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COOPERATIVE WORK: THE ROLE OF EXPLANATION IN CREATING A SHARED PROBLEM REPRESENTATION

par L. KARSENTY

SUMMARY

This paper argues that the expression of explanation needs and explanatory dialogues may lead to an enrichment of the shared problem representation in cooperative work. This role of explanation is illustrated by empirical data stemming from three situations of cooperative work (design activities, reuse of past designs and application of checklists in the aeronautical domain). The function of explanations in cooperative work is then discussed from a conceptual perspective. It is argued that explanation is intended to modify the interpretive context, which is defined as a set of knowledge, beliefs and expectations used to apprehend the current work situation. The changes applied to the interpretive context correspond to a more or less global re-interpretation of the problem. Implications for the design of cooperative work settings enhancing mutual understanding are drawn from this discussion.

Keywords: Collective decision making, Synchronous and asynchronous communication, Shared representations, Cognitive Ergonomics.

I - INTRODUCTION

The problem representation is a determining factor in the choice of appropriate actions and, more generally, in a decision-making process (whether it is individual or collective). Any decision or solution reached is relevant according to a problem representation.

Formally, the notion of problem representation is conceived as being composed by three types of information (Richard, 1990):

- (1) an interpretation of the goal to be reached, or at least, a set of criteria that have to be met by the final decision;
- (2) an interpretation of the current situation, which has to be modified in order to reach the goal;

(3) an interpretation of the different possible paths, or actions, that can lead to the goal from the current situation. According to this view, making a decision consists of identifying the best path (i.e., the shorter, the one that satisfies the more criteria, ...) within the problem space.

The problem representation is not a purely mental entity: its content may be at least partially based on procedures when they exist in the work setting, or any form of organizational rules, which fix some constraints to be met by the final decision. One may also conceive its content as being at least partly socially determined, through the effect of power relationship for instance (the more powerful people may "impose" a specific interpretation of the problem). But, at the opposite, problem representations cannot be reduced to these organizational rules or social factors: they are also determined by cognitive factors which play a role in the construction of a problem representation, such as the workers' past experience, specific knowledge and interests. This is especially true when workers are confronted with a problem characterized by a high level of complexity and/or a lack of accurate data, or are lacking relevant knowledge to fully understand it. In such situations, multiple and sometimes divergent interpretations of the problem are possible, and may co-exist among the workers.

The lack of a *shared problem representation* (SPR in the following) in cooperative work may induce incompatible individual actions or poor coordination, divergent judgements on a given decision, or the choice of a sub-optimal or erroneous decisions if, for instance, the SPR did not include a piece of knowledge held by a given co-worker, which highlights an unanticipated drawback of an action chosen by another co-worker. As a consequence, part of cooperative work in a decision-making process must be devoted to the creation of a SPR (see also Leplat, 1988, Terssac & Chabaud, 1990, Navarro, 1991).

We consider that the creation of a SPR contributes to the articulation work which is "required to manage the distributed nature of cooperative work" (Schmidt & Bannon, 1992). It is a consequence of having inter-dependent workers with different competencies, experiences, interests, and opinions working together.

This paper focuses on some cognitive properties of workers which influence the creation of a SPR. These cognitive properties are related to the way each worker processes the incoming information provided by their co-workers. Information processing dictates some constraints for the assimilation of new information. When these constraints are violated, a worker is unable to directly accept new information. She/he needs *an explanation*. We will argue that the way an explanation need is expressed, sought and satisfied in a cooperative dialogue may allow co-workers to enrich their SPR.

This paper consists of three parts. The first one reports observations made by the author on different cooperative work situations. All these observations illustrate the significance of explanations in cooperative work. In particular, they reveal that the inability to satisfy workers' explanation needs related to some information provided by co-workers may

constitute an obstacle to the work in progress. The second part elaborates a theoretical framework with two purposes: (i) to understand from a general point of view the function of explanations in cooperative work, (ii) to derive some implications for the design of work settings enhancing mutual understanding – especially mutual understanding of others' decisions - in cooperative work. The third part presents and discusses these implications.

II - EMPIRICAL DATA ON EXPLANATION AND COOPERATIVE WORK

In this section, we refer to three studies which stress the basic roles that explanation may fulfil in cooperative work. These three studies come from different professional domains and concern very different task domains. They are not extensively described below, as our goal is simply to argue that, in many different work domains, the articulation between individuals' competence and output may require explanatory dialogues. Readers interested in the details of these studies should consult the original documents where they are extensively described.

II.1. Intercomprehension and collective problem solving in design

The first study which illustrates how explanatory dialogues may influence a decision-making process concerns a collective problem solving situation in mechanical design (see Karsenty & Brézillon, 1995b). Dialogues between engineers and draftsmen were analyzed. During these dialogues, the designers were solving “low level” problems (choice of materials, specification of the size of each piece of equipment, specification of the interfaces between adjacent pieces, etc.). Each of those dialogues had a duration of 10 to 90 minutes.

This study allowed observation of the importance of explanations in design dialogues. An explanation was defined as a communication process within which some information needed to understand a target-information was communicated. The importance of explanations was quantified on the basis of (1) a split of the speech acts composing the design dialogues into task-oriented speech acts (e.g., inform on problem data, proposal of goal, proposal of assessment) and explanation acts, (2) an account of the number of words composing each speech act.

This analysis revealed that 31,5% of the speech acts in these dialogues were made of explanation acts. Thus, almost a third of all speech acts in a design dialogue are necessary to ensure intercomprehension and to reach mutual agreement between workers.

This study also revealed a major fact: explanation is not a phenomenon parallel to the problem solving process, but a very part of it. The following extract (see extract 1) illustrates this intermingling between explanation phases and problem solving phases.

