the RCA is not easy to achieve. The RCA is considered to be among the most difficult techniques from the standard battery of systematic problem-solving tools

widely used for BPR and known as Quality Tools. Confusion usually begins when facilitator tries to introduce a concept of root cause.

On the level of common sense the concept seems to be clear and straightforward. It is easy to provide plenty of examples. For example, a flat tire as a root cause of problems with steering a car, bumpy ride, and noise. Yet even in such relatively simple, completely engineered according to specifications system as an automobile there are many situations when able and experienced mechanics are not able to identify the root cause. There may be no root cause at all as in situations when several small deviations from target performance combine resulting in clear malfunctioning of the system. Such outcome is especially probable in non-linear systems with positive feedback.

Another reason for difficulties with finding root causes lies in the way they are usually sought. Experts rarely look for root causes moving from symptoms backwards along the possible causal links. Usually they first have a hunch based on recognition of the pattern in symptoms. Then they check their guess by looking for deviations from normal in the suspicious part or by replacing it with a definitely good one. If their intuition was correct, they may delineate how symptoms were caused by a malfunctioning part. In this case, both starting and ending points are known before rationalization of causal connection between them. Although root causes and symptoms may be related in several possible ways, the *post factum* explanation usually mentions only one of them. It provides a description or one possible scenario, not a proof, of the causal relation. The proof would require building a shared conceptual model of the whole system (cf. Simon 1977).

When there is no clarity about what is normal and what is not, or replacement by a definitely good part is impossible, even experts will experience problems with finding root causes. The situation is typical for efforts to improve organizational processes. Still, search for root causes can be divided in two stages. First, discovery of possible root causes, which can be based on recognition of familiar patterns or backward causal search starting from symptoms. Second, comparison of generated answers by examining validity of causal links.

On the basis of our observations we would say that workshop participants rarely had difficulty answering "why" question about their everyday surroundings, if they were not forced by somebody, including themselves, to prove that their answer was correct. Within several seconds after being asked, "Why P happens?", they started mentioning causes: "X1", " Because X2", etc. It was more important for participants to have their ideas recorded than to have valid causal statements. From examining contributions of participants after the workshop, it became clear that sometimes, and quite often, statements recorded on flip-charts as "X causes P" were not valid. They would be more correctly recorded as "P causes X", or "both X and P cause Q". Yet to start proving that something is a cause at the stage of discovery, was the surest way to confusion.

Without a shared model, an attempt to prove that something is a cause of something else becomes practically impossible. Four examples illustrate this point.

First, unless a group limits itself to a conceptual construct cut out of the context, or in other words, creates a clearly bounded shared conceptual model, for any complex system it is easy to come up with a scenario when P disappears without changes in X, and changes in X will not eliminate P. If one of the participants comes up with a statement "X causes P", it is not difficult for another one to rebuff it with "Not always."

Second example is even simpler. Same outcome can result from different causes. When we have a cross-functional team with representatives from several departments, a definitely existing causal connection for one participant can be just an exercise in imagination for another.

Third, a participant could be more familiar with details of some of the examined processes than with others. For this reason a statement "X causes P" could be rejected by somebody who knew about such intermediary phenomenon Y, that X causes Y and, in turn, Y causes P.

The fourth example illustrates one more pitfall for proving causal relations according to the RCA methodology. Participants tended to think in terms of solutions: if we do X, problem P will disappear. But they were asked not to talk about solutions prematurely. For this reason they would say ~X causes P. When X causes ~P may be correct, ~X causes P may be not. In other words, often participants unconsciously introduced an assumption that X is necessary and sufficient for P. This is a strong statement, and it is not surprising that it does not hold under a wide array of conditions. Difficulties stemming from the requirement to distinguish between necessary, sufficient, and necessary and sufficient conditions constitute a well-known origin of errors made by humans while using the heuristic search method (Newell and Simon 1972: 228)

All four examples demonstrate that proving validity of causal relations is equivalent to creating a well defined shared mental model of organizational functioning. Holzner and Marx (1979:99-100) noted that building such model requires to resolve possible disagreements about taken-for-granted assumptions, preferences for symbol systems, analytical devices and "reality or truth tests by which both the basic beginning points of the experiential base and the knowledge outcomes are validated." Using their term we can say that creating shared conceptual models is contingent on ability of participants to reconcile their frames of reference. For participants with different professional backgrounds this task is clearly beyond the limits of what can be accomplished during a period of several days. Fortunately, priory to workshop several participants had worked in other departments and were, so to say, cross-trained. Also, as was mentioned before, the proof is not necessary for carrying out the RCA, yet discovering valid causal relations is an important part of understanding the BPR task. This understanding is one of the three components of problem-solving effectiveness, which constitutes our ultimate concern.

The task of distinguishing between valid and not valid causal relations proceeds on two levels: semantic and syntactic. On the level of syntax one attempts to build "P happens because of X" structure. On this level both of the following constructions are equally valid:

- departments are not allowed to hire because there is no budget allocated for this purpose;
- and, departments are not allowed to hire because 2 times 2 is four.

On the semantic level one seeks an existing mechanism which creates an effect when its cause is present. If an individual has no doubt that the mechanism exists and works in this way, s/he considers that the causal relationship is valid. There are different gradations of doubt depending on available evidence, repertoire of processes available in the evoked set, and truth tests employed by individuals. These factors, as well as a host of others, become important when an issue of existence of causal relations is debated in a group.

6.44 Classification scheme for cognitive tasks performed during the RCA.

Studying the conflicts which occurred during the episode we were considering descriptions in terms of several well-known dichotomies: like Bales' (1951) distinction between Adaptive-Instrumental and Integrative-Expressive tasks, Goffman's (1959) distinction between "who is right" and "what is right" orientations, and the distinction between cognitive and emotional approaches to a problem.

Initially we thought that these are three different ways to capture the same difference. But gradually we realized that they are separate though related. Also to analyze differences in problem spaces of participants we needed to distinguish between 3 kinds of tasks.

The observed group clearly performed Adaptive-Instrumental tasks of two kinds: procedural and substantive. Discussions of the former address the question "What should we do now?" when of the latter - the question "What is true or correct." Different goals lead to different problem spaces. Integrative-Expressive tasks rarely are discussed explicitly. Yet they can be considered to be a special class of procedural tasks aimed on managing tensions and anxiety. Consciously or not, participants are looking for what they should do now to avoid disruptions of interaction's dynamics. Therefore, a classification of group tasks in three categories: tasks aimed on interaction management **(IMT)**, procedural tasks of planning application of problem-solving methods **(PT)**, and substantive tasks of correctly carrying out each step of problem-solving methods **(ST)**—better reflects the differences among cognitive states, which are also called problem spaces, of participants.

Participants can evoke an infinite number of other problem spaces. Yet the aforementioned three seem to be exceptional because they represent a set of three tasks that is necessary and sufficient for collaborative problem solving. In other words, to solve a problem in a group participants have to stay together and be productive, to coordinate their actions, and to examine the substantive task at hand. If they succeed in all three tasks, the problem probably will be solved.

Transitions between the three problem spaces occur quite rapidly and after irregular intervals. Just for an illustration, Figure 5 shows the facilitator’s performance of the three tasks during the approximately 8-minute long episode.

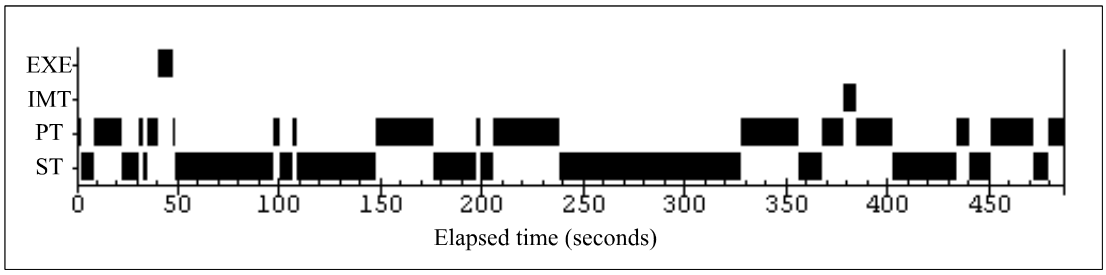

Figure 5. Time-event plot of facilitator's performance of substantive (ST), procedural (PT), and interaction management (IMT) tasks. EXE stands for expressive behavior.

One can see that the facilitator spent approximately 60% of all time in ST mode, and almost all other time in PT mode. He spent only about 1.5% of total time on IMT, and was expressive for another 1.5% of the episode's duration. There were 34 alternations between the ST and PT modes during the episode. The average time between the alternations was approximately 15 seconds.

Working in each of the aforementioned problem spaces participants can become more or less emotional as well as they can engage in more or less intensive reasoning, i.e. they can be more or less cognitive. The relationship between being emotional and cognitive is not of "the less, the more" kind. It means we need at least two separate dimensions to describe in which extent participants are emotional and cognitive at any particular moment.

Goffman's (1959) distinction between working and ideal consensus brings one more dimension relevant for analysis of communication among participants. In their discussions and/or by their actions participants may address a "what"-question. For substantive tasks this will be a question of what is true or correct. Being in PT problem space participants may be asking what should we do in order to complete the substantive task. And while in the IMT mode, participants may focus their attention on what will make everybody present feel comfortable. Yet it is possible to perform each of the three tasks by delegating answering of "what"-question to a subgroup or a single participant. To do so, participants have to resolve a question whose solution they are going to accept: they have to address "who"-question. Usually this is done by considering expertise and trustworthiness of participants, as well as importance of the discussed issues for each of them, and their social capital. In the case of technical tasks this approach involves very different problem space from one used for answering "what"-questions.

6.5 Characteristics of the workshop's site.

As was mentioned in the section 5.5, the last of McGrath's factors influencing group interaction--embedding environment—consists in our case of four parts: observer and observational devices, physical environment, atmosphere created by recent events, and organizational culture. Some of them were already discussed in that section. Now we will describe the workshop's setting and events, that occurred during it and might had influenced group interaction, in more detail.

The workshop took place in a conference room of a yacht club located about a mile away from the headquarters of BASE. The decision to conduct the meeting off-site was made by the Director of Total Quality who maintained that novel environment would facilitate “out-of-box” thinking, and would improve participation by preventing departures of participants to their offices for making phone calls and urgent meetings.

The room was approximately 60 by 40 feet. One long stationary wall and two other walls formed by movable partitions were covered by light gray tapestry with a barely visible texture. A glass wall along the fourth—narrow—side of the room was overlooking a dock with boats. Wall-to-wall carpeting was decorated by floral ornament. For purposes of videotaping the shades on the glass wall were drawn. The room was brightly lit with two large candelabra and additional built-in ceiling lights. In one word, the interior was much more festive than at BASE.

Participants sat around a large table covered with a white tablecloth as shown in Figure 6. Andrew was writing on one—or sometimes two—flip-charts mounted on easels. Filled flip-charts were taped to the walls. During the RCA the front wall, at which the facilitator was working, was covered with flip-charts containing all problems generated during the previous brainstorming session. The glass wall was behind Tom and Judy. The entrance to the room was in the partition behind Sam and Greg. There was a table with donuts, coffee, soda, and fruits in the corner behind Judy and Craig. The Director of Total Quality and the author sat at the small table in the corner behind Mike and Sam. Three cameras were placed as shown in the figure.

The settings were quiet, and it was easy for all participants to see what was written on the flip-charts. Though, only Greg and Sam were able to see flip-charts while Andrew was writing. The table’s size—about 10 by 5 feet without an appendix for the facilitator’s materials—was limited by the requirement to place participants sufficiently close to flip-charts. Yet this made some of them feel being crammed. Mike and Craig complained about this to the author at the beginning of the workshop. Yet all participants reported in the post-workshop questionnaire, that the room was comfortable.

The workshop started at 8am each day. Most participants came 20-30 minutes earlier to eat breakfast. Lunch was served at noon. On the first two days work was continuing until approximately 5pm. On the third day it ended after the lunch. The group was taking 15-minutes long breaks about every 2 hours.

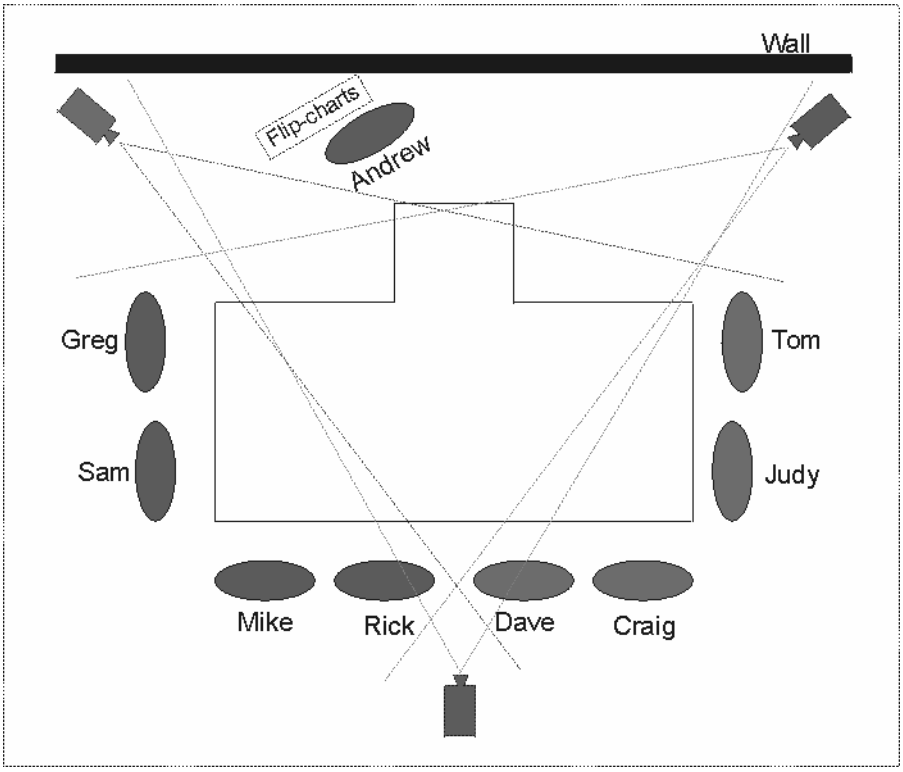

Figure 6. Sitting arrangements and placement of video cameras during the workshop.

One more event had considerable impact on the flow of problem solving. Around 1:50pm during the first day, it a fierce thunderstorm was passing the area, and at 2:49pm one of the bolts hit a boat next to the yacht club. The group ran to the glass wall to see it, and returned to the table a couple of minutes later. The episode, which occurred after the episode examined in the current study, was captured on video. The thunderstorm was over around 3:30pm.

6.6 Analysis of the videotaped group dynamics.

6.61 The structure of the causal analysis of limited manpower.

Defining the scope of the current study we described the structure of the 2.5-day long Business Process Re-engineering workshop shown in Figure 4, and the structure of its 2.5-hour long part devoted to the Root Cause Analysis **(RCA)**. Then we singled out a 16-minute long episode of the RCA for more detailed analysis and explained the reasons for selection. Now we are going to describe the structure of this episode, which is focused on the problem of limited manpower **(LM)**, by dividing it in 28 segments varying in length from approximately 4 to 100 seconds. This will permit describing phenomena that is best visible on this time scale and selecting several segments for a thorough and labor-intensive analysis in order to capture subtleties of interplay between emotions and cognition.

The verbatim transcript of the LM episode is provided in Appendix F and contains speech act numbers, which are further denoted by digits in round brackets, and time stamps.

In this section, first we will introduce the Cognitive Tasks and Actions **(CTA)** coding scheme. Second, we will employ it for describing problem-solving dynamics in sufficient detail for seeing a pattern leading to distinguishing segments. Third, we will move on to the individual cognitive operators level of analysis to show internal working of four of them that determine transitions to new segments: SelProb, SolCause, CloseBra, and IntFitCo.

6.611 Coding scheme for capturing cognitive tasks and actions.

Development of a coding scheme for capturing cognitive tasks and actions **(CTA)** took two months and can be divided into three phases. First, the scheme was developed for an 8-minute long excerpt from the LM episode that started at speech act #90 (~287 sec) and lasted until speech act #340 (~840 sec). The excerpt was chosen because it contained two conflicts stemming from communication failures due to differences in participants' attention focus. Second, the whole LM episode was coded. And third, several changes and additions were made while checking reliability and coding the KC episode.

While coding new footage, we always started from the facilitator and focused on one actor at a time. His or her cognitive behavior first was coded from transcripts. Second, we coded the same episode for the same actor from videotapes. Third, outcomes of coding from transcripts and videotapes were compared and revised. The same routine was then repeated for the next participant.

Starting to code from the facilitator, we were able to utilize the understanding of the RCA gained during the initial task analysis and described in chapter 6.4. The facilitator's behaviors while searching for root causes according to his procedural model described in the section 6.42, and the "proper"—in the sense of being expected according to this model—responses of participants provided a rough outline of what actually occurred. Though helpful for seeing a pattern in the group's dynamics, it accounted only for a part of cognitive behaviors discernable on videotapes. More operators were introduced to describe cognitive behavior that occurred when the facilitator was not able to interpret a contribution, or a participant insisted on discussing an idea that did not seem relevant to the RCA task for the facilitator, etc.

One more factor drove the design of our coding scheme. The dynamic orientation of this study was decisive when determining how coding categories were defined and where boundaries between behaviors coded by adjacent operators were drawn. Though no formal coding of productions was conducted, a question of transitions among operators, which is related to issues of goals and causes, was constantly on our mind, shaping operators.

As early as while working with an excerpt from the LM episode, we paid attention to motivation and emotion. A rudimentary version of CEMA coding scheme—the current version is described in section 6.631--was developed at that time. Yet for purposes of structuring the LM episode, only those operators that were necessary for describing the facilitator's cognitive behavior during the LM episode were used. The resulting coding scheme and manual are provided in Appendix G.

6.612 Structuring LM episode according to the facilitator's treatment of participants' contributions.

During the LM episode Andrew was directing most of the problem-solving flow. At those times when other participants determined the flow's direction, Andrew went along and his behavior reflected the main line of the group's discussion. For this reason, a time-event plot of facilitator's cognitive tasks and actions can be used for describing the episode's structure[7], which is presented in Figure 7.

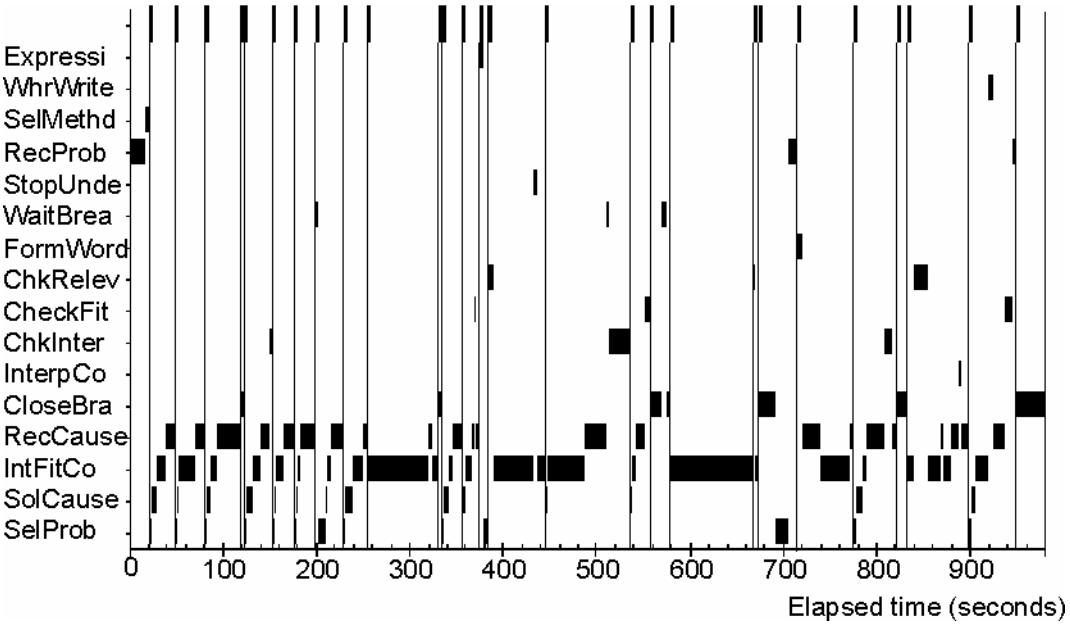

Figure 7. A time-event plot of the facilitator's cognitive tasks and actions during the LM episode.

After selecting the method for soliciting causes (18.0 sec), Andrew set out to record three causes for each focal problem starting from "limited manpower." For each cause he attempted to follow the same sequence of operators: SelProb, SolCause, IntFitco, and RecCause. After three causes were recorded for a focal problem, Andrew closed the branch--CloseBra--and moved on to the next focal problem. Detecting this sequence and taking into consideration which contribution from the list in Appendix H was discussed at any given time, we divided the LM episode in 28 segments as indicated by vertical lines in Figure 7.

Until the time mark 254.8 sec, Andrew was able to carry out his routine basic sequence of operators--SelProb, SolCause, IntFitco, and RecCause--almost perfectly. ChkInter (151.4 sec), WaitBrea (199.2 sec), and absence of CloseBra that can be expected between 8th and 9th segments, constitute the only deviations. Because ChkInter was initiated by Andrew, its occurrence suggests that his routine sequence of operators may be more complex than we have inferred so far. It may include tactics--like

[7] Such approach would be impossible for episodes where discussion is led by participants and Andrew is often just waiting for a convenient moment to regain control. KC episode provides a good case in point.

additional checkups of interpretation, fit, validity, and novelty--that are contingent on states of doubt that were not often encountered during the first 10 segments.

11th segment started with Greg's PropCaus (60) that anticipated Andrew's request for more causes. After a complicated exchange of opinions among Andrew, Greg, Tom, and Sam, Andrew decided that Greg's cause was not new and did not record it. In segment 12 he suggested to cease looking for causes of the currently analyzed focal problem (LM3).

During the segments 13 and 14 the group quickly generated two causes to the focal problem LM4. Segment 15 contained an emotional catharsis triggered by Andrew's comment that all problems are financial (107).

In 16th segment Greg started his battle to record a contribution that was causally misplaced and overtly critical of Judy. Dynamics of this part--that includes segments 16, 17, and 19-23--is marked by prolonged Andrew's attempts to interpret and fit contributions of participants and by strong emotions.

Despite Greg's confirmation in the segment 16 that he was speaking about the causes of the focal problem (115,118), his cause (120,122) did not fit any problem mentioned while analyzing limited manpower. Additionally, as Andrew explained during the interview after the workshop, he did not understand "all this technical details Greg provided--working serially, 25 people, etc." For these reasons Greg's contribution was not recorded.

In the segment 17 Andrew continued to elicit causes (131) and Sam, whose input was on hold (127) contributed. After some additional clarifications, Andrew recorded the cause (487.4 sec). When checking the cause-effect relationship (160, 514.8 sec), Andrew started to realize that Judy was speaking about one more cause of the focal problem. In the segment 18 he gave her an opportunity to contribute (175) and quickly recorded one more cause.

By that moment Andrew had recorded 3 causes of the focal problem at hand (LM 4). After a prolonged review of the flip chart, in the segment 19 he decided to stop eliciting causes of LM4. But Mike suggested to continue trying to record Greg's contribution, and in the segment 20 Andrew made one more attempt to interpret Judy's explanation (205-217). After succeeding, he attempted once again to fit Greg's contribution, which he had understood by now. Finally concluding (223) that Greg did not have a valid cause of the focal problem (LM4), Andrew recorded nothing.

During the short segment 21 Andrew dismissed Craig's attempt (227, 229) to provide a rationale for not recording Greg's contribution. In the 22nd episode Andrew returned to his goal of closing the branch starting from LM4. Under the strong pressure from the group to record Greg's contribution, Andrew accepted Greg's suggestion (226) to write a problem of dual--funnel/expert--role as a cause of "limited manpower." This was a causal error.

Task of recording the contribution was complicated by Greg's use of the term "funnel" to call one of the two Judy's duties. In the segment 23 Andrew was looking and found better wording (252). Probably Andrew felt that he was recording an invalid cause. For this reason he tried to reason aloud with the group (259, 261, 264, 266). Finally he finished formulating the causal statement and checked if it fits with Judy

(268), who made a mistake confirming the fit because her attention was preoccupied with apologizing for "being a bottleneck" (269).

In the segment 24 Andrew took causal analysis one step further by making a focal problem from the cause which was just written (LM5). This segment resulted in the obvious clarification rather than a cause, yet it allowed Andrew to regain control over the problem-solving process and to return to his routine sequence of operators--SelProb, SolCause, IntFitco, and RecCause--that was complemented by ChkInerp (283, 808.3 sec) in the middle of recording the cause.

In the segment 25 Andrew started to wrap up causal analysis of limited manpower by asking participants whether they had spent enough time on this problem. Yet Dave suggested and Andrew recorded (288-307) one more cause (LM4,11) during the segment 26. Making it a focal problem in the segment 27, Andrew recorded one more cause in his routine way. The whole LM episode was closed for analysis in the segment 28.

As was mentioned, Andrew's cognitive activities shown in Figure 7 reflect the main thread of the whole group's problem solving. Yet on several occasions when Andrew was recording or contemplating, some participants were involved in discussions (13-14, 34-42, 94-98, 146-159, 181-193, 232-237, 281-282) that are not reflected in Figure 7. Also, the group discussion sometimes evolved in the direction Andrew was not able or not willing to follow (9-10, 66-71). During these periods participants took initiative raising issues of interest and importance for them. Yet discussions were usually quickly terminated by Andrew's requests for more input from the group.

6.613 Internal working of SelProb, SolCause, CloseBra and some aspects of IntFitCo operators.

Each of the operators and definitely a notation of expressive behavior in the CTA coding scheme stand for complex patterns of behavior. Four of them are especially important for understanding how a new segment is initiated: SelProb, SolCause, IntFitCo, and CloseBra.

SelProb and CloseBra operators are at the core of procedural tasks the group has to solve. They determine how much attention each problem receives during the RCA. From the way Andrew planned writing space, i.e. from the way he placed links to connect causes with their focal problems and from the comment he made considering to close a branch or not (194), it seems that the main rule governing his choice of how many times to ask "why" is essentially very simple: record three causes for each focal problem. Andrew also seems to be inclined to elicit three tiers of causes. After he writes down the intended three causes, very little space is left on the flip-chart for more recordings. This amplifies Andrew's desire to select a new focal problem. In the post-workshop interview Andrew mentioned that he "unconsciously was influenced by physical restrains of writing space." But before that he mentioned two other reasons for selecting a new focal problem:

- "flow of the discussion," i.e. Andrew stated that he stops asking "why" about the same problem when the group is "going in circles," providing different formulations of the same causes, when "nothing new is generated";

- "knowing how much we have to accomplish and how much time is left."

Following the "3 is enough" rule requires to count the number of causes recorded for a focal problem. This is a straightforward task. Andrew had more difficulties, and the group often disagreed about the issue whether a presented statement was a different formulation of the same cause or a new cause (56, 60-84, 155-157, and 227-232).

How Andrew decided if the workshop was on schedule or not - is another complex issue. Andrew had a time-line of the workshop, which was prepared in advance with his participation. But once and again the Director of Total Quality and the author had to remind him about it. After the workshop Andrew told us that it is never possible to follow the schedule of BPR workshops and one has to be flexible with such plans. Anyway, being hired by the Director of Total Quality, Andrew felt being pressed to hurry when the Director asked him to do so.

When Andrew had difficulty with recording contributions or his suggestions were met with resistance, he attempted to move to a new cause increasing the workshop's pace (130-131). When Andrew was in control of the problem-solving flow, he felt less pressed by time. Sometimes, to feel that the group was making progress it was enough for him to be learning new information. For example, when Andrew was able to make sense interpreting Judy's explanation of coordinator/expert duality of her position, he was patiently listening and came up with a causally valid statement (198-223). Being relieved after recording Gary's contribution, Andrew suggested to continue searching for causes of the problem which was just recorded. As was mentioned before, his behavior also can be explained by availability of writing space and his determination to reach the 3rd tier. It will require more data to check this hypothesis of impact of tension on time spent considering causes.

Andrew solicited causes in a pretty uniform way. In 7 out of 14 SolCause operators he made a "Why...?" question out of the statements of focal problems. In 2 more cases he abbreviated the statements, and in 4 more case he did not repeat the focal problem at all asking "What's another answer?", "What more?" or alike. Only in one case at the very beginning of the LM episode, he allowed himself to improvise directing attention from causes of limited manpower, that should be sought, to causes of suffering "in this world of customer problem resolution with limited manpower." Yet participants were able to concentrate on the proper problem as reflected in their contributions (2, 6, 18).

Usually only one participant responded to Andrew's request for causes. If more than one participant spoke up, Andrew's choice was contingent on a combination of his ability to interpret and fit contributions, as well as on their order, how loud they were, and whom he expected to contribute. Thus to figure out the selection's outcome we have to understand internal working of IntfitCo operator and to know who will contribute and who will contribute first. Furthermore, when several participants speak up together, the recorded statement can reflect a mixture of their contribution (44-54).

One may start from an assumption that a participant who is most knowledgeable in the area of the discussed problem, most probably will contribute and will do so earlier than others. Yet, as Judy's case (90-105) demonstrates, this is not always true. Judy is more familiar with the issue of re-answering than

anybody else in the group. Andrew is looking at her while soliciting causes. Still Greg, and then Rick, Craig, and Dave make their contributions while Judy stays silent. Yet when Andrew solicits contributions again (99, 101), Judy is quick to respond. What she says is not a cause of the presently selected problem, but a cause of its cause. From this incident we make a conclusion that Judy's detailed knowledge precluded her from giving a short and obvious answer. When asked, she automatically starts to search for something like a root cause. It takes time, and she misses an opportunity to contribute at all.

The question, what catches Andrew's attention, still is important and interesting to answer. Voice volume and calling Andrew by name (109, 113) obviously should be relevant. Continuity in thought and conversation partnership should influence Andrew's attention too.

In conclusion, we would like to point to a subtle difference between SolCause and CloseBra operators. Both of them can manifest themselves in almost the same wording. For example, a speech act # 131--“Any other reasons?”--represents SolCause. But when Andrew asks “Is there another one?” (196), he considers closing a branch for the focal problem LM4. To distinguish SolCause and CloseBra, one has to consider larger context and infer whether Andrew’s is looking for more causes or, on the opposite, he thinks that enough causes have been recorded and just wants to be sure about that. Nearby comments--like “We’ve got three answers for this.” (194)--help in making correct inferences.

6.62 Reliability of coding cognitive states of participants.

CTA coding scheme was designed in the course of the current study and its reliability had to be evaluated. To do it properly, we had to consider basic conceptual issues underlying calculations of reliability coefficients. It is commonly accepted that inter- and intra-coder coefficients--both of them will be abbreviated as **ICR** from now on--are important measures of quality of coding (Cronbach and Gleser 1953; Cohen 1969; Bakeman and Gottman 1997). If their value is approximately 0.8 or higher, reviewers will have no objections for publishing such paper, and other researchers will take the findings and the paper’s author seriously. But why 0.8 is acceptable? Is Cohen’s Kappa equal to 0.7 still sufficient? Sufficient for what? On a more practical note, how much effort should one invest into drilling his or her coders to maximize ICR? What if one has obtained Kappa=0.1? Should he or she select different coders, simplify coding schemes, or just scrap the whole study? If we want to plunge into philosophy of science, we may ask how getting Kappa=0.8 or looking on this number promotes anybody’s understanding?

This chapter will address the above issues by describing an empirical study of ICR in the case of coding cognitive states of participants in complex collaborative problem solving. The main purpose of the study was to develop and apply a methodology for reliably coding and reliably estimating ICR in the way that facilitates further inquiry and growing understanding and leads to cumulative science (Levy 1993).

The first section formulates concrete goals for estimating inter-coder reliability in the present study. Second, phenomena influencing ICR’s value are discussed. It is shown that selection and training of coders are to be explicitly considered. Third, coder selection procedures--which were derived from the goals formulated in the first section of this chapter, nature of the coding task, and financial constraints

allowing to hire only one person in addition to the researcher--are presented. Fourth, a procedure adopted in this study for calculating an ICR coefficient for time-delimited codes is introduced. Fifth section describes how the coder was trained, how researcher learned too, and what longitudinal data were collected to estimate the training's and coder's impact on inter-coder reliability. Sixth, analyses of the collected data are presented and lessons for reliable coding are drawn. A number of necessary conditions for maintaining this level of reliability are formulated. At this time we will have several dozens of reliability coefficients calculated. They will range from 0.17 to 0.99. The concluding part of this chapter presents a "reliability square," that combines four of them in a visual display helpful for interpreting a number of meaningful facets of the ICR.

6.621 Goals for calculating inter\intra-coder reliability in the present study.

Goals for estimating inter\intra-coder reliability (ICR) have to be aligned with the goals of this dissertation thesis: to contain enough information and to be sufficiently well organized for us to continue and for other researchers to participate in building a truly dynamic theory of collaborative problem-solving group effectiveness. In other words, we would like that other researchers as well as ourselves could use at least part of what we have learned, building on our findings instead of rediscovering everything from scratch. Therefore, our coding methodology is intended to be used and refined in future studies, or at least something has to be learned that is useful for designing similar kinds of coding.

The ICR coefficients can serve a variety of purposes as a valuable descriptive means (Bakeman and Gottman 1997). Because a single person--the author--performed most of the coding, the first goal was to estimate the portion of cognitive states that will be coded by him correctly. At the present stage, this estimate can be related to the ultimate task of coming up with a set of productions determining transitions between cognitive states by noticing the following fact: if the estimated ratio of correctly coded states to all states is equal to X, it cannot be expect that even a perfect set of productions will correctly describe more than approximately X^2 fraction of transitions between two cognitive states.

The second goal was to create materials that would be helpful for researchers who want to use our coding scheme or develop their own schemes for coding cognitive states.

To achieve both of these purposes, it would be ideal to have another researcher participating in the current project. Coding independently and then discussing differences would help to come up with coding that is free of accidental errors, and would focus attention on those instances that are difficult to code. Resolving disagreements should lead to discovering correct coding, updating coding schemes, improving coding manual, and may be changing conceptual framework of the study.

Assessing ICR would provide a benchmark of concordance that can be expected in similar studies. Also, the time necessary to achieve an asymptotic value of ICR coefficient can serve as an estimate of time it will take to learn how to code.

We were not able to find another researcher to code our data. Therefore, issues of selecting and training a coder that would be representative of a population of potential researchers were seriously considered and led us into investigation of possible impacts on ICR in general.

6.622 Phenomena influencing value of inter-coder reliability.

Using multiple coders for checking quality of coding schemes is based on a widely shared belief that coding definitions have to be precise enough so that anyone who uses them will arrive at essentially the same coding. The inter-coder reliability (ICR) coefficients are considered to be a measure of coding scheme isomorphism with studied phenomena and clarity of coding manuals.

Absence of any literature on selecting and training coders probably reflects how ubiquitous is this assumption. If anyone can become a perfect coding device, no selection is necessary and training should continue until an exponential learning curve for reliability coefficients will reach its asymptotic value. There is nothing to discuss. This may be true in some cases when coding is done by our senses and involves very little interpretation. Yet when coders rely on social cognition, variability introduced by selection and training procedures may be of comparable magnitude or even considerably larger than one that emanates from imprecision of coding schemes. Figure 8 depicts how ICR is measured in the case of coding cognitive states.

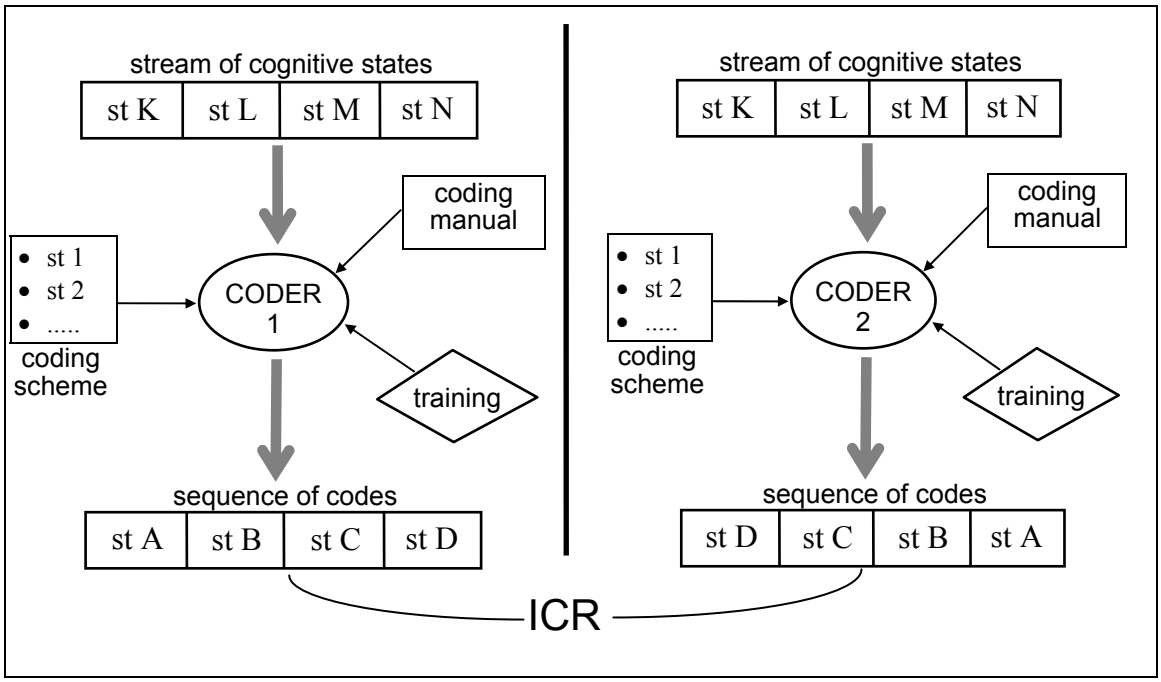

Figure 8. Determinants of inter\intra-coder reliability (ICR).

There is a stream of cognitive states as captured on videotapes. Also there is a coding scheme developed by a researcher. Coders are selected, presented with the same coding scheme and coding manual. They are provided with training. Than coders watch the same sequence of events recorded on videotapes, interpret

it, and produce sequences of codes. These sequences are compared and the ICR measure reflecting the degree of concordance is calculated.

If coders receive uniform training, only coders' personality, experience, and background are varied. Thus we have designed an experiment to discover differences among coders with respect to the coding task. Our hypothesis in this case is, that there is none. In its essence, the current way of checking ICR tests a researcher's ability to create conditions under which individual differences among coders will not be manifested.

Furthermore, only a few if any researchers currently follow the requirement of uniform training. When training varies, we have to account for its impact on the ICR. Indeed, adjusting training to the idiosyncratic needs of coders, researchers attempt to compensate for some differences in coders' backgrounds. The same goal is achieved by selecting coders when hiring for the job. It is not unusual to choose one out of 10 or more candidates. This practice casts doubts about veracity of the assumption supporting the very rationale for testing coding scheme reliability. Namely, that "anyone will arrive at essentially the same coding."

