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COLLECTIVE DESIGN PROCESSES

Résumé : Ce texte présente une approche de l'ergonomie cognitive pour l'étude des situations de conception collective. Les caractéristiques des tâches de conception sont présentées dans la première section. Nous identifions deux types de situations de conception collective : la co-conception et la conception distribuée. Après une première définition de ces situations, on présente deux études illustrant ces situations (co-conception dans une tâche de spécification de réseaux informatiques, et conception distribuée dans le domaine de l'ingénierie électrique). Les observations montrent que la conception collective peut être satisfaite à la fois au travers d'interactions directes (souvent verbales) entre les concepteurs, et à la fois au travers d'interactions indirectes reposant sur les contraintes que les concepteurs imposent sur les processus d'organisation, les dispositifs techniques et les productions intermédiaires. L'analyse des processus de conception collective devrait prendre en compte ces deux types d'interactions.

Mots-clés : coopération, conception collective, co-conception, conception distribuée, synchronization cognitive, synchronization opérative

Abstract : This text presents a cognitive ergonomics approach to collective design situations. The characteristics of design tasks are presented in a first section. We identify two different types of collective design situations : co-design and distributed design. After a first definition, two studies examplifying these situations are presented (co-design in computer network specification, distributed design in electrical engineering). The observations show that collective design can be fulfilled either through direct (often verbal) interactions between designers or through indirect interactions supported by the constraints designers impose on organization processes, technical devices and intermediary productions. A comprehensive analysis of collective design processes should then take into account both type of interactions.

Keywords : cooperation, collective design, co-design, distributed design, cognitive synchronization, operative synchronization

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Collective Design Processes

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DESIGN AS A TASK

Cognitive ergonomics does not identify design in relation to a social function or a status, but qualify as *design tasks* the professional activities in which a set of formal characteristics that can be identified. Therefore, one can identify numerous professional domains that deal with design. It can be the design of material artifacts (e.g. mechanical engineering, electrics, electronics, architecture) or the generation of symbolic or abstract devices (e.g. planning, computer programing or resource allocation).

The specificities of design tasks (which refer to the notion of environment-tasks proposed by Newell and Simon [72]) are well known [Simon 81, Goel & Pirolli 89] :

• Problems tend to be large and complex. They are generally not confined to local problems, and the variables and their interrelations are too numerous to be divided in independent sub-systems.

• One consequence of this complexity is that the resolution of these problems requires that the multiple competences be put together, which leads to develop collaborations within one single work group.

• There are many degrees of freedom in the problem initial state. This is regarded as a lack of information and as a poorly defined characteristic.

• Solutions to a design problem are not single, they belong to a series of acceptable solutions.

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• There is not any pre-determined way that leads to the solution. A certain number of useful procedures and design methodologies are known, one can refer to similar projects already studied or to existing prototypes, but each time, it is necessary to reinvent the steps that separate specifications and production.

• The definition of the problem and the elaboration for the solution are made in interaction. The problem does not exist before the solution - both are built simultaneously.

• The evaluation of the solutions is differred or in any case limited to the establisment of the final solution because the generation of all alternative design solutions is costly or impossible to carry out and also because of the absence of objective metrics. Therefore, final solutions are satisfactory but not optimal.

One of the important objectives of cognitive ergonomics has been to understand how these tasks characteristics determine the building of the problem-space explored by the designers. The purpose was to identify the cognitive processes on which each designer relies when developing the solution. The issues were planning activities [Hoc 90, Visser 90], organization of the problem solving process [Guindon 90, Visser 92], transformation and use of artifact representations [Gero 90], reuse of solutions, management of constraints linked to the problem [Descottes & Latombe 85, Darses 94] and evaluation of solutions [Fischer & al. 91].

From this basis, design tasks have been mostly studied in their individual practices. However, the objective of cognitive ergonomics is to study design tasks in their *individual and collective practices with a reciprocal effect* : it is necessary to understand how collective design practices lead to a modification of the individual practices which are usually carried out.

DESIGN AS A COLLECTIVE TASK

Collective practices of design have been studied for a long time from multiple viewpoints : organizational analysis, social psycho-social and psychic analysis (focused on the role of factors such as the degree of trust in the others, the recognition of personal competence, personal development through work, power redistribution, necessity of protection, etc - see Klein & Lu [89]).