(E has proposed a solution; D and E are talking while commenting a blueprint)

- | | | |
|----|---|-------------------------------------|
| D1 | No, we're going to be worried with this. Look: you've 50 mm here (shows on the blueprint), and there you have a flat surface which is like that (shows with his hands). | [DISAGREEMENT]

[EXPLANATION] |
| E2 | No. Because from the angle viewpoint, it is this one that is crossing. | [DISAGREEMENT + EXPLANATION] |
| D3 | ...OK. Then, the bracket does not matter anymore. | [AGREEMENT + CORRECT PB DATA] |
| E4 | Right. ... This means that we'll need to take some measurements directly on this part, and then we'll make the necessary adjustments. | [AGREEMENT + ALTERNATIVE SOLUTION] |
| D5 | Yes, right. | [AGREEMENT] |

Extract 1 - When explanations modify the problem solving path
(“ D ” stands for draftsman, “ E ” for engineer)

Quand les explications modifient le cours de la résolution de problème

More specifically, extract 1 highlights how the explanation of disagreements (D1 and E2) can lead to *correct* the problem representation (D3: “ then, the bracket does not matter anymore ”) and, as a result, to consider an alternative new solution (E4: “ to take some measurements directly on this part, and then to make the necessary adjustments ”). Explanations of disagreements may lead to re-define the problem because they introduce other perspectives, neglected until then by one or many designers involved in the design process. For instance, the explanation in E2 is aimed at making D to consider a new viewpoint on the solution, "the angle viewpoint". This viewpoint change underlies the identification of an irrelevant problem data (D3).

A collective design process is not “ linear ”, in which a linear process would assume three steps: first, define the problem; second, generate a solution; third, assess the solution. This process is iterative: any generated solution may lead to redefine the problem as it is assessed by other colleagues. Numerous studies on design have stressed the intrinsic necessity of iterations in design (Cross, 1986) given the complexity of this kind of problem, the incapacity to consider all the relevant problem data in the phase of requirement analysis, and the involvement of different skills and communities of practice (Bannon, 1996). But few have noted that the dynamics of these iterations is at least partially underlain by explanatory dialogues which may lead to change the problem to be solved.

II.2 Intercomprehension and reuse of past designs

Another study (Karsenty, 1994, 1996) focused on the reuse of past designs in the domain of mechanical engineering. The cooperation required to reuse past designs is asynchronous and mediated: one wants a group of designers having produced a design at a time t to cooperate with another group of designers who will have to reuse it at a time $t+n$ months or years, without the ability for the former to talk directly to the latter. This cooperative effort relies on how thoroughly the first designers document their design. At the beginning of this study, it was unclear which principles had to be applied to achieve good design documentation. It was the goal of this study to help define these principles. Two phases composed this study: during the first one, an analysis of the designers' information needs during reuse was conducted; during the second one, a method for creating a new design documentation was applied on a real project, and the result of this application was empirically evaluated.

In conducting the first phase, we employed the following experimental setup: twelve designers coming from the same design office were individually asked to understand and to assess two past designs that they did not know before. These past designs were displayed on blueprints. The designers were allowed and even encouraged to verbally ask questions (see Karsenty, 1994 for more details).

The analysis was focused on the designers' questions, which revealed their information needs. Six categories of questions were identified, depending on whether they aimed at clarifying: (1) the blueprint, (2) the structure of the device, (3) its behaviour, (4) its assembling, (5) its manufacturing, (6) its rationales. This last category of questions comprised questions like "Why did they need X?", "Why did they choose X and not Y?", "How did they establish X?" These questions typically correspond to explanation needs. The study revealed that design rationale questions constitute almost 50% out of the total number of the designers' questions. Most of these questions were asked when the designers perceived a component of the solution either never encountered before or contradictory with their expectations.

Moreover, this study uncovered the fact that the inability to know the reasons for a decision is a factor of error in design. Indeed, when designers wonder why a given decision has been taken, it is often because they consider an alternative solution which they judge better than the past one. If they cannot understand why the past design would be better than theirs, they tend to reject it (not to reuse it) and to prefer their own solution. The problem is that, in some cases, the designers' preferences for their own solutions are based on misconceptions or misunderstandings. Often, these misunderstandings concern specific requirements and constraints that the solution had to meet. In other words, the problem representation of the current designers is at least partly different from the past designers' one, which causes them to prefer alternative solutions. These discrepancies between problem

representations are due to changes that inevitably occur with time in a design office (technologies evolve, experience is growing, industrial strategies are different, etc.). Some designers reported that this kind of problems frequently occurs in real work settings and could cause a project to slip by several months when the designers realized that their solution presented a major defect.

One of the conclusions of this first phase of the study was that to improve the reuse of past designs, one should provide designers with means of explaining the rationales of past decisions taken by other designers (see also Fischer, 1987, Conklin and Yakemovic, 1991, Moran & Carroll, 1996 among others). More generally, this study suggested the idea that the asynchronousness of a cooperative work setting may increase the possibility of incorrect or incompatible problem representations. Without the ability to access explanations of the others' decisions, these discrepancies between problem representations may remain undetected and cause erroneous decisions.

In the second phase of this study, a method for capturing the reasons of the design decisions was applied on a real project in the same design office. This method, based on the QOC methodology (MacLean et al., 1991), consisted in keeping a trace of all the design issues tackled during the project; for each issue, the alternative options discussed during design meetings and the chosen option were recorded, as well as the arguments for or against each alternative option. All the specific constraints of a project, as well as the empirical facts learned during the project and the experience acquired by each designer during their professional life appeared in these arguments. This method leads to elaborate a design rationale document which, in a certain way, describes the design problem representation and the solution (represented by the set of chosen options) elaborated by the design team.

An empirical evaluation of this design rationale document was then undertaken. This evaluation highlighted, among other things, that such a document contained information which answered only 41% of the new designers' design rationale questions. Different reasons account for this result, but one among them is particularly relevant for this text: almost 25% of the new designers' questions that had no answer in the design rationale document were based on a problem representation partly different from the one constructed along the design project. In fact, we observed that the new designers frequently asked design rationale questions while considering issues or alternative options not tackled during the project, or specific constraints wrongly attributed to this project.

With these findings, we uncovered an unexpected variability in the way to represent a problem space when confronted with a design solution. We also concluded that even if it is possible to provide designers with some explanations of a past solution, it would be illusory to believe that one could provide them with all the possible explanations because they appeared to be dependent on each one's problem representation.