Quite often a researcher takes on a coder's role for purposes of checking reliability. High ICR in this case would demonstrate that there is no difference between a person who may be passionately involved for years in developing and applying the coding scheme, and a person--usually an undergraduate student--who was hired to perform a task, which she or he probably sees as meaningless put aside her or his hourly pay. An assumption that differences in understanding and motivation are not important in this case probably requires a close look and should not be expected *a priory* in cutting-edge research endeavors[8]. For that reason, issues of selection and training of coders have to be explicitly addressed and sufficient time has to be allocated for the task.

6.623 Coder selection procedures.

Given the goals of this thesis, coders should be representative of researchers that may try to use our findings. The first goal for a coder was to help in making coding rules as explicit as possible. Working with emotional and cognitive states of participants, the process of coding itself falls in the area of social cognition--a still largely unexplored branch of psychology. Creating precise coding schemes and explicit coding manuals may become tantamount to creating a domain specific theory of social cognition. In this light, we can say that the coder's task was to suggest alternative theories for the data. It is very important that the coder is "stubborn" enough to carry on suggesting while the researcher is struggling to understand his/her point.

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[8] An expectation that anyone will be able to code well, may turn out to be outright detrimental for any kind of innovative research. We probably would never get to the present stage when thermometers can be used by virtually anyone to learn how cold or hot it is outdoors, if Galileo was demanded at the end of sixteenth century to prove that anybody can consistently measure temperature with his glass flasks and bowls filled with colored water. Indeed, it would be difficult even explain to almost anyone at that time what temperature is.

Also, a coder had to perform coding *per se*. For that s/he needed to have good typing skills, to handle the VCR's controls, to be able to keep in working memory up to about 40 coding categories, to be able to infer tasks participants work on from their statements and focus of attention (for that, in turn, s/he needed to understand the logic of the Root Cause Analysis, to be familiar with the business process under discussion), to be sensitive to body language, and to be familiar with rituals of professional meetings.

Eight people responded to the ad posted at two university campuses, on the "jobs.pitsburgh" electronic news-board, and informal network of researchers involved in coding audio- and video-recorded data.

Five of the applicants were interviewed in person. All of them were explained the goals of the project and employed definition of group effectiveness. Then they were given 30 minutes to review the same 8-minute long episode and to prepare for telling the researcher what they considered important from the viewpoint of group effectiveness. Candidates were encouraged to ask any questions. When they were done with reviewing, all of them were asked the same question, "What did you see?" Later, more specific questions--like, "What was happening between Judy and Greg?"--were asked, if candidates told nothing about episodes the author wanted them to interpret.

A man selected for the job graduated with honors 4 years ago from the Carnegie Mellon University with BS in computational linguistics. He worked for these years in several positions--like account manager, translator, and office manager--and had experience of participating in business meetings. He was one of two candidates who were able to recall both emotional behavior of participants and the technical content of the discussion. He was the only one who correctly interpreted all three interactions: between Judy and Greg, Greg and Sam, and Sam and Judy. The largest negative point was that he had a day job as office manager in a translation agency and could work only evenings, when he was considerably tired. For this reason, most of our joint work moved to weekends, when he felt much more reinvigorated then during the week.

6.624 An inter\intra-coder reliability coefficient for time-delimited codes.

In our case of coding cognitive states one operator lasts from fractions of a second to several minutes. It may be discerned from both verbal and non-verbal behaviors. Thus, it becomes impossible to separate unitizing from coding. Consequently, usual measures of inter\intra-coder reliability (ICR) that rely on comparing codings of the same unit cannot be used. Instead we relied on a subroutine for calculating ICR that is built into software package for coding videotaped events--The Observer (Noldus 1991). The subroutine places two sequences of codes next to each other as shown in Figure 9 on the following page.

433.8 andrew, StopUnde	435.0 andrew, StopUnde	Window Match
436.0 andrew, ChkRelev		Coding Error
	436.9 andrew, IntFitCo	Coding Error
445.4 andrew, SolCause	445.8 andrew, SolCause	Window Match
444.4 andrew, StopUnde		Coding Error
447.2 andrew, IntFitCo	451.1 andrew, IntFitCo	Window Error

Figure 9. An example of the The Observer's reliability analysis report.

Left column contains one string of codes, middle column - another one, and the third one reports comparison results. Digits show times when coded states begin or when coded events occur. “Andrew” designates in our example an actor, and words with 2 or 3 capital letters in them are names of codes of Andrew’s cognitive states.

The subroutine operates in approximately the following way. First it requires defining the maximum time discrepancy (MTD). Then the subroutine considers each code in chronological order. If two identical codes are within the MTD from each other, the instance is reported as Window Match (WM). If WM is not found, the subroutine will continue searching back and forward in time until it encounters in the other string of codes two codes that “frame” the code that is being matched. If one of them is identical to the code that is being matched, the subroutine reports Window Error (WE). Otherwise it reports Coding Error (CE).

The measure of ICR is called Index of Concordance (IC) and is calculated using the following formula:

$$IC = \frac{WM}{WM + WE + CE}$$

Calculated in this way value of IC can vary from 0 to 1.

The subroutine has one major shortcoming. It “punishes” for miscoding two times more severely than for skipping a code entirely. An example is shown in Figure 9. When ChkRelev at 436.0 was miscoded as IntFitCo at 436.9, two CE were generated, yet when an operator StopUnde at 444.4 was omitted, only one CE was reported. To correct for this inconsistency, in all instances when two CE messages were generated for miscoding, the second one was manually deleted. After that the IC values were re-calculated.

Selecting MTD introduces additional degree of freedom in determining ICR value. Increasing MTD from 0 to 15 seconds would change in our case all WE into WM. For illustration Figure 10 shows a relationship between MTD and IC for independent coding of limited manpower episode at the end of coder’s training.

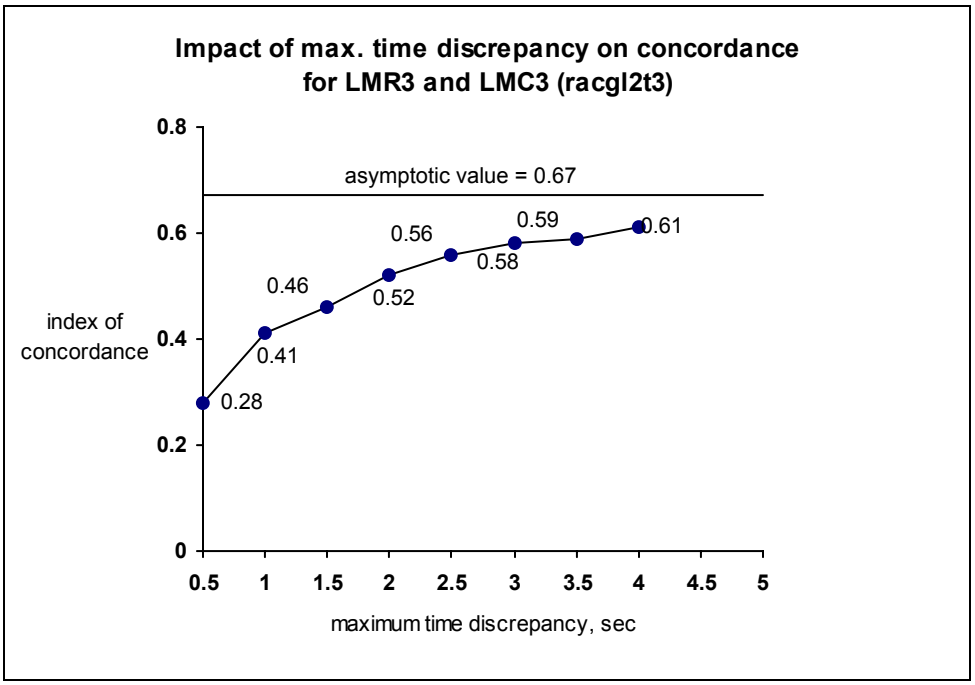

Figure 10. Impact of the MTD on ICR value.

Varying MTD from 0.5 sec to 4 sec increases the value of IC more than two times. The curve is smooth and gradually increasing to its asymptotic value. It provides no rationale for selecting MTD. But analysis of time discrepancies between two strings of code shows that they occur because of two reasons: differences in reaction time and differences in interpretation while assigning codes to cognitive states. Most of the discrepancies that are less than 2 seconds are caused purely by the difference in reaction time. For this reason the MTD was fixed at 2 seconds for the entire reliability study.

6.625 Training a coder, coding, and measuring inter-coder reliability.

Given the goals of this thesis, it makes sense to provide a coder with training that will be available for researchers who intend to replicate the study. At the present initial stage of exploring group problem-solving processes, collaboration between several researchers will require extensive direct communication. Designing a standardized training program seems to be premature. For this reason, the constraints inherent in creating training materials that can be delivered in uniform fashion are not relevant in our case. The situation would be different, if one pursues certification of his/her findings as an ultimate goal.

Ideally training has to be continued until there is no more improvement in the reliability coefficient. Otherwise the question “How much training should be provided?” remains open. It means that one has to go through as many *coding--clarifying origins of discrepancies--improving coding schemes and coding manual--coding--and so on* iterations as needed to achieve saturation. Changes in coding schemes have to be determined not only by maximizing reliability coefficient but also by improving conceptual

validity of coding categories and their usefulness for describing group dynamics: it means, internal and external validity.

The present reliability study was conducted on two episodes: **LM** - the whole episode of analyzing causes of limited manpower (~16-minute long, 103 codes); and **KC** - second half of the episode devoted to analysis of lack of knowledge of contacts available when encountering problems (~10-minute long, 66 codes). Because of limited resources, only the facilitator's cognitive states were coded.

The coder's training started from writing Goal Achievement Stories **(GAS)--**narratives of participants' behaviors organized according to their goals--for the LM episode. The goal was to make coder "see" those behaviors that are important for coding cognitive states in sufficient detail. After the coder wrote a story, researcher reviewed it, marked places that required elaboration and provided general comments: for example, that numbers enumerating speech turns have to be used, or that interpretations should be corroborated with references to observed behaviors. Then the coder worked on the story again. The coder went through 4 iterations which took him approximately 10 hours.

During the following 3 hours or so of training, the researcher introduced the coder to coding manual and thoroughly explained about 20 categories that were used by him for coding cognitive states of the facilitator. Then coder and researcher coded together about 15 first cognitive states in the LM episode. At this time the coder was eager to start independent coding. It took him about an hour more to become comfortable with The Observer--coding software--and VCR controls.

The part of training that has been described so far corresponds to the oval shape with GAS abbreviation depicted in Figure 11. The figure shows the entire flow of activities while working with the LM episode.

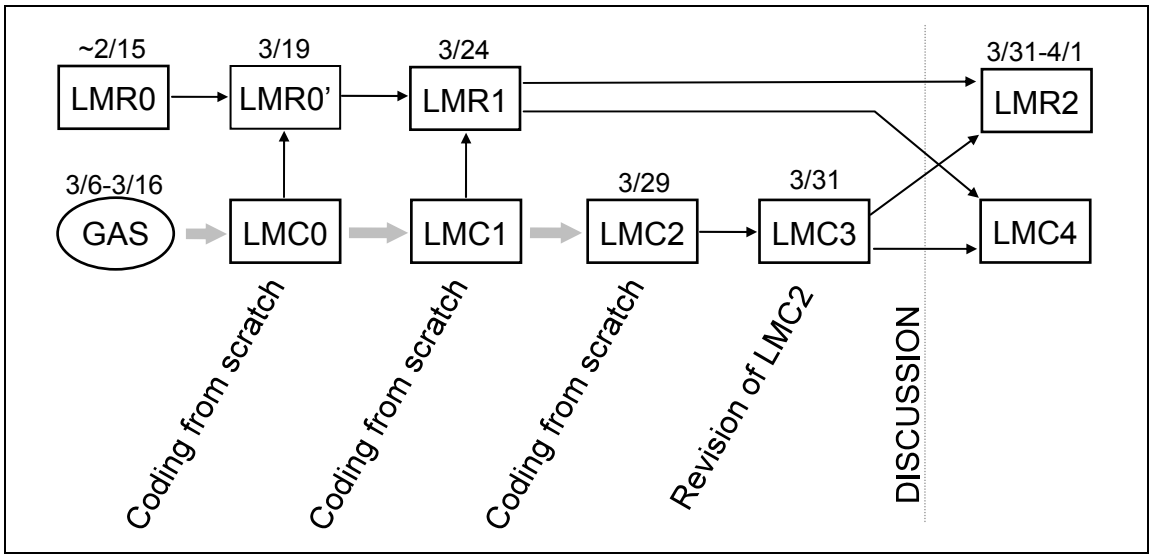

Figure 11. Training and coding activities while working with LM episode.

The next phase of training consisted of three coding runs separated by 5-day long intervals. All of them were conducted from scratch and resulted in coding sequences LMC0, LMC1, and LMC2 as shown in Figure 11. After the first and second run the coder's coding was compared with the researcher's using the reliability analysis function of The Observer. Two right columns from the resulting profiles (see Figure 9) containing the coder's product and discrepancy reports were shown to the coder. Then coder and researcher reviewed the videorecording, and the coder was asked to consider each instance marked as CE or WE to see if he would come up with different coding and how he would explain reasons for both old and new coding decisions. Neither the researcher's coding was shown to the coder, nor his questions about correctness of his guesses were answered directly. But if the coder's explanation revealed lack of knowledge or misunderstanding of information contained in the coding manual, he was referred to it[9].

Although the coder was reminded to check his coding, the outcome of the 3rd run contained many mistakes caused by lack of attention: coding the same state twice, for example. For this reason, researcher insisted on careful examination of LMC2. After about half an hour of reviewing videotapes and looking at LMC2, the coder reported that no changes should be made. At this time researcher explicitly asked to check for double states, and the coder removed some of them and made a couple of other changes producing LMC3.

An updated version of initial researcher's coding--LMR1-- was compared with LMC3 using The Observer's reliability analysis function. The resulting report was used for 2-hour long final discussion between coder and researcher. Both of them discovered mistakes in their coding and corrected them producing LMR2 and LMC4, which were identical with an exception of one code. The discussion was videotaped to provide input for further analysis. It marked the end of formal training stage. When working with the next episode--KC--both coder and researcher were performing identical activities, which are shown in Figure 12.

Coder and researcher started to work on KC episode by independently coding it two times from scratch. In this way KCR1, KCR2, KCC1, and KCC2 were produced. Continuing to work independently, both coder and researcher compared these codings and came up with revised versions KCR3 and KCC3. They were compared and the resulting report from The Observer was used for discussion, which was again videotaped. Updated codings KCR4 and KCC4 were produced during the discussion. The coder was dissatisfied with a number of corrections he had to make and volunteered to perform one more coding from scratch producing KCC5. Because ICR between it and KCC4 was lower than between KCC1 and KCC2, the researcher also performed one more coding from scratch--KCR5--to see if he will have problems replicating KCR4.

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[9] Surely, from these exercises the coder was getting pretty clear idea what was the researcher's opinion about correct coding for particular instances that were analyzed. To examine the magnitude of direct memorization on ICR value, the researcher and coder worked completely independently while coding KC episode.

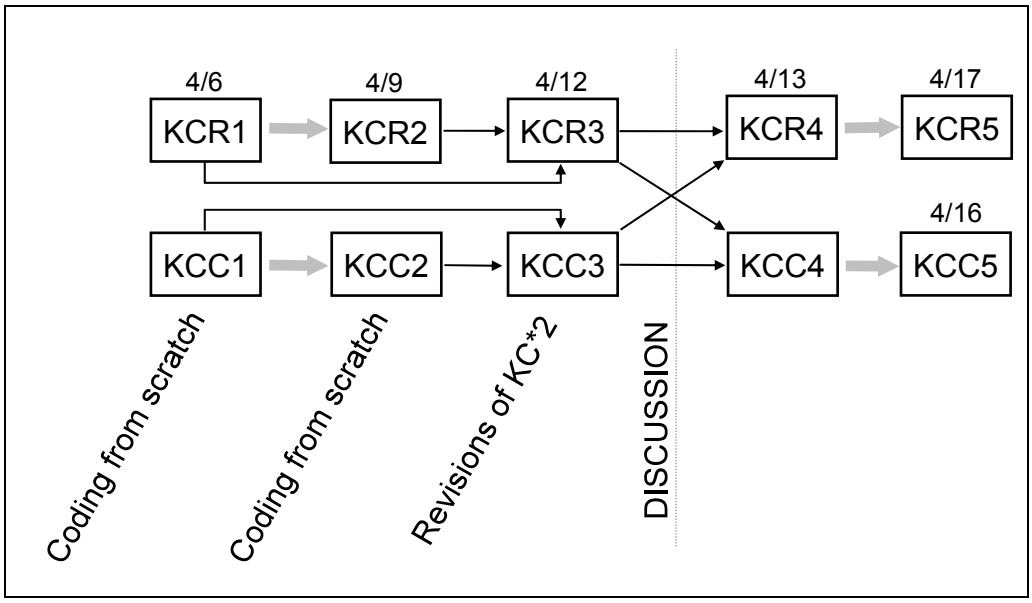


Figure 12. Training and coding activities while working with KC episode.

As we will see below the ICR coefficient between KCR4 and KCR5 was considerably higher than between KCC4 and KCC5.

6.626 Data analysis and discussion.

Examination of data evolved in parallel with data collection, which was not completely planned in advance and was driven by its results. *Post factum* we can divide the conducted analyses in three parts pertaining to estimating replicability of coding, training of coders, and improving coding scheme and coding manual. The section covers these topics.

6.6261 Estimating reliability of coding.

Index of concordance (IC) computed by The Observer merely describes how similar are two sequences of codes. When it is calculated for several consequent codings by the same person, it shows how consistent the person is with time. In the case when two codings are produced by different people, IC provides a measure of consensus (cf. Kozlowski and Hattrup 1992; James et al 1993). Checking inter-coder agreement at several time points, we can estimate consistency of consensus with time. Systematically varying coding conditions for the same coder, we can find out about consistency of coding across these conditions. The basic experimental design for evaluating inter\intra-coder reliability (ICR) that is shown in Figure 8 can be modified to serve a number of goals. Yet all of them aim on obtaining relative measures and provide only indirect indicators of how close coding is to the actual sequence of cognitive states.

By introducing discussions, that took place after LMC3 and KCC3 as shown in Figure 11 and Figure 12, we tried to estimate an absolute value reflecting quality of coding. By virtue of revealing and

debating rationale for coding decisions, the discussions are able to get us beyond merely comparing two or more opinions.

Figure 13 provides a summary of IC values calculated between different coding sequences produced in the course of the present study. As indicated by IC=0.99, after final discussion in both LM and KC episodes there was almost complete agreement between researcher and coder about correct coding. For LM episode they disagreed about one code out of 106, and for KC episode they could not reach agreement about timing of one code out of 66. For this reason, we will refer to the researcher's version of coding produced by the final discussion as a Best Available Coding or **BAC**.

IC values indicating differences between researcher's coding before and after final discussion were considerably higher than the corresponding values for the coder. For LM episode they were 0.89 and 0.56, and they were even further apart--0.91 and 0.33--for the KC episode. It is possible that this situation stems from "more powerful" position of the researcher when "negotiating" BAC. On the one hand, researcher was paying the coder. But on the other hand, he was interested in learning about actual sequences of coding states and misunderstandings caused by vague coding categories and/or coding manual. Also, consensus about proper coding that is far from the coder's, would indicate, although not directly, that he is not qualified for this task. This should make him eager to defend his decisions, if he is interested in continuing his job. If we assume that the researcher's ego and proving to others that consensus is possible are not dominating his behavior, there is a stronger motivation for the coder to stick to his coding than for the researcher.

As was mentioned before, during training the coder was explicitly requested to explain reasons for his coding decisions, he saw that his opinion was valued, and that researcher had recognized his own mistakes on several occasions. Video recordings of both final discussions document the flow of conversation and are available for viewing.

After the final discussion of the KC episode the coder was considerably disappointed with how many mistakes he had done. He volunteered to code the episode from scratch again producing KCC5. Yet the IC value between KCC5 and BAC was only 0.40. If coder was pressed during the final discussion to agree with the researcher's coding, we could expect that he would return to his coding performed prior to final discussion. Yet the IC value between KCC3 and KCC4 is equal to 0.34--almost the same value as between KCC3 and BAC. For comparison, the IC between KCR4 and KCR5 is 0.78 and between KCR3 and KCR5 - 0.70. Possible reasons for these differences are discussed in the following section.

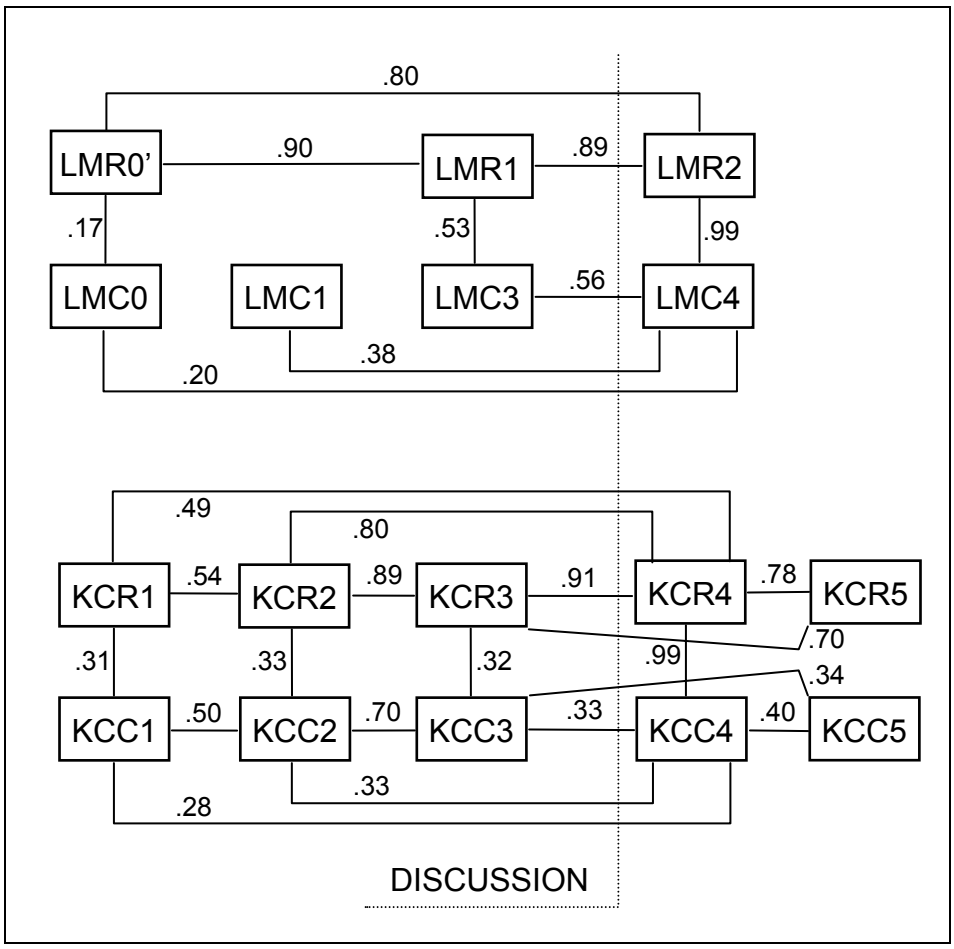


Figure 13. A compendium of ICR measures for LM and KC episodes.

Overall, data shown in Figure 13 allows us to expect that after the researcher produces a revised version of his coding based on comparison of two codings from scratch, he will get at least 75% of codes correct comparing with BAC. For the coder we can expect this value to be in the range from 30% to 40%. For approximately 10-day long time periods we can expect these numbers to describe their level of consistency with time. These findings do not cover the case of conscious re-conceptualization of coding categories.

6.6262 Selection and training of coders.

Everybody who coded from videotapes and from verbal protocols knows how much more information is contained in the former. A task of selecting appropriate facts becomes an order of magnitude more complex. Second, designing valid coding categories corresponding to cognitive states requires to combine unitizing and coding together. That makes the coding task even more challenging. Third, in everyday life we do not usually pay attention to cognitive states. Furthermore, when we do, our goal is not to understand how one reasons, but to understand what he or she tries to convey or to hide. We are not

trying to understand to whom or what one pays attention, but merely if she or he is listening to us. For this reason, "seeing" cognitive states requires a new skill, and what is even more important, it requires to develop a framework for performing the necessary interpretation. Such framework does not exist yet. The task of the current project is to develop it. Thus, coding and conceptualization have to go hand in hand. In general, developing the conceptual framework necessary for coding requires knowledge and motivation that can be rarely expected from an undergraduate student-coder.

The above mentioned three challenges will be the same for anybody involved in coding cognitive states. In the course of this study we designed some concrete means for dealing with them.

A task of showing a coder the appropriate level of detail necessary for coding, can be accomplished, and was accomplished by writing Goal Achievement Stories (GAS). The same outcome could be produced by showing the coder examples of correct coding. Yet writing GAS also served the purpose of familiarizing the coder with the content of videorecordings. This also allowed detecting incorrect interpretations caused by lack of knowledge about context in which videotaping took place. Researcher and coder spent considerable amount of time talking about professional and personal relationships among participants of the videorecorded workshop. This helped to overcome a simplistic division into "bad vs. good guys," that is likely to occur when judgments are made on the basis of limited information contained in short episodes used for reliability study.

Inter\intra-coder reliability (ICR) coefficients--shown in Figure 13 as well as many others--served as a valuable means for monitoring progress in training. Comparison of coding sequences and issuing discussions provided additional detail and better understanding of problems to be addressed by training and/or improving the coding scheme and manual.

Providing the coder only with comments showing where his and the researcher's coding diverged and requiring him to explain reasons for his coding instead of directly telling him the "right answer" during discussions prior to LMC1 and LMC2 was crucial. First, the researcher was able to improve his coding, and this resulted in an updated version of LMR0--LMR0'--as shown in Figure 11. Otherwise the coder would be presented during the next review with the CE or WE messages even in the cases when both he and researcher had agreed that his coding was correct. Second, discussions between coder and researcher helped to improve clarity of coding manual and resulted in modifications of coding scheme. Third, these discussions demonstrated to the coder that he was expected to corroborate his decisions and prepared him for the final discussion, when he was expected to behave as an equal rather than a trainee. Forth, a need to come up with his own coding and corroborate it probably resulted in better learning than in the case when the coder would be just told the "right answer."

Final discussions of coding of both LM and KC episodes served the purposes of training too. Trying to discover correct coding and to corroborate it was useful by itself. Additionally, reviewing the videorecorded discussion of miscoded cognitive states, we were able to generate the following list of major sources of coding errors:

1. **Coding behaviors instead of cognitive states.** For example, drawing a dash next to the focal problem selected for analysis usually manifested that facilitator was selecting a problem. Yet not always. Coding all instances of drawing a dash as SelProb led to several mistakes. Another example would be uniform coding of utterance--"Any other reasons?"--as soliciting causes. Depending on context it was also used by the facilitator to stop undesirable contributions and to close a branch of a causal tree.
2. **Not paying attention to "trailing edge" of operators.** Because we assume that there is a continuous stream of cognitive states, end of the previous operator coincides with the beginning of the next one. Paying attention to behaviors manifesting both beginning and end may serve as a cross-check. Disregarding this opportunity led to several coding and window errors.
3. **Existence of parallel cognitive processes.** Sometimes the facilitator was performing two or more tasks in parallel. All of them required some cognitive processing. Using codes with modifiers provided a solution for obvious cases, when each parallel task was accompanied by considerable cognitive load. Yet there were boundary cases that led to discrepancies in coding. For example, the only disagreement that was not resolved during the final discussion of LM episode resulted from a difference in opinions about extent of cognitive processing directed on stopping undesirable contribution while simultaneously soliciting a new cause. In that case the facilitator interrupted a participant and by speech accent stressed "other" when asking "Any other reasons?"
4. **Operators that last less than 3 seconds** were more often skipped over than the longer ones.
5. **Two operators within the same sentence** sometimes were coded as one.
6. **Getting into rut** was causing errors. For example, most of "Record Cause" had "Interpret Contribution" as a modifier. For this reason this combination was often used automatically.
7. **Keeping the same rhythm of "clicking."** Coding in The Observer is performed by left-clicking a mouse pointed to one of the coding categories displayed as a table on a computer monitor. Most operators last from 3 to 10 seconds. It seems that coders try to maintain this pace.

After this list was shown to the coder at the beginning of coding KC episode, he reported "seeing everything in completely different way," and proclaimed confidence about improved coding. Yet analysis of errors during the final discussion of KC episode demonstrated that coding behavioral states and not paying attention to "trailing edge" of operators were responsible for many errors.

Item-level analysis of coding--which is shown in Table 6 for LM episode and in Table 7 for KC episode--allows to make several more inferences relevant for selection and training of coders. The table is based on comparison of three coding sequences: BAC (=LMR2), LMC3, LMC2, and LMC1. If a cognitive state had been coded the same in LMC3, LMC2, and LMC1, it was considered as consistently coded. If not, it was considered as coded inconsistently. Juxtaposing this categorization with the report of outcomes of comparison of BAC and LMC3, all codes in BAC were placed in one of the 5 categories denoting internal columns in Table 6.

Table 6. Individual-code level of analysis of LMC3--the coder's final coding of LM episode--as compared with BAC[=LMR2]. ("C" - coded consistently; "IC" - coded inconsistently; "+" - coded correctly; "-" - coded incorrectly.)

CODE	C+	C-	IC+	IC-	Failed to use	Freq.
RC	16	0	4	2	1	23
IF	16	0	2	2	3	23
SC	10	0	5	1	0	16
SP	4	0	5	2	2	13
CB	5	0	1	0	2	8
CI	1	0	0	3	1	5
IC	0	0	1	3	0	4
RP	2	0	0	2	0	4
CF	0	0	0	1	2	4
WB	1	0	1	0	1	3
SU	1	0	0	D	0	2
CR	2	0	0	0	0	2
SM	1	0	0	0	0	1
CF	0	0	0	1	0	1
Exp	1	0	0	0	0	1
CV	0	0	0	1	0	1
FW	0	0	1	0	0	1
WW	0	0	0	0	1	1

Table 7 is created similarly to Table 6. Here BAC is identical with KCR4, and KCC3 and KCC5 are used for making inferences about consistency of coding. Inferences about veracity of coding were made from comparing BAC[=KCR4] and KCC5.

Table 7. Individual-code level of analysis of KCC5--the coder's final coding of KC episode--as compared with BAC [=KCR4]. ("C" - coded consistently; "IC" - coded inconsistently; "+" - coded correctly; "-" - coded incorrectly.)

CODE	C+	C-	IC+	IC-	Failed to use	Freq.
WB	0	1	1	4	9	15
IF	9	1	3	0	0	13
RC	5	0	1	1	0	7
CB	2	0	2	1	1	6
SC	2	1	1	1	0	5
RP	1	0	1	2	1	5
SI	2	0	0	2	0	4
SP	1	0	0	1	1	3
OR	0	0	1	0	2	3
CW	0	0	0	1	2	3
CI	0	0	0	0	2	2
Exp	0	0	0	0	1	1
DT	0	0	1	0	0	1
SU	0	0	1	0	0	1
FW	0	1	0	0	0	1

A look at Table 6 reveals that a category "Interpret Contribution" was often confused with "Interpret and Fit Contribution." The distinction is based on inferences of whether facilitator tried to check novelty and/or fit cause while interpreting contribution or not. These inferences are, in turn, based on non-verbal behaviors like looking or pointing at particular recordings on flip-charts or even on another inference that a task of fitting a cause had been completed. The coder was provided with additional information and was asked to pay particular attention to this category. Yet results of item-level analysis for KC episode--which are shown in Table 7--do not show any considerable improvement.

Similarly, a category "Record Problem" was often miscoded in both LM and KC episodes. Yet reasons for errors were different. During LM episode, the coder thought that all recordings on the left side of flip-charts were problems, when, in fact, using "Record Cause" category was required, because these

were causes of an initial problem recorded at the top of flip-charts. This is another example of influence of visual displays on interpretation. Inappropriate usage of “Record Problem” category during KC episode was due to paying more attention to the behavior--writing on the chart--than to the essence of what was being written. Also, during KC episode, the coder was learning to use a new coding category “Organize Records”. It was supposed to be used as a modifier with “Record Problem,” because a mere fact of writing requires cognitive processing and allocation of attention. Not being aware about importance of tracking changes in attention focus in the present study, the coder started to use “Organize Records” instead of “Record Problem.”

Problems when using such seemingly obvious category as “Record Problem” are indicative of fundamental differences between coding behaviors and coding cognitive states.

Table 6 also shows that “Check Interpretation” category was overused by the coder. The reasons for that are quite curious and reveal impact of coder selection on ICR. The coder had difficulties answering why he used “Check Interpretation” so often. Finally, in a humorous tone, he said: “I guess, I like this category. This is what I am doing quite often in my job as an interpreter.” Having no better explanation, we are inclined to think that this was the actual reason.

Comparing Table 6 and Table 7 one can see that coding KC episode required learning and extensive use of a new coding category--”Wait for a Break.” It was not done well by the coder, who provided the rationale that it was inconsistent to code lengthy episodes involving a lot of verbal behavior as a single operator “Interpret and Fit Contribution” and to use several operators with different modifiers to capture cognitive states of the facilitator silently standing for a couple of seconds. This sounds like a problem with unitizing. Yet we think, that the coder was resistant to use inconspicuous changes in focus of attention for discerning instances of ”Wait for a Break.”

Reviewing videotapes of final discussions and looking at consistency data from Table 6 and Table 7, we were able to classify all coder errors in 3 categories: due to incomplete learning, due to bad learning, and due to inattention. The classification is only tentative, because sometimes incomplete learning would not cause an error if compensated by keen attention and concentration would not be so crucial if coding categories were better learned. If there was doubt about classifying an error as due to inattention or due to incomplete learning, incomplete learning was preferred. An error was coded as “bad learning,” if it was coded consistently wrong or if the coder had clear and explicit--but incorrect--reasons for his coding decision. An absolute number of errors in each category is given in parentheses

The data from Table 8 shows that learning incorrect coding rules is not prevalent, and majority of errors are due to incomplete learning and lack of attention. An increase of share of errors because of incomplete learning in KC episode was caused by difficulties the coder experienced when detecting instances of “Wait for Break” operator.

Table 8. Classification of reasons for errors generated by comparing BAC and the last version of coder's coding sequences for both LM and KC episodes.

	LM episode	KC episode
Lack of attention	52% (26)	28% (13)
Incomplete learning	42% (21)	67% (31)
Bad learning	6% (3)	4% (2)

A considerable proportion of errors due to lack of attention may make one doubt whether the coder was sufficiently motivated to perform the coding task. Yet the issue is about the kind of motivation rather than about its presence. Trying to reconcile the following five facts brings us to this conclusion.

First, a ratio of errors due to inattention to all codes is similar both for the coder and the researcher. Second, the coder failed in detecting even obvious mistakes when reviewing his coding. Third, while reviewing the coder was skipping the items that were not clear for him and went on. Fourth, it took the coder about 3 times less time than the researcher to code an episode. Fifth, the coder volunteered to perform one more coding from scratch after the KC final discussion had shown that his coding was far from the BAC.

When considered together, these facts make us think that the coder was motivated to be a successful professional, who gets his job done quickly and well according to some quantitative measures--ICR coefficient in this case. Yet a motivation to understand cognitive processes, that is necessary for quickly learning how to perform such complex and novel task as coding cognitive states from videotapes, probably was lacking. Without it, the coder did not have sufficiently good retention and did not allocate enough mental resources for the task. This may partly explain the low value and almost no improvement in subsequent codings of KC episode when compared with BAC.

6.6263 Coding scheme and manual revision.

Some differences in ICR measures of coder's and researcher's performance probably were due to not sufficiently detailed coding manual: some knowledge the researcher used for coding was not articulated. Full text of the current coding manual for cognitive states is contained in Appendix J. Besides several clarifications and explications, three new coding categories were added. They are: DisTract, SeekAgre, and SolIntrp.

It is difficult to say if the updated coding manual will have a considerable impact on the gap between ICR measures for coder and researcher. A definitive answer to this question would require a study with several coders.

6.627 Reliability Square.

A discussion aimed on revealing and debating rationale for coding decisions can bring a completely new aspect into currently accepted practices of calculating inter\intra-coder reliability (ICR),

which merely compare two or more opinions. Such discussion, if properly conducted, will result in improved coding, and enable inferences about a potential for improving such aspects of the coding process as quality of coding manuals, selection and training of coders, and coding conditions. If there is a considerable agreement among all involved coders about the post-discussion version, it can be considered to be a representation of actual sequence of coded states or events. To remind ourselves that utmost truth is never attainable, we call it "the best available code" or BAC in short.

A measure of agreement among post-discussion versions of coding provides—similarly to a measure of agreement among independently coded versions—another reflection on quality of coding schemes and procedures. Thus we recommend to report both measures. In the case of two coders it can be visually done using the Reliability Square shown in Figure 14.

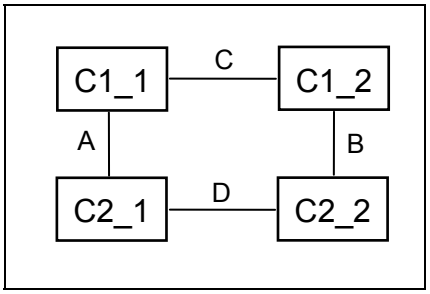


Figure 14. Reliability Square.

Value of A in this figure corresponds to the traditional measure of inter-coder reliability. Value of B shows how much agreement there is between the post-discussion versions of coding. Comparison of the two shows how sure we can be that BAC reflects the actual sequence of coded events or states. If B is high and neither of the coders dominated the discussion, values of C and D provide an estimate of quality of their independent coding.

6.63 Interplay between cognition and emotions while performing analytical tasks.

Five videotaped segments were selected for in-depth analysis of interplay between cognition and emotions. The first three of them unfolded smoothly and quickly resulted in recording causes to focal problems. They were typical for the first part of the LM episode. The other two were chosen because they represent difficulties the group ran in while performing causal analysis. Both of them ended without recording new causes. Interaction between cognition and emotions was especially prominent during two last segments.

The verbatim transcript of the whole LM episode is provided in Appendix F and contains speech act numbers, which are further denoted by digits in round brackets, and time stamps.

In this section we first introduce a coding scheme and a diagram designed for capturing emotional and cognitive operators, as well as their mutual influences. Then procedures of using the diagram for

generating a list of productions governing transitions among operators are described. Next, production lists for each of the five segments are presented and complemented with discussions of knowledge states we have to explicate in order to specify the condition parts of production in sufficient detail to be computable. Finally, we attempt to come up with a number of general cognitive and emotional processes that start shining through the production lists we have compiled. The size and contents of a production system that should suffice for simulating the whole RCA task is estimated.

