INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN, ICED'07
28 - 31 AUGUST 2007, CITÉ DES SCIENCES ET DE L'INDUSTRIE, PARIS, FRANCE

COLLABORATIVE DESIGNERS' DIFFERENT REPRESENTATIONS

Willemien Visser[1]

[1]EIFFEL2 (Cognition & Cooperation in Design) - INRIA (National Institute for Research in Computer Science and Control)-Rocquencourt, France

ABSTRACT

Even if, in order to collaborate, designers need to reach interdesigner compatible representations, the representations they construct are not necessarily identical—even if they co-construct them. This paper analyses different forms of differences between different designers' mental representations in collaborative design. We thus aim to complement the current literature on collaborative design, which, around notions such as "shared representation," "cognitive synchronisation," and "common ground" does not pay much attention to the differences (yet does not exclude them neither).

In general, people do not know the representations other people have constructed. We credit collaborating designers with an implicit hypothesis of interdesigner representation concurrence. Yet, designers may explicitly build conjectures concerning representations of colleagues—and check them. Differences of representation may also become explicit in reaction to objections or questions concerning one's views. Still, many differences of representation are never made explicit, or solved. This is one of the questions discussed in the final section, as are some possible causes of differences between representations, and issues related to their implicit character and their level, amongst which the question of collaborating designers leaving implicit the concurrence or divergence of their colleagues' representations with their own.

Keywords: Cognitive design research, representations, representation sharing, construction of representations, collaborative design, interaction

1 INTRODUCTION

Central issues in the domain of cognitive design research on collaborative design are notions such as "shared representation," "common ground" [1] or "common frame of reference" [2-4]. Even if the authors in question do not assert that the construction of such structures results in *identical* representations, references to differences remaining are rare [but see 5-6: 6 is less explicit concerning the distinctions that are critical here]. Yet, in research on "information sharing," "information exchange," and "social sharedness" in judgment and decision-making groups, authors propose and examine notions such as "unshared" and "partially shared" information [40-41]. In the domain of cognitive design research on collaborative design, however, most studies state that, because of designers' different backgrounds (from different disciplines, with different expertise) and different interests (different stakeholders), "grounding" or "cognitive synchronisation" is necessary, taking for granted that people working together reach a common frame of reference.

We consider that, even if collaborating designers proceed to grounding or cognitive synchronisation, and even if they construct interdesigner compatible representations, each designer remains with a number of more or less representations that are incompatible with representations by their colleagues. Given the lack of attention for this question in the domain of cognitive design research, we wish to open the debate. In this text, we will focus on the differences between the representations constructed and held by different designers involved in collaborative design projects.

Let us underline, right from the start, that the two foci are compatible. Designers may collaborate and have a common frame of reference, in spite of they *also* holding different representations [but see 5]. Designers may hold different representations that are complementary and/or unshared, without this leading to problems—provided that they are conscious of these differences!
After a brief introduction of the theoretical framework that we adopt for representation in collaborative design, we present and illustrate several forms of differences between different designers' representations. We do so through the analysis of protocols from design meetings, a mechanical-engineering project, a series of software technical reviews, and an architectural-design project. We mainly use the architectural data, and have no reasons to suspect that the phenomena identified are specific to this field. The architectural-design corpus was collected in the context of the MOSAIC project conducted under the French CNRS program TCAN [7]. The meeting, which took place in a preliminary phase of a building-renovation project, involved three architectural designers, Charles, Louis, and Marie (designated C, L, and M), discussing a fax with requests for modification sent by the client (who is not present at the meeting).

2 DESIGN AS THE CONSTRUCTION OF REPRESENTATIONS

In our recent work in cognitive design research, we have been defending the idea that design consists in the construction of representations [8, 9]. From a formal point of view [based on the technical cognitive-psychology definitions of "problem" and "problem solving," see 8, 9], design is clearly a "problem-solving" activity [the classical cognitivistic approach to design since 10]: generally, its requirements will not evoke a procedure that the designer knows already (i.e., has in memory). We consider, however, that design *involves*, but "*is*" not problem solving: it is *not only* and *not mainly* problem solving. Characterising design as problem solving does not capture its essence. It does not inform us of the activities used in order to "solve" the corresponding "problem," especially the richness of representation-generation and transformation activities.
Constructing representations is a high-level cognitive activity that designers implement through three main types of activities, i.e., generation, transformation, and evaluation of representations. These activities themselves resort to other activities and operations of various types and various levels, such as interpretation and reinterpretation, analysis, inference, association, hypothesising, exploration, brainstorming, combining, and restructuring. The representations constructed are both external and internal (mental). In this text, we are concerned with mental representations. With respect to external representation, we only want to emphasise that if people "sharing" an external representation (a drawing), they do not necessarily share the corresponding mental representations.
This paper is concerned with representations constructed in collaborative design situations. Besides the before mentioned activities that occur in both individually conducted and collective design situations, other activities are specific to collaborative design, such as construction of interdesigner compatible representations, conflict resolution, management of different representations through confrontation, articulation, and integration. We focus on the observation that, when collaborating designers construct representations of a particular issue, they frequently lack any foundation for their—possibly implicitly held—supposition that their partners in the project share their representations.