II.3. Intercomprehension and application of checklists in commercial aviation

The last study that will be evoked to illustrate the general purpose of this paper is also a situation of asynchronous cooperation, but of a kind very different from the previous one. It concerns the cooperation between engineers and pilots in civil aviation aimed at handling abnormal and emergency situations¹ in flight (see Karsenty, Bigot and DeBrito, 1995 for a full report of this study). This cooperation is based on checklists and written procedures, which assign specific roles to each partner: engineers have the role of prescriber, while the pilots have the role of executant². According to the airlines and the carriers, this distribution of roles is the only one that can ensure efficiency and safety of action. Generally pilots do not have enough time to solve problems, and moreover, do not possess all the technical knowledge needed to act in the more appropriate way (this knowledge is possessed by engineers).

The departure point of this study, initiated by the French General Direction of Civil Aviation, Human Factor Division (DGAC/SFACT), is the acknowledgement that pilots deviate from prescribed instructions which, sometimes, is a factor contributing to accidents. Our task was to understand the reasons of these deviations.

This study was mainly based on a questionnaire which was sent out to pilots of different carriers. We also got some insight into the real time requirements of this problem through observations in flight simulators. Only some results stemming from the analysis of the questionnaires will be reported. These results are based on the analysis of 200 questionnaires that were sent back by pilots belonging to ten airlines world-wide.

A first result concerns the need for understanding the problem when an abnormal or emergency situation is detected. The prescribed behaviour is to immediately apply the appropriate written procedure. The questionnaire analysis revealed that this instruction is *always*³ respected by only 4,2 % of the pilots in abnormal situations and only 7,4 % in emergency situations. In fact, the great majority of pilots first attempts to understand the problem before performing the procedure. Moreover, we noticed that this need for understanding the problem might persist during the execution of the procedure, and even, for a large amount of pilots (more than 47 %), after the execution of the procedure.

It was shown that the need of understanding felt by the pilots does not confine itself to the understanding of the problem. Pilots may question some prescribed actions in an

¹ The difference between abnormal and emergency situations is the following: during abnormal situations, generally caused by a breakdown without seriousness, there is not a strong time pressure on the handling of the appropriate actions; for emergency situations, generally caused by a severe breakdown, this time pressure is strong, just as the level of risk.

² This distribution of roles does not exactly fit the reality. In fact, most of the airlines grant a certain power of decision to pilots, especially in some specific cases. On the other hand, this notion of cooperation between engineers and pilots does exist in the discourse of some organisations linked to the aeronautical world, for instance training centres (Wibaux, 1992).

³ The pilots were asked to answer this question by selecting an item on a 6 items scale ranging from “ never ” to “ always ”.

abnormal or emergency procedure (for 74,3 % of them) especially when they do not understand their rationales (for 56 % of them), their relevance (for 40,4 % of them) and their consequences (for 42,2 % of them).

These results reveal that the main information need of pilots is identical to the designers' one in reuse situations: it concerns the *rationales* of the prescribed actions – i.e., the engineers' decisions. Comments volunteered by some pilots support this comparison: these pilots reported that they wondered why they had to apply a given prescribed action because they first considered an alternative action based on their own experience. Such a situation seems to appear especially when the procedure is new (or, more exactly, when the pilot is unfamiliar with it) and/or when a step composing the procedure is contradictory with the pilot's expectations.

Finally, one may wonder which are the consequences of not understanding the prescribed actions and, more particularly, to what extent this could lead pilots to refuse them and to prefer another mode of action. Surprisingly, we found that 65,3 % of the pilots in abnormal situations and still 53,2 % of them in emergency situations said that they have refused to apply a prescribed action at least once because they did not understand it. The cooperation between engineers and pilots then does not hold anymore when the pilots' explanation needs cannot be satisfied.

It is worth noting that in some cases, the prescribed actions do have drawbacks or are irrelevant. This accounts for the fact that engineers cannot anticipate all the specific situations encountered during flight. In other words, the engineers' problem representation may be incomplete and/or incorrect and causes them to prescribe suboptimal or erroneous actions. In consequence, one must conclude that the pilots' activity of comprehension is required to really ensure safety in flight. On the other hand, one has to grant that the refusal to apply a prescribed action can provoke accidents, especially when the pilots' decision relies on a wrong diagnosis of the breakdown. In other words, the pilots' problem representation may be incomplete and/or incorrect too. In consequence, one must conclude that the decision in a cockpit, especially in abnormal or emergency situations, should not be taken by pilots only: an exchange of knowledge with engineers is necessary.

From this point of view, this study confirms a conclusion drawn from the study on design reuse. The asynchronousness of cooperative work within the aeronautical world increases the possibility of incorrect or incompatible problem representations between pilots and engineers. Without the ability to access explanations of the others' decisions, these discrepancies between problem representations may remain undetected, and cause erroneous decisions.

II.4. Synthesis

The observations reported in this section showed three collective work situations where explanations appeared to be required in a collective decision-making process. Other studies confirm this significance of explanation in human cooperative work⁴. Just to cite a few examples, Teach & Shortliffe (1984) on medical dialogues, Belkin (1988) on assistance dialogues and Karsenty (1999) on remote assistance dialogues, Baker (1993) on problem solving dialogues between children, Terssac & Chabaud (1990) on control process dialogues, and Grusenmeyer (1995) on relief dialogues in chemical industries stressed the important role of explanations.

Explanations seem particularly required when co-workers receive new and/or contradictory information from others. This seems to be inevitable in any collective decision process since, typically, co-workers use different knowledge and experiences to understand the problem at hand and seek a solution.

The interesting fact is that, with the ability to express their explanations needs and obtain some explanations in response, co-workers can detect and correct errors in others' problem representations. Explanations also allow them to articulate their individual problem representations, and thus, build a richer SPR. Moreover, some empirical data reported above suggest that the enrichment of a SPR resulting from explanatory dialogues has potential: since it renders a deeper analysis of the decision space, it could permit co-workers to reach a better decision than the ones previously considered; in addition, since it renders a better knowledge of the others' viewpoints, it could facilitate the coordination in the remainder of the cooperative work. On the other hand, the lack of explanations may hinder cooperative work and even sometimes induces erroneous decisions.