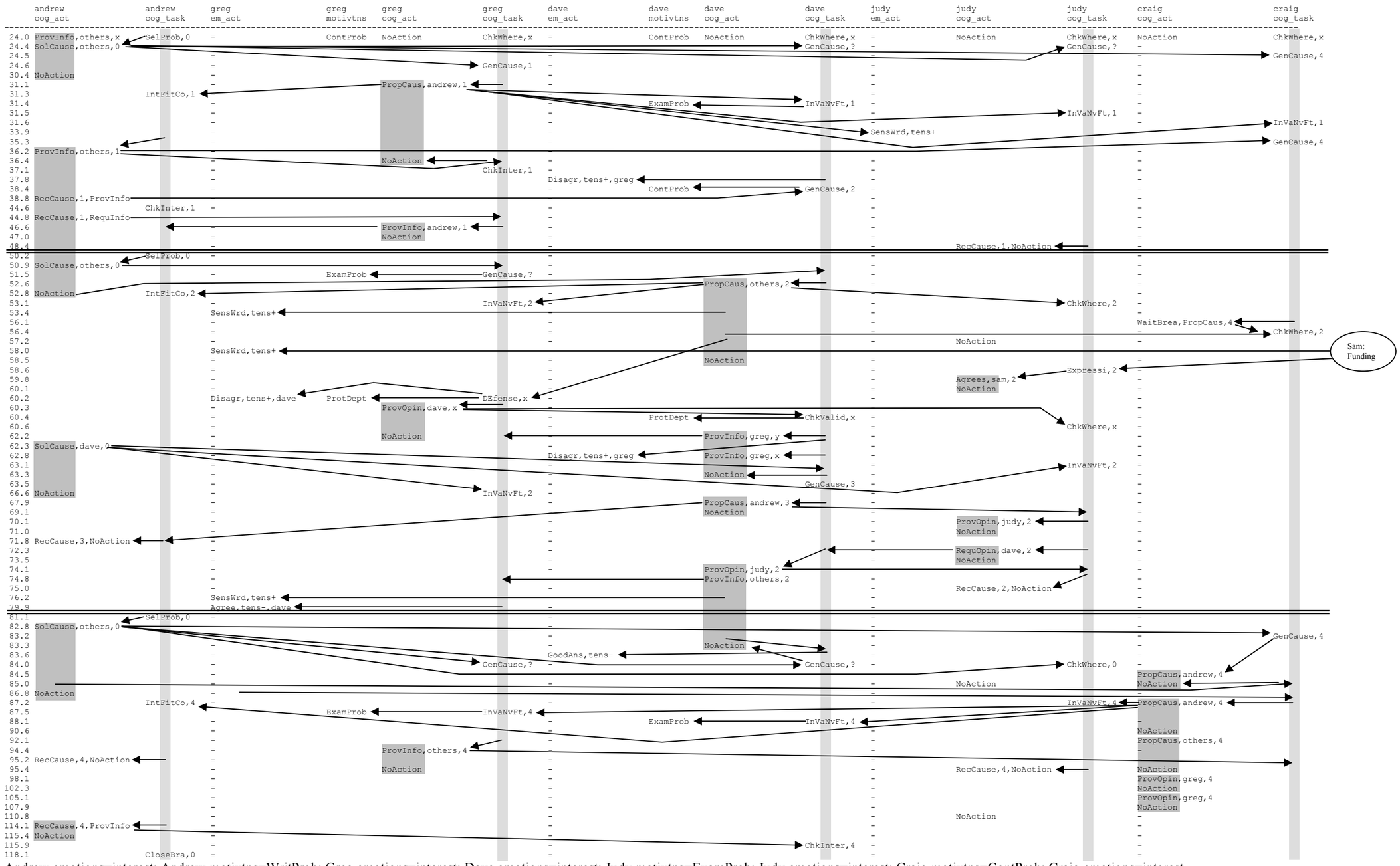
6.631 Description of CEMA coding scheme and diagram.

In order to capture the interplay between emotions and cognition the coding scheme used for describing participants' cognitive behavior was elaborated and considerably expanded. The intention was to record each participant's cognitive, emotional, and motivational state at every time moment. According to the conceptual framework depicted in Figure 1, three behavioral classes were defined and called "cog_task", "emotions", and "motivtns." Two more behavioral classes--"em_act" and "cog_act"--were introduced to capture interaction among participants. Three classes of modifiers were designed to trace: (1) what contribution a participant was working on--"idea#" modifier coded according to the list of contributions shown in Appendix H; (2) to whom an action was directed or coming from--"subjects" modifier; and (3) whether an action had a potential for increasing or decreasing a participant's tension and/or interest--it(+-).

The resulting coding scheme is called The Cognition-Emotion-Motivation-Action or **CEMA** coding scheme. It was applied by coding from videotapes a single behavioral class for one focal actor during each observational pass through the whole duration of a segment.

Behavioral elements for all 5 behavioral classes and 3 modifier classes, their definitions, and coding instructions are presented in the Appendix J. The classes "cog_task" and "cog_act" were obtained from the "cog_oprt" class of the CTA coding scheme by distinguishing between cognitive operators that manifest themselves in actions and not. Several new elements were introduced to capture cognitive actions--NovelObj, Agrees, Disagree, RequInfo, RequOpin, ProvOpin, GoOn--and a new behavioral class was added to trace motivations of participants. The requirement enforced in the CTA coding manual--if any two or more of InterpCo, FitCause, ChkValid, and ChkNovel are occurring next to each other, IntFitCo should be used for the facilitator and InVaNvFt for participants--was relaxed in order to capture more changes in participants' cognitive behavior.

Introduction of two behavioral classes for recording interaction among participants was necessary because the same behavior may carry a cognitive message and be emotionally laden at the same time. Coding a cognitive component of interaction, we focused on the emission source. In other words, "cog_act" elements were coded for participants originating actions. Modifiers in this class show at whom the actions were directed. At the time of coding "cog_act" no attempt was made to determine whether the message reached its destination or not and how it was received.



Andrew,emotions=interest; Andrew,motivtns=WritProb; Greg,emotions=interest; Dave,emotions=interest; Judy,motivtns=ExamProb; Judy,emotions=interest; Craig,motivtns=ContProb; Craig,emotions=interest.

Figure 15. CEMA diagram for LM25, LM51, and LM81 segments.

Coding an emotional component of actions involved much more interpretation, because potential impact on the receiver's emotional state was assessed. There are two reasons for adopting this procedure. First, lack of action may influence some participants as strongly as its occurrence, yet discerning potential impact is possible only when we are watching the video from a particular participant's viewpoint. Second, we needed another, though indirect, characteristic of emotional states of participants for cross-checking our coding of emotional states, which was based mostly on observations of non-verbal behaviors. Comparison of events that are potentially capable of intensifying or alleviating tension of a particular participant with codes in "emotions" behavioral class, which are based on reading body language, should increase reliability of coding.

Coded behavior of participants for each explored segment was presented as a time table on Cognition-Emotion-Motivation-Action or CEMA diagrams like one shown in Figure 15. The diagrams allow us to see how cognitive and emotional dynamics of all participants involved in discussion is unfolding with time. In turn, this enables visual representation of direct influences--shown as arrows--between emotions, cognition, and motivation for the same actor as well as among actors. One can think about CEMA diagrams as a specification of conceptual cycles shown in Figure 1 mapped on the time axis. CEMA diagrams, that are based on time-plot analysis package from The Observer (Noldus 1991), constitute a natural extension of Problem Behavior Graphs (Newell and Simon 1972) for the case of both cognitive and emotional multiple actors. Designing CEMA diagrams is the major contribution of the present study.

Coding scheme design and subsequent coding decisions relied on the dynamic conceptual framework described in chapter 3.0. Yet they were not completely deduced from *a priori* theoretical considerations. This is even truer about drawing causal relations between codes depicted in the CEMA diagram. Our task in the following several sections will be to make the hypothetical underlying processes suggested by data as explicit as possible.

The columns on the CEMA diagram contain codes for combinations of actors and behavioral classes. Because behavioral classes can contain codes of two kinds--states and events--columns have to be read differently. In the case of columns containing discrete events--like all columns for "em_act" class--each code stands for an occurrence of an event. Events do not have time tenure. In contrast, codes in those columns that correspond to behavioral classes containing states--like "motivtns," "emotions,", and "cog_task"--mark transitions between states. The columns containing elements of "cog_act" behavioral class occupy an intermediate position. Codes in these columns mark beginning of actions that last until another action is initiated, or until the code "NoAction." Instances of verbal behavior are shaded in "cog_act" columns with gray.

Light gray bands going downward in "cog_task" columns emphasize continuity of cognitive activity of participants. In turn, this made the origin and destination of arrows representing influences that occurred in the middle of cognitive states clearer.

The columns containing no events are omitted in order to use diagram space more efficiently. Similarly, when an actor remains in the same state, the corresponding column also is omitted. The actor's state maintained for the duration of the segment is recorded immediately below the diagram.

Rarely occurring events that influence behavior of the participants represented on the diagram, are recorded to the right of the last column. Such events may include distractions--like door squeaking or cup clinking--and behaviors of participants whose involvement during the segment is not active enough to warrant their full inclusion in the analysis of group dynamics.

6.632 Guidelines for generating production systems.

Similarly to the case of isolated individuals working on essentially analytical tasks like cryptarithmetic and proving theorems in logic (Newell and Simon 1972), it turned out possible to describe transitions between cognitive operators employed by the participants of the observed group as a set of "if, then" rules or productions.

The production lists were generated in the order they are presented. If a production inferred in a later segment was identical with one already on the list of the earlier one, a reference to the first segment where the production was encountered was made. Thus, it is easy to tell those productions that were first encountered during each segment. For example, productions P2 and P4 in the production set for LM51 segment (see section 6.634) were first encountered during LM24 segment; in contrast, productions P3 and P5 from the same set were original for LM51 segment.

Within each segment, productions were generated by considering one by one each operator recorded in "motivtns," "cog_act" and "cog_task" columns. Looking on arrows drawn on the CEMA diagram for the segment and using verbatim transcripts, we came up with "if, then" scenarios describing how a particular operator was chosen at a particular time. When compiling production lists for each of the 5 segments we attempted to be specific rather than general. A capital letter in parentheses at the beginning of each item shows from whose behavior a production was inferred and points to the approximate time when it was activated.

A bias to write more rather than less events in the left--"if"--part of productions serves the same goal of being more specific. Yet attempting to capture all phenomena that influence selection of operators, we had to rely on terms that are difficult to define exactly. These terms will be discussed immediately after each segment's list of productions in order to make formulations more precise or, at least, to attract readers' attention to potentially confusing places that will require additional work before our description is computable.

Adhering to the above guidelines we generated production systems for the following five segments.

6.633 LM24 segment: successfully filling in a clean slate.

This 26-second long segment opened the RCA part of the workshop. Andrew just had recorded the first focal problem from the list generated during brainstorming. All other participants, except Judy, were motivated to contribute causes; Judy seemed to be more interested in listening what other had to say. Everybody's attention was directed at the facilitator. After he solicited a cause, Greg came up with one (LM1) almost instantly (2, 31.1 sec). It was easily interpreted and fitted to the current focal problem by Andrew, who started recording (38.8 sec) simultaneously pronouncing what he wrote in order to check his interpretation. Greg's confirmation (4, 46.6 sec) ended the segment.

Below is the list of productions necessary to explain occurrence of all behaviors captured in the "cog_act," "cog_task" and "motivtns" columns of the CEMA diagram for this segment. The diagram is presented in the top third of Figure 15

P1. (A:24,51,83) If SelProb,X is successfully completed → SolCause,others,X;
P2. (G:24,84;D:24,84;J:24;C:24,83) If Andrew SolCause, others,... and able to capture his/her attention → GenCause;
P3. (A:31,87,255,390) If a participant PropCaus,andrew, X → IntFitCo,X;
P4. (G:31,289;D:53,68;C:84) If GenCause,X is successfully completed, and nobody else has proposed a cause → PropCause,…,X;
P5. (A:36) If in IntFitCo,X and starting to grasp a contribution, and a participant continues providing more explanations → interrupt the participant by ProvInfo,others,X and RecCause,X;
P6. (A:45) If RecCause,X and needs confirmation → ChkInter,X and RecCause,X,RequInfo;
P7. (G:37,320;D:116) If facilitator announces the cause X to be recorded or RecCause,X → ChkInter,X;
P8. (G:47) If working on X and Andrew RequInfo,…,X → ProvInfo,andrew,X;
P9. (D:31,88; J:31;C:31;G:53,87) If in GenCause,X and is not very involved yet, and another participant PropCaus,Y → InVaNvFt,Y;
P10. (D:31,88;G:88;S:393) If another motivation is not very strong and another participant PropCaus → ExamProb;
P11. (D:38; cf. LM383, P24) If motivated by ExamProb and is in InVaNvFt,X and disagrees with a participant who suggested problem X about responsibility for this problem, and sees that Andrew is already recording X → ContProb and GenCause,Y (where Y is at least partially causing X and clarifies the issue of responsibility);
P12. (J:48,75,95) If motivated by ExamProb and InVaNvFt,X is successfully completed → RecCause,X;
P13. (C:36) If in InVaNvFt,X and sees that Andrew records a cause X that is different from the cause Y that started to crystallize during the GenCause,Y immediately preceding InVaNvFt,X → return to GenCause,Y.

Conditional statements in the left part of above productions contain several terms that require additional elaboration. For example, "successfully completed" in P1 and P12; "starting to grasp a contribution" in P5; and "started to crystallize" in P13 refer to knowledge states of participants. We will have to specify them in order to make our description computable. To describe when a facilitator is "able to capture … attention," like in P2; or a participant "needs confirmation," like in P6; or is "not very involved," like in P9; or his or her "motivation is not very strong," like in P10—all these will require considering processes that resulted in particular knowledge states, especially processes of allocating attention.

Production P10 may seem to be excessively specific. Yet it is a part of the distinctive approach employed by Dave for correcting those participants whose contributions are encroaching on others' feeling

of security and are factually incorrect. Instead of directly confronting them, Dave re-formulates their statements in the way that sheds light on those additional aspects that make their mistakes salient. Later in the LM episode Dave employs the same tactic once again (180-192).

6.634 LM51 segment: resolving disagreement ignited during the previous segment.

Behavior of participants during this 30-second long segment was driven by Andrew's requests as much as by a confrontation between Dave and Greg. Yet Andrew's insistence on generating new causes effectively terminated the conflict, which probably would continue for much longer in a non-facilitated group.

The middle part of CEMA diagram shown in Figure 15 describes this segment. Differently from the previous segment, when Andrew solicited a new cause (5, 50.9 sec), Greg, Dave, Judy, and Craig were preoccupied each with a different task. Craig was still thinking about the cause of limited manpower he concived at the beginning of LM24 segment, and Judy was recording the cause fitted during that segment. Both of them disregarded Andrew's call for new causes. Greg switched into GenCause mode. Dave contributed a cause (LM2) he started to think about toward the end of LM24 segment (38.4 sec). Dave's cause was instantly recognized by Greg as an attempt to correct him. The ensuing conflict (9,10) was interrupted by Andrew's request to Dave to repeat his cause (11, 62.3 sec). Yet feeling under pressure from Greg, Dave changed it. If previously his problem could be formulated as "not clear who should pay for CPR manpower," now it sounded "no one wants to pay for it" (LM3). This is a considerable modification, because it suggests a completely different set of solutions; namely, instead of analyzing who should pay, now they have to make somebody to pay.

Judy tried (13, 70.1 sec) to direct Dave to his original contribution (LM2). He agreed and started to provide more contextual information (14, 74.1 sec). At this time Andrew had finished recording LM3 as a cause and interrupted Dave with a request of a new one (15, 82.8 sec) initiating the next segment.

Below is the list of productions necessary to explain occurrence of all behaviors captured in the "cog_act," "cog_task" and "motivtns" columns of the CEMA diagram for the LM51 segment.

P1. (A:50,81) If RecCause is completed and the focal problem Y has less than 3 causes recorded → SelProb,Y;
P2. (A:51; see LM24) If SelProb,X is completed → SolCause,others,X;
P3. (G:51) If his contribution was recorded during the immediately preceding segment, and Andrew SolCause, and no other causes have been proposed in this segment → ExamProb and GenCause;
P4. (D:53,68; see LM24) If GenCause,X is successfully completed, and nobody else has proposed a cause → PropCause,…,X;
P5. (G:53; see LM24) If in GenCause,X and is not very involved yet, and another participant PropCaus,Y → InVaNvFt,Y;
P6. (J:53,84) If recording a cause and a participant SolCause,…,X or PropCaus,…,X → ChkWhere,X;
P7. (C:56) If GenCause,X successfully completed and discussion about Y is strong at that time → WaitBrea, PropCaus,X and ChkWhere,Y;
P8. (J:58) If a participant Y ProvOpin,X that is emotionally laden and acceptable → Expressi,X and Agrees,Y,X;
P9. (G:60) If a participant Y makes statement X contradicting Greg's previosly made statement and attacks FE → DEfense,X, ProtDept, and ProvOpin,Y,X attacking Y;

P10.(D:60) If a participant Y provides conflictual opinion about the issue X related to relations between departments → ChkValid,X and ProtDept;
P11.(D:62) If ChkValid,X results in a conclusion that the statement is incorrect or irrelevant to X → ProvInfo to calm down and restrain the participant Y who made the statement, and ProvInfo,Y,X.
P12.(J:63;S:393) If in Expressi and Greg makes a statement about X in loud voice → ChkWhere,X;
P13.(A:62; cf. LM254, P8) If in IntFitCo,X and cannot do that, and a participant Y who made this contribution is involved in conversation that does not help to interpret, and conversation is strong → SolCause,Y,X;
P14.(J:63;G:64) If Andrew SolCause,Y,… for a cause X that has been proposed by another participant Y earlier in this segment → InVaNvFt,X;
P15.(D:63;G:286) If a participant SolCause,Y,… → Y ContProb (if motivation is different at this moment) and GenCause;
P16.(A:72,95) If in IntFitCo,X and has been able to interpret and fit the contribution → RecCause,X;
P17.(J:70) If a cause proposed by participant Y has changed comparing with his/her previous formulation X → in low voice—like to herself—ProvOpin,judy,X about veracity of X and if not heard, RequOpin,Y,X about which formulation is correct;
P18.(D:74) If participant Y requested opinion about a current focal issueX → ProvOpin,Y,X;
P19.(D:75) If another participant supports his views on issue X that still causes disagreement among participants → ProvInfo,others,X;
P20.(J:75; see LM24) If motivated by ExamProb and InVaNvFt,X is successfully completed → RecCause,X;

Similarly to the previous segment, quite a few productions on the current list refer to knowledge states or their assessment that determine activation of productions; for example, "successfully completed" and "strong" in P7 and "has been able to interpret and fit the contribution" in P16.

Also, the segment contains an instance of conflict resolution. Productions that were inferred from the corresponding behaviors--P8 through P11--involve assessments of emotional states of participants and of expressive aspects of their actions. They clearly demonstrate how emotions influence cognitive dynamics.

Production P17 describes situation that is unlikely to happen again. This was the first time Judy spoke up in the RCA part of the workshop. She was motivated to examine problems suggested by other participants, rather than contributing her own. For these two reasons she started to talk too low for other participants to hear her and had to correct herself. While adjusting volume of her voice, she also changed her utterance from stating her opinion for Dave to check, to more polite action of requesting his opinion. In its essence, P17 describes an instance of self-reflective behavior.

6.635 LM81 segment: thinking aloud when proposing a cause.

This 35-second long episode followed the pattern of almost the minimum conversational exchange necessary for recording a new cause. Andrew solicited a new contribution (15, 82.8 sec), Craig responded with a cause he had been working at since the beginning of LM24 (16, 18, 21). Andrew had no problems with interpreting, fitting and recording Craig's contribution (114.1 sec). Greg, Dave, and Judy--after she completed recording the previous cause--attended to the conversation.

The way Craig was presenting his ideas--both proposing a cause and providing his opinion of how to deal with it--is the only notable nuance distinguishing this segment. He spoke for 23 seconds with 4

breaks: two interruptions by other participants (85.0 sec and 95.4 sec), and two pauses for formulating his ideas (90.6 sec and 102.3 sec).

Below is the list of productions necessary to explain occurrence of all behaviors captured in the "cog_act," "cog_task" and "motivtns" columns of the CEMA diagram for this segment. The diagram is presented in the bottom third of Figure 15.

P1. (A:81; see LM51) If RecCause is completed and the focal problem Y has less than 3 causes recorded → SelProb,Y;
P2. (A:83; see LM24) If SelProb,X is successfully completed → SolCause,others,X;
P3. (C:83; see LM24) If in ChkWhere and Andrew SolCause, others,... → GenCause;
P4. (C:84; see LM24) If GenCause,X is successfully completed, and nobody else has proposed a cause → PropCause,…,X;
P5. (G:84;D:84; LM24)) If Andrew SolCause, others,... and able to capture his/her attention → GenCause;
P6. (J:84; see LM51) If recording a cause and a participant SolCause,…,X or PropCaus,…,X → ChkWhere,X;
P7. (A:87; see LM24) If a participant PropCaus,andrew, X → IntFitCo,X ;
P8. (G:87;D:88; see LM24) If in GenCause,X and is not very involved yet, and another participant PropCaus,Y → InVaNvFt,Y;
P9. (J:87; cf. LM24,P9) If in ChkWhere,X and another participant PropCaus,Y → InVaNvFt,Y;
P10. (G:94; cf. LM254,P15) If in InVaNvFt,X and thinks that has better formulation than a participant that has proposed the cause → ProvInfo,others,X;
P11. (A:95; see LM51) If in IntFitCo,X and has been able to interpret and fit the contribution → RecCause,X;
P12. (J:95; see LM24) If motivated by ExamProb and InVaNvFt,X is successfully completed → RecCause,X;
P13. (A:114; cf. LM24,P6) If RecCause,X and first needs confirmation but later decides that he does not→ RecCause,X,ProvInfo;
P14. (D:116; see LM24) If facilitator announces the cause X to be recorded or RecCause,X → ChkInter,X;

Most of productions in the current episode have occurred before and are discussed in previous sections. Production P10 is similar to production P15 in LM254 segment in the fact that Greg does not hesitate to provide unsolicited information when he feels that his wording is better. He may be more apt to do so than other participants, yet as demonstrated on several occasions by the conversation flow (for example: 43-53, 162-168, 244-253) during the LM episode, everybody felt comfortable to contribute their ideas most of the time. The answers to post-workshop questionnaire--that contained an item "I was (always / not always) comfortable to speak my mind openly"--support this point. All participants, except Judy and Rick, marked "always."

Production P13 is quite unique and probably will not be encountered often. Essentially, it constitutes a truncated version of production P6 in LM 24 segment. To understand why an attempt to request participants' opinion was abandoned we have to understand why Andrew first noticed the difference between re-solving and re-answering and then decided that it was not important enough for spending time on clarifying it.

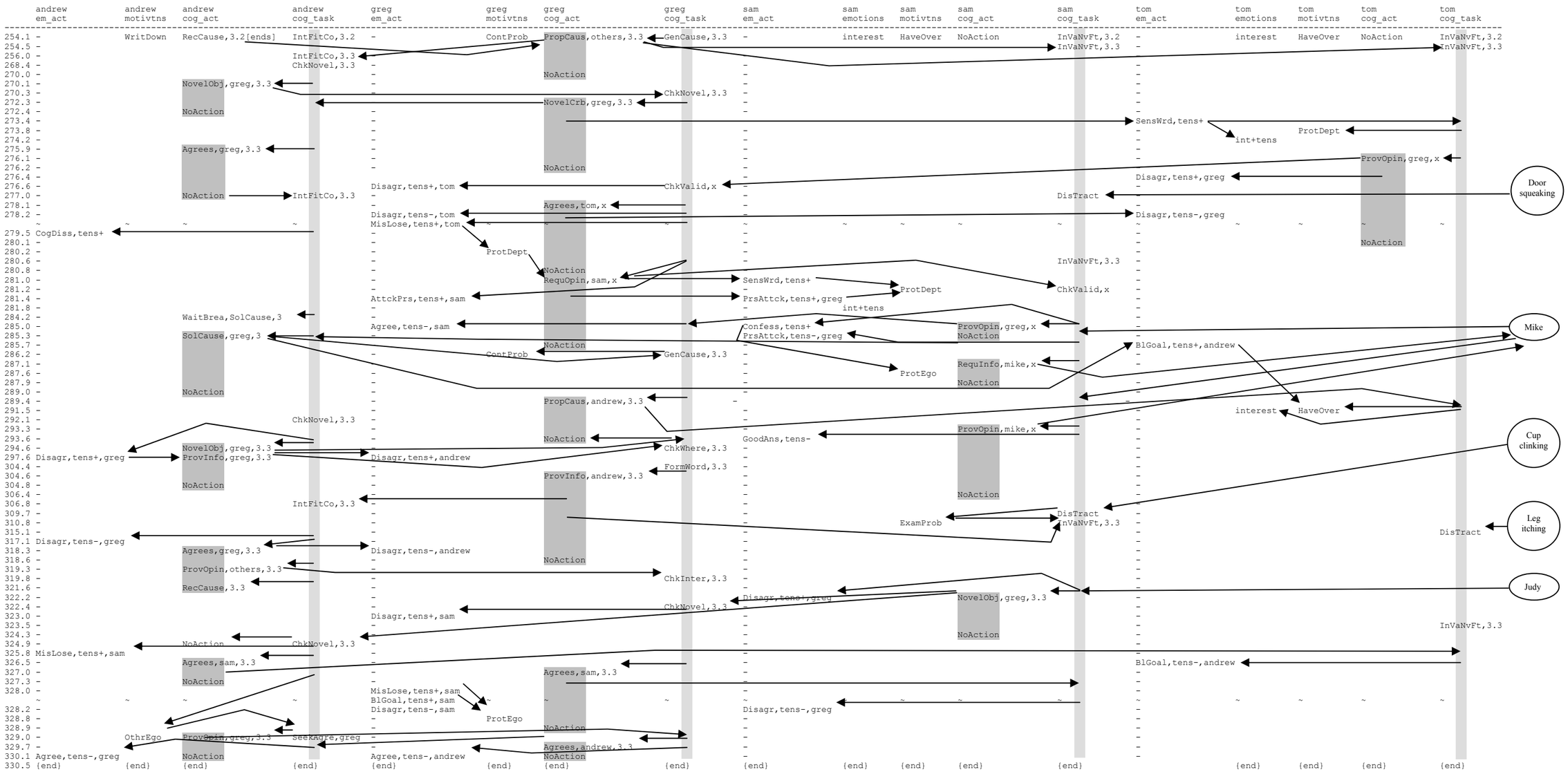
Craig's lengthy utterance calls our attention to one more operator that has been neglected when inferring productions--NoAction. In general, there are three causes for participants who are speaking to stop: (1) because their speech was completed and they waited for a response; (2) because they were

interrupted; and (3) because they needed to pause for thinking. *Post factum* it is quite simple to distinguish between the three from videotaped materials. Deciding in border-line cases, whether a pause just marks separate sentences or was used for thinking what to say, constitutes the only difficulty. Yet to come up with a description that will allow us to compute when people finish their utterances or pause for formulating their thoughts is beyond the limits of the current study. For this reason, productions governing activation of NoAction are not recorded. Actually, NoAction is not a genuine cognitive operator, because it does not change an actor's cognitive state. Interruption cases are indicated in CEMA diagrams by arrows ending at "NoAction."

6.636 LM254 segment: simultaneously interpreting and establishing a contribution's novelty.

The segment started at the time mark 254 sec and lasted for approximately 75 seconds. It originated from Greg's contribution (LM 3,3) of a new cause of the focal problem recorded as "no one wants to pay" (LM3). Greg, Andrew, Sam, and Tom were actively involved in the discussion. Sam had a prolonged side conversation with Mike (287-310 sec), and Judy made two short comments (76, 80).

CEMA diagram of the segment is presented in Figure 16. It has 6 main components. First, Andrew and Greg were discussing the novelty of Greg's contribution (254-277 sec). While doing so, Greg contradicted his own previous argument (2, 9) that low priority of CPR is limited to the SE department. During the second component, Tom made sure that Greg confirms that low priority of CPR is a universal problem (276-281 sec). Third, Greg put Sam on the spot asking for confirmation that this problem exists in his department too, and Sam agreed (281-285 sec). Fourth, Andrew asked Greg to repeat his contribution, objected to its novelty again, but agreed to record it after Greg's explanation (285 - 322 sec). Fifth, Sam insisted that Greg's contribution had been already recorded. Greg had to agree, and Andrew stopped recording it (322-329 sec). Sixth, there was a short tension-releasing exchange between Andrew and Greg (329-330).



Andrew emotions = interest; Greg emotions = interest.

Figure 16. CEMA diagram for LM254 segment.

Below is the list of productions necessary to explain occurrence of all behaviors captured in the "cog_act," "cog_task" and "motivtns" columns of the CEMA diagram for the LM254 segment.

P1. (G:254) If in GenCause, and has an inkling of a cause, and facilitator is done with recording → PropCaus;
P2. (A:255; see LM25) If a participant PropCaus,andrew, X → IntFitCo,X;
P3. (A:268,292) If in IntFitCo and words previously recorded as contributions are mentioned when a participant PropCaus → ChkNovel;
P4. (A:270,295;S:322) If in ChkNovel or InVaNvFt and comes up with a conclusion that a contribution has been previously recorded → NovelObj;
P5. (A:325;G:322) If a participant NovelObj,Y,X →Y ChkNovel,X;
P6. (G:272) If in ChkNovel,Y and sees difference between his present contribution and what has been recorded → NovelCrb,Y;
P7. (A:276) If in ChkNovel,Y and NovelCrb,Y by X, who did propose the currently examined contribuion, makes sense → Agrees, X and IntFitCo,Y;
P8. (A:284) If in IntFitCo,X and cannot do that, and a participant who made this contribution is involved in conversation that does not help to interpret, and conversation is strong → WaitBrea, SolCause,X;
P9. (A:285;S:432,446) If in WaitBrea,<operator> and natural break occurs → <operator>;
P10. (G:286; see LM51) If a participant SolCause,Y,… → Y ContProb (if motivation is different at this moment) and GenCause;
P11. (G:289; see LM24) If GenCause,X is successfully completed, and nobody else has proposed a cause → PropCause,…,X;
P12. (A:298) If NovelObj is accompanied by tension increase, and the proposed cause can be reached going up the causal tree → ProvInfo about undesirability of recording causal loops;
P13. (G:298) If addressed by another participant and not clear why → ChkWhere;
P14. (G:304) If ChkWhere results in an opinion that Andrew doesn't like current wording → FormWord in order to reformulate it in different terms;
P15. (G:305; cf. LM81,P10) If in FormWord,X and thinks that has better formulation → ProvInfo,andrew,X;
P16. (A:307) If in ChkNovel, a participant disagrees with NovelObj and provides description of a business process → IntFitCo;
P17. (A:318) If in IntFitCo, Greg disagrees with NovelObj for 2nd time and provides a formulation without recorded terms → Agrees,Greg, and ProvOpin to the group about desirability of recording the contribution by restating it;
P18. (A:322) If nobody speaks up in negative responding to ProvOpin about recording a contribution → RecCause;
P19. (A:325) If RecCause, a participant NovelObj, and hears the objection → ChkNovel and stop RecCause;
P20. (A:327) If in ChkNovel and NovelObj by X, who did not propose the currently examined contribution, makes sense → Agrees,X and OthrEgo;
P21. (A:329) If OthrEgo and X is a participant who made the contribution that was just rejected as not novel → SeekAgree,X by frinedly and tentatively ProvOpin,X;
P22. (G:320; see LM24) If facilitator announces the cause X to be recorded or RecCause,X → ChkInter,X;
P23. (G:327) If in ChkNovel because X NovelObj and does not see difference between his present contribution and what has been recorded → Agrees,X;
P24. (G:330) If X ProvOpin to him while SeekAgre → Agrees,X;
P25. (G:277) If a participant ProvOpin,Y,X that leads to Disagr, tens+ → ChkValid,X;
P26. (G:278) If in ChkValid,X because of previous ProvOpinY,X and thinks that X is true → Agrees,Y,X;
P27. (G:280) If in ChkValid, X and establishing that X is true will help to protect his department and participant Y may help to evaluate veracity of X → ProtDept and RequOpin,Y,X;
P28. (S:281) If Y ReqOpin about veracity of idea X mentioning SensWrd and starting PrsAttck against his department → ProtDept, ChkValid,X and ProvOpin,Y,X;

P29.(S:287) If missed something probably addressed to him by X → ReqInfo,X;
P30.(S:293) If Y ProvInfo,Z,X → participant Z ProvOpin,Y,X;
P31.(S:255;T:255) If a participant PropCaus → InVaNvFt;
P32.(T:274) If Y recognizes that a problem related to idea X is not limited to SE but exists in Y's department too → ProtDept and ProvOpin,Y,X to ensure appropriate recording on flip-charts;
P33.(S:277,310;T:315) If sufficiently strong distraction occurs → DisTract;
P34.(S:281,310;T:324) If DisTract is over and idea X is being currently examined → InVaNvFt,X.

A definition of the very first production—P1—refers to "inkling of a cause." This term is used, because compared with other participants Greg often started contributing when he had only a vague notion of what he was going to say. When asked to generate a cause he relied on complex intuition developed over many years of every-day involvement in FE practice and was quick to come up with essential issues related to the analyzed problem, though not necessary in a clear manner. This created the first complication in Andrew's attempts to fit contributions, and makes us speak about "an inkling of a cause."

Second, being well familiar with problems in his work, but not required by circumstances to articulate them, Greg often contributed (2, 26, 60, 75, and others) a concrete and cursory description of processes that caused him difficulties. He did not articulate much of their context. This obstructed the transfer of knowledge Andrew needed for interpreting Greg's contribution.

Third, sometimes--and Greg, PropCaus (60) provides a good example--Greg was developing his contribution while already speaking. He was using the so-called directed line of reasoning (Hume et al 1996; Katz 1997) to help himself with formulating his statement. In the present case, Greg started from the outcome--"nobody has that resource in manpower"--he was going to provide a cause for. Then he mentioned another process contributing to the same outcome--"no one wants to pay for it"--in order to distinguish his idea from one that had been already mentioned. "It" here refers to payments made to existing manpower for providing CPR services. Greg did not make this clarification that was crucial for understanding novelty of his contribution. Next he mentioned a process that resulted in manpower shortage--"they have trimmed manpower down." Finally, he added a qualifying process hinting to decision making that led to manpower reduction--"to handle the product that you're getting out, not to handle five years old..."

Being not familiar with particular CPR-related processes and confronted with such a complex and condensed remark, Andrew was not able to interpret it at once. The expected difficulty of the task may be the reason why Andrew switched to checking novelty of the contribution, subconsciously seeking to discard it. This may be an instance of emotional control of cognition--wishful thinking--essence of which was outlined in the literature review section 3.0. As production P3 suggests, mentioning words that were already recorded combined with inability to interpret their meaning led Andrew to check the contribution's novelty. The desirability of abandoning the contribution, even when countered by his intent to write down 3 causes for each focal problem, probably made Andrew in P4 to come up with a conclusion that the contribution had been previously recorded. A number of words that had been already recorded and how

prominent they were in Andrew's current evoked set, may constitute another determinant of concluding that contributions were not new.

NovelObj in P4 may have many gradations of how strong the objection is. For example, it may be stated as a question to a participant proposing a cause (61), or it may take a form of an opinion declared with various degrees of confidence and friendliness (74, 81). Different levels of the objection's strength directly lead to different developments in emotional dynamics captured in the em_act column.

Left parts of productions P6 and P23 refer to participant's ability to see differences between their present contribution and what has been recorded. Greg's utterance in (64) demonstrates that differences are not always related to novelty. He focused on the distinction between SE and FE that is irrelevant for explaining what makes his current contribution different from LM1,2. This failure, as well as other occasions when Greg introduces or explains his ideas, suggest that he is comparing memories of a set of actual events that occurred at particular time in particular space, not abstract ideas. In the present example, he observed one of them in FE department and another one in SE. But, in principle, both processes can be found in any department. Computing Greg's behavior will be impossible without determining mechanism of selecting a subset of features utilized for examining novelty.

Productions P7 and P20 will require a better definition of what it means NovelCrb or NovelObj "makes sense." To accept (63) Greg's NovelCrb as reasonable, Andrew had to disregard the content of Greg's statement or to make a logical mistake. This shows once again that Andrew was just starting to grapple with Greg's contribution. His understanding was still on the intuitive level. Probably, he just grasped that Greg is speaking now about a different department. This is correct. Yet, as mentioned earlier, the difference is not related to novelty. Furthermore, if Andrew's sensemaking was completely logical, he should come to the conclusion that Greg's contribution did not have to be recorded, because LM1,2 had been already stated in general form as it was true for any department. This opinion was expressed by Tom (66), but Andrew disregarded it, because his focus had switched already to IntFitCo. Yet, Greg's contribution was novel. Just his NovelCrb (62, 64) statement failed to explain what made it different from LM1,2. So, acting on the intuitive level and being led in his sensemaking by the fact that Greg disagreed with his objection rather than by analysis of Greg's statement, Andrew made a correct decision to try to record Greg's contribution.

Andrew's reaction to Greg's clarification (75) also shows that Andrew employed information mostly from a single small fragment of Greg's lengthy statement. Probably he was picking up semantically completed units that could be used for accomplishing his current task. For example, Greg's words "I can't justify the dollars" (77) could be fitted as a cause to "no one wants to pay." Satisfied with this, Andrew started to write them down and disregarded the very next statement--"I can't hire the people"--that captures the novel part of Greg's contribution, but does not fit the current focal problem. Interesting, that Greg did not argue with this shift neither when checking Andrew's recording (319.8 sec), nor later when Sam challenged the novelty once again (79, 322.3 sec). It is possible that the fact of recording his contribution was most important for Greg at that time.

Sensemaking process in P20 equates “cannot justify the financial [return]” with “no perceived financial return.” In reality, the latter may be, but does not have to, a cause of the former. There may be four mechanisms--or any combination of them--that led Andrew to conclude that the two “are almost the same thing” (81, 326.5 sec). First, presence of the same key word combination--”financial return”--in both statements. Second, ostensible close causal association. Third, Andrew could be swayed by the bold Sam’s pronouncement “It’s still the same thing,” that followed the explanatory part of Sam’s NovelObj. Fourth, Andrew objected novelty of the current Greg’s contribution two times himself, and probably was not completely convinced by the last Greg’s explanation.

The above analysis of several vaguely defined expressions in the left part of productions demonstrates that explicitly modeling knowledge states of participants will be necessary for creating a computable description of group dynamics. Terms like “conversation that does not help to interpret, and conversation is strong” in P8, “not clear why” in P13, “establishing truth” in P27, “probably addressed” in P29, “recognizes that a problem is not limited to SE” in P32, ” sufficiently strong distraction” in P33, and probably some others will have to be specified.

Discussing how the productions governing selection of cognitive operators work, we have referred already to a gamut of emotional phenomena. The segment suggests a couple more of dynamic links between emotions and cognition.

As one can see in Figure 16, emotional actions of participants, which are recorded in “em_act” columns, originated from one of two sources. Majority of them stemmed from participants’ own performance of cognitive tasks, but some were triggered by actions of other participants. In concord with their definition from the literature review section--”a signal that an organism gives to itself when it prepares to act after interpreting a situation”--emotional actions often led to transitions to new motivations.