The approach chosen by cognitive ergonomics differs from these types of analysis. While acknowledging that the dimensions described above obviously affect collective work and the development of a design activity, we have chosen to focus more on the cognitive aspects of collective design.

In this paper, we propose a first framework for classifying collective design tasks. The actors involved in a design process are not all involved in the same way - some are involved in *co-design* activities while others participate in *distributed design* activites. These two situations can be found during one single design process and can also be taken in charge one after the other by one single actor.

Co-design

In the first case, design partners develop the solution together - they share an identical goal and contribute to reach it through their specific competences, they do this with very strong constraints of direct cooperation in order to guarantee the success of the problem resolution. The competence of the partners can vary depending on the level of competence (e.g. interaction between designers of different seniority) or on the type of competence (e.g. interaction between drafters and engineers). The co-design has been studied by different authors [Karsenty 94, Malhotra & al. 80] and in a study of computer network designers which we will present later.

Distributed design

In the second case, i.e. the distributed design, the actors of the design who are simultaneously (but not together) involved on the same cooperation process carry out well determined tasks, those tasks having been allocated beforehand, and they pursue goals (or at least sub-goals) that are specific to them and have as an objective to participate as efficiently as possible in the collective resolution of the problem. Distributed design is typical for concurrent engineering in which the various sides of the production system must function in strong synergy during the product development cycle. Distributed design is also very frequent in drafting rooms or methods [Béguin 94, Karsenty 94]

COOPERATION PROCESSES IN *CO-DESIGN*

It is useful to make a distinction between *distributed design* and *co-design* because each of these forms of collaboration in a product development induces different cooperation processes.

We present two different studies which permit to stress these cooperation processes. The study of *co-design* was made in the domain of computer network configuration. The study of *distributed design* was in the domain of electrical engineering.

Field of investigation and method

We have performed an experimental study of situation of shared-design of computer network, involving on the one hand an experienced designer, and on the other hand, a less competent designer [Falzon & Darses 92, Darses & al. 93]. The ecological validity of the study is guaranteed because this situation of co-design was an usual practice of those concerned. The less competent designer had to propose a solution to the problem of network configuration that was given to him. The instructions given to the expert demanded that he would collaborate with the operator without himself taking charge of the problem. The operators were not face to face but communicated by connected terminals. They shared a common representation of the network being designed, on which both could act. The dialogues between the operators have been collected and analyzed.

Results

The results indicate that the design of a given stage of a solution to the problem -- to generate the solution, evaluate the solution, to plan, etc. -- , is not always taken over by the same operator, even when neither one of them has the same level of ability. Specific conversational rules are at work in these cooperative situations when partners do not possess the same level of domain expertise.

In addition, the analysis of interventions (notably of those of the more competent operator) proves the central role of criticism (positive, negative or mitigated) in the progression of reasoning. The activity of criticism has three characteristics :

- it is spontaneous : there are few explicit requests for evaluation on the part of the less experienced operator but much criticism formulated by the expert. This translates the action of conversionally specific rules to these situations of shared assistance in which the partners don't have the same level of knowledge in the speciality [Darses & al. 93] ;

- it is backed : the evaluations are systematically accompanied by justifications. The role of these justifications is multiple : they specify the knowledge element on which the criticism is grounded but they can play a role in the processes of cognitive synchronization. It must be noted that the justifications also accompany the positive evaluations in order to reinforce the choices made ;

- it is extended : the evaluations are frequently prolonged by diverse extensions. In the case of negative evaluations, there are alternative propositions ; in the case of "mitigated" evaluations, there are amendments or preventive information ("that can work, but then we will have to think about ...") ; in the case of positive evaluations, there are additions of new elements in the proposed solution.

A crucial mechanism in co-design : cognitive synchronization

A major result of this study is to stress cognitive synchronization as a crucial mechanism in co-design.

Cognitive synchronization enable the partners to reach two objectives :
- to assure that they each have a knowledge of the facts relating to the state of the situation - problem data, state of the solutions, accepted hypothesis, etc.

- to assure that they share a common knowledge regarding the domain - technical rules, objects in the domain and their features, resolution procedures, etc ...

Cognitive synchronization therefore aims at establishing a context of mutual knowledge, at building a common operative system of reference [Terssac & Chabaud 90, Karsenty & Falzon 92].