III - THEORETICAL PERSPECTIVES ON EXPLANATION

The conceptual framework presented in this section results from an attempt to generalize the empirical facts mentioned in the previous section, by relating them to theoretical studies of comprehension. Note that these studies are not originally concerned with the specific issue of creating a problem representation: they are rather intended to cover all types of representations. This framework should allow us to understand, from a more general point of view, the function of explanation in cooperative work. Another goal of this section is to draw some useful conclusions regarding the design or the redesign of cooperative work settings. Three issues in particular are addressed, concerning:

1. The sources of explanations needs
2. The purpose of an explanation process
3. Context-dependent and recursive explanations.

⁴ The need for explanations was also demonstrated in another field of research concerned by the interaction between humans and knowledge-based systems. For a review on this topic, see Karsenty & Brézillon (1995a).

III.1. The sources of explanation needs

According to Schank (1986), we are not always trying to explain everything. We are only trying to explain the perceived phenomena that do not fit our expectations. This notion is based on the idea that understanding is a process which links new experiences to old ones stored in memory. When we directly access these memories, we do not need explanations. But when we hold expectations motivated by our knowledge which are inconsistent with the new experience, we look for an explanation.

The psychologists Abelson and Lalljee argue for a similar notion: "We view the process of explanation [...] as a common-sense problem of connecting the thing to be explained with some available conceptual pattern, appropriately modified to fit the circumstances." (Abelson and Lalljee, 1988, p.175).

Explanation needs then appear if there is a conflict between an event and the knowledge available to understand it. O'Malley (1987, quoted by Draper, 1987) lists three sources for it:

- *Conflict with active predictions*, e.g., not finding a set of actions in a written procedure you had read to find it.
- *Conflict with passive assumptions*, e.g., seeing a yellow alarm where your standard default assumption about alarm includes their not being yellow.
- *Conflict with retrospective expectations*, e.g., finding, in a written procedure, the description of a command which appears to be unavailable in the current work setting.

In brief, an explanation need arises from an *inconsistency between new information and the individual's cognitive context* which bears some expectations, whether they are passive or active. The cognitive context here is defined as the set of knowledge and memories activated by the current situation and used to understand the new information (Karsenty & Pavard, 1998). More specifically, considering collective decision-making settings, the set of knowledge and memories constituting the workers' cognitive context are those that are used to create a problem representation. According to the description of the elements composing a problem representation given by Richard (1990), one can state that explanation needs may arise from different sorts of cognitive conflict. They may come from a conflict between :

- the worker's goal and a description of the goal to be reached provided by another co-worker,
- the worker's interpretation of the current situation and its interpretation by another co-worker,
- or, the worker's selection of the relevant actions to be applied in the current situation and their selection by another co-worker.

These types of conflict are not rare in cooperative work since, typically, cooperative work brings together co-workers with different competencies and experiences and/or is

required to deal with complex problems which, by definition, cannot be unambiguously interpreted.

A conflict between problem representations held by different co-workers within a group is not always detected. It may remain hidden and, thus, cause some troubles (poor coordination, inconsistent individual decisions, etc.). When an explanation need is expressed, it may reveal the conflict which is at its source and allow co-workers to resolve it. This is a reason why explanatory dialogues should be promoted in cooperative work when face-to-face dialogues are possible. Alternatively, helping co-workers to make their problem representation explicit should improve cooperative work efficiency. However, such an aim is not sufficient to know how to create useful explanations for co-workers. The creation of useful explanations requires, in particular, to understand the purpose of an explanation process.

III.2. The purpose of an explanation process

According to Schank (1986), explaining is a process of *generalization* which consists of retrieving an old explanation pattern (i.e., a fossilized explanation), or creating a new one from old patterns. For instance, in order to explain the unexpected perceived event of finding a young dead cat, one might consider that it has been run over by a car by accessing a pattern of knowledge stating that small animals may die by being run over by a car (generalization). In the following, we will focus on the creation of new explanation patterns since, in cooperative work settings, explanation needs typically arise from situation where there is no available explanation.

The creation of new explanation patterns may be supported by two resources: tweaking rules and a contrastive reasoning. Tweaking rules constitute a form of reasoning by analogy (Schank, 1986): "the idea behind a tweaking rule is *to change what we were looking at* into something else that might give us new ideas" (p.113, italics added by us). Examples of tweaking rules are: transpose objects in similar environments, transpose objects that are alike in function. This idea is coherent with Baker's proposal (1993), who claimed that a major process underlying the search for explanation is a *representational change*.

Again, some observations mentioned in the first section are consistent with this view if we consider that the internal process described by Schank or Baker may also manifest itself as a communication process. During design dialogues, for instance, explanations produced by one participant often introduce a new viewpoint: this new viewpoint, not yet considered by the explainee, may help her in understanding a specific information. Design is a domain especially favourable to the coexistence of multiple viewpoints and any design solution may be seen as the result of a negotiation between them (Walz et al., 1987, Klein & Lu, 1989). This might account for the fact that the rationales of design solutions are often difficult to

grasp during reuse activities because designers typically fail to consider all the viewpoints taken into account in a given choice.

A newly created pattern of explanation constitutes a new belief. A process of testing this new belief may then be engaged. It may imply a confrontation with the external world or others' opinions and knowledge, which will be oriented by the structure of the new explanation pattern. For instance, if the explanation "the cat has been run over by a car" is considered, one should check that "the cat is lying on the roadside", if this is a pre-condition of the pattern of knowledge "small animals may die by being run over by a car". In this case, one would say that this pattern of knowledge is *instantiated*. Such observed features can validate the explanation or at least make it more likely. In this sense, one may consider that creating an explanation may lead to *re-analyze or to re-interpret the situation*. Again, this validation process may appear as an internal process or a communication process. This is perfectly illustrated by the example of design dialogue presented above where an explanatory dialogue induced the designers to realize that some problem data initially taken into account actually were irrelevant.