Cognitive dynamics during the segment was influenced by emotions in two more instances of wishful thinking, additionally to one already mentioned when discussing processes enacted in P3 and P4. Andrew’s agreement with Greg’s defense of his contribution’s novelty, seems to be influenced by the desire to remove their disagreement (297.6 sec). Also, Sam’s diversion into a lengthy side conversation with Mike (287 - 310 sec) was in a large extent driven by his attempt to alleviate tension caused by his confession about problems in his department (68, 285.0 sec). The bits and pieces of the conversation that can be heard demonstrate that Sam tried to sound as a fair person who had deliberately recognized that avoiding responsibility for malfunctioning old products constitutes a problem to be considered. Giving this answer to Mike (GoodAns, 293,6 sec) helps Sam to cope with his tension.

6.637 LM383 segment: clash of two trains of thought.

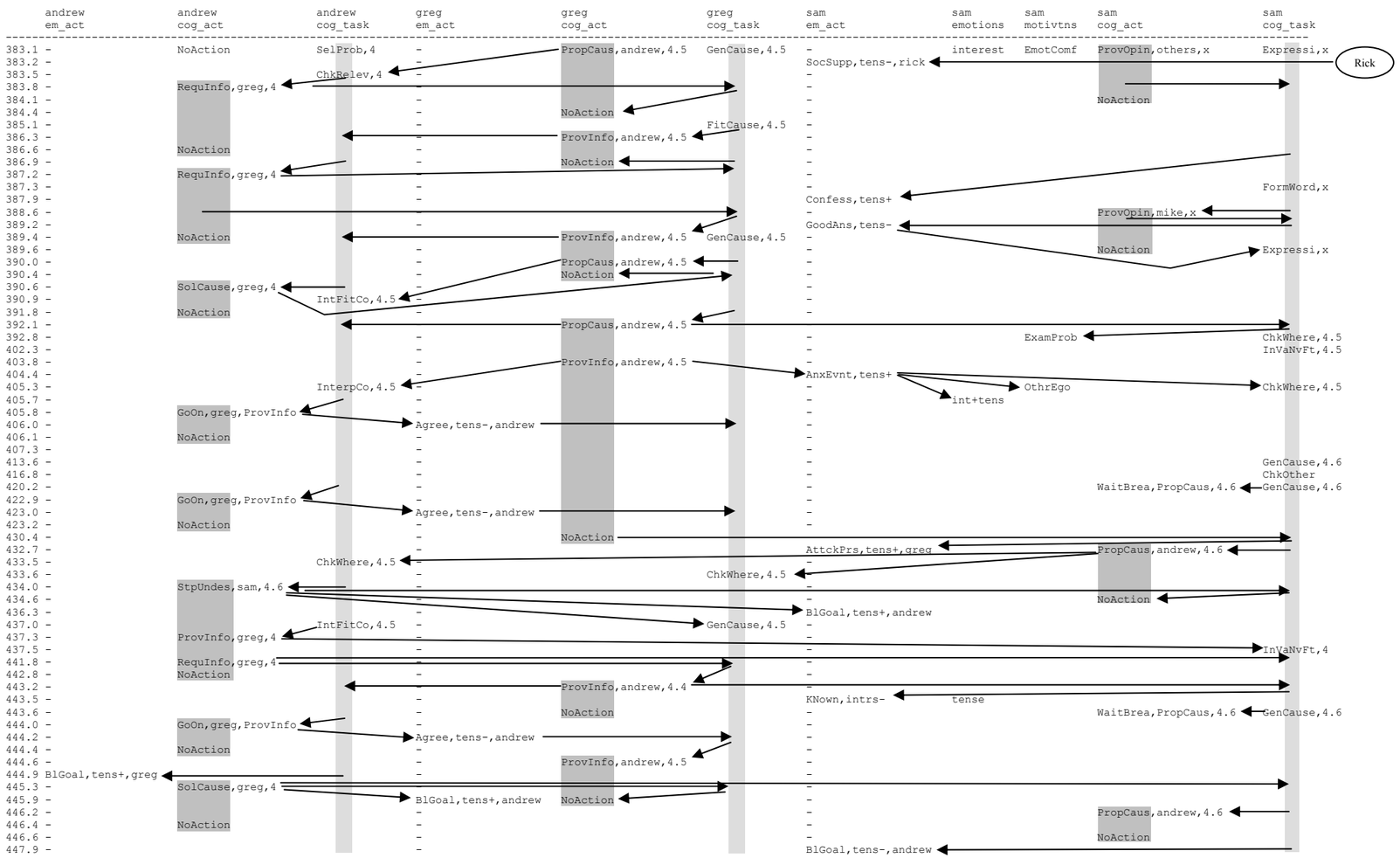
The segment lasted from time mark 383 sec to 446 sec. It started after an emotional catharsis following Andrew’s remark about the issues the group was discussing: “this is all financial” (107). In the midst of uproar Dave and Greg continued suggesting possible causes (109, 113). Greg got Andrew’s attention and started proposing a cause. The discussion unfolded between these two, but all others attended

to it, because of Greg's aggressive tone directed at Judy. Judy made one short comment to herself (125) that was not heard by others.

After Greg started speaking, Andrew interrupted him, asking whether he was suggesting a cause of the current focal problem. Greg answered in the affirmative, though this was incorrect: he was speaking about remote consequences rather than causes.

Next Greg proposed the cause--"the person that takes the call is also the person that's re-answering the same problem many times"(120, 392.1 sec)--and supported it by a 30-second long explanation during which he--probably not intentionally--attacked Judy. His pointing at her was especially offensive. This made Sam anxious and he attempted to counterattack Greg, but Andrew stopped him in order to draw more information from Greg. While posing questions, Andrew "sidetracked" Greg's train of thought attempting to follow his own (127, 434.0 sec). Not getting desired answers, he suddenly solicited another cause. Greg was confused by this abrupt change, and Sam had an opportunity to contribute, leading the discussion in a new direction.

CEMA diagram of the segment is presented in Figure 17. Most of interaction occurred between Andrew and Greg. Yet we included Sam too, because he was visibly involved emotionally, and his unequivocal facial expressions and body language provide an opportunity to analyze an emotional component of behavior that is more difficult to decipher in other participants.



Andrew emotions = interest; Andrew motivtns = WritDown; Greg emotions = interest; Greg motivtns = ContProb.

Figure 17. CEMA diagram for LM383 segment.

Below is the list of productions necessary to connect all behaviors captured in the "cog_act," "cog_task" and "motivtns" columns of the CEMA diagram for the LM383 segment.

P1. (A:383) If in SelProb,X and participant Y PropCaus → ChkRelev,X and RequInfo,Y,X;
P2. (A:384) If in ChkRelev,X of participant's Y contribution and is not sure about the information the participant has provided already → RequInfo,Y,X;
P3. (G:385) If PropCaus,Y,X and participant Y RequInfo about relevance of X → NoAction and FitCause,X and ProvInfo,Y,X;
P4. (A:390) If a participant PropCaus,andrew, X → IntFitCo,X;
P5. (G:390) If was interrupted while PropCaus, andrew,X and have already provided info about the X's relevance and Andrew asks for confirmation → switch back to GenCause,X and confirm by ProvInfo,andrew,X and PropCaus, andrew,X;
P6. (A:391) If relevance of Y's contribution to X is established → SolCause,Y,X;
P7. (G:392) If already PropCaus,Y,X and participant Y SolCause → NoAction and then again PropCaus,Y,X after Y is done;
P8. (G:404) If PropCaus,Y,X is finished and Y seems not getting the point → ProvInfo,Y,X clarifying how the problem occurs;
P9. (A:405) If a participant ProvInfo detailing how the proposed cause X influences the focal problem → InterpCo,X;
P10. (A:406,423,444) If Y pauses while providing information, and Andrew wants him/her to continue → GoOn,Y,ProvInfo;
P11. (A:433;G:433) If working on contribution X and a participant suddenly introduces a new idea Z → ChkWhere,X;
P12. (A:434) If ChkWhere,X results in a conclusion that participant Y suggests Z while Andrew still wants to pursue X → StpUndes,Y,Z and IntfitCo,X;
P13. (G:437) If Greg have been working on his own contribution X, and is interrupted by another participants suggestion of a new cause, and Andrew StpUndes → GenCause,X;
P14. (A:440) If an interruption while IntFitCo,X or InterpCo,X suggested by a participant Y is over → ProvInfo,Y,Z and RequInfo,Y,X (where Z is the focal problem to which X is being fitted);
P15. (A:445) If not getting information helpful for interpreting/fitting contribution Z to focal problem X, and the participant Y who suggested it is known for proposing not novel causes → SolCause,Y,X and StpUndes,Y,Z;
P16. (G:443) If working on X and Andrew RequInfo,greg,Z → ProvInfo,andrew,Z and wait for Andrew's reaction.
P17. (G:445) If working on X and ProvInfo,andrew,Z on Andrew's request and encouraged to go on → ProvInfo,andrew,X;
P18. (S:388) If driven by EmotComf and realizes that while talking about X made a negative remark/confession → FormWord,X and ProvOpin,mike,X;
P19. (S:390) If gave GoodAns reducing tension from previously made remark while working on problem X → Expressi,X;
P20. (S:393; see LM51) If in Expressi and Greg makes a statement about X in loud voice → ChkWhere,X;
P21. (S:393; see LM24) If another motivation is not very strong and another participant PropCaus → ExamProb;
P22. (S:404) If Greg PropCaus,Y,X and ChkWhere,X makes clear what Greg is doing → InVaNvFt,X;
P23. (S:406) If AnxEvnt,tens+ have occured while discussing X → OthrEgo and ChkWhere,X in order to understand reasons and consequences of the anxiety raising event;
P24. (S:414; cf. LM24, P11) If an examination of an anxiety raising event suggests that a participant has to be defended → GenCause that is critical of the offender;
P25. (S:417) If preparing to propose a critical cause → ChkOther in order to estimate their reaction;
P26. (S:420) If ChkOther resulted in decision to PropCaus → GenCause;
P27. (S:420,444) If in GenCause and has formulated the cause, and Andrew is involved in a discussion or RecCause → WaitBrea,PropCaus;
P28. (S:432,446; see LM254) If in WaitBrea,<operator> and natural break occurs → <operator>;

P29.(S:435;G:446) If participant Y starts speaking to Andrew about X and Andrew StpUndes,Y,X → Y NoAction;
P30.(S:442) If Andrew ProvInfo,Y,X → InVaNvFt,X;
P31.(S:443) If in InVaNvFt and concludes that a participant's ProvInfo has no new information → switch to the most important goal at that time;

Productions P2 and P5 shed some light on how relevance of a contribution is established by Andrew during ChkRelev. In P2 he was not sure about Greg's answer (115, 386.3sec) probably because Greg's tone revealed that Greg treated Andrew's question as a distraction and did not pay much attention to it. When Andrew requested relevance information for the second time, Greg's tone revealed the same lack of attention to checking relevance, and willingness to return back to proposing a cause (118, 389.4 sec). Yet Andrew accepted the answer now. Two affirmative answers in a row were convincing enough for Andrew to consider that relevance had been established.

Interestingly, Greg's contribution was causally misplaced but he did not notice that despite of repeated questioning by Andrew. This can be explained in 5 ways or as a more complex mental process combining all of them. First, Greg's attention was primed by expert=Judy association. Second, it could be primed by an analogy between problems with distribution of answers--that served as a focal problem at that moment--and with distribution of requests for answers--that constituted the essence of his contribution. Third, although Greg's contribution was not a cause of the current focal problem, but they were related. Namely, re-answering the same question, was not causing but aggravating the conflict between Judy's duties to answer questions and to direct them to other experts. Fourth, Greg obviously was trying to contribute a process that caused him much hardship in everyday work. He wanted it to be recorded. Fifth, from Greg's statements made during the workshop (187, for example) and interviews with him and Judy, it became clear that Greg thought that Judy is not capable and should not perform the expert's role. He probably was driven by a desire to announce a problem that supported his judgment.

Productions P7 and P16 demonstrate that pauses play important role in a dialogue. They may signal difficulties with understanding and expectations of reaction to what was said. They also may indicate that additional time is necessary for cognitive processing. We will need better understanding of how pauses are generated and interpreted before our description is computable.

Production P14 was inferred after assuming that Andrew intended to perform it but made a mistake: instead of RequInfo,4.5 he returned to the already recorded contribution LM4.4. In any case, reasoning mistakes do happen and we might want to understand how in order to create a realistic description of collaborative problem solving. In this particular case, stopping Sam's contribution probably made Andrew forget, at least partially, what Greg was speaking about. Yet his difficulty with interpreting Greg's contribution probably was caused by confusion about the relationship between Judy and "expert," and Andrew remembered that with some degree of clarity. To help himself, he started the directed line of reasoning (Hume et al 1996; Katz 1997) tracing it to the focal problem. Yet then Andrew suddenly read the already recorded contribution LM4.4 reformulating it in such way--"Cause we have not communicated ...."--that participants had to complete the sentence telling Andrew by whom or to whom answers were not

communicated. This abrupt development can be explained by Andrew's desire to return to successfully but incompletely recorded contribution after spending 50 seconds trying to interpret Greg's input.

Production P15 looks like a mistake too, especially after considering Andrew's encouragement of Greg to proceed (129, 444.0 sec) that immediately preceded the abrupt interruption (131, 445.3 sec). Yet probably Andrew's "OK" was also an attempt to buy more time trying to utilize information from Greg's "everybody" for figuring out the relationship between "expert" and Judy. Not getting any help from Greg for continuing his thread of thought, and knowing that Sam has another contribution that would permit recording 3 causes for the current focal problem, Andrew decided to terminate his attempt to interpret Greg's contribution LM4.5. The way he does it by saying "any other reasons?" (131, 445.3) suggests that he viewed Greg as a person whose contributions are not novel.

Productions P18 and P19 assume that Sam is reflecting not only on actions of others but on his own too. In P17 he did not need a feedback from other participants to realize that his remark not only had shown himself in negative light but also implied the same quality in others (111). In P18 Sam laughs showing satisfaction just after explicitly stating that his previous remark was only about himself (117, 388.6 sec). In general, it is possible that participants evaluate not only their own actions but even thoughts.

Productions P25 and P26 describe how an operator central for performing IMT tasks--ChkOther--is applied and utilized. Admittedly, the processes of estimating reaction of participants to what is happening and how ChkOther results in any decisions do require further clarification.

6.638 Toward generalized description of cognitive and emotional group dynamics.

Combined with the initial theoretical framework delineated in the literature review section, the above mentioned production systems and interpretations of particular processes lead us to postulate existence of the four more general and abstract cognitively-emotional mechanisms, that are directly related to quality of resulting causal maps. First, allocating attention to a new goal required time and effort on participants' behalf, and they had difficulties performing more than one task at a time. Second, different levels of familiarity with an issue required different information processing approaches and caused mutual misunderstanding. Third, perceiving or anticipating resistance participants focused on the task of making their point to the extent of forgetting about other goals. Fourth, it was difficult for all participants to maintain their thread of thought during the discussion.

The participants coped with these challenges in a variety of ways, which are described below in more detail. The resulting production system is quite large. From the following sections, it is clear that the footage analyzed in the current study is not sufficient for generating a nearly exhaustive production system for the collaborative RCA. Yet at the end of this section we make an attempt to estimate size of such system.

6.6381 Allocation of attention to several goals.

The tasks of interpreting and fitting proposed causes, as well as the tasks of checking their validity and novelty, are intrinsic to the RCA. There are, in principle, an infinite number of other goals that can be brought in by the workshop participants. These goals are more stable than those related to cognitive tasks and correspond to motivations of the participants.

The "motivtns" columns in CEMA diagrams--Figure 16 through Figure 17--present the dominant motivations at each point in time for the participants who were actively involved in discussion. One can see, that goals of causally fitting contributions, which are major constituent parts of ExamProb and, in a smaller degree, ContProb motivational states, were not prominent at all during problematic segments LM254 and LM383.

One can see that during the LM254 segment Greg, Tom, and Sam were motivated by the goal of protecting the image of their departments. Being distracted by this task (280.2 sec) in the middle of his efforts to propose a new cause, probably contributed to Greg's failure to interpret his suggestion and to demonstrate its novelty. Tom's post-workshop questionnaire and his emotional outburst at the end of LM254 segment, when he mocked Andrew's intention to have 5 tiers of "why" recorded on the flip-charts, show that the ignored need to convince participants in the value of the RCA approach led some of them--for example, Tom in this segment--to wish the exercise would be over as soon as possible and to look in the meanwhile for flaws in this problem-solving methodology.

During both LM254 and LM383 segments Greg was motivated to contribute problems. He failed both times and this led to increase in his tension (328.0 and 445.9 sec). The situation probably was caused by his excessive motivation. First, Greg spoke up before he formulated his contributions well enough to be understood by Andrew. Second, at the beginning of both segments Greg's extreme focus on proposing causes clashed with Andrew's goals, creating obstacles for interpreting Greg's ideas. During the LM254 segment, trying to finish with checking novelty as soon as possible, Greg did not provide Andrew with any definitive statement. Furthermore, being careless in his expressions he plunged Tom and Sam into defensive mode while protecting their departments. During the LM383 segment, he paid only superficial attention to the task of checking relevance of his contribution to the focal problem. Consequently, he made a false statement about causal fit. In turn, this obstructed Andrew's efforts to interpret and fit Greg's contribution, which was abandoned without recording it.

One also can trace allocation of attention among several competing goals corresponding to cognitive tasks by following sequences of operators recorded in "cog_task" column of CEMA diagram. The dialogue between Andrew and Greg during the LM254 segment provides a good example. It was supposed to help Andrew to interpret Greg's contribution and to fit it to the current focal problem. Yet the goal of checking novelty of the contribution took precedence over the facilitator's behavior. With attention focused on defending novelty, Greg failed to provide Andrew with adequate understanding of his contribution.

At first glance, it seems that interpreting a contribution is a prerequisite for deciding on its novelty. Anyway, advances toward the goals of interpreting, fitting, validating, and discovering novel aspects of a contribution can go hand in hand amplifying each other. Rapid switches back and forth between these tasks are usual while searching in the problem space of the RCA. This was the reason for introducing combined operators InVaNvFt for participants and IntFitCo for the facilitator. Yet, as will be shown in the next section, during collaborative information processing it is possible to make a decision about a contribution's novelty without even interpreting it. As was the case, pursuing one of these goals may interfere with the progress toward another one.

6.6382 Pre-rational, rational, and post-rational collaborative information processing.

Participating in group problem solving, a person does not have to figure out everything himself or herself. For example, if a contribution's novelty or its relevance to the currently analyzed focal problem is an issue, a facilitator can ask contributors or other participants for their opinion.

Because the facilitator was not familiar with the functioning of the company, he relied on the participants' opinions in the considerable degree. That was especially salient when new causes were introduced and Andrew did not have a close analogy in his repertoire formed by facilitating problem-solving workshops in other companies. When discussion provided Andrew with more detail, he began cross-checking bits of information contained in the participants' opinions, abandoned superficial and fuzzy analogies, and spent more time figuring out mechanisms underlying causal links. His attention gradually switched from assessing trustworthiness of participants toward analysis of their statements' substance. In other words, Andrew moved from looking for working consensus to looking for ideal one (Goffman 1959). Yet there were cases, like the one illustrated by LM254 segment, when the pressure to write down a contribution prevented Andrew and the group from entering the rational stage necessary for prudently fitting causes to their consequences.

We also can say that while fitting a new and unfamiliar cause to a focal problem, Andrew proceeded from more intuitive level that is strongly influenced by emotions, to more rational one. The term "intuition" raised substantial controversy in cognitive psychology. To avoid joining the debate without clarifying the issue, we need to make one distinction building on work of Simon (1983) and (Prietula and Simon 1989). These authors view intuition as a post-rational, so to say, product. For example, Prietula and Simon (1989) wrote: "Intuition grows out of experience that once called for analytical steps. As experience builds, the expert begins to chunk information into patterns and bypasses the steps." We are using the notion of intuition for denoting essentially pre-rational phenomenon. It is characteristic of initial exploration of a new domain, when available knowledge comes from tentative analogies with other domains and scarce trial-and-error experience. One can say that pre-rational intuition is indicative of constructing a problem space that has to be sufficiently rich and well elaborated for using analytical methods. If intuitive shortcuts made by experts reflect their ability to extract the most essential features of a problem they work on and to skip those analysis that are highly unlikely to turn out a surprising result, a

cursory approach of novels displays their lack of knowledge of detail and necessary examination procedures.

Andrew's failure to see novelty of Greg's contribution during the LM254 segment, also can be considered as Greg's failure to get his point through. Or more precisely, Andrew and Greg did not succeed in establishing appropriate communication for bridging their disparate reference frames. If Andrew was pre-rationally intuitive, Greg knew what he was speaking about very well and was post-rationally intuitive. Being rational could serve as a common ground for them to meet, but this did not happen.

A conflict between Dave and Greg during the LM51 segment exemplifies an instance of an argument between two participants who are equally well familiar with the subject and could communicate well within a post-rational framework. It is unfortunate from the analyst viewpoint, that the argument was terminated by the facilitator. We can only note that emotional intensity of pre-rational conflicts is not necessary higher than of post-rational ones. Yet in the latter case we can expect more tension stemming from differences about substantive points and unwillingness to listen rather than from misunderstandings and partners' inability to understand each other.

6.6383 Tunnel vision and emotional trade off.

Another dynamic pattern responsible for the flow of the LM254 segment and Greg's inability to communicate his ideas involves emotions. We presuppose that when Greg met with resistance to record his contribution in the form of Andrew's objection to novelty (61, 270.1 sec), he concentrated his attention at corroborating it to the extent of forgetting about the goal of protecting his department and about his recent argument that the problem of low priority of CPR is limited to SE department (2, 9). The phenomenon, is known as "tunnel vision." Several resulting mishaps in interacting with other participants led Greg to the series of actions aimed on managing tension (277.0 - 284.2 sec). As already mentioned, this highly emotional episode was at least a partial cause of Greg's forgetting his initial formulation of the contribution that contained a novel element.

Some people are better than others with respect to pursuing several goals simultaneously even under stress. Dave and Sam seem to be such "skillful politicians." For example, while protecting SE department from Greg's criticism during the LM51 segment, Dave was able both to keep on pushing his cause and to preserve relatively friendly tone of the argument. Though, Judy's involvement (13, 70.1 sec) probably was instrumental for maintaining this balance. Also, Dave's behavior during the workshop as well as our encounters before and after it proved that he always was naturally tactful. Thus, his skills of creating an amicable atmosphere were automatic and should not require much cognitive processing.

The LM254 segment also demonstrates interesting examples of emotional trade off. They ensue from a process that may be called a search in emotional space. Because Greg had put himself into embarrassing situation of contradicting his own earlier statements, there was no way for genuinely resolving it. Each action aimed on reducing tension was linked to another one that increased it. To finish his disagreement with Tom, Greg had to recognize that he was contradicting himself (67, 278.1 sec). A

couple of seconds later, he attacked Sam in order to obtain his confession that CPR has low priority in the PM department too (~281-285 sec). In principle, it was possible to manage the situation in more tactful way. Yet anxiety precluded Greg, who does not seem to posses a large repertoire of readily available scenarios for managing conflict interaction, from doing so.

6.6384 Interaction and elaboration of thought.

To explore causal fit, it is important to search through the problem space in a relatively systematic manner, using many qualifiers and contingent statements, and working on the question until it is resolved or transformed into a new question or several questions. All that requires maintaining the thread of thought and is more difficult to do in a group than when working on a problem individually.

For example, looking on the cog_task columns in Figure 16 for Andrew and Greg--two people who were most active during the LM254 segment, and whose cognitive states we can code with most confidence--one can see that majority of their cognitive tasks do not build upon the previous ones performed by the same person. On the opposite, they are induced by cognitive actions of other participants. Andrew, who, in general, was in control of his activities during the segment, has only 2 of the 7 cognitive tasks emerging from the previous one. Yet they account for 51 of the 76 seconds of the segment's duration. Only 1 of 8 of Greg's cognitive tasks was induced by the previous one. He was pursuing the same thread of thought for 27 seconds of the 76.

The end of the LM383 segment demonstrates that reasoning of participants may clash even when they perform complementary cognitive tasks as in the case of Andrew's IntFitCo,4.5 and Greg's GenCause,4.5 (437.0 sec). Although on the surface Andrew is requesting information (127, 441.8 sec) and Greg immediately provides it (128, 443.2 sec), this is not what Andrew was expecting. Without attempting to reformulate his question or to explain Greg what he was looking for, Andrew abruptly abandoned his efforts to interpret Greg's contribution and solicited a new one (131, 445.3).

In principle, it is possible that thinking of two or more people is synchronized in such degree that a contribution of one of them will trigger in others ideas they were going switch to anyway. This does not seem to be the case for Greg and Andrew, whose train of thoughts was usually interrupted by contributions of each other and the rest of participants.

6.6385 Estimation of the production system size for the RCA task.

While reviewing more and more video footage, we expect convergence of a production system in the sense of accounting for the occurrence of new operators without introducing new production rules. But because: (1) 2 out of 5 segments were selected to serve as illustrations of different patterns of interaction between emotions and cognition; (2) we wanted to account for 100% of cognitive operators; and (3) our goal was to capture as many subtleties as we were able to discern--90% of the 5th segment's still is constituted out of new productions. This is not surprising.

We expect that the production system for collaborative Root Cause Analysis task will be much larger than for individually performed analytical tasks examined by Newell and Simon (1972). To achieve

high degree of accuracy simulating our data we may need hundreds of productions. There are at least 4 reasons for that.

First, the CEMA coding scheme is quite elaborate. The three behavioral classes that are described using productions--"cog_task," "cog_act," and "motivtns"--contain approximately 50 operators.

Second, different participants may apply the same operator under different conditions. For example, Andrew becomes motivated by OthrEgo in P20 (LM254 segment) because of quite complex combination of desire to disassociate himself from the participant who had lost the argument and to comfort him. In contrast, Sam switched in the OthrEgo mode after becoming anxious because of Greg's apparent attack on Judy P23 (LM383). So far we hope that cognitive and emotional dynamics of each participant can be described by the same production system. Yet it is possible that production systems of at least some participants will be distinctively different. In this case we may want to consider several smaller production systems in order to analyze individual differences.

Third, there is a host of emotional processes that have to be accounted for in the left part of productions, if we are interested in the interplay between emotions and cognition. Productions P8 through P11 from LM51 segment; P25 and P28 from LM254 segment; P18, P19, P23, and P24 from LM383 segment--provide us with examples.

Fourth, when selecting the next operator to be carried out, a participant often takes into consideration by whom of 8 other participants the current situation was created. For example, Andrew might simply dismiss a disagreement with less powerful participant than Greg under conditions stated in the left part of the production P17 from LM254 segment. Similarly, Greg was able to capture participants' attention when they were in Expressive mode (see P12 in LM51), when other participants might be not so bold. Productions P7, P20, and P21 from LM254 are also contingent on actions of a particular kind participants.

During our analyses, each group of 1-3 operators in CEMA diagrams generated 1 production rule. Because there are approximately 200 operators in our current data set, it is not surprising that we have not exhausted the whole production system for the RCA.

Making a couple of assumptions based on 5 segments we have analyzed so far, one can estimate how much video footage has to be utilized for obtaining a nearly complete list. If there is a single production system for the RCA task and it contains approximately 1,000 productions; and if the left side of each production contains on the average 2 operators; and if there is an average of 1 operator per 1.5 seconds of video footage; and if we want the number of productions induced immediately from reviewing CEMA diagrams to be 3 times larger than a number of productions in the whole production system - then we need to code and analyze 9,000 seconds or 2.5 hours of video footage.

Another approach is also possible for generating a nearly complete production system for the RCA task. One can use productions induced immediately from reviewing CEMA diagrams and videotapes for further inferring what actors take into account while selecting cognitive operators. For example, from productions P7, P17, P20, and P21 one can tentatively conclude that Andrew's reaction to NovelCrb will

depend at least on 3 conditions: (1) whose objection to novelty led to NovelCrb; (2) who spoke up corroborating novelty; and (3) does NovelCrb makes sense for Andrew or not. Considering all possible combinations of these 3 factors, it is possible to speculate about possible productions describing Andrew's reaction to NovelCrb operator.

Combining both approaches should increase reliability of the resulting production system and decrease the length of necessary video footage. Still, the task of compiling the complete production system for the collaborative RCA is beyond the time limits of the present study.

Design of coding schemes and CEMA diagrams was shaped by two goals: first, to produce a computable description; and, second, to create a description that facilitates building a truly dynamic theory of problem-solving group's effectiveness. In this chapter we addressed the issues of generating computable description and presented most recent results. The following chapter explicates what we mean when saying truly dynamic theory and presents our current understanding of processes influencing a problem-solving group's effectiveness.

6.7 F-points, conflicts and their impact on group effectiveness.

Building a truly dynamic theory of problem-solving group's effectiveness **(PSGE)** requires relating behaviors of participants to 5 components in the definition of PSGE outlined in the introductory chapter 1. How was that done? First, bearing in mind the PSGE definition we watched videotapes and surveyed CEMA diagrams in order to detect and record instances that should increase or reduce effectiveness. Second, using CEMA diagrams we explained how they occurred. While working with diagrams, we elaborated them to capture behaviors that were necessary for the explanation. Then videotapes and CEMA diagrams were examined again. In principle, we might have needed to update the methodology of designing CEMA diagrams. Yet only approximately 1% of operators were changed at the stage of figuring out PSGE. All of them were due to inattention. For this reason, it was not warranted to consider methodological questions at that stage.

Asking "how PSGE was influenced" resulted in re-drawing and adding of approximately 10% of arrows connecting operators on CEMA diagrams. Out of them, approximately 1/3 was added due to focused attention on NoAction operator in order to indicate its causes, another 1/3 was re-drawn to improve readability and consistency of graphic representation, and 1/6 was re-drawn to emphasize cognitive processes that control actions.

Looking for events clearly influencing direction and coordination of participants, we considered both separate actions and their sequences. When such events correspond to a single action coded in "cog_act" or "em_act" column of CEMA diagrams, we call them **effectiveness points** or **F-points** hereafter. Yet sometimes several temporally adjacent actions are so strongly intermeshed, that explaining influence of one of them on effectiveness requires considering the others. It becomes natural to analyze the whole episode as one unit. All conflicts fall into this category. Intentional character of actions during a conflict and participants' acute awareness of each other's actions renders impossible to examine influence

of separate actions on effectiveness. Participants continue re-interpreting their actions during the conflict in the light of the way it is being resolved--or not resolved.

Both F-points and conflicts were related to four individual dimensions of the PSGE via their influence on three fundamental tasks. First, we examined their influence on IMT, ST, and PT[10]; and second, we related these tasks to the PSGE. The last dimension of effectiveness--quality of resulting solutions--was approached differently. Starting from the comparison of causal diagrams that were generated during the workshop and those that were further elaborated after it, and asking about reasons of the discrepancy, we related the group's problem solving processes to differentially successful outcomes. The following 4 sections provide more detail about each approach to exploring the PSGE.

6.71 F-points.

CEMA diagrams and verbatim transcripts, which are enclosed in the Appendix F, were used for detecting F-points. For each code in the "cog_act" and "em_act" columns we reviewed the corresponding part of the transcript, asking ourselves whether IMT, ST, or PT was directly influenced by it. IMT was considered affected, if one or more participants lost or gained interest to the problem-solving activity, or if they manifested increase or decrease in tension. ST was considered affected, if one or more participants missed or misunderstood relevant information, made wrong inference, or their train of thought was interrupted. PT was considered affected, if group activity was led in productive or unproductive direction, or it was slowed down or accelerated. Impact of each action was assessed on the set of all subsequent events we were able to relate to a particular F-point. For example, interrupting Greg, Andrew gained some time (3, 36.2 sec), but missed an important point that Greg was speaking only about the SE. This issue came up later (61-71) slowing down the discussion and, probably, nullifying any time gained due to the interruption.

Reviewing all five segments, for which CEMA diagrams were produced, we obtained 29 instances of F-points. They were grouped in 15 classes. Table 9 presents them, helps to locate on CEMA diagrams, and discusses how they influence the three basic group-problem-solving tasks. Bold text in the 4th column of the table names each of the 15 classes. The 3rd column shows which of the tasks was affected and in which direction. The question mark in the parentheses denotes that one of the basic tasks was affected but differently for different participants; or that there were several mechanisms resulting in opposite outcomes, and it was difficult to single out the major influence.

[10] Differently from our use of acronyms IMT, ST, and PT for denoting the cognitive component of the corresponding tasks, here we are speaking about the tasks themselves.

Table 9. List of F-points.

F-point #	Location on CEMA diagrams	Positively and negatively affected tasks	What happened, how it happened, and other comments.
F1.	(a_sc,24.4sec)	st(-)	**Confusing wording while soliciting a cause.** Andrew's wording directed participants' attention to specific consequences of limited manpower rather than to its causes. This may be the reason for Craig's causally misplaced contribution (LM4). It is noteworthy that Greg was not misled by Andrew's confusing language.
F2.	(c_gc,36.2sec)	st(?)	**Elaborating one's own idea, but dropping out of discussion.** After Craig sees that Greg's contribution is being recorded, he returns back to generating the contribution he conceived at 24.5sec. Involved in this task he missed group discussion till (c_cw,56.4sec) and then just scanned it for an opportunity to contribute his thoughts until (c_gc,83.2sec). On the one hand, Craig is able to concentrate on generating a new cause, on the other hand he is not participating in group discussion for almost 50 seconds.
F3.	(g_na,36.4sec) (d_na,63.3sec) (d_na,83.3sec) (c_na,86.8sec) (c_na,95.4sec) (g_na,384.4sec) (g_na,386.9sec) (g_na,390.4sec) (g_na,445.9sec)	imt(-), st(-),pt(?) imt(-),st(?),pt(+) imt(-),st(+),pt(+) imt(-),st(-) imt(-) imt(-),st(-),pt(+) imt(-),st(-),pt(+) imt(-) imt(-),st(?),pt(?)	**Interrupting a speaker.** Interruptions always create discomfort for a speaker, hence negatively influencing IMT. The degree of influence differs depending on whether a speaker accepts an interruption as relevant or not. Impact of interruptions on ST and PT varies from case to case as discussed below. (g_na,36.4sec): Interrupting Greg, Andrew missed an important point that Greg was speaking only about SE. This issue came up later (61-71) slowing down the discussion and, probably, nullifying any time gained due to interruption. (d_na,63.3sec) and (d_na,83.3sec): Interrupting an irrelevant argument between Dave and Greg, Andrew was able to keep the group focused on ST and to accelerate the process. Yet, if he paid attention to the argument, he could detect the difference between LM2 and LM3 and would not miss the former. (c_na,86.8sec): The interruption was not especially helpful for Andrew to maintain his train of thought and was slightly disruptive to Craig. (g_na,384.4sec) and (g_na,386.9sec): Greg proposed a cause (113,383.1sec) without Andrew's request. In order to establish and then confirm relevance of Greg's contribution, Andrew interrupted him two times. That should help Andrew to latch on IntFitCo (390.9sec). But because Greg was interrupted while in GenCause and did not pay sufficient attention to FitCause, he gave Andrew the wrong answer. Andrew had no means to detect it before interpreting Greg's contribution. (g_na,390.4sec): This interruption is due to Andrew's automatism and/or subconscious desire to lead the discussion. It was not necessary for eliciting Greg's contribution. (g_na,445.9sec): Being abruptly stopped after receiving Andrew's approval to go on (129,444.0sec), Greg is stupefied. Although the event has clearly negative impact on IMT, it is difficult to say if pursuing the inquiry into Greg's contribution would succeed.

			TABLE 9 (CONT'D)
F4.	(j_rc,48.4sec) (j_rc,75.0sec)	st(-),pt(+) st(-),pt(+)	**Skipping over the discussion while recording a cause.** Recording causes helped in keeping track of them, but distracted attention from discussion that was going on .
F5.	(j_ex,58.6sec)	imt(+)	**Expressive catharsis.** Becoming friendly expressive for a couple of seconds helped to achieve emotional comfort and to strengthen solidarity feeling.
F6.	(c_pc,87.2sec) (g_pc,383.1sec)	st(-) st(-)	**Causally misplaced contribution.** (c_pc,87.2sec): Craig's contribution is causally misplaced. It may be a cause of "suffering," as Andrew put it at the beginning of the RCA (1), but is not a cause of limited manpower. (g_pc,383.1sec): Greg's contribution is causally misplaced and difficult for Andrew to interpret.
F7.	(c_po,98.1sec)	st(-)	**Providing a solution.** Goal of the RCA is to generate a variety of causes and to select those of them that will yield best results when taken care of. It is considered harmful to focus on solutions at this stage, because search is prematurely narrowed down and confrontations are more probable when participants commit themselves to particular solutions.
F8.	(g_nc,272.3sec)	st(-)	**Sudden challenge leads to inappropriate defense.** Greg's instantly activated response to Andrew's novelty objection did not address what was really new in his contribution. Instead it focused on what was "hot" in his memory; namely, on the issue recently debated between Dave and Greg about who is to blame for low priority of CPR (2, 9-10).
F9.	(a_ag,275.9sec)	imt(+),pt(+)	**Agreeing without deeply analyzing a statement.** Probably Greg's confident tone and just syntax of his statement telling that he has some kind of difference in mind, are enough for Andrew to agree that Greg's contribution is novel. Thus, his reasoning is wrong, but it still led to correct action--IntFitCo,3.3 (277.0sec). Quick agreement should make both Andrew and Greg feel good.
F10.	(t_bg,286.2sec) (t_bg,325.8sec) (a_bg,444.9sec)	imt(-),pt(-) imt(+) imt(-)	**Blocked goal.** (t_bg,286.2sec): Tom's suggestion (66,276.2sec) hinted that Greg's current contribution is the same as LM1 and shouldn't be considered again. Tom accepted Greg's agreement (67,278.1sec) as a sign that the issue was closed. But Andrew missed the discussion between Tom, Greg, and Sam. To Tom's surprise, Andrew went against Tom's suggestion continuing to solicit Greg's contribution (69,285.3sec). Consequently, Tom's motivation switched to HaveOver (292.1sec) and he withdrew from participation. (t_bg,325.8sec): The fact that Andrew finally agreed that Greg's contribution should not be recorded (81,326.5sec) released Tom's anxiety due to the previously blocked goal (286.2sec). (a_bg,444.9sec): Being not able to get an answer he expected from Greg (see F14 and F15), Andrew felt that his line of thought was blocked, and purposefully interrupted Greg.
F11.	(s_ri,287.1sec) (s_po,293.3sec)	st(-) imt(+),st(-)	**Side conversation.** Side conversations usually distract participants' attention from substantive tasks pursued by Andrew. Yet sometimes it may promote ST by providing an opportunity to elaborate complex issues, and/or it may serve IMT by providing and opportunity for social support.