Cognitive synchronization activities will vary depending on the amount of shared knowledge. This means in particular that the parity or non-parity of the dialogue (dialogue between pairs vs. expert/novice dialogues, or dialogues between subjects with distinct knowledge) will have an effect on the necessity to communicate general knowledge. It has been shown before [Falzon 91] how the common knowledge hypothesis in this domain in dialogues between experienced operators enables an economy in communication by using operative languages, and how operators used repair dialogues when this hypothesis is at fault, these repair dialogues aiming precisely at leveling general knowledge. The necessity to assure the nature of the common operative system of reference leads each partner in the dialogue to build a model of the other as it has been shown in different studies [Cahour & Falzon 91].

COOPERATION PROCESSES IN *DISTRIBUTED DESIGN*

Field of investigation and method

We will cite here a study made in an engineering company by Béguin [94]. The need came from difficulties due to the use of CAD (Computer Aided Design) systems. The study deals with individual aspects as well as collective aspects of design. These will be developed here.

The methodology consisted on the one hand in carrying out video recordings of operators in the midst of designing, and on the other hand of long observations (many months) of designers from diverse backgrounds (electricity, civil engineers, thermal engineering, piping).

Technical drafting, central in the activity of the considered designers, has multiple functions. At the individual level, like in numerous design tasks, drafting is the result of an individual work and enables hypothesis testing [Lebahar 83]. At the collective level, it fulfills other functions : communication tool with other actors (upwards, downwards, or at the same level), it is also a material on which designers operate in common. Design can then be seen as a process of distributed decision making which uses graphics as a management tool of interdependance between designers.

Results

A mechanism seems then central in distributed design : reusing. It has several functions :

- First, reusing graphic production of others enables technical and graphic integration : integration enables to take into account in one's own production others' production and assures coherence of design decisions.

- Second, reusing means that each designer becomes the creator of the work conditions of the downstream designer because of the design decisions which constrain later decisions and because of graphic decisions (choice of colors, distribution of drafts on layers, etc ...). These graphic decisions will facilitate or complicate more or less some software operations and will therefore bear on the content of later technical decisions. The upstream designer knows that, and takes it into account. Designers are thus linked by a relation of reciproqual prescriptions.

The author notes two modes of regulation of the collective reuse process [Béguin 94] :

- In one team, paper prints are made and the designers meet in order to discuss the use of CAD (file organization, graphic and technical decisions) and they distribute the tasks. The designers start then a phase of solitary work. The process is repeated, if need be. In this team, negociation guarantees the reuse. The use of the software is adapted to the project specificities but is not usable for future projects.

- In another team, the designers have adapted the software (in particular by adding a series of graphic symbols) and they have systematized the file organization. There, the software adaptation guarantees the reuse. The adopted functioning can be generalized but is less adapted to project specificities.

A crucial mechanism in *distributed design*: operative synchronization and coordination

As we have seen above, coordination processes are crucial in distributed design : operators determine the task distribution, discuss the constraints which everybody's solutions impose on the partners' solutions, plan the work to carry out, and then have so that each person can solve, individually, part of the problem. Even if designers solve the problem in group during meetings, operative synchronization still is foremost.

Operative synchronization fulfills two functions. First, it aims at assuring that the tasks are shared between the partners of the collective activity. A part of the work dialogues will be devoted to the discussion of this tasks allocation. This discussion is all the more needed when the task is new - in usual cases, task allocation is known and will not necessarily lead to coordination activities.

Second, it aims at assuring, depending on the case, the start, the end, the simultaneity, the sequencing, the rythm of the actions to be carried out. The fundamental dimension here is therefore the time. Not necessarily the objective time (ie. the clock-time) but the system time (e.g. to start the action when the machine shows such value) or the partner time (e.g. to start the action when the partner starts such action).

Operative synchronization leads to coordination activities which can be verbal (e.g. task allocation negotiation) or non verbal (e.g. visual information source, gestures). Operative synchronization allows :

- The sharing of representation transformations in the collective problem-space ;

- The integration of these multiple representations, not only in the phase of representing the problem but equally on the description of the solution which itself can be seen under different circumstances.

CONCLUSION

Two different types of collective design situations have thus been identified in the reported studies : co-design and distributed design. They can be viewed as different ways to cope with the complexity of design problem solving. As reminded in the first section, design implies necessarily the integration of multiple sources of expertise. The observations have shown that this integration can be fulfilled either through direct (often verbal) interactions between designers or through indirect interactions supported by the constraints designers impose on organization processes, technical devices and intermediary productions. A comprehensive analysis of collective design processes should then take into account both type of interactions.

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