Another theory (Hilton and Slugoski, 1986, Hilton, 1988), concerned by the comprehension of causal attribution processes⁵, stresses the propensity of human beings to compare similar situations in order to identify the causes (or explanations) of a target event, which is being talked about as a *contrastive reasoning*. This view is similar to Garfinkel (1981)'s one, who claimed that an event, by being explained, is always distinguished from a set of alternative events (he called this set the "contrast class"). It is also consistent with the idea that explanations "encourage the forming of discriminations" (Waern et al., 1995, p.249). Contrasting similar situations may lead to detect some differences between these situations not previously perceived (also called "abnormal conditions"). These differences may then take the status of causes of the target event.

The important thing is that a difference detected between two (or more) situations may be a relevant piece of problem data not yet considered. In this sense, the confrontation between alternative events required to find an explanation may cause an enrichment of the problem representation.

This process, which is typically described by causal attribution theories as an internal cognitive process, can occur in a dialogue - in this case, the participants take up a position for divergent opinions - and produce the same effects. Extract 1 (above) is a sound illustration of this: in this example, the divergent opinions of the designers caused a disagreement which, once resolved, led them to change their SPR.

In conclusion, it appears that explanations are produced to *change the interpretive context* - or, in a collective decision-making process, the problem representation - within which a target-information has been first processed. This change may consist in taking a more

⁵ Theories of causal attribution aim at identifying the processes by which ordinary people attributes causes to events, knowing that generally any event has many possible causes.

general point of view (generalization), reasoning by analogy (use of tweaking rules), or invoking other similar situations (contrastive reasoning). All these strategies may lead to re-define the problem representation either because the building of a new pattern of knowledge requires adopting a new point of view and, eventually, checking some features of the situation (instantiation process), or because a contrastive reasoning makes new features of the situation visible. So, the search for explanation also results in changing the way the current situation is perceived. This effect constitutes a major argument giving support to the idea that explanatory dialogues may enrich the SPR.

Empirical data reported in the previous section showed that a worker could fail to cooperate with another (not present) worker due to a lack of explanations. These observations exemplify a type of situation where a change in the worker's problem representation is required, but not made possible neither by the knowledge available to the worker, nor by her/his work setting. There exist two means by which we could help workers in finding satisfactory explanations. The first one consists of improving their training and, thus, to provide them with better and more complete knowledge. This approach should be especially required for work situations under time pressure, which typically preclude co-workers from asking their colleagues explanations or accessing explanations through any form of documentary system. While this is an important issue, sometimes underestimated by corporate executives⁶, we will not tackle it further. The other means consists of designing work settings giving access to explanations or at least material allowing workers to build satisfactory explanations. This aim, on which the section 4 will be focused, raises a new question: To what extent can one anticipate explanation needs and the corresponding explanation contents? This issue is addressed in the following section.

III.3. Context-dependent and recursive explanations

The study on design reuse, briefly described in section II, led to the conclusion that it should not be possible to provide designers with all the possible explanations of the decisions taken during a past project: this would require to anticipate all the possible (erroneous) inferences concerning the goals pursued by the design team, the imposed constraints, and the alternative options considered at the time of the project. For practical reasons, such an aim is hardly conceivable. But there is a more basic reason that allows us to generalize this conclusion: a satisfactory explanation always depends on the specific cognitive context of the explainee which, itself, is very dependent on numerous contingencies of the situation. Because all these contingencies are not foreseeable, every explanation need and explanatory content cannot be predicted.

⁶ This is particularly true in the aeronautical world, where the tendency is at the opposite: for economical reasons, airlines are looking for means to reduce the current time of training.

The causal attribution theory, already mentioned above, gives a theoretical account for this. According to this theory, which emphasises the role of the contrastive reasoning in creating explanations, the object to be explained is not an object having a specific property, but rather an object of comparison, a difference. Hence explanations are “ context relative ”: the explanation looked for by an explainee depends on the set of considered alternatives. Let us take a very simple example, in which an employee hears, without being prepared for this, that her company has just decided to cut down its total number of employees by 10%. Such an information will probably not be acceptable if this employee considers that the company benefits are high and its order book quite full. In this case, an explanation, to be satisfactory, should distinguish the case of other companies that make benefits and have a full order book with hers. Such an explanation could be: "The market competition would seriously threaten the company survival if it cannot drastically reduce its production costs". This explanation emphasises the fact that the employee's company is on a market where competitors sell their products at a lower price. In doing so, it should help the employee to distinguish between her company and other companies making profits but not being subjected to the same cut-throat competition.

However, if the same employee knows or hears that at least one other company subjected to the same competition had not planned to reduce its number of employees, this explanation will not be satisfactory. A better explanation could then be: "The market competition would seriously threaten the company survival if it cannot drastically reduce its production cost. To do so, the company must reduce its total number of employees given that its new production lines require only half the previous number of workers." This explanation allows the employee to learn a new fact – the use of a new production line requiring less people - which should help her to distinguish between her company and other companies subjected to the same competition.

This example illustrates the fact that explanation acceptability depends on the explainee's problem representation – i.e., how s/he conceives the problem for which the dismissal could be a solution. It also allows us to realize that explanations acceptability depends on justification or support knowledge that may be available for some explainees and not available for others. The study of design reuse provided us with sound illustrations of this: we noticed that, occasionally, an explanation of a design decision provided in the design rationale document could fail to be accepted by a portion of designers because of a lack of support knowledge.

The first response that crosses one's mind to handle such a problem would consist in adding some support knowledge to any explanation (i.e., a second level of explanation). Actually, this would only be a way to push the problem a step further because the support knowledge introduced in the explanation may itself require its own support knowledge to be acceptable. This *recursiveness* of explanation has been especially acknowledged by Toulmin (1958) who proposed to distinguish between different levels of explanation for any claim: a

first level introduces some background knowledge which supports the claim; the relationship between the background knowledge and the claim may itself be explained with other knowledge called a "warrant"; moreover, introducing further supportive arguments in the form of "backing" may be necessary to make the warrant convincing. In addition, any information composing the background, the warrant or the backing may itself be considered as a claim and further explained.