			TABLE 9 (CONT'D)
F12.	(g_pi,386.3sec) (g_pi,389.4sec)	st(-) st(-)	**Not seeing that a contribution is causally misplaced.** Although explicitly asked two times in a row which focal problem his contribution fits, Greg gives the wrong answer. He seems to be not much concerned about validity of causal links.
F13.	(a_ri,441.8sec)	st(-)	**A mistake in the directed line of reasoning.** While reminding participants about the currently analyzed focal problem and trying to figure out how Judy is related to "the person that takes the call," and "the person that's re-answering the same problem" (120,122), Andrew, probably, notices that the already recorded contribution LM4,1 suffers from the same lack of clarity about the object who should be posted but is not. This analogy may be responsible for derailing his attention to already recorded contribution.
F14.	(g_pi,443.2sec)	st(-)	**Dismissing irrelevant question.** Surprised that Andrew had returned to already recorded cause and willing to continue presenting his contribution, Greg dismisses Andrew's question with a trivial answer (128, 443.2sec), that means just "who cares."
F15.	(a_go,444.0)	pt(-)	**Agreeing in order to win more time for analysis.** Greg's instant response (128.443.2sec) was not answering Andrew's question. Yet Greg stopped and waited for Andrew's reaction. To gain time, Andrew made Greg to go on, only to stop him abruptly less than 3 seconds later.

The results presented in the above table may be valuable for pragmatic purposes of improving the methodology of collaborative RCA. Some specific suggestions will be made in section 7.3. Yet the criteria considered when evaluating impact of action on the fundamental group-problem-solving tasks—it was described at the beginning of this section—does not directly map on coordination and direction of participants. For example, though speed at which problem solving proceeded may be used as a measure of effectiveness, whether this measure is meaningful or not will depend on how this speed is related to workshop outcomes that are preserved in recordings and properties of participating individuals. We will touch upon these issues after reviewing impact of sequences of events on the fundamental tasks in the following section.

6.72 Interpersonal conflicts.

We will define a conflict here as an expressed and deliberate disagreement with opinion, suggestion, statement, or action. Behavior is considered to be a conflict only when actions manifest conscious disagreement. Conflict's participants are aware of a specific person with whom they disagree. Conflicts can manifest themselves verbally, through body language and facial expressions, or through actions, which go contrary or interrupt the proposed plan or presently performed action. A deliberate attack with an aim to hurt somebody's feelings was counted as a conflict too. Assuming that usually people act in the way that brings them emotional comfort, we regard it as a particular case of an action going contrary to

another person's plan. With respect to tension dynamics it is important to distinguish between conflicts which are resolved or not.

The 5 segments that were analyzed contained 7 conflicts:

I. between Dave and Greg(6-10, started at ~53 sec);
II. between Judy and Dave (13-14, started at ~63 sec);
III. among Tom, Greg, and Sam (66-68, started at ~274 sec);
IV. between Andrew and Greg (74-78, started at ~294 sec);
V. among Sam, Greg, and Andrew (79-84, started at ~322 sec);
VI. among Sam, Greg, and Andrew (126-127, started at ~433 sec);
VII. between Andrew and Greg (131, started at ~445 sec).

All of these conflicts, with an exception of Conflict IV, lasted less than 10 seconds. Conflict IV lasted 30 seconds because both Andrew and Greg provided relatively long explanations corroborating their positions. These were minor conflicts well within the limits of accepted norms of disagreeing. In general, during the whole LM episode there were only 2 instances of prolonged conflicts (135-159 and 223-237). Both of them occurred when participants were driven by different goals: interaction management, substantive, and procedural. The conflicts I, VI, and VII were not resolved; it means, there was no indication of reaching an agreement at the end of them.

A look on the CEMA diagrams reveals how many cognitive and emotional actions may occur even during short and relatively peaceful conflicts. It is interesting to trace how conflicts happen, and how they are resolved. Because according to the definition conflicts always are intentional, they have strong influence on IMT. Emotional and cognitive dynamics are tightly interwoven during conflictual episodes.

Conflict I began to develop when Dave disagreed with Greg's contribution implying that SE is the only department to be blamed for low priority of CPR (37.8 sec). Without directly contradicting Greg, Dave proposed another cause of limited manpower; namely, that it was not clear who had to pay for CPR (6, 52.6 sec). This moment can be considered as a beginning of the conflict, because Dave's action expressed a conscious disagreement. Dave's and Greg's statements were not logically contradictory, but Greg apparently detected the disagreement and already openly disagreed with Dave (9, 60.3 sec), who started to answer when Andrew ended the conflict by requesting Dave to repeat his cause.

Conflict II ensued from the first one. Swayed by Greg's confrontation, Dave reformulated his contribution in the way that eliminated the question of who has to pay for CPR, and Judy obviously did not like this development. Next, she suggested returning to the initial formulation of Dave's contribution (13, 70.1 sec). This went against the current Dave's action, and was counted as a conflict for this reason. Dave agreed with Judy (14, 74.1 sec), returned to the first formulation, and started to develop his thought, when Andrew again interrupted him.

To explain how Conflict III occurred, we have to return back to Greg's statement made about 4 minutes earlier (2, 31.1 sec), and said that low priority of CPR is peculiar to SE, it means to Tom's department. Now, when Greg's attention is devoted to corroborating novelty of his last contribution (62, 272.3 sec; 64, 274.4 sec), and he himself contradicts his previous statement, Tom is ostensibly agreeing with Greg in order to make Greg's new position noticed and reflected on flip-charts. In other words, Tim

uses this opportunity to voice his old disagreement with picking his department as a culprit for problems with CPR (66, 276.1 sec).

Caught off guard, Greg agrees. Trying to make his own department to look better, he attacks PM requesting Sam to confirm that there is a problem with low priority in his department too (67, 278.1 sec). Sam becomes visibly anxious, but agrees with Greg (68, 285.0 sec). In this case, it is difficult to state with certainty that Greg deliberately tried to hurt Sam or his department. But irrespectively of how purposeful was Greg's attack, Sam probably felt as being a subject to Greg's offensive.

Conflict IV starts because Andrew cannot interpret Greg's contribution (LM3.3) and refuses to record it suspecting that it is not novel (74, 294.6sec). His statement does not explain why he considers that the contribution was already recorded, but describes perils of recording causal loops using expressions "chasing our tail here" and "going in a big circle." It seems that Greg does not understand his reasoning, and just dismisses it. He continues explaining his contribution paraphrasing it (75, 304.6 sec; 77, 315.4 sec) and gradually completely loosing its novel aspect of budget for hiring new employees. Yet at this time, being driven by the pressure to alleviate tension caused by Greg's insistence, Andrew agrees to record his contribution (78, 319.3 sec).

Right after Conflict IV is over, Sam primed by Judy's barely audible remark (76, 315.2 sec), notices lack of novelty and voices his disagreement with recording Greg's contribution (79, 322.2 sec). This initiates Conflict V. Sam's objection may serve also as a revenge" for putting his on the spot several seconds earlier (67, 278.1 sec), but it was logically correct, and Greg is compelled to agree (82, 327.0 sec). Andrew has to handle a peculiar situation of disassociating himself from Greg, with whom he just agreed, and alleviating Greg's frustration (83, 329.0 sec).

Conflict VI began to take shape when Greg aggressively pointed to Judy and became unusually critical and personal in his remarks while proposing his cause of re-answering the same problem (120, 392.1 sec). At that time Sam became visibly anxious (404.4 sec) and then immersed in himself generating a new cause, which was critical of Greg (LM4.6). Using a natural break in a conversation between Andrew and Greg, he starts proposing it (126, 432.7 sec). Because Sam was preparing to attack Greg, we regard this moment as a beginning of the conflictual episode. Yet the confrontation further develops between Sam and Andrew. The latter briefly considers Sam's statement and stops him asking to postpone his contribution (127, 434.0 sec). Because the interruption is deliberate, we regard this as a conflict too. It is quickly resolved when Andrew grants Sam a permission to contribute (134, 447.9 sec). After that Sam announces the cause that is critical of training quality in Greg's department, starting a conflict between them two (135, 448.6 sec). Thus, in this case one conflict was postponed due to another one. Conflict VII also occurs during this period, when Andrew's attention is switching from Greg to Sam. Not being able to interpret and record Greg's contribution for over a minute and disappointed with Greg's last explanation, which failed to answer his question, Andrew decides to interrupt Greg and solicit more causes (131, 445.3 sec).

6.73 Relationship between fundamental tasks and individual dimensions of PSGE.

As already mentioned, it is rarely possible to connect direction and coordination to isolated events or even their short sequences. Yet inferences based on instances of completion of ST, PT, and IMT may be able to serve as a bridge between problem-solving events and effectiveness.

There should be a positive relationship between participation in a successful ST and both components of direction. In general, a successful history of resolving cognitive dissonance (Festinger 1954) should be positively related to D_M. Participation in PT and IMT, especially while searching for working consensus, should increase participants' understanding of each other and, consequently, should lead to an increase in C_U . For this reason, the practice of assigning rigid predetermined roles to participants, which is widely used in order to prevent potential conflicts while searching for working consensus, may reduce opportunities for participants to learn about each other and, in turn, negatively influence the C_U value. C_M should be dependent on perception of personal qualities attributed by participants to each other when experiencing or observing blocked goals, interpersonal attacks, and instances of mutual support (Weiner 1986). Existence of unresolved interpersonal conflicts at the end of the problem solving should be negatively related with C_M.

6.74 Quality of causal maps.

Quality of outcomes of the RCA can be defined via completeness and validity of causal diagrams created during the workshop. As a reference point we will use diagrams drawn by us, after carefully reviewing videotapes. Several causes, which were contributed by participants during the workshop and recorded on videotapes but not on flip charts, were added. Several recordings were reformulated, and some of the causal links were retraced.

Defining quality of the RCA's outcomes in this way, we detect errors of commission but may miss some of the errors of omission. Some causes which, may exist and be important for creating a complete diagram, probably were never mentioned by participants and, consequently, will not be found on videotapes. Consultations with participants and modeling the business process provide a better reference point for judging completeness and validity of causal diagrams produced during the workshop.

Both updated and flip-chart version of diagrams for the RCA of a "limited manpower" problem are shown in Figure 18. One can see that the a number of causes was not recorded and several causal relationships—most remarkably, the one between limited manpower and a conflict within coordinator/expert role—were misplaced. Comparison of videotaped contributions of participants with facilitator's interpretations recorded on flip-charts shows that three of them--"no one wants to pay," "lack recog that weve solved prob before" and "no commun syst"--could be more specific. Also the recording "too many handoffs" is not the same as the original statement "hand off of the problem."

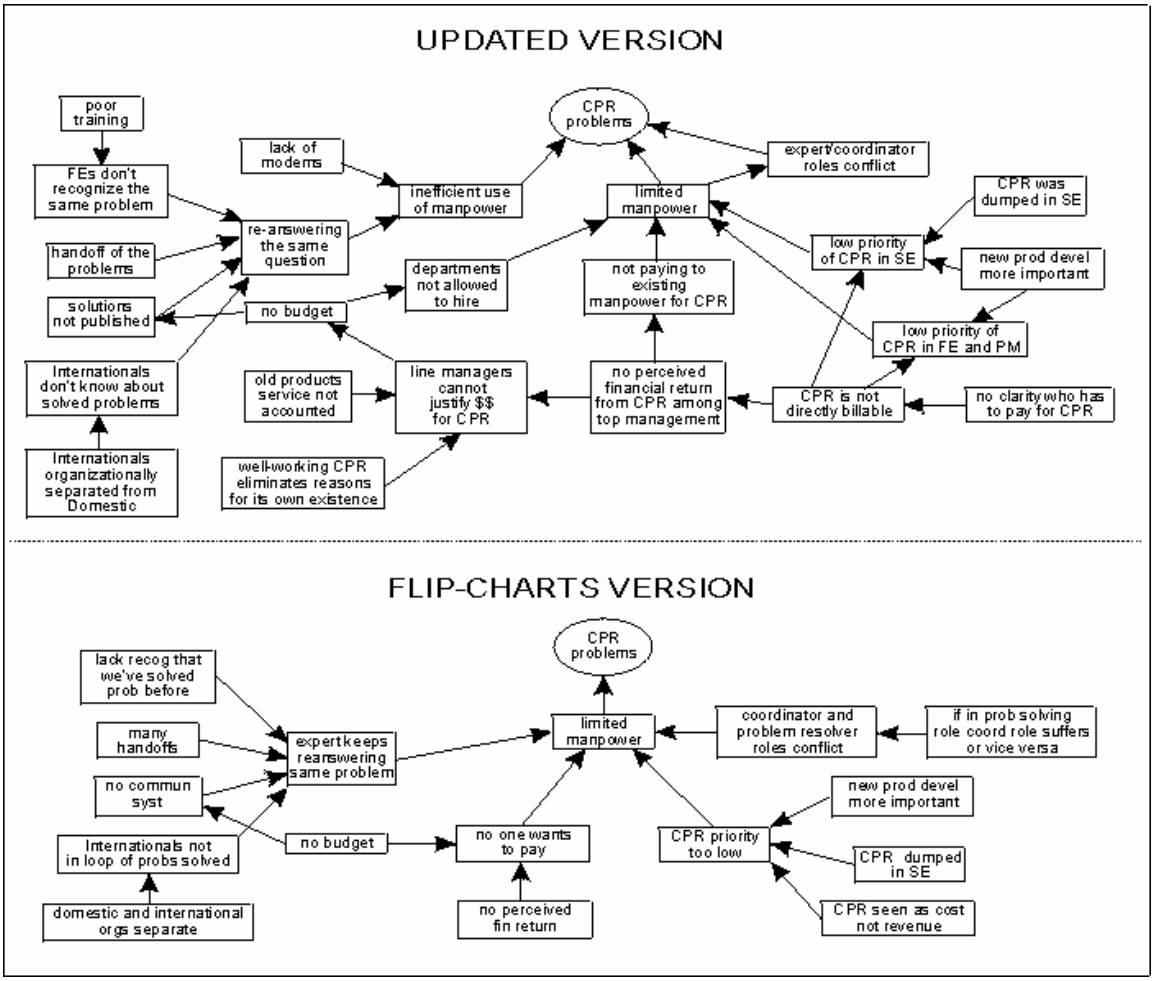


Figure 18. Causal diagrams recorded on flip-charts during the workshop and revised by the author after watching videotapes.

CEMA diagrams in combination with a transcript permit in many cases to trace how these kinds of errors occurred and how some of them were corrected. Below we apply existing CEMA diagrams for this purpose.

Greg's contribution—LM1—was recorded on flip-charts as "Priority too low, CPR." His remark about SE was ignored by Andrew. Using CEMA diagrams helps to come up with a plausible scenario of how this happened. We see that Andrew interrupted Greg when he was making a reference to SE department. Andrew was looking at that moment for confirmation of his interpretation of the first part of Greg's contribution. Probably Andrew even did not hear the last part of it, which mentioned SE. He was focused on figuring out what kind of priority was low, and was satisfied that Greg confirmed it. Interestingly that Greg did not try to correct Andrew with respect to including the qualifier in the recording. Only indirectly—seeing that Judy was sensitive to mentioning of SE (33.9 sec), and that Dave disagreed (37.8 sec) with using this qualifier—we can assume that Greg did not want to invite more scrutiny to his contribution.

The CEMA diagram also is helpful for explaining how it occurred that Dave's contribution (52.6 sec) was not recorded in its initial form—LM2. We can see that Andrew was not able to interpret it at once and was listening to the group (52.8 sec). Yet at that time Greg attacked Dave (60.3 sec) and their argument became not helpful for Andrew, who interrupted it, soliciting a cause from Dave once again (62.3 sec). Yet under Greg's pressure, Dave proposed a different cause—LM3—that was instantly interpreted and recorded by Andrew (71.8 sec). Because Andrew never interpreted the initial Dave's contribution, he should not notice that the second cause was different from the first one.

CEMA diagrams are of no particular help for explaining how Craig's contribution—LM4—was causally misplaced. In general, only once during the whole duration of the RCA Andrew placed a contribution to the focal problem other than was considered at the time when contribution was made, or where a participant suggested it causally belonged. This shows that validating causal links is cognitively demanding.

While starting to interpret Greg's contribution (256.0 sec)—LM3.3—Andrew was confused by the wording "nobody has that resource in manpower," and his attention was distracted by the task of checking novelty (268.4 and 292.1 sec). Two conflicts that occurred at that time obstructed Andrews's efforts to interpret and fit Greg's contribution, which was finally abandoned without recording it.

The CEMA diagram for the last of the examined segments clearly shows how another Greg's contribution did—LM4.5—did not make it onto the flip-charts. First, the episode was complicated by the need to check relevance (383.5 sec) and by the incorrect response by Greg (386.3 and 389.4 sec). Starting from the causally misplaced contribution and interrupted by Sam's attempt to contribute an unsolicited cause (432.7 sec), Andrew made a mistake carrying out the directed line of reasoning (Hume et al 1996; Katz 1997), confusing Greg and getting no helpful information from him as a result. After that, Andrew abandoned efforts to interpret the contribution, and rapidly switched to the one Sam was already trying to present (447.9 sec).

7.0 Summary of results.

McGrath's inaugural article in "Group Dynamics: Theory, Research, and Practice" (1997) declares and documents a now widely shared opinion among researchers of small groups that the area has reached a period of stagnation. To move forward, he proposed a new approach, which conceptualizes and studies groups as complex, adaptive, dynamic systems. According to McGrath, for capturing complexity of group processes, we need to assume that functional relationships that are appropriately reflecting reality are bi-directional, nonlinear, and non-additive. To reckon with the adaptive dimension of groups, they have to be studied in context. And for adequately addressing the dynamic nature of group activities, we need to use "continuous measurements, or repeated measurements taken at short time intervals." Proceeding in this direction requires collection of new kinds of data and developing new ways of analyzing it. In turn, that calls for new methodologies of data collection and analysis. In the concluding comments McGrath wrote:

> To carry out an empirical research program fitting these requirements, working with groups conceived of as complex, adaptive, dynamic systems, will certainly be a difficult, costly, and demanding matter. (p. 19)

The current study makes a couple of initial steps in the proposed direction. It contributes to our knowledge of emotional and cognitive group dynamics and advances methodology of studying problem-solving groups. It also provides several practical recommendations for improving effectiveness of collaborative Root Cause Analysis **(RCA)**.

In this chapter we will summarize new results obtained in each of these three areas. All of them were derived while working with data collected from a single case, with the sole exception of the cognitive task analysis of the RCA. Still, the developed methodological approach will be valuable for studying other groups, and the substantive findings provide us with a novel opportunity to see dynamics of cognitive and emotional processes as they unfold in natural settings.

7.1 Advances in the methodology of studying problem-solving groups.

Analyzing group processes, time and again we encountered methodological issues we had to tackle in order to collect our data and make sense from it. Considerable efforts were devoted to developing analytical techniques and even elaborating approaches for designing such techniques. The analytic and meta-analytic pendants, which are summarized in this section, became of equal or may be larger importance than the substantive findings.

7.11 Developing and testing an unobtrusive technique for videotaping business groups.

Recent advances in the field of video recording have made it possible to collect data necessary for nonlinear analysis of small group processes. There are still quite a few technical issues that have to be mastered before making recordings of acceptable quality, yet reluctance of business groups in organizational setting to be videotaped constituted the main challenge. In other words, fulfilling both requirements of contextuality of data and their suitability for continuous measurements was difficult to

combine. First, we had to find an unobtrusive way of videotaping problem-solving meetings, which also would provide a sufficiently close and detailed picture of both verbal and non-verbal interaction. Second, we had to learn how to convince managers and group participants that our data collection activities would not interfere with their efforts.

Similarly to other studies mentioned in the section 5.51 we can summarize our experiences by saying that team members quickly forgot about unattended cameras located as shown in Figure 6. Three small microphones—one per each camera—located on the table seemed completely escape attention of team members. The questionnaire administered right after videotaping almost the whole 2.5-day long workshop lent the following results: replying to an item “Videotaping (was /was a little / was not) disturbing me.” in the post-workshop, five out of eight participants marked “was not,” and other three participants marked “was a little.”

Being observed seems to be not so distracting for team members as two other factors. First, training and facilitated problem solving are perceived as services provided to participants. Being selected for a problem-solving team is usually considered an honor. Videotaping may change the whole definition of the situation, putting participants in the role of "guinea pigs" in a scientific experiment. To eliminate this impact is possible, if videotaping is a constituent part of training as in the case when recorded episodes are used for individual feedback on interaction styles of participants.

Second, participants may be sensitive to videotaping because it creates a record of their performance that can be used by superiors for performance evaluation. This kind of influence can be diminished, if participants are promised by somebody they trust, that tapes will not be seen by anybody who is not present during videotaping.

The trust established during the fieldwork is also very important for convincing participants and management to allow videotaping. General findings published in the research literature are helpful. Yet in our case, management always asked whether we had videotaped business groups before or, at least, knew others who did. The current study creates a precedent that will allow researchers to answer this question in affirmative.

7.12 Coding time-delimited states in emotional and cognitive dynamics.

In its essence any kind of measurement is a transformation of some aspects of data into the form that is better amenable for the intended analysis. The term also has a quantitative connotation, but abstracting from it, coding may be considered a form of measurement too. Issues of purposeful transformation and selection are prominently manifested in coding.

Everybody who has coded from videotapes and from verbal protocols knows how much more information is contained in the former. A task of selecting appropriate facts becomes an order of magnitude more complex. Second, designing valid coding categories requires a combination of unitizing and coding, which cannot be performed consecutively because dynamic processes determine the boundary between cognitive and emotional states and interstate transitions. That makes the coding task even more

challenging. Third, in everyday life we do not usually pay attention to cognitive states. Furthermore, when we do, our goal is not to understand how one reasons, but to understand what he or she tries to convey or to hide. We are not trying to understand to whom or what one pays attention, but merely if she or he is listening to us. For this reason, "seeing" cognitive states requires a new skill, and what is even more important, it requires to develop a framework for performing the necessary interpretation. Emotional states that were discerned during the current project—interest and anxiety—are routinely monitored when we interact with others. Hence, this is done automatically and without being conscious of the employed procedure. Scientific research of emotions relies on content analysis of verbal statements, self-reports, physiological measurements, analysis of facial expressions (Clore et al 1994). In our study we relied on body language and facial expressions, though in much less detailed way than researchers that are specializing in this area and work in the lab. We also had to select emotional states that have major impact on problem-solving dynamics. Thus, coding and conceptualization of both cognitive and emotional states had to go hand in hand.

In this way, two coding schemes were developed. First, a coding scheme for capturing cognitive tasks and actions **(CTA)** was designed. It is presented in Appendix G. The scheme contains 16 operators describing cognitive behavior of the facilitator. Starting to code from the facilitator, we were able to utilize the understanding of the Root Cause Analysis **(RCA)** gained during the initial task analysis and described in chapter 6.4. The facilitator's behaviors while searching for root causes according to his procedural model described in the section 6.42, and the "proper"—in the sense of being expected according to this model—responses of participants provided a rough outline of what actually occurred. Though helpful for seeing a pattern in the group's dynamics, it accounted only for a part of cognitive behaviors discernable on videotapes. More operators were introduced to describe cognitive behavior that occurred when the facilitator was not able to interpret a contribution, or a participant insisted on discussing an idea that did not seem relevant to the RCA task for the facilitator.

Using the CTA scheme we described the structure of the episode focused on the problem of limited manpower, by dividing it in 28 segments varying in length from approximately 4 to 100 seconds as shown in Figure 7. This permitted describing phenomena best visible on this time scale and selecting several segments for a thorough and labor-intensive analysis in order to capture subtleties of interplay between emotions and cognition. To carry out the last task, we designed the Cognition-Emotion-Motivation-Action or **CEMA** coding scheme.

The intention was to record each participant's cognitive, emotional, and motivational state at every time moment. According to the conceptual framework depicted in Figure 1, three behavioral classes were defined and called "cog_task", "emotions", and "motivtns." Two more behavioral classes--"em_act" and "cog_act"--were introduced to capture interaction among participants. Three classes of modifiers were designed to trace: (1) what contribution a participant was working on--"idea#" modifier coded according to the list of contributions shown in Appendix H; (2) to whom an action was directed or coming from--"subjects" modifier; and (3) whether an action had a potential for increasing or decreasing a participant's

tension and/or interest--it(+-). The resulting coding scheme is presented in Appendix J and is described in the section 6.631.

Coded behavior of participants for each of the 5 explored segments was presented as a time table on CEMA diagrams like one shown in Figure 15. The diagrams permit us to see how cognitive and emotional dynamics of all participants involved in discussion is unfolding with time. In turn, this enables visual representation of direct influences--shown as arrows--between emotions, cognition, and motivation for the same actor as well as among actors. One can think about CEMA diagrams as a specification of conceptual cycles shown in Figure 1 mapped on the time axis. CEMA diagrams, that are based on time-plot analysis package from The Observer (Noldus 1991), constitute a natural extension of Problem Behavior Graphs (Newell and Simon 1972) for the case of both cognitive and emotional multiple actors. Designing CEMA diagrams is one of the major contributions of the present study.

7.13 Assessing and improving reliability of coding.

Development and application of coding schemes for cognitive and emotional states still is in the state of art, and a question of replicability had to be seriously addressed. Both coefficients of inter-coder and intra-coder reliability were assessed for the CTA coding scheme and conclusions for selecting and training coders were drawn from extensive analyses of reliability data. In general, using multiple coders for checking quality of coding schemes is based on a widely shared belief that coding definitions have to be precise enough so that anyone who uses them will arrive at essentially the same coding. The inter-coder and intra-coder reliability **(ICR)** coefficients are considered to be a measure of coding scheme isomorphism with studied phenomena, and clarity of coding manuals and coding procedures.

Absence of any literature on selecting and training coders probably reflects how ubiquitous is this assumption. If anyone can become a perfect coding device, no selection is necessary and training should continue until an exponential learning curve for reliability coefficients will reach its asymptotic value. There is nothing to discuss. This may be true in some cases when coding is done by our senses and involves very little interpretation. Yet when coders rely on social cognition, variability introduced by selection and training procedures may be of comparable magnitude or even considerably larger than one that emanates from imprecision of coding schemes. For this reason, we directed our main efforts at discovering phenomena influencing value of ICR coefficients as described in the sections 6.622 and 6.6262, and shown in Figure 8. We were able to generate the following list of major sources of coding errors:

1. **Coding behaviors instead of cognitive states.** For example, drawing a dash next to the focal problem selected for analysis usually manifested that facilitator was selecting a problem. Yet not always. Coding all instances of drawing a dash as SelProb led to several mistakes. Another example would be uniform coding of utterance--“Any other reasons?”--as soliciting causes. Depending on context it was also used by the facilitator to stop undesirable contributions and to close a branch of a causal tree.

2. **Not paying attention to "trailing edge" of operators.** Because we assume that there is a continuous stream of cognitive states, end of the previous operator coincides with the beginning of the next one. Paying attention to behaviors manifesting both beginning and end may serve as a cross-check. Disregarding this opportunity led to several coding and window errors.
3. **Existence of parallel cognitive processes.** Sometimes the facilitator was performing two or more tasks in parallel. All of them required some cognitive processing. Using codes with modifiers provided a solution for obvious cases, when each parallel task was accompanied by considerable cognitive load. Yet there were boundary cases that led to discrepancies in coding. For example, the only disagreement that was not resolved during the final discussion of LM episode resulted from a difference in opinions about extent of cognitive processing directed on stopping undesirable contribution while simultaneously soliciting a new cause. In that case the facilitator interrupted a participant and by speech accent stressed "other" when asking "Any other reasons?"
4. **Operators that last less than 3 seconds** were more often skipped over than the longer ones.
5. **Two operators within the same sentence** sometimes were coded as one.
6. **Getting into rut** was causing errors. For example, most of "Record Cause" had "Interpret Contribution" as a modifier. For this reason this combination was often used automatically.
7. **Keeping the same rhythm of "clicking."** Coding in The Observer is performed by left-clicking a mouse pointed to one of the coding categories displayed as a table on a computer monitor. Most operators last from 3 to 10 seconds. It seems that coders try to maintain this pace.

Using the lessons learned in this study we intend to increase ICR values in the future. The current values are shown in Figure 13. Using the developed coding methodology, which requires a comparison of two codings from scratch, the author achieved the value of intra-coder reliability of at least 0.75. For the coder this value was in the range from 0.3 to 0.35. The values do not reflect the case of conscious re-conceptualization of coding categories. The traditional value of inter-coder reliability in this study also was 0.32. Yet comparing with the Best Available Coding or BAC, the author's coding reliability value was higher than 0.75, when the coder's – less than 0.4.

Examining reliability of coding schemes, we went far beyond just getting a conventional quantitative measure. Our objective was to develop and apply a methodology for reliably coding and reliably estimating ICR in the way that facilitates further inquiry and growing understanding and leads to cumulative science (Levy 1993). Pursuing this goal we improved a technique for evaluating reliability of coding time-delimited events, when unitizing and coding cannot be separated (section 6.624); and proposed a new method for meaningful interpretation of ICR coefficients—Reliability Square—shown in Figure 14 (section 6.627).

7.2 Contributions to knowledge of emotional and cognitive processes in problem-solving groups.

7.21 Collecting data for analysis of problem-solving processes in a business group.

To the best of our knowledge, videotaping a problem-solving workshop in business setting in the way that allows following both verbal and non-verbal activity of each participant was first performed in the course of the current study. Additionally to almost 14 hours of footage, the notes from 1.5-month long fieldwork are available to support the analyses of videotaped materials. Also, the audio-recorded responses of participants during the tests of their interaction and problem-solving preferences are archived. Of independent interest for reliability research and the studies of social cognition, in general, are 4 hours of videotapes documenting final discussions of coding produced by the author and the coder.

7.22 Describing interplay between emotional and cognitive behavior in a business group.

Five videotaped segments were selected for in-depth analysis of interplay between cognition and emotions. The first three of them unfolded smoothly and quickly resulted in recording causes to focal problems. They were typical for the first part of the LM episode. The other two were chosen because they represent difficulties that the group ran into while performing causal analysis. Both of them ended without recording new causes. Interaction between cognition and emotions was especially prominent during two last segments.

Sections 6.633-6.637 describe each of the explored segments. Coded behavior of participants was presented as a time table on Cognition-Emotion-Motivation-Action or CEMA diagrams, which are shown in Figures 15-17. The diagrams permit us seeing how cognitive and emotional dynamics of all participants involved in discussion is unfolding with time. In turn, this enables visual representation of direct influences--shown as arrows--between emotions, cognition, and motivation for the same actor as well as among actors. One can think about CEMA diagrams as a specification of conceptual cycles shown in Figure 1 mapped on the time axis.

Similarly to the case of isolated individuals working on essentially analytical tasks like cryptarithmetic and proving theorems in logic (Newell and Simon 1972), it turned out possible to describe transitions between cognitive and emotional operators employed by the participants of the observed group as a set of “if, then” rules or productions. The production lists for all five segments are presented in the sections 6.633-6.637. They clearly do not cover the whole production system for a group involved in the collaborative RCA. In the section 6.6385 we estimated that the comprehensive system for this task will consist of several hundred productions, and we will need to code and analyze approximately 2.5 hours of video footage to derive one.

7.23 Elaborating the concept of group effectiveness and applying it to problem-solving groups.

CEMA diagrams were designed for conducting a truly dynamic analysis of group effectiveness, in the sense of relating cognitive and emotional processes going on in a problem-solving group to variables describing its effectiveness. Thus, we had to define problem-solving group effectiveness and employed Hackman's formulation (Hackman 1987) as a starting point. Later it was modified to be applicable to cognitively intensive tasks in general and the collaborative RCA in specifically. The definition currently consists of 5 components: one describing quality of the causal diagrams generated by a group, and four describing individual characteristics of participants.

Individual characteristics of participants relevant to effectiveness can be divided into two classes—direction and coordination—each of which has a motivational and understanding components. Thus there are 4 individual characteristics in the definition of effectiveness:

- D_U - understanding component of direction, i.e. understanding of solutions and other knowledge generated during the problem solving;
- D_M - motivational component of direction, i.e. willingness to use solutions and other knowledge generated during the problem solving;
- C_U - understanding component of coordination, i.e. understanding of roles, goals, abilities, and problem-solving preferences of others;
- C_M - motivational component of coordination, i.e. willingness to work with others.

Having 4 individual variables and 1 group variable means that $4\times N+1$ values are required for describing effectiveness of a group with N participants. The dimensions are not independent because understanding components of both direction and coordination may have strong influence on the motivational component of the same variable.

7.24 Carrying out a cognitive task analysis of collaborative RCA.

Before embarking on coding, in order to establish a starting point for designing coding schemes we performed cognitive task analysis of the collaborative RCA. Our extensive, though not systematic, observations conducted prior to and during the workshop, and an inquiry into difficulties observed when groups were applying the RCA, allowed us to clarify cognitive tasks of the "ideal" RCA. There was a clear sequence of steps the facilitator tried to follow:

1. select focal problem; if this is the last problem of the fifth tier, stop;
2. ask why this problem happens. If no contributions provided, go to 1;
3. interpret and fit the contribution to the focal problem;
4. record contribution;
5. check if the group agrees with what was recorded; if not, go to 3;
6. go to 2.

Understanding this sequence was quite helpful when designing the CTA coding scheme. Two phases of the RCA—generation and verification of causes—were clearly seen. Also, during the RCA a facilitator of each of the observed groups was under constant strain while attempting to pursue 2 goals in parallel: to interpret contributions in order to record valid causal relations and to ensure a productive environment for eliciting causes. The issue of facilitating contributions of participants has at least 3 aspects too. First, they have to

understand the logic and purpose of the exercise. Second, they have to follow the evolving chain leading from one cause to another. And, third, they have to be willing to reveal problems with their work processes and to be given an opportunity to contribute when they are ready.

In general, the cognitive task analysis of the RCA reported in section 6-41-6.43 may be considered as the first attempt to come up with some features of the RCA that are common to all groups.

7.25 Relating problem-solving group effectiveness to cognitive and emotional processes of its members.

The cognitive task analysis also led to classifying group tasks into three categories: tasks aimed on interaction management **(IMT)**, procedural tasks of planning application of problem-solving methods **(PT)**, and substantive tasks of correctly carrying out each step of problem-solving methods **(ST)**. The classification well reflects the differences among cognitive states of participants, which are also called problem spaces.

Participants can evoke an infinite number of other problem spaces. Yet the aforementioned three seem to be exceptional because they represent a set of three tasks that is necessary and sufficient for collaborative problem solving. In other words, to solve a problem in a group participants have to stay together and be productive, to coordinate their actions, and to examine the substantive task at hand. If they succeed in all three tasks, the problem probably will be solved. Thus, performance on these tasks can serve as a bridge between cognitive and emotional processes and group effectiveness. Sections 6.44 and 6.73 describe specific mechanisms relating the two.

Findings reported in the section 6.73 are based on the "bottom-up" analyses conducted in the sections 6.71 and 6.72. Here we utilized CEMA diagrams for detecting isolated actions and sequences of actions—all of which were conflicts between two or more participants—having strong impact on group problem-solving effectiveness, and explaining how they occurred. Dynamics of several more conflicts is examined in another recent article (Khaimovich 1998). The article contains analysis of two episodes when participants contested each other's statements while being in two distinctively different problem spaces: one person perceived disagreement as a technical issue and another one as interpersonal rivalry.

Combining the initial theoretical framework delineated in the literature review section with the production systems and interpretations of particular processes, which are described in section 6.63, we detected four other general and abstract cognitively-emotional mechanisms that have major impact on problem-solving group effectiveness. First, allocating attention to a new goal required time and effort on participants' behalf, and they had difficulties performing more than one task at a time. Second, different levels of familiarity with an issue required different information processing approaches and caused mutual misunderstanding. Third, perceiving or anticipating resistance participants focused on the task of making their point to the extent of forgetting about other goals. Fourth, it was difficult for all participants to maintain their thread of thought during the discussion. The participants coped with these challenges in a variety of ways, which are described in the sections 6.6381-6.6384 in more detail.

Additionally to individual dimensions of group effectiveness—motivation and direction of participants—we examined the quality of outcomes of the RCA, which was defined via completeness and validity of causal diagrams created during the workshop. As a reference point we used diagrams drawn by us, after carefully reviewing videotapes. Several causes, which were contributed by participants during the workshop and recorded on videotapes but not on flip charts, were added. Several recordings were reformulated, and some of the causal links were retraced. Both updated and flip-chart version of diagrams for the RCA of a “limited manpower” problem are shown in Figure 18. CEMA diagrams in combination with a transcript permitted to trace how contributions made during the RCA were missed, causes misplaced, and contributions were recorded imprecisely or were insufficiently specified, and how some of these errors were corrected. The section 6.74 reports the findings.

7.3 Practical suggestions for an effective collaborative Root Cause Analysis.

After analyzing F-points, conflicts, and deficiencies of causal maps, we can draw some practical suggestions. Because the present study is based on systematically recorded observations from only one group, no claims can be made about how general and exhaustive they are. It is up to the readers to check our recommendations against their intuition about what may be useful and under what conditions.

Examination of videotapes clearly showed that pursuit of ST, PT, and IMT during the RCA is shaped by 2 fundamental dilemmas of facilitation: understanding vs. interaction management and generation vs. verification of causes. The two dilemmas escalate each other because both of them drain vigor of participants. Lack of vigor, in turn, makes it more difficult to resolve the dilemmas.

When attempting to learn about the business process in order to fit causes to focal problems the facilitator--Andrew-- almost completely abandoned the task of ensuring smooth interaction and involvement of all participants. Furthermore, Andrew usually preferred to follow his own train of thought rather than supporting the participants’ reasoning and helping them to build and clarify their own mental models. This resulted in a "l'aissez-faire style" of facilitating communication when participants were dragged along with Andrew's efforts to perform ST and PT. In this way interpersonal conflicts were effectively terminated when Andrew addressed the group with a new question. Participants did not really resisted the interruptions because they accepted the facilitator's authority to behave so. Sometimes everybody was relieved when a non-productive conflict was brought to the end. In other cases, Andrew's interruption led to blocked goals and unresolved arguments resulting in prolonged tensions.

Two participants took on the role of facilitating group interaction. Dave, by the virtue of being known as a tactful and considerate person, was able to present contributions, which would cause a strong defensive reaction if they had been uttered by anybody else on the team. The following episode (179-193) is indicative of Dave’s facilitation. We see that Greg is becoming increasingly frustrated because his contribution is not recorded, and Andrew is involved in selecting a new problem and does not pay attention to Greg’s growing exasperation (180). At this time Dave shows interest in Greg’s contribution (182) and

simultaneously re-formulates Greg's words so that they become not so critical of Judy as they were (190). This encourages her to participate in the joint attempt to record Greg's contribution (193).

Sam performs the facilitation task in a different manner. He tries to maintain the balance by attacking those who attack others. He does so by making them consider problems in their own areas of responsibility. In this way Sam both performs the IMT and simultaneously contributes to the ST by generating new causes. For example, speech turns 134-152 follow Greg's critical remark about Judy's performance. Using an opportunity to contribute, Sam comes out with an issue of poor training (135). Although he does not mention FE directly and uses "people she'll talk to" instead, it is obvious for all participants except the facilitator, that he is talking about field engineers who constitute the majority of Judy's customers. This makes Greg to stop his offense on Judy and start defending quality of training in his department (147-152).