3 COLLABORATIVE DESIGN

Collaborative design brings about different representations, among other causes through collaborative design requiring partners from various domains proceeding through interaction including grounding.

3.1 Collaborative Design Requires Partners from Various Domains

Given that they incorporate components from various domains of specialty, design projects generally require multiple skills. As designers generally are no experts in every domain, design requires collaboration between professionals from different domains—one of the causes of participants in a collaborative design project holding different representations of the "same" issues. These domains are not only the application domain and that of design methods, but also the underlying technical and theoretical domains (mathematics, science, engineering)—and even nontechnical domains [11]. Additionally,

designers, one may suppose, also draw on ergonomics and knowledge of social, political, economic, and legal aspects of the artefact and its use.

3.2 Collaborative Design Proceeds through Interaction

Besides the functions that representations play in both individual *and* collective design settings [mainly cognitive offloading, reminding, keeping track, storage, communication, organizing, reasoning, and discovery, see 8, 9], various aspects of the externalisation possibilities of representations provide additional functions specific to collective design. These functions go together with cooperative activities that vary according to the moments of the design project. During distributed design, when designers' central activity is coordination in order to manage task interdependencies and then proceeding through individual design, representations of course play a role. Yet, it is in co-design that they have a particular function due to the collaborative setting.

If, in co-design situations, individual design also plays an important role [as we have emphasised in 12, 13], yet an essential part of design then proceeds through interaction. This apparently unequivocal statement—which may even seem tautological—conveys essential characteristics of collaborative design. Indeed, we consider that the different forms that interaction may take in collaborative design—especially, linguistic, graphical, gestural, and postural—are not the simple *expression* and *transmission* (communication) of ideas previously developed in an internal medium (such as Fodor's "language of thought"). They are not the trace of a so-called "genuine" design activity, which would be individual and internal, and which verbal and other forms of expression would allow sharing with colleagues.

Notice that, in these interactional contexts, a fundamental part is played by other than cognitive variables (representations, knowledge): in interaction, an important role comes to emotional [14, 15] as well as social, institutional, and interactional factors, such as the different roles of the design partners [16, 17].

4 REPRESENTATIONAL STRUCTURES IN COLLABORATIVE DESIGN

Representations differ with respect to many dimensions, such as their form and function, or the phase of the design process in which they are being constructed and used. As regards this last dimension, we make two distinctions: (1) between distributed and co-design, and (2) between representations at the source of a design project (requirements, or "design problems"), intermediate representations, and representations at the end of a design project (specifications, or "design solutions").

During distributed design, designers each have their own tasks and specific goals to pursue. When co-designing, they have a common goal that they aim to reach by applying their specific skills and expertise. It is then essential that designers, who each have their personal, possibly private representations, establish "common ground" [1] or a "common frame of reference" [2, 3] (other notions have been proposed as related, conveying more or less important differences in view: for example, "shared context", "mutual referential", "mutual awareness", and "mutual manifestness"). These representations concern agreements, especially on the definition of tasks, states of the design, references of central notions, and weights of criteria and constraints. They are often qualified as "common" or "shared", but, as there is no objective reference to check for sharedness, we prefer to qualify them as "interdesigner compatible representations" [8, 9].

The notion of "compatibility" in this context is based on the constructivist ideas formulated by Von Glasersfeld [18] by reference to the legacy left by Piaget:

> In order to live in a society, a sufficient number of our ideas—our concepts and schemes of action—have to be compatible with those of others. And this compatibility confers on them a viability that goes beyond the merely individual. The same goes for the acquisition and use of language. Communication with others requires that the meanings we attribute to words prove compatible with those of other speakers.
>
> Compatibility, however, does not entail the kind of "match" that is implied when people speak of "shared ideas" or "shared knowledge". Compatibility . . . means no more and no less than to fit within constraints.

This text focuses on a particular dimension of intermediate representations constructed by designers working in a co-design situation: such representations may be private to a particular designer or may be interdesigner compatible representations that are in joint use.

4.1 Intermediary Representations in Collaborative Design

In addition to being *intermediate* between the requirements at the start of a design project and the specifications at its other extremity, representations may also have an *intermediary* function. Two types of intermediary representations can be distinguished: those between designers and the object of their activity, and those between several designers. In this text, we are mostly concerned with intermediary representations in their second role ("intermediary objects", "coordinative artefacts" [19], "entities for cooperation" [20], or "boundary objects" [21]).