While this model is helpful to structure explanations (Wick & Slagle, 1989, Ramberg, 1996), it does not account for the fact that, typically, recursiveness in human explanation is not infinite (and rarely requires more than two or three levels): this is only conceivable if one accepts the fact that explanations acceptability always relies on knowledge shared between the explainer and the explainee (Clancey, 1983, Slugoski, Lalljee, Lamb & Ginsburg, 1993).

A challenge for an explainer is thus to determine the right level of knowledge that s/he can assume to be shared with the explainee. When the explainee is well identified, this can be achievable. But when the explainee is not individually identified, as in situations of design reuse or procedure use, there is always a chance that the explainer makes wrong assumptions about the knowledge really shared with the explainee and, hence, produces inadequate explanations.

Numerous authors observed that an *interaction* between the explainee and the explainer is the best way to ensure the sharing of support knowledge and, as a result, the production of a satisfactory explanation (Goguen, Weiner and Linde, 1983, Moore, 1989, Gilbert, 1989, Baker, 1993, Cawsey, 1993, Karsenty & Brézillon, 1995b). They noticed that mutual understanding often requires several turn-taking in dialogue, inducing local adjustments between the speakers' representations. The occurrence of these phases of successive local adjustments highlights that the explainee's cognitive context, very dependent on the her/his own knowledge and experiences, is rarely grasped by the explainer alone.

IV – DESIGN IMPLICATIONS

The data and conceptual perspectives presented above imply to turn one's attention to the co-workers' explanation needs when designing cooperative work settings. Mutual understanding in cooperative work is often crucial for task success, but also often neglected. One could remedy this state of affairs by adopting the following directions.

In cooperative work settings where synchronous communication is possible, *face-to-face dialogue* should be preferred to any form of asynchronous explanatory communication. The interactive nature of face-to-face dialogues is the best way to ensure the providing of satisfactory explanations. Indeed, interaction in dialogue allows explainers not only to uncover the elements of the explainee's problem representation that are responsible for misunderstandings but also to rapidly identify a level of shared knowledge. Thus, considering design reuse situations for instance, one should recommend preserving and, even, promoting

dialogue between designers rather than automatically looking for computer-based solutions (Bannon & Kuutti, 1996).

Note that explanatory dialogues may take place either during task accomplishment (e.g., Grusenmeyer, 1995) or, when this is not possible, before or after. It is however unclear how the moment for explanatory dialogues may affect the co-workers' satisfaction. Some data collected by Denis et al. (1990) from an experiment with a group decision support system seems to highlight that explanation needs expressed during the late phase of a collective decision-making process may provoke dissatisfaction since they force co-workers to revisit their well-established problem representation.

Of course, it is not always possible to join people in face-to-face meetings. The need of an interactive explanatory process may come into conflict with the constraints imposed by some collaborative work settings. In this case, mutual understanding of each other's decisions⁷ may be improved by providing explanation facilities. Such an objective raises two main issues: What to explain? And how to explain it? Note that, in the following, we will not prejudge which concrete medium should be used to convey explanations (paper, computer, etc.).

- *What to explain?* The decisions that primarily need to be explained are those that may appear as new or contradictory with other already known decisions. Determining which decisions could be new or contradictory cannot be objectively done: the novelty and contradictory aspect of decisions depend on the addressees' knowledge and representations. As a consequence, studying the addressees' knowledge and representations should be a prerequisite to every attempt to provide easily comprehensible explanation. Bisseret, Sebillote and Falzon (1999) present a set of techniques that can be used with this aim. A pragmatic approach to this problem consists of asking a representative sample of workers to identify the new or potentially contradictory decisions.

- *How to explain?* Once the information to be explained has been identified, the material that will be used to explain it must be chosen. The following generic rules should help to guide this choice:

1. *Take the co-workers' existing knowledge into account and contrast (or distinguish between) the current situation with already known situations.* A typical explanation format showing this contrast is: "By comparison with [the already known situation S1], [the new situation S2] exhibits [characteristic C]. This accounts for the need of [decision D]". Using this type of explanation format amounts to the same thing that explaining the "why" – introducing support knowledge for accepting a given decision - and the "why not" – introducing support knowledge for rejecting other alternative decisions (Waern et al., 1995). A contrastive explanation format should be generally preferred to a "partial" explanation such as: "[Decision D] is required because [characteristic C]". It is worth noting that a graphical version of this contrastive explanation format constitutes one of the

⁷ The word "decision" is used here as a generic notion, covering every type of information resulting from the reasoning of a co-worker or a group of co-workers and intended to be used by other co-workers.

basic element of different notations already used by many researchers and practitioners to trace and account for a design. This is the case, in particular, with gIBIS (Conklin and Yakemovic, 1991), QOC (MacLean et al., 1991) and DRL (Lee and Lai, 1991). These notations use three types of concepts: (1) the issue (or question, or problem to be solved, according to the notation) that motivates the design discussions, (2) the alternative options responding to this issue, (3) the arguments for or against each option. Using these notations to explain a design is totally coherent with the contrastive theory of causal attribution: the report of alternative options may help in constructing a "contrast space" to understand the chosen option; the arguments for and against each option belonging to this contrast space may help in identifying the conditions necessary to choose the option that were present within the context of the chosen option and missing within the context of the alternative options. This coherency leads us to assume that this type of notation should be useful not only for design offices, but also for other work fields wherein decision-making processes play a crucial role. However, using a contrastive explanation format, whether it is textual or graphical, is not sufficient to determine the most satisfactory explanations for a given audience. In particular, it does not help to determine how variability of co-workers' explanation needs should be handled.