Would it be better if Andrew was facilitating more actively, and Dave and Sam did not need to perform this role? It is difficult to say, because in the groups with more than 4-5 participants it becomes hard to maintain the flow of activities that makes everybody to feel involved. If we define a pace as a rate of events relevant to the goals and needs of an individual, we can say that maintaining paces has a crucial impact on participants' behaviors. The participants who were satisfied with their pace were willing to engage in activities requested by the facilitator even when they were not among their goals. They were focused on the group discussion. When pace was too low, a person had difficulties in maintaining attention and became bored. When a pace was too high, a person was not able to complete the tasks, and the resulting blocked goals led to growing anxiety. Perception of the rate will be as idiosyncratic as the participants' goals and needs. Because only a limited amount of activities can be carried out simultaneously, it may be advantageous to allow participants to facilitate interaction, if they posses the necessary skills. The role of the facilitator shifts toward assuring that the pace of activities is satisfactory for all participants.

To delegate recording on flip-charts to one of the participants would be one obvious way to increase paces for most participants on the observed team. Recording took approximately 25% of the total time. Yet it provided Andrew with an additional opportunity to interpret and fit the causes he was recording. Without detailed knowledge of the process that was redesigned, Andrew, like any outside facilitator, needed this time to learn about the process. Thus, delegating recording to one of the participants could be done only together with increasing involvement of somebody who was well familiar with formal and informal operating procedures of the division. Tom--the team leader--was supposed to perform this role. With Andrew performing the team leader's role, Tom's involvement became minimal, but he was able to maintain concentration and was making useful procedural remarks, when they were needed most.

Andrew's lack of knowledge about the re-designed process resulted in one more drawback to the team's effectiveness. It indicates an important difference between the requirements of modeling a process and conducting the RCA of its problems. To model a process, one has to describe a large amount of non-problematic mechanisms that work reliably and for this reason usually become "invisible," because they

are taken for granted by anybody familiar with the process. These mechanisms constitute a context in which the critical cause-effect sequences, which are sought by the RCA, are situated. A person familiar with the process usually can quickly distinguish mechanism that are probably trouble-free, from the potential candidates for root causes. Yet an outside facilitators lack this knowledge. For this reason, they will pursue with the same care the links that probably are healthy and those that might lead to the origins of problems. Because organizational processes are complex social-technical systems, it is rarely possible to cover all their components during the several hours devoted to the RCA. In the observed case, for example, the facilitator chose to ask an obvious question--why coordinator and problem solver roles conflict?--and did not pursue a potentially fruitful problem of numerous hand-offs.

Verification of causes presented another major challenge to maintaining satisfactory paces. A considerable amount of time was spent on finding valid causal links for contributions, yet it was not sufficient for this complex task. Verification of causes seems to be rarely among the goals of the participants. They withdrew their attention and became bored, while the facilitator and Mike became frustrated by attempting to carry out the verification in the midst of growing unrelated discussion and pressure to continue generating new causes. The situation is typical. Almost all of approximately 30 groups we have observed performing the RCA ran into prolonged and frustrating difficulties trying to verify causes, which often ended in vain. On the other hand, a number of causes grows in geometric progression with each tier of the RCA. If verification does not create a natural restraint to generation of causes, a group is quickly lost in a large number of incorrectly connected causes. Probably this kind of experience made Andrew try to limit the causal search to 3 tiers and 3 causes written for each focal problem. Even with this artificially imposed constraint, the RCA lasted almost 3 hours and produced 108 causes.

As was explained above in section 6.42 on cognitive tasks inherent to the RCA, a convincing verification of causes requires developing an explicit shared model of the whole or parts of the re-engineered process. The task may demand days or months of time even for relatively simple organizational processes. If during the workshop there is a continuing disagreement about validity of a causal link, it may be worth to record the contribution on a separate flip-chart and to continue generation of causes. Most participants seem to be driven by recording important problems and will be satisfied with such solution. After the workshop, the facilitator alone or supported by those participants who are interested in modeling can fit the separately recorded causes. Videotaping is quite valuable here, because it preserves many details that are not recorded on flip-charts, escape attention of those who will work on verification after the workshop, or will fade away out of their memory. Figure 18, which contains causal diagrams of the same process as it was recorded on the flip-charts and as it was reconstructed after watching videotapes, provides a case in point.

Finally, the three more practices, additionally to videotaping, will improve the quality of the RCA. They are not new, but are consistently violated during the RCA.

First, recording causes that were already mentioned in different context is perfectly legitimate. Yes, it will result in interconnections between the causal trees generated for different focal problems and it

may lead to looping. But this corresponds to the nature of complex systems as it is convincingly demonstrated for organizational processes by Forrester (1961) and many other researchers working in the field of system dynamics[11]. Resistance of the facilitator to what he calls "chasing my tail" imposed an artificial constraint on the flow of the RCA and was perceived by participants as such.

Second, recording on the flip-chart should be as specific as an original participant's contribution. When a team member suggests a cause, he or she often has something specific in mind. It is important to record it without putting anybody on defensive by pointing on them. Otherwise, while searching for causes of too generally formulated problem, misunderstandings and arguments about validity will arise. For example, a conflict occurred when looking for causes of "no one wants to pay" because the causes for this situation were different in SE and FE.

Third, those who are recording should be trained to feel less restricted by the shape and size of flip-charts. We do not think that facilitation literature pays sufficient attention to the problem we observed time and again; namely, Andrew and many other facilitators we saw working, were strongly influenced by the boundaries of a flip-chart. They tried to cram between lines, write in small letters, and even disregard contributions in order to stay on the same flip-chart. On the opposite, after starting a new flip-chart, they tried to draw contributions to fill it, even when the topic seemed to be exhausted.

8.0 Future extension of the study.

As mentioned in the introductory chapter of this thesis, our search for an appropriate description of cognitive and emotional group dynamics was focused by two considerations. First, we were looking for a computable formalism. In other words, given cognitive and emotional states of all participants at any moment, we would like to be able to compute what will happen next. Second, the formalism was intended to be helpful for developing a truly dynamic analysis of group effectiveness, in the sense of relating cognitive and emotional processes going on in a problem-solving group to variables describing its effectiveness. We intend to maintain this focus, and more specific activities for continuing in this vein are presented below.

8.1 Design of computable descriptions.

CEMA diagrams and productions generated for 5 segments described in sections 6.633 -6.637 are ready for the next step in formalizing our findings; namely, for designing computable descriptions. Requirements of rigor that are intrinsic for mathematical and computer modeling, will further drive the development of coding schemes. The task may require conducting lab experiments for detailed examination of cognitive operators. The production lists will be refined too.

Updated coding schemes will be applied for coding more footage of the RCA until the complete, or almost complete, production system for this task is obtained. At that time our endeavors will be ready

[11] For a recent annotated bibliography see a book by Morecroft and Sterman (1994).

for a critical test; namely, a correspondence between our computable description and a newly coded episode will be estimated and origins of discrepancies will be examined, providing better defined requirements to quality of coding and modeling procedures.

The available footage contains an episode with the team applying another sophisticated problem-solving tool: Process Mapping. The recorded material shows how understanding of problems generated during the RCA, and disparate solutions proposed later during the workshop were integrated into operating procedures to be implemented. Mapping a new business process was characterized by an intensive interaction between political issues—like, who will be in charge of particular activities—and of technical issues—like the kind of necessary communication channels. Also, Process Mapping heavily relies on visual displays. It would be interesting to apply the dynamic analysis of effectiveness to such tasks.

8.2 Conceptualization and operationalization of group effectiveness.

This thesis just started conceptualizing group effectiveness. So far, we only needed an initial idea permitting us to extract from videotapes information relevant for purposes of relating group dynamics to its effectiveness. On the next stage this goal has to be explicitly addressed. First of all, the task requires operationalizing 5 components of effectiveness outlined in the introductory chapter. As mentioned, clarification of the links between performance of 3 basic tasks—ST, PT and IMT—and group problem-solving effectiveness seems to be the best way to proceed. Working on the above mentioned substantive issues we intend to propel the alternative research proposal for studying small groups "as complex, adaptive, dynamic systems," which was recently proposed by McGrath (1997).

8.3 Drawing generalizations and modeling larger groups.

From the very beginning the current study was planned as a part of the much larger project developing a truly dynamic theory of problem-solving group effectiveness. In section 2.3 we delineated the two-stage research program to achieve this goal. To carry it out, we have to collect data and analyze them for more groups. Moving in this direction we will be able to address the issue of generality of our findings. Studying more groups also will permit us to fill in the gaps that are unavoidable when collecting longitudinal field data. For example, implementation of decisions made during the workshop we observed was shaped mostly by abrupt changes caused by a departure of one of the division's staff managers. Under these circumstances it was difficult to discern more subtle influence of workshop's dynamics on implementation. Observing other groups should provide better input for studying long-term effects on effectiveness.

Another ambitious goal is to study the whole organization or department simultaneously in order to model the whole structural unit as a network of problem-solving activities.

APPENDICES

APPENDIX A

Spring Breeze Air Conditioner Test

The Spring Breeze Air Conditioner plant, located in the suburbs of a large city, is well known for the quality and efficiency of its product. Even at the present time of year, its peak period, things generally run smoothly. The two individual conveyor-paced production lines produce three air conditioners: the deluxe, medium, and efficiency models. All three air conditioners are similar in size, engineering, and design. Completed units produced in this plant are sold to a large auto-maker. The factory obtains many parts from outside sources and also produces some itself. The assembly process includes retrieval of parts, washing, adjustment, assembly, painting, and inspection (see the enclosed diagram). All parts necessary to complete the air conditioners are stored close to the lines for quick and easy access. No problems have ever been encountered in producing and buying high quality parts.

The Spring Breeze products have been continually recognized for the high quality of their product in all three different units. The management of the factory believes that high quality is their competitive edge on the market. Even though quality control standards are very high, less than one and one-half percent of the air conditioners are rejected. Production, now in the peak season, is 40 per hour for deluxe, 70 per hour for medium, and 120 per hour for the efficiency model. The regular rate of production is 30, 55, and 95 units per hour.

The majority of factory workers are women assemblers. Their work on the lines is very standardized. Assembly begins with the main air conditioner body being placed on the line. Next, the electrical work is done, including fan installation, wiring, and switches installed for quick auto installation. Next, the cooling coils are installed along with the hose connections, and they are checked for leakage. In the final assembly section, air ducts and air directors are installed. The cover is then put on and tightened down.

Each of the female assemblers works in a pair and performs a small part of the total operation. On line 1, the assembly of the deluxe and medium air conditioners takes place. Assemblers with more experience work on the deluxe units. The efficiency line runs much the same way, with assemblers also being paired up. Two weeks before the peak period, new assemblers are hired and placed with experienced workers for training.

All air ducts, air directors, connectors, and covers, prior to being placed on the line, are put through a special phosphate wash. Two large wash tanks are provided for each line. Parts are run through the tank on conveyors and are then blown dry. While parts are being washed in one tank, the other tank is being filled with fresh solution. The solution is changed every half hour to ensure all contaminants and oils are removed. Both tanks are refilled from a common central tank.

When the assembly of the air conditioners is completed, all units go through one central painting booth. Deluxe, medium, and efficiency units are placed on hooks on the single conveyor and then sprayed. The paint is mixed in a "homogenizer" and then pumped to a storage tank before being applied. Using this process, the quality and consistency of paint can be controlled in a continuous operation. After painting, the units go through a drying booth where they are blown dry. Finally, the units come to quality control where each one of them is checked visually and operationally. Leakage, motor strength, air pressures, and paint coverage are all checked closely.

In the Spring Breeze factory, a problem has come to the attention of the management during the last few days. A similar problem occurred a year ago in the peak month. The quality control foreman has reported an increase in the rejection rate to the 6 percent level on efficiency model. The foreman said that

the problem was detected during the final visual paint inspection. He stated that there was "nonuniform coverage and random cratering" on the painted surface and that the problem "tends to occur in bunches." A year ago when the problem occurred, management explored the problem and found that many of the women were using a silicone-based hand lotion. Upon investigation, it was found that the lotion could prevent adhesion of paint. A year ago, after discovering this situation, management placed a sign in the women's rest room restricting the use of certain hand creams for the women on the assembly lines.

Some of the women were displeased about the strict way the situation was handled by management, but in terms of the rejection rate, it returned to normal in a week.

You are participating in a meeting called to prevent another recurrence of the problem during this year's peak period. How would you suggest handling the case?

APPENDIX B

CPR Workshop Participant Questionnaire

JUNE 26, 1996

In the following text, please circle one of the several alternatives contained in the parentheses and separated by forward slashes, or answer the questions.

1. My name is: _____
2. The workshop turned to be (better / same / worse) than I expected?
3. During the workshop I have learned (quite a few / some / very few / no) new things?
4. What are the best suggestions, ideas, recommendations mentioned during the workshop?
5. What are the benefits, if any, for you personally from participating in the workshop?
6. If implemented, the new CPR process:
   - (will / may / hardly will / will not) help to improve customer satisfaction;
   - (will / may / hardly will / will not) make my work more enjoyable;
   - (will / may / hardly will / will not) speed up resolution of customer problems;
   - (will / may / hardly will / will not) result in doing right things right the first time.
7. Chances to implement the new CPR process are (good / slim / uncertain). What makes you think so?
8. I was (always / not always) comfortable to speak my mind openly. If you circled "not always", please explain.
9. I was (always / not always) able to participate in discussions whenever I wanted. If you circled "not always", please explain.
10. Videotaping (was / was a little / was not) disturbing me.
11. Was there anybody on the team, who was especially good in creating good working atmosphere?

    ___yes ___no

    If you answered "yes," who were they?
12. Was there anybody on the team, whose ideas and suggestions were especially useful?

    ___yes ___no

    If you answered "yes," who were they?
13. Was there anybody on the team you didn't feel comfortable with?

___yes ___no

If you answered “yes”, please explain why for each of these people without naming them.

Person 1: _____

Person 2: _____

Person 3: _____

Person 4: _____

14. The room setup was (comfortable / not comfortable).
15. The facilitator was (effective / ineffective) in drawing ideas from the group.
16. The facilitator was (very / reasonably / not very / absolutely not) helpful.
17. Management expectations (were / weren’t) clear.
18. Management expectations (were / weren’t) useful.
19 Customers' expectations (were / weren’t) clear.
20. Customers' expectations (were / weren’t) useful.
21. Customers' expectations (were / weren’t) representative enough.
22. Time spent on “5 whys” cause analysis was (excessive / appropriate / insufficient).
23. Time spent on process mapping was (excessive / appropriate / insufficient).
24. In general, pace of the workshop was (too rapid / just right / too slow).
25. The process map (is / isn’t) detailed enough.
26. What about this workshop did you like?
27. What about this workshop did you not like?
28. Any other comments?

APPENDIX C

Results of The Problem-Solving Test

Name: Tom
Date: June 19 Time: 1-2pm

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1. ALTERNATIVES CONSIDERED.
a) causes of defects;
Silicone-based lotions.
b) relevant facts;
not mentioned
c) solutions;
-to make a requirement that people handle the product with gloves;
-to provide more training and indoctrination about use of lotions to all new workforce.
d) ways to proceed.
- making gloves mandatory to explain why and to provide gloves;
-to explain both to males and females why silicone-based lotions are forbidden. Because it is difficult to find out which lotions contain silicone, it's important to cite brand names;
-provide several alternative acceptable brands of lotion.

2. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Few explanations were made. Explanations supported suggestions. Ex: "company should supply gloves like any protective equipment." "Training for everybody, because men might use hand lotion."

3. SENSITIVITY TO FEELINGS OF WORKERS AT SPRING BREEZE.

Considerable. Seen from the proposed ways to proceed (see 1)

4. RECOMMENDATIONS (WHICH, HOW MANY, HOW BOLD).

Two recommendations made succinctly and ranked according to how complicated it will be to implement them.

5. ASSUMPTIONS ABOUT RELIABILITY OF MANAGEMENT'S FINDINGS.

Took them on face value.
.
6. REASONING TYPE (RECOGN., G-A-T, HEURISTIC SEARCH, DECLARATIVE VS. PROCEDURAL).

Reasoning was not displayed.

7. MOTIVATION (MY REQUEST, A PUZZLE [reveals soc. vs. tech. orientation]).

It looks like my request was the main "motivator."

8.FLOW OF THE ANSWER.

I started from asking Tom, if it's worth it to ask workshop participants for a formal agreement to use videotapes. Then I told him that this exercise will be used for foreseeing possible problems in interaction between workshop participants.

Then Tom asked if he is supposed to provide only one solution, concisely answered my questions and we moved to watching the tape.

9. USE OF NUMBERS.

Didn't look on the table with production rates because "numbers were in here [in text]."

10. USE OF A PROCESS FLOW DIAGRAM.

"Most information was in the text, but pictorials was always beneficial to see what is going on very, very quickly."

11. COMMENTS.

Characteristically doubles "very, very." Or "much, much."

Name: Judy
Date: June 14 Time: 3:30-4:30

---

1. ALTERNATIVES CONSIDERED.

a) causes of defects;

hand lotion, rarely changed washing solution, more people during peak season handle parts and some of them may use "bad" lotion.

b) relevant facts;

6%, increase during peak time only, efficiency line only.

c) solutions;

training on procedures, special handwashing, gloves for <u>all</u> employees, incentives to decrease defects, monitoring process to check for possible causes of defects, and to make sure that hand washing procedure is followed.

d) ways to proceed.

See c).

2. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Explanations of two kinds. First, clarifications how to proceed to have motivated and pleased workers. Second, show her reasoning. F.e.: "Because it happens during peak periods and only on efficiency model, maybe washing solution has to be refreshed more often than each ½ hour." "First I thought it was a hand lotion, but then I thought that people have same habits all year long, why defects increase only at peak load periods? It could be, if more people working, more people touch the parts, more people use this cream."

3. SENSITIVITY TO FEELINGS OF WORKERS AT SPRING BREEZE.

Strong. “If everything is looked on, not only people, people wouldn’t be displeased.” Advocates incentives to keep rejection rate down: time off, picnic, thanks, and pat on the back. Suggests to involve workers in search of solutions.

4. RECOMMENDATIONS (WHICH, HOW MANY, HOW BOLD).

Recommended to do several things (see 1) simultaneously in “should be”, ”I thought, there may be” form. Reads from her list in past tense, like “First I said ..., second I said...”

5. ASSUMPTIONS ABOUT RELIABILITY OF MANAGEMENT’S FINDINGS.

“First I thought it was a hand lotion, but then I thought that people have same habits all year long, why defects increase only at peak load periods? It could be, if more people working, more people touch the parts, more people use this cream.”

6. REASONING TYPE (RECOGN., G-A-T, HEURISTIC SEARCH, DECLARATIVE VS. PROCEDURAL).

Because event1, event 2, this should be done. To achieve X, Y should be done. Heuristic search suited for discovery rather verification.

7. MOTIVATION (MY REQUEST, A PUZZLE [reveals soc. vs. tech. orientation]).

Seems that Judy took the problem as a description of real problem and tried to help me to solve it. May be she wanted to look as a capable person, f.e. saying that numbers were definitely of help, but not being able to explain how she used them (see 9).

8. FLOW OF THE ANSWER.

Suggests ways to proceed. Explaining reasons for monitoring the process, mentions possibility of other causes of defects than just hand lotion. Touches on the issue of incentives. After my question: “what is more probable as a cause of defects: lotion or old washing solution?”, Judy tries to analyze causes. Decides that washing is more probable cause of defects, although other causes are also possible. Her answer was “iterating” between probable causes, dealing fairly with workers, and suggested ways to proceed.

9. USE OF NUMBERS.

Says that “numbers definitely helped, because you can tell....I think it helps to see numbers just so you can know what is going on with the process.”

10. USE OF A PROCESS FLOW DIAGRAM.

Not asked, not mentioned.

11. COMMENTS.

Voice Activated Recording makes it difficult to hear beginning of speech episodes.

Name: Craig
Date: June 19 Time: 10-11am

1. ALTERNATIVES CONSIDERED.
a) causes of defects;
lotion
b) relevant facts;
none
c) solutions;
all in the form of recommendations of how to proceed
d) ways to proceed.
Starts from addressing an issue of feelings hurt by prohibition to use lotion. "First and easiest" explain all of them "why" and show what happens when they use lotion. Second, make it mandatory to use gloves. Third (a nice and relatively cheap solution), supply acceptable hand lotion. Fourth, combine explanation and acceptable lotion, because "they may say 'I don't like this lotion'..." Fifth, add a wipe section before paint. Sixth (a little more comical), automate the process and fire all women. Or, seventh, hire men because they don't use lotion ("Just kidding."). Automating the process will cost too much in a short run. Summarizing, eighth, combine acceptable lotion in restrooms and explanations and wipe section.

2. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

More explanation at the beginning. Seems, Craig tries to reassure himself.

3. SENSITIVITY TO FEELINGS OF WORKERS AT SPRING BREEZE.

Very strong concern about hurt feelings.

4. RECOMMENDATIONS (WHICH, HOW MANY, HOW BOLD).

Recommendations made pretty boldly.

5. ASSUMPTIONS ABOUT RELIABILITY OF MANAGEMENT'S FINDINGS.

Assumptions accepted and even protected from me when I raise this issue. "It sounded that when they yelled about lotion, the problem went away. That the way the document read itself. To the best of our knowledge that's the problem."
.
6. REASONING TYPE (RECOGN., G-A-T, HEURISTIC SEARCH, DECLARATIVE VS. PROCEDURAL).

Something like g-a-t. Checks proposed solutions against criteria of: hurting feelings, chances to be accepted by assemblers, cost, and even side effects.

7. MOTIVATION (MY REQUEST, A PUZZLE [reveals soc. vs. tech. orientation]).

Too look confident, sharp, and cool.

8. FLOW OF THE ANSWER.

Starts answering from the question "can he swear, if I record?" Also asks what I am going to do with the tapes. Then provides several inexpensive ways to proceed without hurting anybody's feelings, reliably eliminating problems. Strives to finish his answers, interrupts me. Throws in a comical solution to replace women by men. Considers automatization replacing everybody. At the end becomes serious again and suggests to combine three of his proposed solutions.

9. USE OF NUMBERS.

Not demonstrated.

10. USE OF A PROCESS FLOW DIAGRAM.

Not demonstrated.

11. COMMENTS.

No analysis of causes at all. All efforts concentrated on proposing solutions to use of lotion. Strove to create an amicable atmosphere. Was guarded and tense all the time.

Name: Dave
Date: June 21 Time: 10-11am

---

1. ALTERNATIVES CONSIDERED.

a) causes of defects;

Insufficient drying time; new assemblers are hired and still learning; because working in pairs, one person fills for another 6% of time (this is Dave's first suspicion); lotion; time of the year--winter-- leads to more lotion use (assuming that peak period is seasonal).

b) relevant facts;

Defects on only one of two lines; higher speed of lines; new assemblers may be not aware about lotion ban; defects come in bunches; 6% increase in defects.

c) solutions;

wash hands, put different kind of lotion in bathrooms.

d) ways to proceed.

"Question the cause of problems, and not necessarily assume it's the same as last year."
Look how the cause of defects was determined last year, than provide this information to the team and brainstorm or accept lotion as the cause.
Somebody needs to watch operations, if filling for another worker is suspected to cause defects.

2. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Dave reasons with me looking for things that are different from when things are OK.

3. SENSITIVITY TO FEELINGS OF WORKERS AT SPRING BREEZE.

Not emphasized. But Dave was the only participant who mentioned about Judy and Rick's divorce.

4. RECOMMENDATIONS (WHICH, HOW MANY, HOW BOLD).

Many recommendations generated as possible remedies for potential causes of defects. Recommendations made naturally in the course of analyzing the situation.

5. ASSUMPTIONS ABOUT RELIABILITY OF MANAGEMENT'S FINDINGS.

Assumptions questioned (see 1d).

6. REASONING TYPE (RECOGN., G-A-T, HEURISTIC SEARCH, DECLARATIVE VS. PROCEDURAL).

The best example of heuristic search among all participants. Dave looks for processes that can lead to defects appearing in bunches, occurring only at peak period, and only on effectiveness line. For example: "if lotion, but why only at peak periods. ... Speed? But why drying will produce defects in bunches? Generates many ideas, but doesn't accept any one.

7. MOTIVATION (MY REQUEST, A PUZZLE [reveals soc. vs. tech. orientation]).

A puzzle draws Dave in. No need to stimulate his answers.

8.FLOW OF THE ANSWER.

Dave introduces his answer by: "I guess I am in the team meeting trying to find solutions now." (It shows his sensitivity to situation's requirements.) Starts from warning against accepting lotion as a cause without considering more information. Then searches through possible causes of defects coming to his mind until he begins to repeat himself.

9. USE OF NUMBERS.

Mentioned 6% and speed increase.

10. USE OF A PROCESS FLOW DIAGRAM.

Not demonstrated.

11. COMMENTS.

A good example of how a person jumps between causes, solutions, relevant facts, and ways to proceed.

Name: Rick
Date: June 18 Time: end at 5:30

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1. ALTERNATIVES CONSIDERED.

a) causes of defects;

not enough inspectors for a peak load; lotion; 2 weeks not enough for new hires to become confident and comfortable; wiring, etc can cause defects; pairing two new hires.

b) relevant facts;

hiring 2 weeks priory to peak load; assumes that not all defects come from painting; assumes that new hires may be paired; assemblers working in pairs.

c) solutions;

if there are more assemblers, there should be more inspectors; why wouldn't we be willing to introduce more intermediate inspection points (to take care of wiring, etc before painting); to pair a new hire with an experienced person.

d) ways to proceed.

Mandate gloves as a part of the uniform; hire additional workers earlier than 2 weeks prior to peaks. Also Rick suggested a 3-step method to find origins of defects. Namely, first, address the problem to <u>all</u> employees (because of problem's gravity). Second, identify as much data as we possibly could: charts, frequency, timing. Third, going back to workgroups and brainstorm what smaller groups perceive as a problem.

2. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Average amount of thinking aloud in order to serve my needs. Told me about his train of thought.

3. SENSITIVITY TO FEELINGS OF WORKERS AT SPRING BREEZE.

Not demonstrated.

4. RECOMMENDATIONS (WHICH, HOW MANY, HOW BOLD).

Politely introduces suggestions: “if you will,” “may be”.

5. ASSUMPTIONS ABOUT RELIABILITY OF MANAGEMENT’S FINDINGS.

“That was only one possible solution”
.
6. REASONING TYPE (RECOGN., G-A-T, HEURISTIC SEARCH, DECLARATIVE VS. PROCEDURAL).

Comes up with many possibilities retrieving them from LTM. F.e. number of inspectors and moving inspection points forward are reminiscent of TQ training.

7. MOTIVATION (MY REQUEST, A PUZZLE [reveals soc. vs. tech. orientation]).

Trying to serve my needs as revealed by introductory question: “Do you really want me...”. Also my “I see” stopped Rick immediately from further explanations.

8. FLOW OF THE ANSWER.

Rick first asked me what do I really want: “to address that from an overview how we should identify the plan to resolve the problem or, secondarily, should we address the specific problem and how I would think of specific solutions?” My response is: both.
Then Rick proposes a 3-step procedure to find origins of defects. And after that he proposes 5 solutions on “individual” and organizational level. I really spur Rick with questions during the interview.

9. USE OF NUMBERS.

Numbers “not too much” useful. Looked that production of everything went up approximately 30%.

10. USE OF A PROCESS FLOW DIAGRAM.

Not demonstrated.

11. COMMENTS.

Pays attention to organizing work rather than technical issues.

Name: Mike
Date: June 27 Time: 9am

1. ALTERNATIVES CONSIDERED.

a) causes of defects;

-not enough time to train new workers hired for a peak season;
-lotion ban is not complied with because at this season only a particular lotion works well on their skin;
-the process is optimized for normal production rate, not for peak period;
-seasonal changes in temperature, humidity.

b) relevant facts;

-only peak season;
-only efficiency line;
-relative increase of production rate for lux (~30%) is larger than for efficiency line (~25%);
-a week after lotion ban the rejection rate went down to normal.

c) solutions;

Gloves, longer training.

d) ways to proceed.

If lotion causes defects, institute gloves. This is easier to spot-check than a silicon-based lotion ban;
If training is insufficient, 3-4 weeks should be enough because defect rate went back to normal in a week after that ban.
If plant problems cause defects, vary the processes: drying time, paint application, change the wash more frequently.
Do solutions in the order of their ease of implementation.

2. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

A lot of explanations in order to show the underlying reasoning. Mike reasons with me.

3. SENSITIVITY TO FEELINGS OF WORKERS AT SPRING BREEZE.

From Mike's notes: "If the employee disgruntlement is the issue... Informational session, hopefully, will ease disappointment." (Crossed out in the notes.)

4. RECOMMENDATIONS (WHICH, HOW MANY, HOW BOLD).

Recommendations made for all possible causes of defects.

5. ASSUMPTIONS ABOUT RELIABILITY OF MANAGEMENT'S FINDINGS.

Mike assumes compliance with the ban and makes a logical conclusion that "this is a problem elsewhere."
.

6. REASONING TYPE (RECOGN., G-A-T, HEURISTIC SEARCH, DECLARATIVE VS. PROCEDURAL).

Example: "may be there is not enough experienced workers on efficiency line, but it would cause problems all the time." Uses "because" often. Performed calculations of relative increase in production rates for both lines.

7. MOTIVATION (MY REQUEST, A PUZZLE [reveals soc. vs. tech. orientation]).

First my request, later becoming engaged in the puzzle.

8. FLOW OF THE ANSWER.

From notes it can be seen that Mike first assumed that lotion was the cause. But then he writes:" Assuming compliance with the ban, this is a problem elsewhere." When presenting his findings to me, Mike states four possible causes, and solutions for each of them. After I point him to the fact of defects appearing in bunches, and only on efficiency line, he takes time to analyze possibilities. He uses both relative and absolute increase in production rates and comes to the conclusion that the process might be breaking down above 110 units per hour.

9. USE OF NUMBERS.

Calculated relative and absolute increases in production rates. Number of weeks for training and from lotion ban to normal rejection rate used for analysis.

10. USE OF A PROCESS FLOW DIAGRAM.

Used for locating possible sources of defects.

11. COMMENTS.

Interesting example of thinking aloud.

Name: Sam
Date: June 21 Time: 11am

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1. ALTERNATIVES CONSIDERED.

a) causes of defects;

Hand lotion.

b) relevant facts;

not mentioned.

c) solutions;

different hand cream, use of gloves

d) ways to proceed.

First, confirm current problem is due to the use of silicone-based hand cream. Second, if the current problem is found to be the same as last year, advise employees that they have 2 options: do not use hand cream or wear latex gloves. Third, if the need for hand cream was due to something work related (phosphate solution dries the skin), the company should supply the gloves. If not, the employee supplies the gloves. Fourth, make sure that all employees, male and female, are dealt with consistently. Fifth, develop a letter that describes the problem and the solution and issue to <u>all</u> employees.

2. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Almost no explanations why.

3. SENSITIVITY TO FEELINGS OF WORKERS AT SPRING BREEZE.

Considerable (see 1)

4. RECOMMENDATIONS (WHICH, HOW MANY, HOW BOLD).

Recommendations about ways to proceed were made in a careful, thoughtful tone.

5. ASSUMPTIONS ABOUT RELIABILITY OF MANAGEMENT'S FINDINGS.

Suggests to confirm that this year's problem is same as the last year's. Hinted to this suggestion by use of word "similar" in the test's text

.

6. REASONING TYPE (RECOGN., G-A-T, HEURISTIC SEARCH, DECLARATIVE VS. PROCEDURAL).

Not evident because of no explanations. Probably, retrieval of relevant stories from LTM.

7. MOTIVATION (MY REQUEST, A PUZZLE [reveals soc. vs. tech. orientation]).

My request. Is relieved when I stop asking questions.

8.FLOW OF THE ANSWER.

Explains which way he would go. Delineates check points with "if, then" statements

9. USE OF NUMBERS.

Said that didn't use them. They wouldn't help because: "This is the same process 1 or 100."

10. USE OF A PROCESS FLOW DIAGRAM.

"Pictures worth the thousand of words."

11. COMMENTS.

No attempt to find causes.

Name: Greg
Date: June 28 Time: 10-11:30

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1. ALTERNATIVES CONSIDERED.

a) causes of defects;

-wearing out of the washing solution;
-sweating and increased need for lotion because of higher production rate;
-combination of the two above mentioned causes.
- new hires are NOT A PROBLEM, because "it's done for years, I assume, and there were no problems."

b) relevant facts;

defects in bunches; solution changed not on usage but by time; 32% combined increase in productivity for both lines; both lines produce more during the peak; hiring new workers before the peak; problems started a year before (Greg doesn't consider a possibility that increase in defects was first noticed only a year before).

c) solutions;

-change washing solution more often or increase concentration;
-have a meeting with workers and explain damages from sweat or lotion;
-change the layout of the assembly line: additional cleaning stations or painting components before assembling.

d) ways to proceed.

-Examine phosphate tanks, trace bunches of defective units through the process. If washing is the problem, change washing solution more often or increase concentration;
-If increased production makes worker sweat or want to refresh lotion, have a meeting with workers and explain damages from sweat or lotion;
-If defects go up after breaks when workers apply new lotion, increase concentration of wash and talk with workers;

-If paint quality is so important, change the layout of the assembly line: additional cleaning stations or painting components before assembling.

2. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Extended explanations are aimed to persuade. Explanations are well thought through. But if something doesn't fit the logic of explanations, Greg is inclined to disregard a piece of information. For example, Greg never mentions the fact that defects come from efficiency line only. When I point him to this fact, he comes up with the vague idea that when wash is worn out on both lines, and washing becomes marginal, anything can cause problems.

3. SENSITIVITY TO FEELINGS OF WORKERS AT SPRING BREEZE.

In general, Greg was discussing mostly technical issues. But he made a cursory remark about "Stupidity to ban lotion by posting and without providing any explanations."

4. RECOMMENDATIONS (WHICH, HOW MANY, HOW BOLD).

Many recommendations (see 1d) made boldly in the form: check X. If X is the problem, do A or B. Uses words like "definitely" and "obviously."

5. ASSUMPTIONS ABOUT RELIABILITY OF MANAGEMENT'S FINDINGS.

Harm from lotion is accepted, but stronger wash is suggested as a solution instead of the lotion ban. In general, Greg prefers to deal with technology rather than with people.

6. REASONING TYPE (RECOGN., G-A-T, HEURISTIC SEARCH, DECLARATIVE VS. PROCEDURAL).

Complex cause-effect chains with contingencies used for reasoning.

7. MOTIVATION (MY REQUEST, A PUZZLE [reveals soc. vs. tech. orientation]).

To improve the process like it would be a real issue, to get rid of stupid arrangements.

8.FLOW OF THE ANSWER.

Greg extensively uses his notes and provides 3 ways to deal with the situation and explains why. When I ask about the reasons for defects coming only from efficiency line, Greg still insist on strengthening wash on both lines and provides a vague but noteworthy explanation why.

9. USE OF NUMBERS.

He was the only one to calculate the production rate increase with the unit accuracy - 32%.

10. USE OF A PROCESS FLOW DIAGRAM.

Used for finding a place for painting before assembling.

11. COMMENTS.

Doesn't mention gloves as a solution at all. It seems that after Greg makes his mind on the basis of pretty deep analysis and just personal preferences (like against gloves), he jumps into advocating phase and argues "by all means possible."

Name: Art
Date: June 26 Time: 4:10-4:45pm (just after the workshop)

1. ALTERNATIVES CONSIDERED.

a) causes of defects;

lotion is on his mind, but when he pronounces it, he adds that it's not necessary the cause of defects.

b) relevant facts;

-problem occurs on the efficiency line;
-problem occurs during peak period;
-rejection rate during peak period 6%;
- normal rejection rate 1.5%;
-defects are described as non-uniform coverage and random cratering.

c) solutions;

not suggested

d) ways to proceed.

First, collect data from the last month and conduct Pareto Analysis. If most defects are "random cratering," "we need to gather the people together" from efficiency line only and ask them how to find cause of defects. "We can ask people on the line" about opportunities to find causes of defects and design measures or control checks within the efficiency line.

2. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Uses "in the other words" several times, but in general, explanations are quite limited. Most of explanations involve showing me a diagram.

3. SENSITIVITY TO FEELINGS OF WORKERS AT SPRING BREEZE.

Didn't discuss an issue of displeased workers, or motivation to follow his recommendations.

4. RECOMMENDATIONS (WHICH, HOW MANY, HOW BOLD).

One recommendation about how to find cause of defects presented boldly as a sequence of "to do" steps.

5. ASSUMPTIONS ABOUT RELIABILITY OF MANAGEMENT'S FINDINGS.

"We are not sure that hand lotion is the problem, somebody thinks that this is the problem because it happened a year ago."

6. REASONING TYPE (RECOGN., G-A-T, HEURISTIC SEARCH, DECLARATIVE VS. PROCEDURAL).

Drew pictures and said that he "thinks in flowcharts."

7. MOTIVATION (MY REQUEST, A PUZZLE [reveals soc. vs. tech. orientation]).

To look as a competent facilitator;
To have it over, because Art was evidently tired after the workshop.

8. FLOW OF THE ANSWER.

Started answering from stating facts, then suggested how to check that lotion is causing defects.

9. USE OF NUMBERS.

Doesn't look like he was using production rate numbers. But Art noted 6 and 1.5%, and gave a numerical example explaining use of Pareto Analysis.

10. USE OF A PROCESS FLOW DIAGRAM.

Yes, Art used it extensively.

11. COMMENTS.

According to common problem-solving techniques, Art doesn't rush to jump to cause and solutions.

APPENDIX D

Results of Interaction Test

Name: Tom
Date: June 19 Time: 1-2pm

1.WHAT IS MENTIONED FIRST (UNSATISFIED NEEDS).

"Their scope of discussion was much, much wider than I have considered." "It seems they weren't sure that lotion was a problem."

After I directed Tom's attention to interaction: "You have two very, very vocal people, who seemed to be dominating the discussion." The vocal people " have different opinions. Somebody, probably, needs to guide them through some means of compromise. ... Or that can go for days."

2. WAYS TO SPEAK ABOUT OTHERS, INCLINATION TO ATTACH LABELS.

Doesn't attach labels.

3. WITH WHOM S/HE WOULD/WOULDN'T LIKE TO BE ON THE TEAM.

Would like: Vocal ones. Because "you would like to have people who are providing input, thoughts."
Wouldn't like: D. Because he kept silent.

4. WHAT PROMOTES/HINDERS EFFECTIVENES OF THE P-S TEAM LIKE THIS?

Leader or facilitator should cut off people who become too philosophical and start creating a list of concrete suggestions. Hinted by my use of "environment", Tom speaks about importance of having a meeting in the conference room with no other people walking around. (There was too much activity around the room where we spoke.)

5. SUGGESTED WAYS TO PROCEED IN THE VIDEOTAPED SITUATION (TO RESOLVE THE CONFLICT).

See 1, 4.

6. REACTION TO C'S EXPLOSION (UN\EXPECTED AND UN\DESIRABLE).

No reaction.

7. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Introduces his statements with "may be I'm incorrect..." Explanations aimed on making balanced statements.

8. FLOW OF THE ANSWER.

Started from “apologizing” that his scope of consideration was too narrow. Explained why he thought that lotion was the cause. Asked me two times “what do you mean?” when I asked him questions. Answered my questions succinctly.

9. COMMENTS.

Tom seems to be very self-conscious and concerned with the impression he makes. But he doesn’t become too aggravated when pointed to deficiencies in his thought. For example I interrupted Tom’s explanations of why he thinks the lotion caused defects. He only had time to say that “in a week after lotion ban, defects went back to normal,” when I say that peak period lasted only 2 weeks altogether (I don’t know where I took it from). He just responded : “OK”

Name: Judy
Date: June 14 Time: 3:30-4:30

1.WHAT IS MENTIONED FIRST (UNSATISFIED NEEDS).

“A matter of disagreeing who makes a decision”
“Both sides came up with opinions and stuck to them”

2. WAYS TO SPEAK ABOUT OTHERS, INCLINATION TO ATTACH LABELS.

Called C “opinionated” describing his style.

3. WITH WHOM S/HE WOULD/WOULDN’T LIKE TO BE ON THE TEAM.

S - yes, H - no.

4. WHAT PROMOTES/HINDERS EFFECTIVENES OF THE P-S TEAM LIKE THIS?

(Very difficult to hear this part) Everybody’s involvement is a big plus, a guy like H - biggest obstacle.

5. SUGGESTED WAYS TO PROCEED IN THE VIDEOTAPED SITUATION (TO RESOLVE THE CONFLICT).

Not asked.

6. REACTION TO C’S EXPLOSION (UN\EXPECTED AND UN\DESIRABLE).

Not mentioned.

7. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Little. Probably because of me rushing through the questions and not allowing enough time for explanations. Described how discussion was hindered by S’s unwillingness to go on and leave the issue alone.

8. FLOW OF THE ANSWER.

After describing what she saw with a single statement: “A matter of disagreeing who makes a decision”, Judy adds: “I disagreed with them.” and starts to present her point of view. Than I started asking questions sometimes cutting off her answers. It seems me I was concerned with keeping her past 4:30.

9. COMMENTS.

Judy reacted to personalities very sharply. She clearly and positively singled out S. When asked an abstract question about obstacles for a productive meeting, Judy replied: “A guy like H”.

Name: Craig
Date: June 19 Time: 10-11am

1.WHAT IS MENTIONED FIRST (UNSATISFIED NEEDS).

“These guys are bickering forever! How should they get the problem resolved?”

2. WAYS TO SPEAK ABOUT OTHERS, INCLINATION TO ATTACH LABELS.

Doesn’t attach label except saying “this guy seems to have a psych degree” about C. Explains in terms what who is/is not doing (see 3).

3. WITH WHOM S/HE WOULD/WOULDN’T LIKE TO BE ON THE TEAM.

Would like to work with lady. Lady “seems to be looking on it from the real world point of view. Well. Some of your people are going to be this way, some of them are going to be this way. And she seems to know the people better and adjusts the way people need to be.” Third guy (D) “doesn’t say too much.” C “probably, is easy to work with, if you are a social person that’s going to explain what’s going on. He doesn’t strike me as a person who could make a decision.”

4. WHAT PROMOTES/HINDERS EFFECTIVENES OF THE P-S TEAM LIKE THIS?

Promotes: “The group, it means the four of them together will come up with a solution. #1(S) would be too harsh, #4(C) would never come with solution,” but with S’s help they should come up with a solution.
Hinders: “Going in circles, in circles, in circles... because nobody is willing to put a foot down and say: hey, these are our solutions, and do something about. ...People don’t want to take responsibility.”
For the workshop Craig suggests to define objectives in advance.

5. SUGGESTED WAYS TO PROCEED IN THE VIDEOTAPED SITUATION (TO RESOLVE THE CONFLICT).

See 4.

6. REACTION TO C’S EXPLOSION (UN\EXPECTED AND UN\DESIRABLE).

Doesn’t feel bad about it. See 3.

7. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Not much explanations. I felt like pulling explanations from him. But, in general, Craig, will even interrupt me to conclude his train of thought, usually providing more details and related stories proving his point.

8. FLOW OF THE ANSWER.

After the short comment about bickering Craig briefly restates what he saw as "these guys have decided that lotion is the problem and try to figure out how to make people agree." I disagree and correct him that they are not sure that lotion is the problem. We slip into a discussion for a while how to figure out the cause of defects. Craig offers that foreman should ask to stop using lotion for a while. "But he may not know how to do that."

Then Craig answers my questions. Supports his answers with related stories, restates, and makes relevant distinctions.

9. COMMENTS.

Craig, so to say, "speaks from his heart." Everything what emerges in his heart needs to be pronounced.

Name: Dave
Date: June 21 Time: 10-11am

1.WHAT IS MENTIONED FIRST (UNSATISFIED NEEDS).

Guy on the left (H) said "have the people and the foreman to solve the problem" and the guy on the right (C) started arguing the same point. And H picked up on this argument and started to argue back. ... Woman tried to say, not very clearly, that they both were telling the same thing.

2. WAYS TO SPEAK ABOUT OTHERS, INCLINATION TO ATTACH LABELS.

No such inclination.

3. WITH WHOM S/HE WOULD/WOULDN'T LIKE TO BE ON THE TEAM.

Would like: A woman ("she was listening") and D ("I cannot remember what he said. If something good, I would like to be with him on the team. I think, he [D] was quiet because other were talking so much."). Wouldn't like: C ("He was not listening that well.") and H ("was talking, talking, and talking and not listening.")

4. WHAT PROMOTES/HINDERS EFFECTIVENES OF THE P-S TEAM LIKE THIS?

Promotes; "An appointed leader who will, may be, keep, may be, is good in running a meeting like that.... Woman could be more aggressive in controlling because she was thinking clearly and could pull up things together."

Hinders: "Probably, overly aggressive people. People arguing for arguing sake. If you have a really smart, hard working leader who is arguing - it may come out OK. But if this is a mediocrity who monopolizes the meeting - it's tough."

5. SUGGESTED WAYS TO PROCEED IN THE VIDEOTAPED SITUATION (TO RESOLVE THE CONFLICT).

See 4.

6. REACTION TO C'S EXPLOSION (UN\EXPECTED AND UN\DESIRABLE).

"I don't understand why he had to come up with such strong statement like 'No, I totally disagree!'"

7. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Dave is thinking aloud.

8. FLOW OF THE ANSWER.

Dave was thoroughly and thoughtfully answering my questions. It was interesting to listen to him, so I didn't interrupt his quite long monologues.

9. COMMENTS.

Dave mentioned after the "movie", that when he looked on the list of prospective participants in the workshop, it made him almost not willing to participate because of too many vocal, mediocre people. By the way, Dave worked in Field Engineering and in projects under Sam. Dave also noted to me about Rick and Judy.

Name: Rick
Date: June 18 Time: ended at 5:30pm

1.WHAT IS MENTIONED FIRST (UNSATISFIED NEEDS).

"It appeared to be quite a difference of opinions. And J don't think that this group displayed a lot of teamwork. .... No one took over as a team leader trying to direct the discussion."

2. WAYS TO SPEAK ABOUT OTHERS, INCLINATION TO ATTACH LABELS.

C is "too abrupt, too abrasive. He had his opinion and he was not going to consider anyone else's."

3. WITH WHOM S/HE WOULD/WOULDN'T LIKE TO BE ON THE TEAM.

S or H - yes. C - no.

4. WHAT PROMOTES/HINDERS EFFECTIVENES OF THE P-S TEAM LIKE THIS?

Hinders: When there is no specific objective. When there are no time constrains. Nobody willing to become a leader of discussion.
Promotes: Better sitting arrangements, notations on the board.

5. SUGGESTED WAYS TO PROCEED IN THE VIDEOTAPED SITUATION (TO RESOLVE THE CONFLICT).

See 4.

6. REACTION TO C'S EXPLOSION (UN\EXPECTED AND UN\DESIRABLE).

Not mentioned.

7. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

No "because"-type of explanations. Answers questions concisely and clearly.

8. FLOW OF THE ANSWER.

Rick's answers are very specific. Allows me to conclude my long monologues. Waits for my questions.

9. COMMENTS.

Rick looks like a person who is very sensitive to his closest intellectual and emotional surroundings.

Name: Mike
Date: June 27 Time: 9am

1.WHAT IS MENTIONED FIRST (UNSATISFIED NEEDS).

"This is a fictitious company? What is not really clear, who these people represent. ... If people are assigned roles, they may start thinking in certain ways." Mike finally complained that it's hard watching groups like this, when you don't know who are these people.

2. WAYS TO SPEAK ABOUT OTHERS, INCLINATION TO ATTACH LABELS.

H was most participatory, looked like production manager.
C is playing a devil's advocate, not closely involved, speaks almost from academic standpoint.
D looked like a foreman.

3. WITH WHOM S/HE WOULD/WOULDN'T LIKE TO BE ON THE TEAM.

Would like: H.
Wouldn't: D, because he was not participating much, just laying back and listening. May be he was thinking about a great idea.

4. WHAT PROMOTES/HINDERS EFFECTIVENES OF THE P-S TEAM LIKE THIS?

Promotes: You probably want to avoid some of the politics and partisanship like between management and union. If you cannot do this, bring in not managers but one step down. (After referring to our workshop) Distribute statistics and technical info in advance.
Hinders: Size may be an obstacle, if there is no structure. (After referring to our workshop) Impartial facilitator may be not the best. You want a person who knows where are the sensitive issues, who has vested interests, to run the meeting. Team leader should already have a good grasp of processes discussed. Cut off detailed talk during high-level discussion. Minimize dead time, like when ripping flip-charts, because this is when unrelated conversations start. Try to have one person speaking at a time.

5. SUGGESTED WAYS TO PROCEED IN THE VIDEOTAPED SITUATION (TO RESOLVE THE CONFLICT).

Didn't cover this issue.

6. REACTION TO C'S EXPLOSION (UN\EXPECTED AND UN\DESIRABLE).

Not revealed.

7. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Mike reasoned aloud about the ways to make team effective.

8. FLOW OF THE ANSWER.

Mike started from explaining that it's hard watching groups like this, when you don't know who are these people. Then briefly answered my questions about with whom he would/wouldn't like to work together. And then mentioned and supported several ideas about effective teamwork.

9. COMMENTS.

Interesting that Mike had such a difficulty watching the tape without knowing who were the people in the video.

His answers about efficiency of teamwork reflected on the past workshop. The issue of facilitator who was not familiar with the discussed processes was, in my opinion the major drawback during the workshop.

Name: Sam
Date: June 21 Time: 11am

1.WHAT IS MENTIONED FIRST (UNSATISFIED NEEDS).

First of all, Sam asks me "Which side I would be on?" referring to the argument between H and C. After I tell him that I am interested in anything he has to say about this episode, he presents his own point of view how foreman should be involved.

2. WAYS TO SPEAK ABOUT OTHERS, INCLINATION TO ATTACH LABELS.

Says that H looks to him as a manager, as somebody who is in business of making money. C looks more as a foreman or HR, as somebody who is very people oriented, with no background in making money.

3. WITH WHOM S/HE WOULD/WOULDN'T LIKE TO BE ON THE TEAM.

First reacts: "I don't agree with the fellow on the right [C], I am a big believer in diversity." Continues to explain how important is to hear different suggestions.
When asked again "with whom would you like...", answers: "Anyone, anyone of them."

4. WHAT PROMOTES/HINDERS EFFECTIVENES OF THE P-S TEAM LIKE THIS?

Promotes. "Control, these two fellows will never agree. Somebody has to make a decision and go on."
Hinders. Those participants whose solutions are not selected become bitter. Having a team meeting when this is a clear-cut matter and only decision is needed. When asked what makes people argue that today is Thursday on Friday afternoon, responds: "Personalities." "If you are arguing with equal peers, and bosses are present, and you start to look bad...." "You cannot shut people off, if you already invited them to be on a team."

5. SUGGESTED WAYS TO PROCEED IN THE VIDEOTAPED SITUATION (TO RESOLVE THE CONFLICT).

Question not asked, but see first sentence in 4.

6. REACTION TO C'S EXPLOSION (UN\EXPECTED AND UN\DESIRABLE).

Not mentioned.

7. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Explanations sound like storytelling.

8. FLOW OF THE ANSWER

First, Sam is continuing to elaborate on his proposed ways to proceed adding how he would deal with a foreman. Then he answers my questions. Elaborates on obstacles to collaboration at much greater length than on facilitating forces.

9. COMMENTS.

Sam seems to be very much "ways to proceed" oriented. His concerns about people are like something permanently in conflict with his image of a manager: somebody who is in business to make money.

Name: Greg
Date: June Time: 10-11:30

1.WHAT IS MENTIONED FIRST (UNSATISFIED NEEDS).

"I don't know if in this case the employee can determine the concentration..."

2. WAYS TO SPEAK ABOUT OTHERS, INCLINATION TO ATTACH LABELS.

"They missed the whole thing." "I think they argue on the wrong thing too early." "He [C] got really nasty."

3. WITH WHOM S/HE WOULD/WOULDN'T LIKE TO BE ON THE TEAM.

Greg responds to my question with: "They missed the whole thing." He approaches this question as "with whose opinion would you agree?" and says that with H he is agreeing more than with others.

4. WHAT PROMOTES/HINDERS EFFECTIVENES OF THE P-S TEAM LIKE THIS?

Promotes: "An ability, to be allowed, to say what you want to say, instead of being ridiculed."
Hinders: "Everybody have their own build in bias. If your mind is closed, you are not going to find the problem." Greg mentions that S is more inclined to accommodate and becomes self-critical.

5. SUGGESTED WAYS TO PROCEED IN THE VIDEOTAPED SITUATION (TO RESOLVE THE CONFLICT).

Not mentioned.

6. REACTION TO C'S EXPLOSION (UN\EXPECTED AND UN\DESIRABLE).

"He [C] got really nasty."

7. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Greg just continues to reason aloud about the best way to take care of defects by technical means without involving workers. He mentions humidity and temperature as possible causes of defects. Declines an idea that lines are different.

Reasoning becomes more important than persuasion comparing with his response to the problem-solving test. Still when I introduce an idea that goes against his reasoning, he accepts it by "Yes, but..." and changes the topic.

8. FLOW OF THE ANSWER.

Greg jumps into discussion of who should be involved in solving the problem talking about indicators of washing solution wear. He talks vehemently leaving me almost no chance to introduce my questions. Repeats most of the ideas from the problem-solving test.

9. COMMENTS.

Greg's remark about C (see 2) seems to be the only his comment about personalities and behavior of participants.

While advocating not to blame employees, Greg is losing facts. F.e. he forgets that more people are hired for peak period and claims that we have to respect that "these guys are cranking out" 30% more than usually.

Greg's self-criticism about having bias and being close-minded (see 4) is revealing.

Name: Art
Date: June 26 Time: 4:10-4:45pm (just after the workshop)

1.WHAT IS MENTIONED FIRST (UNSATISFIED NEEDS).

Starts from asking who are the people on the tape. Are they insiders or outsiders of Spring Breeze plant? "They obviously don't seem to agree on the right approach. This fellow (C) saying: 'Foreman is there to do his job,' and this fellow (H) here says that the workers are closest to the work, workers need to be involved. And the have not reached an agreement on ... how to go. This is not very productive because they are not making progress so far."

2. WAYS TO SPEAK ABOUT OTHERS, INCLINATION TO ATTACH LABELS.

Close- and open-minded are the only adjectives used by Art.

3. WITH WHOM S/HE WOULD/WOULDN'T LIKE TO BE ON THE TEAM.

Would like: S and H "seem more open-minded".
C is more close-minded.

4. WHAT PROMOTES/HINDERS EFFECTIVENES OF THE P-S TEAM LIKE THIS?

Promotes: "Diversity of opinions is fine, but they cannot reach consensus and move forward."
Hinders: "They cannot reach consensus on the strategy, on the action plan.... They debating about the approach and are not any closer to the root cause."

5. SUGGESTED WAYS TO PROCEED IN THE VIDEOTAPED SITUATION (TO RESOLVE THE CONFLICT).

"We can go around the table and get ideas, then dote voting. May be not needed for a group of only four people. Just some kind of compromise is needed. May be bring in a foreman to participate in the discussion. Yes, involve the foreman 'cause he can shut down the workers."

6. REACTION TO C'S EXPLOSION (UN\EXPECTED AND UN\DESIRABLE).

None.

7. AMOUNT AND PURPOSE (TO PERSUADE / TO SHOW UNDERLYING REASONING) OF EXPLANATIONS.

Constantly relapses in speculations about the role of foreman, is not interested in what is happening on the videotape. Explanations elaborate on possible consequences of Art's suggestions.

8. FLOW OF THE ANSWER.

Starts from asking who are the people on the tape. Are they insiders or outsiders of Spring Breeze plant? Constantly relapses in speculations about the role of foreman (see 6 for an example), is not interested in what is happening on the videotape. Often repeats the same statement twice in similar words.

9. COMMENTS.

It seems that Art identifies himself with H. It may be because of similar age and manner to speak, and/or because H is arguing with C, who is, according to Art, advocating importance of foreman's job. It seems that Art had tough time with a foreman.

Answering item 6 Art is very specific, in contrast with all other respondents to this test, and speaks in term of facilitation techniques.

In general, Art was tired after 3 days of workshop. I was angry about the rigid, schematic way he facilitated.

APPENDIX E

"Portraits" of workshop participants.

Judy.
An engineer in software validation department of SE. Tom is her boss. Worked in FE under Greg before and did not like it. Administers now a larger part of the process that was re-designed during the workshop. Is concerned with utilizing what is learned by her priory to the workshop. Recently returned to work after raising her son and is becoming more and more confident about her ability to perform engineering duties. Enjoys helping FE and customers to solve problems more than testing software. Hopes to be promoted to the Lead Engineer in charge of the team running the re-designed process. The only lady participating in the workshop. Mid-forties. Recently divorced from Rick. During p-s and interaction tests she explained her reasoning rather extensively and used heuristic search suited better for discovery rather than verification.

Rick.
A manager in International PM (Asia). Was on the Advisory Team and volunteered to participate in the workshop. Suggested Dave and Mike as participants. Is very sensitive to others and usually makes them feel comfortable. Recently divorced from Judy. Late forties. In the questionnaire he made a surprising statement that Judy dominated the whole workshop. During p-s and interaction tests he came up with many possibilities retrieving them from LTM rather than from analyzing the case; was focused not on technical issues but on organizing and managing; very politely introduced suggestions: "if you will," "may be"; did not speak about people-issues at all.

Craig.
An engineer in Houston FE office. For the last 4(?) months priory to the workshop worked with Judy learning about the last generation of equipment and about the new one coming in 1997. Early thirties. Tries to establish amicable atmosphere and to be cool. During p-s and interaction tests he had very strong concern about hurt feelings; did not analyze causes at all, but checked proposed solutions against criteria of: hurting feelings, chances to be accepted by assemblers, cost, and even side-effects; spoke boldly, with southern accent and "from his heart"; accepted management assumption about lotion and even protected it from me when I raised this issue. "It sounded that when they yelled about lotion, the problem went away. That the way the document read itself. To the best of our knowledge that's the problem."

Tom.
A manager of software validation in SE. Judy's boss. Late fifties. Agreed to be a team leader during the workshop. Seems to be very thorough but his answers to the test were surprisingly brief. Respected by everybody. Definitely knows "the protocol" and helped me on several occasions to behave according to it. Talks rapidly but clearly in the emotional and friendly manner characteristically doubling "very, very" or "much, much." During p-s and interaction tests he took management assumptions on face value; suggested several ways to deal with defects caused by lotion without upsetting workers; succinctly answered my questions.

Dave.
An engineer in Rick's group: International Project Management (Asia). Worked in FE and domestic projects under Sam before. Late thirties. Said me before the workshop, that there were so many "very vocal

mediocre" participants, that this almost maked him not willing to participate. Told me about Rick's and Judy's divorce. Looks as a kid from a good family, wears thick eyeglasses. During p-s and interaction tests he was the best example of heuristic search among all participants; made, similarly to Rick, many plausible but unnecessary assumptions about the production processes at Spring Breeze; reasoned with me looking for things that are different from when things are OK; stopped short of calculations; urged to question the cause of problems; was the one of two people (Greg was another one) who revealed their reaction to the Chris's explosion: "I don't understand why he had to come up with such strong statement like 'No, I totally disagree!'"

Sam.
A manager in Domestic Project Management. Late fifties. Is very proud of his son who is an editor of one of the Pittsburgh university's student newspaper. Constantly extolled "bottom line," but I have a strong impression that his concerns about people are permanently in conflict with his image of a manager: somebody who is "in business of making money." During p-s and interaction tests he suggested to confirm that this year's problem was same as the last year's, but in the meanwhile he accepted lotion as the cause of problems and proposes how to deal with it; delineated check points with "if, then" statements.

Andrew.
Facilitated the workshop. Worked at Westinghouse before as an internal consultant at PQC. Mid-sixties. Dominant but ready to bent in front of those who pay him. Set in his ways: both his workshops I saw followed exactly the same format. During the workshop he had a large difficulty in learning about the process at hand (Mike mentioned that this was the largest problem during the workshop). Was visibly afraid of being lost and losing control. We became angry because I was unhappy with his rigid imposition on a lively thinking process. During p-s and interaction tests he made only one recommendation about how to find cause of defects presented boldly as a sequence of "to do" steps; used a flow diagram extensively; according to common problem-solving techniques, Andrew did not rush to jump to cause and solutions, and just mentioned many relevant facts he had noticed.

Mike.
An engineer in International Project Management (Europe). Late thirties. Produced the most thorough and given-information-based analysis of defects at Spring Breeze. During p-s and interaction tests he suspected washing solution; after I pointed him to the fact of defects appearing in bunches, and only on efficiency line, he used both relative and absolute increase in production rates and came to the conclusion that the process might be breaking down above 110 units per hour; complained about the videotape that it's hard watching groups like this, when you don't know who are these people; answering about efficiency of teamwork reflected on the past workshop.

Greg.
A manager of headquarters' office of Field Engineering. Early sixties. Operating heavy construction machinery as his hobby. Paternalistic with his engineers ("there is a guy dying in trenches, and..."). Prefers to deal with technology rather than with people. Came to the workshop being almost sure that he would get a group running the re-engineered process. Was shocked when the team decided that Judy should do it. Managed his emotions extraordinary well. During p-s and interaction tests he boldly made many recommendations in the form: check X. If X is the problem, do A or B; used words like "definitely" and "obviously"; accepted an idea of harm from lotion, but suggested a stronger wash as a solution instead of the lotion ban; useed complex cause-effect chains with contingencies for reasoning; after Greg made his mind on the basis of pretty deep analysis and just personal preferences (like against gloves), he jumped into advocating phase and argued "by all means possible"; speaking about characters from the videotape said "They missed the whole thing." "I think they argue on the wrong thing too early." "He [Chris] got really nasty."

APPENDIX F

A Transcript of "Limited Manpower" Episode.

WITH SPEECH ACT NUMBERS AND TIME STAMPS.

SP. ACT #	TIME	CON TRIBU TOR	TRANSCRIPT
1.		Andrew	So lets' s uh, let;s get up, I see (Looks for a place to put flip chart stand) I think they need to see these (points to charts and talks to Leon) as we talk about them . Just for reference. Cause something up there might jog them for the solutions. So limited manpower is the issue (WOFC LIMITED MANPOWER (12). Pause.) And we've got uh 12 votes, 12 points, I should say. (WOFC END) So uh, I am not gonna do the Round Robin, I just wanna ask you individually or as a group . Why do we suffer in this world of customer problem resolution with limited manpower?
2.	31.1	Greg	Its priority too low... Andrew, in strategic engineering the priority is... (Andrew interrupts)
3.	36.2	Andrew	So, one answer is, one answer is the priority (pause) is too low. (WOFC PRIORITY TOO LOW, CPR) That is the CPR, Customer Problem Resoluition priority...
4.	46.6	Greg	Sure
5.	50.9	Andrew	...it's too low. (WOFC END) Whats another answer to that why?
6.	52.6	Dave	Who's gonna pay for it? What department. Its like a problem that crosses all (inaudible)
7.	58.0	Sam	(to Rick and Mike, with a big smile) Funding
8.	59.8	Judy	(Smiling) Funding.
9.	60.3	Greg	If this is a software problem, why shouldn't it be?
10.	62.2	Dave	Yes, I know, but we used to have...
11.	62.3	Andrew	Why? What the answer. Why is manpower too limited?
12.	67.9	Dave	No one wants to pay for it. (WOFC NO ONE WANTS TO PAY)
13.	70.1	Judy	(to herself) Who pays? (To Dave) Is it a question of who pays?
14.	74.1	Dave	Right, it used to be that field engineering supported field engineering with a centralized department. (WOFC END) Now we're looking more towards strategic engineering.
15.	82.8	Andrew	(Cutting off Dave) Whats another answer?
16.	84.5	Craig	The experts...
17.	84.6	Andrew	Why is manpower limited?
18.	87.2	Craig	...the experts keeps re-ansering the same question, instead of getting a... database together of who knows the answers, because he has dealt with it.
19.	94.4	Greg	(Cutting off Craig) Redundancy in the...
20.	95.2	Andrew	(WOFC EXPERT KEEPS RE-ANSWERING SAME PROBLEM. No more space on the chart.)

21.	98.1	Craig	...If we keep track of who's worked on certain things there'd be more people to do...to find out the answers from , instead of hittin the same person every time. (Pause)
22.	114.1	Andrew	Re- answer or re-solving, whatever (WOFCEND) Ok if we just stay with those three, those first answers, ok, Let's pursue that one (points to first answer). Why is the uh, CPR, CPR priority too low?
23.	133.4	Craig	No funding.
24.	134.8	Judy	Theres more of a push on new products than supporting (inaudible)
25.		Andrew	(WOFC NEW PROD DEV MORE IMPT.) New product development .... more important, Right? (WOFC END) Another why. Why is CPR priority too low?
26.	158.4	Greg	It was something that was dumped into that group, Andrew. It used to be a part of , there used to be a team in field engineering that took (WOFC CPR "DUMPED INTO SE) that, did that. And it was dumped into strategic engineering. (WOFCEND)
27.	178.0	Dave	Like CPR is...
28.		Andrew	(parallel to Dave) What more?
29.		Dave	...like, not considered, like, directly billable...
30.		Judy	It's a money looser.
31.		Greg	It's a looser, yeah.
32.		Dave	...profitable
33.		Sam	It's a cost. (WOFC CPR SEEN AS COST - NOT REVENUE)
34.		Greg	Its a cost, yeah, direct cost
35.		Dave	Or it's not perceived that way. I mean I feel that ...
36.		Sam	(to Dave) [If there are no money earned, it's] solely a cost
37.		Greg	(parallel to Sam) It's a cost
38.		Dave	...Its a cost, but I think that if we looked at it like if you have 20 field engineers charging warranty time (WOFCEND There is no space for 2nd tier answers for "cpr priority too low"), verses if they were solving those problems faster...
39.		Andrew	OK
40.		Dave	...it would actually not be a cost.
41.		Greg	It might be less of a cost, but It would still be a cost.
42.		Dave	Right, Right
43.		Andrew	Same question here (pointing to solution 2 of first tier "no one wants to pay"), why does no one want to pay for this effort?
44.	213.1	Greg	Cause nobody has it budgeted
45.	213.9	Rick	There' no return
46.		Andrew	What?
47.		Greg	(to Rick) Uhm?
48.		Rick	(to Greg) There's no return, it's cost. (WOFC NO PERCEIVED FIN.RETURN)
49.		Sam	(to Rick) Well there's no...
50.		Dave	No perceived return
51.		Sam	...percieved return... for the individual.
52.		Rick	Right, no financial return.
53.		Sam	(to Rick) No perceived financial return, because you can...
54.		Andrew	(while writing) No perceived financial return. (WOFCEND) Are there any other reasons why no one wants to pay? (Pause) Is that the only one? (Pause)
55.		Dave	Like, no ones...
56.	241.9	Sam	Well, there's not enough budgeted... There's no budget. That may be a little bit different.
57.		Dave	Right.
58.		Andrew	(pointing to what he's just written down) No perceived financial retrun. No budget? (WOFC NO BUDGET).

59.		Sam	(repeats after Andrew to himself) No budget.
60.	254.1	Greg	(to himself) Well... That's just... Nobody wants to pay...(Pause.) There, theres another one too is that (WOFCEND)nobody has that resource in manpower. Not only do they, no one wants to pay for it but they they have trimmed manpower down to handle the product that you're getting out, not to handle five year old....
61.	270.1	Andrew	Weve already got that covered, right. (As he points to the first set of answers)
62.	272.3	Greg	(Pointing at the chart) That's just for strategic engineereing ...
63.	274.4	Andrew	OK
64.	274.4	Greg	.... I have the same thing in field engineering.
65.	275.9	Andrew	Aha! OK.
66.	276.1	Tom	Well , but it could be general, it could be in general. It's across the board.
67.	278.1	Greg	Yeah, its across the board. (Turns to Sam) In projects , you guys don't wanna handle projects that that we shipped three years ago.
68.	285.0	Sam	(to Greg) No.
69.	285.3	Andrew	Greg, tell me again what to put up here. Why does no one want to pay?
70.	286.2	Mike	(to himself) We don't.
71.	287.1	Sam	(turns to Mike) Uhm?
72.	287.8	Mike	(to Sam and smiling) We sure don't.
73.	289.4	Greg	Uh, no manpower (pause) permitted...
74.	294.6	Andrew	(points to the top of the chart) That's up here. We've got limited manpower and we're tryin to find out why. Now I don't wanna hafta chase my ... If ya just put limited manpower then were chasing our tail here...Were goin in a big circle
75.	304.6	Greg	What what I'm sayin is that when I go and say I want to have two more headcounts just to handle customer problems, they ask me why, what amount of money am I gonna generate.
76.	315.2	Judy	(to herself) That would be "no budget."
77.	315.4	Greg	And if I can't justify the dollars, I can't hire the people.
78.	319.3	Andrew	Ok so the reason no one wants to pay is: can't justify dollars ... (WOFC CAN'T J
79.	322.2	Sam	Well that's still perceived financial return. It's still the same thing.
80.	324.6	Judy	And no budget. You don't have a budget... (WOFCEND Saying to himself "it's almost the same thing")
81.	326.5	Andrew	(to Greg) Its almost the same thing
82.	327.0	Greg	(turning to Sam) But it ends up not being, ok, alright (turns back to Andrew)
83.	329.0	Andrew	Its almost the same thing. .
84.	329.7	Greg	Yeah ok
85.		Andrew	Maybe its only those two. Maybe its strictly financial issue.
86.		Dave (Tom?)	(parallel to Andrew) Yeah.
87.		Andrew	Lets not, lets not create something
88.		Greg	Yeah.
89.		Judy	Laughs or coughs
90.		Andrew	Experts keep re-answering the same problem. Why is the expert doing that?
91.	342.8	Greg	No communication system
92.		Rick	(nods agreeing) No communication
93.	345.3	Craig	(WOFC NO COMMUN SYSTEM) Its not documented. We're not...
94.		Sam	(to Rick and Mike and pointing to first problem mentioned on chart #5 "Experts are involved") It's number 5 over there.
95.		Craig	...The documentation is not dispersed.
96.		Rick	(responding to Sam) Right.
97.	351.8	Dave	(to himself) It's not centralized

98.		Craig	(to Dave and smiling) Here you go (Pause. WOFCEND)
99.		Andrew	Are there any other whys or answers?
100.		Greg	Well...
101.		Andrew	(interrupting Greg) Why does he keep reanswering the same problem?
102.		Greg	Well...
103.	360.8	Judy	Its not budgeted to make that happen.
104.		Andrew	Thats almost to here (points to the previous answer given). Why don't we have a communication system? (WOFC NOT BUDGETED written as a cause of NO COMMUN SYST) Not budgeted, right, correct?
105.		Judy	Right
106.		Dave	Right. (Pause. WOFCEND)
107.		Andrew	Are you getting the feeling that this is all financial? (Laughs)
108.		Sam	That's all it is about.
109.		Dave	We don't have a centralized, we don't have a centralized system
110.		Judy	Pretty much. It's bottom line.
111.		Sam	That's all it is about, all what we care about is cost....
112.		Rick	(nodding and smiling to Sam) That's why we are here.
113.	383.1	Greg	(pointing to the chart) Andrew , Andrew, the other why is that that the...
114.	383.8	Andrew	Which why? (Points to board)The why here?
115.	386.3	Greg	This one here, yeah.
116.	387.2	Andrew	why does the expert keep re-answering the same problem?
117.	388.6	Sam	(to Mike and Rick) ... Well, I am, may be.
118.	389.4	Greg	Yeah and ...
119.	390.6	Andrew	And why, why does he do that?
120.	392.1	Greg	(pointing to chart) Well one of the problems in that is the person that takes the call is also the person that's reanswering the same problem many times. (Pointing now to Judy). See, Judy is the funnel in...
121.	405.8	Andrew	Right right (moves away from board and caps marker, stands to listen to Greg)
122.	406.1	Greg	...Judy. If she was just the funnel. In other words if she didn't take the time to answer the question just was the funnel, then and that went to the other person, then we could have 25 people working on them, 25 different problems in parallel.
123.	422.9	Andrew	OK
124.	423.0	Greg	But what happens is that it comes to Judy. Judy has that solution , walks that person through it. And she's doing it serially .
125.	432.5	Judy	(to herself) We need a group (smiles)
126.	432.7	Sam	And another thing for that last one is .....
127.	434.0	Andrew	(To Sam) Woah , wait hold that thought. (Walks to chart points at last problem) Lets try and answer why does the expert keep reanswering the same problem? Cause we have not communicated
128.	443.2	Greg	Everybody.
129.	444.0	Andrew	OK
130.	444.6	Greg	So she walks that person....
131.	445.3	Andrew	Any other reasons?
132.	446.2	Sam	Yeah
133.	447.1	Judy	There's only one...[person who has both to coordinate and to solve problems]
134.	447.9	Andrew	(To Sam) Go ahead
135.	448.6	Sam	Training. The people don't understand what they're doing. Cause the people that she'll talk to, or whoever, tells the person you gotta do this and they don't understand, and they don't recognize the next problem as being the same one.
136.		Dave	Keeps telling them...
137.		Craig	(parallel to Dave) [It's very true]

138.		Dave	Right. You have to keep telling the same thing over and over again to the same person.
139.		Leon	(Inaudible) ...nobody delegates, so to say, this communication ...(Inaudible)
140.		Sam	(to Mike, Rick, and Dave) Training of his audience...
141.		Andrew	So, the expert...
142.		Sam	Its not an expert problem. The expert knows very well.. Its the, its the audience he is...
143.		Andrew	Why is it that he's getting the same...
144.	482.3	Sam	because they don't recognize that its the same problem over and over again...
145.		Andrew	Aha! (WOFC LACK RECOG THAT WEVE SOLVED PROB BEFORE) Lack of recognition ...
146.		Sam	... and they keep callin him. And he keeps re-explaining
147.		Greg	(to Sam) its a different person each time
148.		Craig	(in unison with Greg) it's the different person every time
149.		Sam	Not always
150.		Greg	Well
151.		Sam	That's not what I've heard
152.		Greg	Usually it is
153.		Judy	(To Craig) [That's what I was going to say] (To the group) It's another problem there. Hand off of the problem is another reason for that.
154.		Sam	(to Judy) Well I ve got input from strategic engineering on that , just that they told us that , that they told the same people the same thing over and over and over again...
155.		Judy	(to Sam) Yeah, but that's two separate issues.
156.		Greg	(Pointing at Judy) But. but...
157.		Judy	(to Sam) Telling the same person, plus the same project may have the same problem (WOFCEND) but three different field engineers have worked on it so you have to say it three times.
158.		Greg	But what I'm saying is...
159.		Judy	(parallel to Greg) Two separate...
160.		Andrew	(interrupting Greg and Judy) So is this right? Lack recognition that we've solved this problem before?
161.		Greg	(moving his head expressing doubt) Mmmm.
162.		Judy	(preparing to speak) Mmm...
163.		Andrew	(turning to Judy) Is that one of the whys?
164.		Craig	(to himself, agreeing with Andrew) Uhu.
165.		Judy	I thought it was an understanding issue more than a recognition .
166.		Andrew	Lack understanding?
167.		Sam	Well if they could recognize it, this is the same one that I had before.
168.		Judy	OK
169.		Sam	In a lot of cases they don't think, they just...
170.		Greg	(parallel to Sam) Its usually not the same person though
171.		Judy	(to Sam) Yeah Yeah
172.		Andrew	So that's another answer.
173.		Judy	(to Andrew) There are, there is...
174.		Andrew	Why does the expert keep reanswering the same problem?
175.	539.1	Judy	Its a hand off of the problem
176.		Andrew	Aha! Too many hand offs.
177.		Sam	(to himself, reacting to Judy's contribution, Parallel to Andrew) [It's true.]
178.		Andrew	Ok, good. (WOFC TOO MANY HAND OFFS)
179.		Greg	But, but part of this, what I brought up initially was that the expert is also the funnel. And so everything waits... (WOFCEND)

180.		Andrew	OK Is that... (Reviewing the chart and pays no attention to the conversation)
181.		Greg	The, the funnel should not be the expert...
182.		Dave	Youre saying that there's a bottle neck?
183.		Rick	(to himself and nodding) Right
184.		Judy	(smiles and says something to Dave.)
185.		Greg	Oh yeah. Tremendous. Because, because Judy is the one that's, that's...
186.		Dave	Right
187.		Greg	...solving the problem. She should not be. Or somebody else should have her role. (Andrew scratches CAN'T J from the chart)
188.		Dave	That's right.
189.		Rick	(to himself and actively nodding, parallel to Dave)Right.
190.		Dave	If she gets a real big critical problem, everybody has to wait.
191.		Greg	Everybody else backs up (Andrew turns from the chart to the group)
192.		Dave	Yeah
193.		Judy	(to the group) So we need a support group.
194.		Andrew	Alright, too many hand offs . We we've got three answers for this.
195.		Mike	About the single point of...
196.		Andrew	Is there another one?
197.	580.1	Mike	...A single point of contact for these problems.....I guess what Greg's saying.....
198.		Andrew	This expert (points to EXPERT KEEPS RE-ANSWERING...) is a single point of contact?
199.		Tom	(to himself and parallel to Judy) No.
200.		Dave	(to himself) Well...
201.		Judy	Sometimes
202.		Greg	Its a dual role right now
203.		Mike	No... Maybe not the expert but ....
204.		Andrew	So the role between Judy and expert is confused?
205.		Judy	(to Andrew) I don't.... (to Mike) Tell me if I'm sayin, restating what you said. (Andrew caps his marker)(to Andrew) I'm suposed to be the funnel, but a lot of times because these problems are configuration issues...
206.		Andrew	Yes
207.		Judy	...more so than software problems. And I've seen them before...
208.		Andrew	Yes
209.		Judy	...I'm also, I also become the expert...
210.		Andrew	Right. Right. Aha.
211.		Judy	...so I can answer questions as well as become the coordinator....
212.		Andrew	You don't have to go find a problem solver in all cases.
213.		Judy	(in parallel with Andrew) ...of to whom the problems go to.
214.		Andrew	You may be able to solve the probelem.
215.		Judy	Right...
216.		Andrew	OK
217.		Judy	...and so if I end up on a modem for a couple of hours solving somebody's problems then, and these problems are comin in, they're stackin up because I'm working over here.
218.		Greg	She's doing the expert role rather than the funnel role.
219.		Andrew	OK, yah carrying on both roles.
220.		Dave	(parallel to Andrew) [That's a symptom of it.]
221.		Andrew	So uh is that an answer for here? (pointing to TOO MANY HAND OFFS and then to EXPERT KEEPS RE-ANSWERING...)
222.		Greg	Yeah. Only except that Judy is the person now. She's telling field engineer after field engineer, after field engineer, and meanwhile there's other problems coming in that nobody's getting any resoulution on at all. (Pause)

223.		Andrew	Ok I, I hear ya but I don't think that we are in the the right place for that issue
224.		Judy	(To Andrew. Greg and Dave begin to talk too. Inaudible.) Yeah... (to the group) ...that's thats an offshoot of that
225.		Dave	(prevailing) ...that's a symptom of , that's a symptom of reanswering problems that....
226.		Greg	(breaking in) Well, well my answer. There maybe needs to be a fourth category in there there
227.	667.4	Craig	(to the group and parallel to Greg) The answers are just not getting published
228.		Rick	(to Craig) Right it's the bottom line
229.		Craig	(parallel to Rick) The answers just are not getting published (turns to Greg) and this is the bottom line here
230.		Judy	(to the group, replying to Craig) which is the first thing we said.
231.		Andrew	Which was what we already have...
232.		Craig	(starts to say something) If they were...
233.		Greg	Well, Craig there is still no way to get the thing through the funnel. Judy is not even looking at them so that they would go on to somebody else and be being worked on. They're being held up cause she's four hours on the phone.
234.		Judy	(to Greg) No, I...
235.		Sam	(to Greg, simultaneously with Judy and Andrew) This is how it gets through the funnel.
236.		Greg	(turns to Sam, quickly replies, and turns back to charts) No, [it can't work like it]
237.		Judy	(speaks at the same time reacting to Greg) ...No...
238.		Andrew	(pointing to the EXPERT KEEPS RE-ANSWERING group of 2nd tier answers) Let me stop this chain. Is it fruitful to pick one more up at this level? (Pointing to the 1st tier of answers) Or not, like the one where you are playing the dual role of the funnel and the expert? (Pause)
239.		Judy	(to Andrew in low voice) Yeah
240.		Dave	(after a glance on Judy) Yeah
241.		Tom	(interrupting Andrew) I think you have to. Cause that doesn't seem to fit into the other three...
242.		Dave	Right.
243.		Greg	(to Tom) Yeah, right.
244.		Andrew	(flipping the page of the chart and WOFC LIMITED MANPOWER (CONT.)) So, limited manpower. How about that? (Large pause as Andrew writes. (WOFCEND)) and uh, this is the... (explosion of several voices)
245.	718.4	Dave	(to Andrew) Strategic Engineering interface.
246.		Greg	Coordinator.... coordinator.
247.		Andrew	...Engineer.?.. Coordinator? (To Judy) Shall I call you the coordinator? The traffic cop coordinator?(WOFC COORDINATOR/PROBLEM SOLVER ROLES...)
248.		Judy	(to Andrew) Strategic Engineering Westation support coordinator.
249.		Dave	(to Judy in parallel to Andrew) Strategic Engineering interface.
250.		Judy	(to Dave in parallel to Andrew) Strategic Engineering Westation support coordinator.
251.		Greg	(to Andrew) Problem resolution coordinator.
252.		Andrew	(writing) Problem resolution coordinator slash problem solver roles... (WOFCEND)
253.		Greg	Conflict.
254.		Andrew	(To Judy) Roles what? Conflict? Confuse? Or conflict? You tell me what to write here.
255.		Judy	I...