4.2 Interdesigner Compatible Representations

Given that designers come into a project with their personal representations—some private, some supposedly or definitely shared with colleagues—, collaboration between them calls for articulation of these different representations, in order for the designers to be able to reach interdesigner compatible representations for their common activity. The activities through which such representations are constructed and adjusted are qualified as "grounding" [1] and "cognitive synchronisation" [22, 23]. They proceed through a negotiation process resulting in "social constructions" [24] or through argumentation resulting in the settling, "dodging", or substitution of "issues" [25]. Much time is spent on these activities [26-30]. The confrontation of personal representations clearly also leads to conflicts between designers [see a remarkable early study on conflict resolution in the domain of architectural design by 31].

4.3 Different Designers' Different Representations

Besides jointly used representations that are identical across all or most design partners, many may remain more or less different—some even incompatible. It is not only when they are compatible that designers may manifest no opposition when colleagues express an idea different from theirs. Designers may of course change ideas, but they may also say nothing while thinking their own thoughts [as 15, is able to show, using, 32's explicitation method].

The representations covered in discussions of designers' representations generally concern aspects of the design artefact specification. In the main examples used in this text—coming from a meeting between architectural designers—these are, for example, representations of the horizontal (e.g., corridors) and the vertical (e.g., staircases) circulation in the building, the different functions, the different spaces, but also the bar, the lifts, the offices, or the swimming pool. Representations, however, may also concern not this type of content of what is discussed during the meetings—aspects of the building—, but these representations themselves and their elaboration. Third, representations may concern the meeting, the design process, or the group of designers. We distinguish three different representation spaces, concerning (1) the artefact specification (generating and evaluating representations of the artefact), (2) the interaction concerning this specification by the different design partners (communicating around different representations and articulating them into interdesigner compatible representations), and (3) the organisation of the specification and interaction (planning, organising, and managing the interaction, the meeting, the design process, or the group of designers).

Differences between designers' representations may then be due to differences (1) between elements inside each one of the spaces or (2) between elements from different spaces. These two types of differences can be considered to be at different "levels". This text is mainly concerned with the "lowest" level, especially with the specification of the artefact, but it will also present some examples of differences between elements from different spaces.

5 DIFFERENCES BETWEEN REPRESENTATIONS

Analysis of the data of the design protocols has led to the following, preliminary results.

In general, people do not know the representations their colleagues hold or construct—especially with respect to objects not explicitly discussed. Yet, many aspects of a design project are never explicitly discussed, even if they are included in the design. One might suppose that, without any proof of the opposite, people attribute their own representation of things to their partners—even if when questioned, they may become conscious that (1) this may not be so, and/or (2) they do not have any basis for this assumption.

In addition to holding this implicit hypothesis of representation-concurrence, designers may explicitly build hypotheses concerning colleagues' representations. They may or may not test and/or explicitly express them. In the MOSAIC meeting, the absent client is a design partner whose representations are often the object of conjectures, which may or may not be formulated explicitly by the three architects (see Ex. 1 and 2). The line numbers in the examples refer to the verbal turns in the transcription of the MOSAIC corpus: they run from 1 to 2097, between the opening of the meeting at 11:27:55 and its closing at 12:45:39; we put some comments or clarifications between { and }.

1. Charles formulates a hypothesis concerning the client's view—probably in order to make understandable, to himself and to his colleagues, a modification requested by the client.
   758. C. ... when there is a big group… they are all going to gather in the bar so that he {the client} *can have his meeting rooms*
   ....
   760. C. in the restaurant
   ....
   762. C. I think that's why…

2. *803. C. ... according to what I understood, he* {the client} *would not be against… stop up everything finally even widen*

Differences of representation may become explicit (see Ex. 1, 2, and 3), but often they do not (see Discussion).

3. Charles, reasoning aloud, formulates his interpretation of the design constraints (here: part of the existing building as it is), which leads to objections by Louis who makes explicit his interpretation.
   358. C. ... if one puts the rooms over there in that case one would almost need two emergency staircases… so it is finally in this existing staircase… no one cannot dig it more in order to=
   359. L. =but yes one can dig it more actually as a matter of fact on the plan that is over there you will see a staircase that descends but that gets much farther and much deeper

Different representations elaborated by different design participants may each be formulated explicitly, in parallel. In the MOSAIC meeting between the three architects, we observed this happening for representations elaborated by two, not by all three participants. We present two examples, at different levels: in Ex. 4, the different representations concern the way in which an aspect of the artefact should be specified (lowest level); in Ex. 5, they concern the aspect of the artefact that is to be specified (level above the lowest level).