2. *Use different types of explanation:* there exists a great variability of explanation needs depending on the specific problem representations elaborated by the co-workers and their underlying knowledge. In particular, it has been often acknowledged that the workers' level of expertise considerably affect their explanation needs (Wallis & Shortliffe, 1984, Paris, 1988, Kemp & Kemp, 1991, Ramberg, 1996). Generally, expert workers do not need support knowledge that is especially required by novice workers. Any explanation of a decision should help to connect the decision with a particular goal or criteria and/or a uncommon aspect of the decision situation. In doing so, the explanation makes explicit part of the explainer's problem representation underlying the decision to be explained. But for a novice, this should not be sufficient as Ramberg (1996) demonstrated it: this first level of explanation should be further explained with background knowledge and, possibly, general abstract principles.
3. *Use different viewpoints to explain a decision:* co-workers may experience difficulties in understanding a given decision because they have not considered a specific viewpoint. Explanations should help them to change "what they were (firstly) looking at". Thus, for instance, any decision in a HCI design office may be considered from the marketing, engineering and human viewpoints just to take a few ones. As a result, any explanation of a decision taken in this design office should bring in each of these viewpoints (e.g., Bellotti, 1993).

Finally, a fourth rule should be applied. But, contrarily to the previous ones, it is not specific to the goal of providing explanations. We recall it only because it is so obvious that

one may easily forget it: *explainers should use, in creating their explanations, notions and expressions familiar to the addressees*. When this is not possible, a definition should be added to every new notion or expression.

V - CONCLUSION

Supporting the articulation of distributed activities is a key issue in the computer-supported cooperative work field (Schmidt & Bannon, 1992). In a number of studies taking up this topic, the emphasis is placed on communication tools (file sharing, shared view, email, audio and video conferencing, ...) or mechanisms of interaction (Schmidt, 1994). The aim of this text was to highlight that the articulation work required by a collective decision-making process may *also* rely on explanations, of which the function is to articulate and make compatible problem representations possibly divergent in a group. As a consequence, supporting articulation work may also consist of enhancing explanations in cooperative work.

This text provides the reader with a set of data and conceptual perspectives that should be helpful in promoting explanation in cooperative work settings and, if necessary, creating explanations. A set of design implications and rules was presented with this end in view.

One may wonder if these rules can be sufficient to ensure the providing of satisfactory explanations in any circumstance (in particular, in asynchronous work settings). Based on evaluation studies of pre-defined explanations (Karsenty, 1996) and the conceptual perspectives presented in this text, one must acknowledge that the answer is probably no. Explanation needs are context-dependent and it is often difficult, even impossible, for an explainer to consider all the possible problem representations wherein a given decision will be understood. For this reason, pre-defining explanations is an enterprise inevitably limited. Other complementary approaches improving mutual understanding must be defined as well.

Thoughts on the nature and the functions of explanatory dialogues in cooperative work were reported in this text. These thoughts answer some questions, but raise also others, still unresolved: When do explanations influence the decision-making process and when do they not? When are explanations provided and when (and why) are they not provided? What contingencies within the organizational context allow or do not allow for the exchange of explanation? Do explanation needs have the same effect when they are expressed during the early phases or the late phases of a decision-making process? Can any detected discrepancy between workers' problem representations be repaired by an explanatory dialogue? Depending on the answers to these questions, the design implications proposed in this text could be refined.

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REFERENCES

- Abelson R.P. and Lalljee M. (1988), Knowledge Structures and Causal Explanation. In: *Contemporary Science and Natural Explanation. Commonsense Conceptions of Causality*, ed. D.J. Hilton, Harvester Press.
- Baker M.J. (1993), Negotiation in Collaborative Problem-Solving Dialogues. In *Natural Dialogue and Student Modelling*, eds. M.J. Baker, R.J. Beun and M. Reiner, Springer-Verlag: Berlin.
- Bannon L.J. (1996), From requirements as texts to requirements as constructions: Emphasizing use, process and iteration in systems development. *Workshop on Requirement Engineering in a Changing World, CAISE 96*, 20-21 May 1996, Crete.
- Bannon L.J. & Kuutti K. (1996), Shifting Perspectives on Organizational Memory: From Storage to Active Remembering. Presented at the *29th Annual Hawaii International Conference on System Sciences (HICSS-29)*, Maui, Hawaii, January, IEEE Computer Press.
- Belkin N.J. (1988), On the nature and function of explanation in intelligent information retrieval. *11th Conf. on Research and Development in Information Retrieval* (p. 135-145), June 13-15, Grenoble, France.
- Bellotti V. (1993), Integrating Theoricians' and Practicionners' Perspectives with Design Rationale. *Human Factors in Computing Systems. INTERCHI'93 Conference Proceedings*. Amsterdam, 24-29 April, pp. 101-106.
- Bisseret A., Sebillotte S. & Falzon P. (1999), *Practical techniques for the study of expert activities*. Toulouse: Octarès (in french).
- Cawsey A. (1993) Planning interactive explanations. *International Journal of Man-Machine Studies*, 38, 169-199.
- Clancey W.J. (1983), The Epistemology of a Rule-Based Expert System - A Framework for Explanation. *Artificial Intelligence*, 20, 215-251.
- Conklin J.E. and Yakemovic B. (1991), A Process-Oriented Approach to Design Rationale. *Human-Computer Interaction*, 6(3-4), 357-391.
- Cross N. (1986), Understanding design: the lessons of design methodology. *Design Methods and Theories*, 20(2), 409-438.
- Dennis A.R., Heminger, Nunamaker J.F. and Vogel D. (1990), Bringing automated support to large groups: The Burr-Brown experience. *Information and Management*, 18(3), 111-121.
- Draper S.W. (1987), Spontaneous Explanation. *Proceedings of the 3rd Alvey Explanation Workshop*, 74-82, Guilford, UK: University of Edinburgh.
- Fischer G. (1987), Cognitive view of reuse and redesign. *IEEE Software*, 4, 60-72.
- Garfinkel A. (1981), *Forms of Explanation. Rethinking the Questions in Social Theory*. New Haven, CT: Yale University Press.
- Gilbert N. (1989), Explanation and Dialogue. *The Knowledge Engineering Review*, 4(3), 235-247.
- Goguen J.A., Weiner J.L. and Linde C. (1983), Reasoning and natural explanation. *International Journal of Man-Machine Studies*, 19, 521-559.
- Grusenmeyer C. (1995), *De l'analyse des communications à celle des représentations fonctionnelles partagées. Une application à la relève de poste*. Ph.D. Thesis, Université René Descartes-Paris V.
- Hilton D.J. (1988), Logic and Causal Attribution. In: Hilton D.J. (ed.) *Contemporary Science and Natural Explanation. Commonsense Conceptions of Causality*, Harvester Press.
- Hilton D.J. and Slugoski B.R. (1986), Knowledge-based causal attribution: The abnormal conditions focus model. *Psychological Review*, 9(1), 75-88.
- Karsenty, L. (1994), *Explaining a solution in design dialogues*. Ph.D. dissertation, Dept. of Cognitive Ergonomics, University Paris VIII, July 1994 (in french).
- Karsenty L. (1996), An Empirical Evaluation of Design Rationale Documents, *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI'96)*, Vancouver, April 14-18, ACM Press.
- Karsenty L. (1999) Cooperative work and shared visual context: An empirical study of comprehension problems in side by side and remote help dialogues. *Human-Computer Interaction*, 14(3), 283-315.
- Karsenty L. & Brézillon P. (1995a), Coopération Homme-Machine et Explication. *Le Travail Humain*, 58(4), 291-312.
- Karsenty L. and Brézillon P. (1995b), Cooperative problem solving and explanation. *International Journal of Expert Systems with Applications*, 8(4), 445-462.
- Karsenty L., Bigot V. and De Brito G. (1995), *The use of written instructions in new generation aircrafts*, EURISCO report n°T-95-023, Toulouse, Nov. 1995 (in French).
- Karsenty L. & Pavard B. (1998), Various levels of context analysis in the ergonomic study of cooperative work. *Reseaux: The French Journal of Communication*, 6(2), 167-193.