256.		Andrew	Conflicting?
257.		Judy	(to Andrew) I would think its like dual roles kind of.
258.		Greg	(to Judy) That what he's done. He has, coordinator problem solver... He's got em both (pointing to Andrew)
259.		Andrew	What does that, what does that... Again we're back to limited manpower.
260.		Judy	(to herself and nodding, parallel to Andrew) OK. Conflict.
261.		Andrew	We're asking why do we have limited manpower....
262.		Judy	(to herself and nodding) Conflicting
263.		Dave	(paralle to Andrew, to himself but looking on Judy) Yeah.
264.		Andrew	Because the coordinator and problem solver roles...
265.		Greg	Conflict.
266.		Andrew	...may conflict.
267.		Dave	(parallel to Andrew, to himself) May conflict.
268.		Andrew	Right?
269.		Judy	(nods agreeing) May conflict.(WOFC ... MAY CONFLICT) And I try as much as I can to funnel things on before I start workin on a problem, but... (WOFCEND)
270.		Andrew	Alright, if you wanna take that another step, why do you think they conflict? Why do those two roles conflict?
271.		Sam	(to Greg, parallel to Andrew) (inaudible)
272.		Greg	(responds to Sam, parallel to Greg) (inaudible)
273.	784.1	Judy	Because If I'm in a problem solving role then, then I can't coordinate them anymore. (WOFC IF IN PROB SOLVING ROLE, COORD. ROLE SUFFERS)
274.		Tom	(interupting Judy and answering for her) Yeah, they're inherently different.
275.		Greg	(to Tom) Yeah.
276.		Tom	One is to pass everything on as quick as you can, another is to solve the problems.
277.		Greg	Which is timely.
278.		Tom	Which is different
279.		Greg	Which takes time.
280.		Andrew	(Writing and mumbles) (Inaudible) ...role suffers... (Inaudible)
281.		Sam	(in Mike's direction as Andrew writes, Sam points to charts) We have enough time to take care of that...[All problems proposed for RCA]
282.		Greg	(overhearing Mike and Sam's conversation) Yeah, right. (WOFCEND)
283.		Andrew	If you're in the problem solving role, your coordinator role suffers. (Looks on Judy)Correct?
284.		Judy	(Nods agreeing)
285.		Andrew	Or you could say, vice versa.
286.		Judy	vice versa
287.		Andrew	Or vice versa. (WOFC , OR VICE VERSA WOFCEND) Enough on that? (Points to IF IN PROB SOLVING ROLE COORD ROLE SUFFERS OR VICE VERSA) Could keep going but....Ok , alright....Uh back here(Flipping chart back a page). Did we take this (points to CPR PRIORITY TOO LOW) far enough?
288.		Dave	I just have one thing. Is there maybe some way that we could add the Asian and European communications too?Cause I think there's like the communications, there's the communications between the regional offices here in the US.
289.		Andrew	Is this an answer to why do we have limited manpower.
290.		Dave	I think its more like the re-answering the same problems
291.		Andrew	Expert keeps re-reanswering the same problems and why is...
292.	857.9	Dave	(Interrupting) Right. We're like kind of on our own little solving problem too.
293.		Andrew	Should I say international or should I say Asian?

294.		Dave	I think international
295.		Andrew	(WOFC INTL) International..
296.		Dave	Yeah just to highlight that is ... we get more extra work (WOFCEND)
297.			Greg and Sam have own small conversation
298.		Andrew	International not in loop on...
299.		Dave	Right
300.		Andrew	International not in loop on... (pointing to NO COMMUN SYSTEM) Its almost up here.
301.		Rick	(nodding) Yeah...
302.		Dave	Yeah, that's right.
303.		Rick	...Just insert international before communication.
304.		Andrew	(mumbling to himself and WOFC NOT IN LOOP RE ...) Not in loop regarding..
305.		Dave	Right (WOFCEND)
306.		Andrew	(turns for a second to Dave) Problems solved...
307.		Dave	Right.
308.		Andrew	...or problem fixes? (WOFC PROB'S SOLVED)
309.		Dave	Right. Takes a lot more effort to get them involved
310.		Greg	Does that go through Judy also then?
311.		Dave	Kind of
312.		Judy	Eventually.
313.		Mike	(parallel to Judy) Sometimes.
314.		Judy	Its like another layer in there. (WOFCEND)
315.		Andrew	(to Dave) Why aren't you in that loop?
316.		Dave	I think that...
317.		Andrew	(interrupting Dave) Why isn't international in that loop?
318.	905.5	Dave	...Well, because... A lot of our field engineering is run by management out of the country. And its also been staff level, we're under a different group. So even though we're havin the same.....
319.		Andrew	(Interrupting) So its an organization?
320.		Dave	...Yeah, it's like our organization (WOFC DOM/INTL ORG'S SEPARATE) tends to be segregated even if we are doing the same work. (To Greg and Sam) Like you guys are all under Rod Loving, but we're under a different...
321.		Andrew	(parallel to Dave, talking and writing) Domestic...
322.		Greg	(parallel to Dave) Yeah. Europe is off.
323.		Dave	...staff manager.
324.		Andrew	(talking and writing) International...
325.		Dave	Right.
326.		Andrew	(talking and writing) ...organization...
327.		Dave	Right.
328.		Andrew	(talking and writing) ....Which is separate?
329.		Dave	It promotes a little bit of isolation.... (WOFCEND)
330.		Greg	(to himself) Yeah.
331.		Andrew	I'll just to cap...get the point...International not in the loop regarding the problems solved. Why's that (pointing and reading from the chart) Cause international and domestic organizations (correcting chart) plural, are separate.
332.		Greg	Right.
333.		Dave	Right.
334.		Andrew	Ok. You wanna pursue any more whys here or did we cover that one? (Long pause) I don't wanna just chase, chase my tail here, I wanna really get the meaty stuff. I , I think youre gettin some meaty stuff here. I don't wanna over-do it . (Greg and Sam still talking) Have we exhausted this one? For now, we

			can always come back to it.(Pause) Ok its maybe magic time. What time is it? (To Leon) OK. Then what do we take? 45? An hour?
335.			**A lot of joking and kidding about amount of time to take for lunch.**

APPENDIX G

Cognitive Tasks and Actions (CTA) Coding Scheme Description.

METHODS

```
  Sampling Method..................: Focal Sampling
  Number of Actors.................: Multiple
  Maximum Duration of Observations.: Open Ended
  Maximum Duration Based on........: Elapsed Time
  Sampling Interval................: 00:00 (mm:ss)
  Timing Resolution................: 0.1 Second
```

SUBJECTS

```
  Number of Subjects...............: 1
  Length of Input code.............: 1
```

	Subject Name	Code
1	andrew	a

DEFINITIONS

	Subject Name	Definition
1	andrew	facilitator

Behavioral Class 1: cog_oprt

```
  Number of Elements...............: 16
```

	Element Name	Code	Type
1.	SelProb	sp	State
2.	SolCause	sc	State
3.	IntFitCo	if	State
4.	CheckFit	cf	State
5.	InterpCo	ic	State
6.	CloseBra	cb	State
7.	ChkRelev	cr	State
8.	FormWord	fw	State
9.	ChkInter	ci	State
10.	RecCause	rc	State
11.	Expressi	ex	State
12.	WaitBrea	wb	State
13.	RecProb	rp	State
14.	StopUnde	su	State
15.	SelMethd	sm	State
16.	WhrWrite	ww	State

DEFINITIONS
Behavioral Class 1: cog_oprt

	Element Name	Definition
1.	**SelProb**	[Facilitator] selects the next problem to work on. Participants are coded SelProb when they pay attention to this task. The task often is performed very quickly and there is no related verbalization. The operator can be inferred from the

facilitator's look on the flip-chart or drawing a dash connecting the selected problem with the place to write down a cause.

2. **SolCause** [Facilitator] solicits causes from participants. Differently from SolIntrp she/he has no prior knowledge about the cause that may be contributed in response to his request.
3. **IntFitCo** [Facilitator] interprets (builds "The problem is X" structure) a contribution, fits (builds "Problem X causes the focal problem" structure) it as a cause of a focal problem, and checks its novelty (is it the same as one of the already discussed?).
4. **CheckFit** Checking if the recorded cause really fits a focal problem. This operator is different from FitCause, because it is performed only after the examined cause has been written on flip-charts. Only a confirmation is sought. Not used when this is a part of IntFitCo.
5. **InterpCo** Interpreting a contribution in terms of a problem (building "The problem is X" structure). InterpCo is used only when there is evidence or strong reasons to believe that the cause is not being fitted at the same time or immediately before or after this operator. Not used when this is a part of IntFitCo.
6. **CloseBra** [Facilitator] closes a branch originating from the focal. CloseBra often is accompanied by checking whether participants have more causes to contribute. For this reason, it can be easily confused with SolCause or SolIntrp. The difference is in facilitator's inclination not to record more causes at the time of CloseBra.
7. **ChkRelev** [Facilitator] checks relevance of the contribution. This operator is easy to confuse with FitCause or CheckFit. Yet the distinction is essential, because ChkRelev is a procedural operator. It is enacted by explicitly asking a contributor, causes of which problem s/he has in mind. No attempt is made to build "Problem X causes the focal problem" structure.
8. **FormWord** Formulating wording in order to please management and participants. Differntly from InterpCo and ChkInter the goal of coming up with or verifying the substance of the contribution is not important.
9. **ChkInter** Checking interpretation of the contribution. This operator is different from InterpCo, because it is performed only after the examined contribution has been written on flip-charts. Only a confirmation is sought.
10. **RecCause** Recording a cause.
11. **Expressi** Cognitive state while pursuing immediate emotional comfort.
12. **WaitBrea** Waiting for a natural break in discussion to make a contribution. Instances of this operator often can be inferred or verified *post* factum by utilizing the break for contributing. WaitBrea captures locus of a participant's or facilitator's attention.
13. **RecProb** Recording a problem or anything else but causes on the flip-chart or notebook.
14. **StopUnde** [Facilitator] stops an undesirable contribution by making a statement or providing other evidence of considerable cognitive processing allocated to this task. Instances of just interrupting a speaker are not coded as StopUnde.
15. **SelMethd** [Facilitator] selects a method to perform a task. For example, arranging flip-charts in a particular manner, "round robin" vs. addressing the group.
16. **WhrWrite** [Facilitator] selects a place on flip-charts to write down a cause. This operator is similar to ChkRelev. But during WhrWrite the facilitator does not look for input from a contributor. His decision is influenced by his "3 whys is enough" predisposition, by his routine of recording "up-down and then next tier," and by availability of empty space on a flip-chart.

--- End of Review ---

APPENDIX H

A List of Participants' Contributions

CONTRI-BUTION # (as su-ggested)	ELAPSED TIME[12], SPEECH ACT #	ORIG-INATOR	ANNOUNCED	RECORDED	MY INTRPRETATION	COMMENTS
LM	3, 1	Andrew	Limited manpower is the issue	Limited manpower	Limited manpower is the issue when available people able to solve a problem are located.	
LM1	31, 2	Greg	ANDREW Why do we suffer in this world of customer problem resolution with limited manpower? GREG Its priorities for them... In strategic engineering the priority is...	Priority too low, CPR	In SE CPR priority is lower than new product design .	Greg explicitly mentions SE, but Andrew doesn't record it. Andrew is correct, because the problem is not limited to the SE.
LM2	53, 6	Dave	Who's gonna pay for it? What department. Its like a problem that crosses all (inaudible)		Not clear who should pay for CPR manpower	
LM3	68, 12	Dave	No one wants to pay for it.	No one wants to pay		Under Greg's attack and being directed by Andrew to formulate a problem statement Dave changes the essence of LM2 to what becomes

[12] Elapsed time is measured in seconds from the beginning of the limited manpower episode--first sound in the sentence "So, limited manpower is the issue." in speech act # 1. Beginning of the episode corresponds to the time code 34.2 on the videotape.

CONTRI-BUTION # (as su-ggested)	ELAPSED TIME[12], SPEECH ACT #	ORIG-INATOR	ANNOUNCED	RECORDED	MY INTRPRETATION	COMMENTS
						LM3
LM4	87, 18	Craig	the experts keeps re-ansering the same question, instead of getting a database together of who knows the answers	Expert keeps re-answering same problem	Craig and Judy keep re-answering the same question	
LM1,1	133, 23	Craig	No funding			Craig's contribution would be appropriate as a cause of LM, but not LM1
LM1,2	135, 24	Judy	Theres more of a push on new products than supporting (inaudible)	New prod dev more impt	In SE new product development more important than supporting old products	
LM1,3	158, 26	Greg	It was something that was dumped into that group, Art. It used to be a part of , there used to be a team in field engineering that took that, did that. And it was dumped into strategic engineering	CPR "dumped" into SE		
LM1,4	178, 27	Dave	Like CPR is....like, not considered, like, directly billable...profitable	CPR seen as cost - not revenue		
LM3,1	214, 45	Rob	There's no return, it's cost STEVE (to Rob) Well there's no... DAN No perceived return STEVE ...percieved return... for the individual. ROB Right, no financial return. STEVE (to Rob) No perceived financial return, because you	No perceived financial return		There is a subtle distinction between LM2,1 and LM2,2, that is probably obvious for participants because it maps on two separate sources of funds: discretional budgets and allocated (budgeted) funds.

CONTRI-BUTION # (as su-ggested)	ELAPSED TIME[12], SPEECH ACT #	ORIG-INATOR	ANNOUNCED	RECORDED	MY INTRPRETATION	COMMENTS
			can...			
LM3,2	242, 56	Sam	Well, there's not enough budgeted... There's no budget	No budget		
LM3,3	255, 60	Greg	There, theres another one too is that (WOFCEND)nobody has that resource in manpower. Not only do they, no one wants to pay for it but they they have trimmed manpower down to handle the product that your getting out, not to handle five year old		Disregarding and/or trying not to see the need to serve old equipment makes impossible to justify hiring people for CPR	This contribution introduces a distinction between willingness to pay for servisces of existing manpower and for hiring more manpower.
LM4,1	343, 91	Greg	No communication system	No commun system	No system to disseminate information about problems solved	
LM4,2	345, 93	Craig	Its not documented. We're not... ...The documentation is not dispersed			
LM4,3	352, 97	Dave	It's not centralized			It=documentation
LM4,4	361, 103	Judy	Its not budgeted to make that happen.	Not budgeted		Recorded as LM4,1,1
LM4,5	392, 120	Greg	Well one of the problems in that is the person that takes the call is also the person that's reanswering the same problem many times.			Recorded as LM5
LM4,6	449, 135	Sam	Training. The people don't understand what they're doing. Cause the people that she'll talk to, or whoever, tells the person you gotta do this and they don't understand, and they don't recognize the next problem as being the same one.		Poor training of FE engineers	
LM4,7	482, 144	Sam	because they don't recognize that its the same problem over and over again and they keep callin him. And he keeps re-explaining	Lack recogn. that solved prob. before	FE engineers don't recognize problems they solved before	Lm4,6 should be a cause of LM4,7

CONTRI-BUTION # (as su-ggested)	ELAPSED TIME[12], SPEECH ACT #	ORIG-INATOR	ANNOUNCED	RECORDED	MY INTRPRETATION	COMMENTS
LM4,8	539, 175	Judy	Its a hand off of the problem	Too many hand offs.	When a problem is handed off to another field engineer, information is not shared.	
LM4,9	580, 197	Mike, Judy	MIKE A single point of contact for these problems.. JUDY I'm suposed to be the funnel, but a lot of times because these problems are configuration issues more so than software problems. And I've seen them before, I'm also, I also become the expert so I can answer questions as well as become the coordinator of to whom the problems go to. ....if I end up on a modem for a couple of hours solving somebody's problems then, and these problems are comin in, they're stackin up because I'm working over here.			This is an attempt to reformulate LM4,5. Here Judy explains that cordinator/probl. solver roles conflict, and also explains why she started to perform the expert's role.
LM4,10	667, 227	Craig	The answers just are not getting published			Craig doesn't try to suggest a new cause, but presents LM4,2 as a "bottom line" of LM4,5
LM5	718, 245	Greg, Judy, Dave		Coordin/prob. solver roles conflict		Greg, Judy, and Dave actually just help Andrew to formulate wording.
LM5,1	784, 273	Judy	Because If I'm in a problem solving role then, then I can't coordinate them anymore	If in prob solving role, coord. role suffers	Coordination and problem solving cannot be performed at the same time.	This is a clarification rather than a cause.
LM4,11	858, 292	Dave	We're like kind of on our own little solving	intl. not in	International PM and FE	

CONTRI-BUTION # (as su-ggested)	ELAPSED TIME[12], SPEECH ACT #	ORIG-INATOR	ANNOUNCED	RECORDED	MY INTRPRETATION	COMMENTS
			problem too	loop regarding prob's solved	don't know about solutions discovered by domestic PM and FE.	
LM4,11,1	906, 318	Dave	A lot of our field engineering is run by management out of the country. And its also been staff level, we're under a different group.	dom/inl org's separate	Internationall PM and FE are organizationally separated from domestic.	

APPENDIX J

Cognition-Emotions-Motivation-Actions (CEMA) Coding Scheme Description.

METHODS

```
  Sampling Method..................: Focal Sampling
  Number of Actors.................: Multiple
  Maximum Duration of Observations.: Open Ended
  Maximum Duration Based on........: Elapsed Time
  Sampling Interval................: 00:00 (mm:ss)
  Timing Resolution................: 0.1 Second
```

SUBJECTS

	Subject Name	Code
1	andrew	a
2	greg	g
3	sam	s
4	mike	m
5	dave	d
6	craig	c
7	rick	r
8	judy	j
9	tom	t
10	others	o

DEFINITIONS

	Subject Name	Definition
1	andrew	facilitator
2	greg	FE manager
3	sam	PM/Domestic manager
4	mike	PM/Europe engineer
5	dave	PM/Asia engineer
6	craig	FE engineer
7	rick	PM/Asia manager
8	judy	SE engineer
9	tom	SE manager
10	others	The group as a whole

Behavioral Class 1: cog_task

	Element Name	Code	Type	Modifier 1	Modifier 2	Recip.	Default
1.	SelProb	sp	State	idea#	(none)	No	No
2.	IntFitCo	if	State	idea#	(none)	No	No
3.	CheckFit	cf	State	idea#	(none)	No	No
4.	InterpCo	ic	State	idea#	(none)	No	No
5.	FitCause	fc	State	idea#	(none)	No	No
6.	CloseBra	cb	State	idea#	(none)	No	No
7.	ChkRelev	cr	State	idea#	(none)	No	No
8.	FormWord	fw	State	idea#	(none)	No	No
9.	ChkInter	ci	State	idea#	(none)	No	No
10.	GenCause	gc	State	idea#	(none)	No	No
11.	InVaNvFt	iv	State	idea#	(none)	No	No
12.	ChkWhere	cw	State	idea#	(none)	No	No
13.	OrgRecrd	or	State	(none)	(none)	No	No
14.	RecOrNot	nr	State	idea#	(none)	No	No

15. ChkOther	co	State	(none)	(none)	No	No
16. ChkNovel	cn	State	idea#	(none)	No	No
17. DfnsAttc	da	State	(none)	(none)	No	No
18. GnrSolu	gs	State	idea#	(none)	No	No
19. ChkValid	cv	State	idea#	(none)	No	No
20. Expressi	ex	State	idea#	(none)	No	No
21. SelMethd	sm	State	(none)	(none)	No	No
22. WhrWrite	ww	State	(none)	(none)	No	No
23. DisTract	dt	State	(none)	(none)	No	No
24. TracePrb	tp	State	idea#	(none)	No	No
25. IdeaDevl	id	State	idea#	(none)	No	No
26. SeekAgre	sa	State	Subjects	(none)	No	No

Behavioral Class 2: p-s states

Element Name	Code	Type	Modifier 1	Modifier 2	Recip.	Default
1. substant	ST	State	(none)	(none)	No	No
2. procedur	PT	State	(none)	(none)	No	No
3. InteracM	IM	State	(none)	(none)	No	No
4. EXPRESSI	XX	State	(none)	(none)	No	No

Behavioral Class 3: emotions

Element Name	Code	Type	Modifier 1	Modifier 2	Recip.	Default
1. interest	ii	State	(none)	(none)	No	No
2. tense	tt	State	(none)	(none)	No	No
3. int+tens	it	State	(none)	(none)	No	No
4. bored	bb	State	(none)	(none)	No	No

Behavioral Class 4: em_act

Element Name	Code	Type	Modifier 1	Modifier 2	Recip.	Default
1. PrsAttck	pa	Event	it(+-)	Subjects	No	No
2. BlGoal	bg	Event	it(+-)	Subjects	No	No
3. OthAnx	oa	Event	it(+-)	Subjects	No	No
4. AttckPrs	ap	Event	it(+-)	Subjects	No	No
5. Disagr	dp	Event	it(+-)	Subjects	No	No
6. MisLose	ml	Event	it(+-)	Subjects	No	No
7. AgrGest	ag	Event	it(+-)	Subjects	No	No
8. AnxEvnt	ae	Event	it(+-)	(none)	No	No
9. SocSupp	ss	Event	it(+-)	Subjects	No	No
10. CogDiss	cd	Event	it(+-)	(none)	No	No
11. Confess	cs	Event	it(+-)	(none)	No	No
12. RecApol	ra	Event	it(+-)	Subjects	No	No
13. Agree	ar	Event	it(+-)	Subjects	No	No
14. SensWrd	sw	Event	it(+-)	(none)	No	No
15. GoodAns	ga	Event	it(+-)	(none)	No	No
16. EnmyTalk	et	Event	it(+-)	Subjects	No	No
17. KNown	kn	Event	it(+-)	(none)	No	No

Behavioral Class 5: motivtns

Element Name	Code	Type	Modifier 1	Modifier 2	Recip.	Default
1. ProtDept	pd	State	(none)	(none)	No	No
2. ContProb	cp	State	(none)	(none)	No	No
3. ProtEgo	pe	State	(none)	(none)	No	No
4. ExamProb	ep	State	(none)	(none)	No	No
5. HaveOver	ho	State	(none)	(none)	No	No
6. WritDown	wd	State	(none)	(none)	No	No
7. OthrEgo	oe	State	(none)	(none)	No	No
8. EmotComf	ec	State	(none)	(none)	No	No

Behavioral Class 6: cog_act

Element Name	Code	Type	Modifier 1	Modifier 2	Recip.	Default
1. SolCause	sc	State	Subjects	idea#	No	No
2. SolIntrp	si	State	Subjects	idea#	No	No
3. PropCaus	pc	State	Subjects	idea#	No	No
4. RecCause	rc	State	idea#	Behavior	No	No

5.	NovelObj	no	State	Subjects	idea#	No	No
6.	NovelCrb	nc	State	Subjects	idea#	No	No
7.	Agrees	aa	State	Subjects	idea#	No	No
8.	Disagree	dd	State	Subjects	idea#	No	No
9.	NoAction	00	State	(none)	(none)	No	No
10.	RequInfo	ri	State	Subjects	idea#	No	No
11.	ProvInfo	pi	State	Subjects	idea#	No	No
12.	RequOpin	ro	State	Subjects	idea#	No	No
13.	ProvOpin	po	State	Subjects	idea#	No	No
14.	WaitBrea	wb	State	Behavior	idea#	No	No
15.	StpUndes	su	State	Subjects	idea#	No	No
16.	GoOn	go	State	Subjects	Behavior	No	No

DEFINITIONS

Behavioral Class 1: cog_task

Element Name	Definition
1.	**SelProb** [Facilitator] selects the next problem to work on. Participants are coded SelProb when they pay attention to this task. The task often is performed very quickly and there is no related verbalization. The operator can be inferred from the facilitator's look on the flip-chart or drawing a dash connecting the selected problem with the place to write down a cause. "Comments" field contains a code of the problem that is finally selected.
2.	**IntFitCo** [Facilitator] interprets (builds "The problem is X" structure) a contribution, fits (builds "Problem X causes the focal problem" structure) it as a cause of a focal problem, and checks its novelty (is it the same as one of already recorded causes?). Modifier 1 denotes the contribution that is being interpreted.
3.	**CheckFit** Checking if the recorded cause really fits a focal problem. This operator is different from FitCause, because it is performed only after the examined cause has been written on flip-charts. Only a confirmation is sought. Modifier 1 denotes the contribution that is being fitted.
4.	**InterpCo** Interpreting a contribution in terms of a problem (building "The problem is X" structure). InterpCo is used only when there is evidence or strong reasons to believe that the cause is not being fitted at the same time or immediately before or after this operator. Modifier 1 denotes the contribution that is being interpreted.
5.	**FitCause** Fitting a contribution as a focal problem's cause (building "Problem X causes the focal problem" structure). Modifier 1 denotes the contribution that is being fitted.
6.	**CloseBra** [Facilitator] is closing a branch originating from the focal problem denoted by Modifier 1. CloseBra often is accompanied by checking whether participants have more causes to contribute. For this reason, it can be easily confused with SolCause or SolIntrp. The difference is in facilitator's inclination not to record more causes at the time of CloseBra. Modifier 1 denotes the focal problem.**ChkRelev** Check relevance of the contribution to the focal problem.
7.	**ChkRelev** [Facilitator] is checking relevance of the contribution. This operator is easy to confuse with FitCause or CheckFit. Yet the distinction is essential, because ChkRelev is a procedural operator. It is enacted by explicitly asking a contributor, causes of which problem s/he has in mind. No attempt is made to build "Problem X causes the focal problem" structure. The focal problem facilitator is referring to is denoted by Modifier 1.
8.	**FormWord** Formulating wording in order to please management and participants. Differntly from InterpCo and ChkInter the goal of coming up with or verifying the substance of the contribution is not important. Modifier 1 denotes the contribution that is being formulated.
9.	**ChkInter** Checking interpretation of the contribution. This operator is different from InterpCo, because it is performed only after the examined contribution has been written on flip-charts. Only a confirmation is sought or provided. Modifier 1 denotes the contribution that is being interpreted.
10.	**GenCause** [Participant] is silently generating causes. Inferred from the participant's focus of attention on the facilitator or flip-chart's part where the focal problem is recorded. Also can be inferred from the participant's contribution of the cause (PropCause) after a period of focused contemplation. GenCause is usually a response to SolCause. Usually, but not always, group members will switch from GenCause to InVaNvFt, IntFitCo or something similar after a cause is suggested. Modifier 1 denotes the contribution a participant is working on.
11.	**InVaNvFt** [Participant] interprets (builds "The problem is X" structure), validates(answers "Is the problem really existing or not?"), checks novelty (checks if this problem was mentioned and recorded earlier during the RCA), and fits a contribution (builds "Problem X causes the focal problem" structure). All four tasks are interrelated and performed almost simultaneously, if a participant does not run into difficulties performing any of them. InVaNvFt is usually a response to PropCaus. Modifier 1 denotes the contribution that is being interpreted and fitted.

12. **ChkWhere** Checking where is the mainstream discussion at the present time. The state often follows RecCause or RecProb and discussions in sub-groups. Performing this operator a group member tries to answer two questions "what do they speak about?" and "why do they speak about it?" When facilitator performs this operator, he is scanning group discussion in order to catch information that should be recorded as new causes or elaboration of already written ones. Modifier 1 denotes the contribution that is being discussed.
13. **OrgRecrd** Organizing recordings on flip-charts or a notebook. The state is used as a modifier for RecProb, if recording takes place simultaneously with OrgRecrd. Selecting a place for writing down a contribution is coded WhrWrite instead of OrgRecrd.
14. **RecOrNot** Deliberating whether to record a contribution considering who suggested it and whether it is recorded by the facilitator rather than validity, novelty, and fit. Modifier 1 denotes the contribution.
15. **ChkOther** Checking reaction of others to what is happening at that moment. Attention is to IMT rather than to ST or PT issues.
16. **ChkNovel** Checking novelty of the proposed contribution. Not used when this is a part of IntFitCo or InVaNvFt. Modifier 1 denotes the contribution.
17. **DfnsAttc** Preparing for defense/attack. While in this state, a person looks for the way to demonstrate that s/he is not bad (worse than others) or mistakes can be easily corrected.
18. **GnrSolu** [Participant] generating/looking for a solution of the discussed/focal problem. Participants were required to think in term of problems, but they were inclined to generate solutions instead. Because we can learn about this only from the subsequent PropSolu operator, we can infer which solution was being generated during GnrSolu. Modifier 1 captures the solution.
19. **ChkValid** [Participant] checks validity (does the problem really exists?) of a problem or veracity of a statement (Is this true?). A facilitator rarely uses this operator because he does not know much about actual business processes that are analyzed. Yet he can compare statements with what was said earlier in the workshop or with his general knowledge of similar processes. Modifier 1 captures the problem or statement.
20. **Expressi** Cognitive state while pursuing immediate emotional comfort. The contribution that makes a participant expressive is denoted by Modifier 1.
21. **SelMethd** [Facilitator] selects a method to perform a task. For example, moving flip-charts, "round robin" vs. addressing the group.
22. **WhrWrite** [Facilitator] selects a place on flip-charts to write down a cause. This operator is similar to ChkRelev. But during WhrWrite the facilitator does not look for input from a contributor. His decision is influenced by his "3 whys is enough" predisposition, by his routine of recording "up-down and then next tier," and by availability of empty space on a flip-chart. This operator is a particular case of the broader operator OrgRecrd.
23. **DisTract** Paying attention to any kind of distraction: thunderbolt, adjusting cameras, side conversation not related to the RCA, etc.
24. **TracePrb** [Facilitator], after SP, goes 1 or several tiers back in order to remind himself and/or participants about the problem's context.
25. **IdeaDevl** Developing a related idea when the group discussion is going in another direction.
26. **SeekAgre** Speaking up in order to reach consensus. The intention is to establish or confirm solidarity. Modifier 1 captures with whom agreement is sought.

Behavioral Class 2: p-s states

	Element Name	Definition
1.	substant	Performs substantive task
2.	procedur	Performs procedural task.
3.	InteracM	Performs interaction management task.
4.	EXPRESSI	Expressive state (coincides with EX)

Behavioral Class 3: emotions

	Element Name	Definition
1.	interest	Interested in the task (cognitively).
2.	tense	Anxious to perform the task (emotional).
3.	int+tens	Both interested and anxious.
4.	bored	Bored, i.e. nor interested neither anxious.

Behavioral Class 4: em_act

	Element Name	Definition
1.	PrsAttck	Being under personal attack

2.	BlGoal	Blocked p-s goal
3.	OthAnx	Others' anxiety makes a subject anxious
4.	AttckPrs	Attacking a person
5.	Disagr	Dissagreement with a powerful participant
6.	MisLose	Publicly losing an argument or making a mistake.
7.	AgrGest	Aggresive gesticulation or tone directed on the subject
8.	AnxEvnt	Instances of potential anxiety-causing events not directed on the subject.
9.	SocSupp	Receiving social support
10.	CogDiss	Cognitive dissonance about the subjective task
11.	Confess	Making a confession or apologizing
12.	RecApol	Receiving an appology
13.	Agree	Agreeing or reaching an agreement
14.	SensWrd	Utterance of a word sensitive for the subject
15.	GoodAns	Providing good answer or constructive suggestion
16.	EnmyTalk	An enemy (dangerous/unpleasant) person starts/ends talking
17.	KNown	Loosing interest because of perceived lack of novelty

Behavioral Class 5: motivtns

	Element Name	Definition
1.	ProtDept	Motivated to protect his/her department from criticism
2.	ContProb	Motivated to contribute a problem.
3.	ProtEgo	Motivated to protect his/her ego.
4.	ExamProb	Motivated to examine the discussed problem (InVaNvFt)
5.	HaveOver	Motivated to finish the current task and move on.
6.	WritDown	Motivated to write down a cause (IntFitCo).
7.	OthrEgo	Motivated to help others to protect ego and feel comfortable.
8.	EmotComf	Seeking immediate emotional comfort (being expressive).

Behavioral Class 6: cog_act

	Element Name	Definition
1.	**SolCause**	[Facilitator] solicits causes from participants. Differently from SolIntrp she/he has no prior knowledge about the cause that may be contributed in response to his request. Modifier 1 shows from whom the cause is solicited. Modifier 2 denotes the focal problem that is being analyzed.
2.	**SolIntrp**	Soliciting an interpretation when having an idea about a possible cause but not knowing yet what to write. Having a prior idea about what may be contributed is critical for distinguishing this operator from SolCause. Modifier 1 shows who is addressed, and Modifier 2 denotes a possible cause that is being solicited.
3.	**PropCaus**	[Participant] proposing a cause to the focal/discussed problem. This operator usually follows GenCause. Modifier 1 shows who was addressed while proposing the cause. Modifier 2 captures the cause..
4.	**RecCause**	Recording a cause. Because while writing a person can perform a variety of cognitive tasks, Modifier 2 is intended for capturing them. If no other tasks can be inferred when a person is recording, NoAction is assigned to the Modifier 2. Modifier 1 captures the cause.
5.	**NovelObj**	Objecting novelty of the cause.
6.	**NovelCrb**	[Participant] corroborating novelty of a cause. “Comments” field captures the cause.
7.	**Agrees**	Agreees with the statement.
8.	**Disagree**	Disagreeing with the statement.
9.	**NoAction**	No action that may influence others.
10.	**RequInfo**	Request factual information.
11.	**ProvInfo**	Interpreting info request and providing factual information. Modifier 1 shows who is addressed while providing information. Modifier 2 captures the statement.
12.	**RequOpin**	Request opinion/evaluation.
13.	**ProvOpin**	Providing opinion/evaluation.
14.	**WaitBrea**	Waiting for a natural break in discussion to make a contribution. Instances of this operator often can be infered or verified *post* factum by utilizing the break for contributing. WaitBrea captures locus of a participant’s or facilitator’s attention. While waiting a person can perform a variety of cognitive tasks. Modifier 1 captures them and Modifier 2 denotes the subject of the cognitive task.
15.	**StpUndes**	[Facilitator] stops an undesirable contribution by making a statement or providing other evidence of considerable cognitive processing allocated to this task. Instances of just interrupting a speaker are not coded as StopUnde. Modifier 1 shows who was stopped. Modifier 2 denotes a contribution that was halted.
16.	**GoOn**	[Facilitator} encouraging a participant to continue his/her contribution.

MODIFIERS

Modifier Class 1: it(+-)

	Modifier Name	Code
1.	tens+	t+
2.	tens-	t-
3.	intrs-	i-
4.	intrs+	i+

Modifier Class 2: idea#

Modifier Name	Code
0	0
1	1
2	2
3	3
4	4
1.1	5
1.2	6
1.3	7
1.4	8
3.1	9
3.2	a
3.3	b
4.1	c
4.2	d
4.3	e
4.4	f
4.5	g
4.6	h
4.7	i
4.8	j
4.9	k
4.10	l
4.11	m
5.1	n
x	x
y	y

DEFINITIONS

Modifier Class 1: it(+-)

	Modifier Name	Definition
1.	tens+	A tension increasing event
2.	tens-	A tension decreasing event.
3.	intrs-	An interest decreasing event.
4.	intrs+	An interest increasing event.

Modifier Class 2: idea#

Modifier Name	Definition
x	An idea external to RCA task
y	An idea external to RCA task

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