- Kemp E.A. & Kemp R.H. (1991) Explanation in Knowledge-Based Systems: A User Perspective. *IJCAI-91 Workshop on Explanation Generation for KB Systems*, Sydney, August, 25.
- Klein M. & Lu S.C.Y. (1989), Conflict resolution in cooperative design. *Artificial Intelligence in Engineering*, 4 (4), 168-180.
- Lee J. and Lai K. (1991), What's in Design Rationale? *Human-Computer Interaction*, 6(3-4), 251-280.
- Leplat J. (1988), Organization of activity in collective tasks. *Workshop "Distributed decision making"*, Bad Homburg.
- MacLean A., Young R.M., Bellotti V.M.E. and Moran T.P. (1991), Questions, Options, and Criteria: Elements of Design Space Analysis. *Human-Computer Interaction*, 6(3-4), 201-250.
- Moore J.D. (1989), *A Reactive Approach to Explanation*. Ph.D. Thesis, University of California, UCLA, December 1989.
- Moran T.P. & Carroll J.M. (Eds.) (1996), *Design Rationale: Concepts, Techniques, and Use*. Mahwah, NJ: LEA.
- Navarro C. (1991), Une analyse cognitive de l'interaction dans les activités de travail. *Le Travail Humain*, 54(2), 113-128.
- Paris C.L. (1988) Tailoring object descriptions to a user's level of expertise. *Computational Linguistics*, 14(3), 64-78.
- Ramberg R. (1996), Construing and Testing Explanations in a Complex Domain. *Computers in Human Behavior*, 12(1), 29-48.
- Richard J.F. (1990), *Les Activités Mentales. Comprendre, Raisonner, Trouver des Solutions*. Paris: Armand Colin.
- Schank R.C. (1986), *Explanation Patterns. Understanding Mechanically and Creatively*. LEA, Hillsdale: NJ.
- Schmidt K. (1994), Cooperative work and its articulation: Requirements for computer support. *Le Travail Humain*, 57(4), 345-366.
- Schmidt K. & Bannon L. (1992), Taking CSCW seriously: Supporting articulation work. *Computer Supported Cooperative Work*, 1(1-2), 7-40.
- Slugoski B.R., Lalljee M., Lamb R. & Ginsburg G.P. (1993), Attribution in conversational context: Effect of mutual knowledge on explanation-giving. *European Journal of Social Psychology*, 23, 219-238.
- Teach R.L. & Shortliffe E.H. (1984), An Analysis of Physicians' Attitudes. In: Buchanan B.G. & Shortliffe E.H. *Rule-Based Expert Systems: The MYCIN Experiments of the Stanford Heuristic Programming Project*. Reading, Mass: Addison-Wesley.
- Terssac G. de & Chabaud C. (1990), Référentiel opératif commun et fiabilité. In: Leplat J. & de Terssac G. (Eds.) *Les facteurs humains de la fiabilité dans les systèmes complexes*. Octarès.
- Waern Y., Osterlund B. & Ramberg R. (1995), On the role of explanations in understanding complex domain. *Zeitschrift für Psychologie*, 203, 245-258.
- Wallis J.W. & Shortliffe E.H. (1984) Customized Explanations Using Causal Knowledge. In: Buchanan B.G. & Shortliffe E.H. *Rule-Based Expert Systems: The MYCIN Experiments of the Stanford Heuristic Programming Project* (pp. 371-388). Reading, Mass: Addison-Wesley.
- Walz D., Elam J., Krasner H. & Curtis B. (1987), A Methodology for Studying Software Design Teams: an Investigation of Conflict Behaviors in the Requirements Definition Phase. In: Olson G.M., Sheppard S. & Soloway E. (Eds.) *Empirical Studies of Programmers*. Norwood, NJ: Ablex.
- Wibaux F. (1992), *L'implicite dans la prescription: Le cas de la formation au pilotage de l'A320*. Mémoire de DEA d'Ergonomie du CNAM, Paris, Oct. 1992.
- Wick M.R. & Slagle J.M. (1989), The Partitioned Support Network for Expert System Justification. *IEEE Transactions on Systems, Man, and Cybernetics*, 19(3), 528-535.