4. Marie and Louis are elaborating, in parallel, each one a different representation of the linen room.
   1094. L. ... and that means that there is a linen room close by ((cough))
   1095. C. yes that's it that's it that's it that's it that's it [xxx
   1096. M. [that could be
   1097. (..)
   1098. L. that could be
   1099. M. [in the base-
   1100. L. [one has
   1101. M. –ment ((small laughter))
   1102. L. perhaps something like that
   1103. M. ((laughter))
   1104. L. with the linen room over here {L shows the ground-floor}
   1105. (..)
   1106. C. oh yes it would be better in the basement
   1107. M. yeah
   1108. C. rather [than in a space
   1109. M. [yeah it could be there / {M shows the basement}

1110. (..)
1111. M. no it could be there /
1112. (..)
1113. C. yes or adjoining yes and there yes [there
1112. M. [there
1113. C. is no reason at all to have it on the ground-floor
1114. M. no n[o
1115. C. [that's it ... that's [it
*1116. M. [no one doesn't need any light for the linen room *

5. Marie and Louis are elaborating, in parallel, their representation, each, not only a different one, but also concerning different aspects of the artefact to be specified. Marie—supported by Charles—works on the bar in the little lounge. Louis interrupts the bar elaboration by his proposal for another issue, that is, a lift (the digging that he mentions would be for a lift, not for the bar).
991. M. that would have been a space
992. C. yes better=
993. M. =ideal for the bar and… when one is there one feels that… something is taking place that will be:=
994. L. =or indeed if one decides to [dig
995. M. [xxx little sounds or while there… it is silent and it is too far from there to go and sit there to wait
996. C. yes
997. (..)
998. M. ... in fact one is waiting over here
999. (..)
1000. C. yes… that's true
1001. L. no indeed if one decides to dig one coul[d
1002. M. [or otherwise one may wait in the bar

"Level" is a relative notion. Inside the levels that we set apart, one may distinguish other ones. In our "analysis of co-operation in practice" between designers working on an industrial, aerospace design project [12], we observed that many evaluation criteria were shared by all designers. Nevertheless, we noticed that, "in addition to these, on the one hand, different designers use still other criteria; on the other hand, even if designers use the same set of criteria, they do not always agree on their relative importance. Finally, they may disagree on the degree to which a solution satisfies a certain criterion" (p. 389). We presented the example of different representations concerning the rigidity criterion: designers agreed that criteria C1 to Cn were to be used, but there were discrepancies on (1) the use of Cn+i, (2) the relative weight, and (3) the satisfaction threshold of each criterion.

Differences between representations may become explicit because, in reaction to a designer presenting her/his view, a colleague formulates a different view: "No,…," or "I (rather) think that…." The absence of any explicit objection following a proposal does not imply, however, that all participants hold the same representation. Besides, often an objection is not introduced by "No," or "I don't agree" (or a paraphrase). Neither in Ex. 4 (line 1100), nor in Ex. 5 (line 994), Louis uses such an introduction.

Differences may be made explicit together with, or indirectly through, their justification ("I don't agree, because…"). Justifications generally are requested or provided for design proposals with which designers disagree. Proposals concerning which there is no—explicitly formulated—disagreement may also be justified, however. Spontaneously providing a justification for one's proposal, a designer may be anticipating possible objections [12] (see Ex. 6 and 7).

6. After Louis has asserted that one needs cloakrooms and toilets, Marie justifies why she considers that one also needs showers.
402. M. yeah no but… often there are also showers people come clothed / they change they do what they want to do and afterwards they take a shower=

403. C. =that's[it
404. M. [and they leave in their normal cloths

7. Charles justifies the client's view, which differs from theirs (i.e., the team of architects), adopting temporarily the client's position.
659. C. ... having said that it's true that that makes up already if there is one over here and one over there that makes up already two lifts
....
661. C. given the price of lifts that costs already a lot

Certain types of questions may lead the design participants to make explicit their representation of a particular issue. The leader of the MOSAIC meeting, Charles, often asks his colleagues "What do you think (about that)?" One architect sometimes asks one or both colleagues: "Don't you think that…" or "Don't you consider a bad idea…"—even if such a question often is argumentative rather than a "real" question, that is, a request for information (as in Ex. 8).

8. Louis asks his colleagues if three-stars rooms without a bath do not shock them.
1945. L. and you you aren't shocked by three-stars rooms without a bath
...
1950. M. yes yes I am not shocked… if it's really well handled… if you can move around

Many differences of representation are never "solved": their authors abandon—even often not explicitly: they may initiate a new issue. In Ex. 5, where Marie elaborates a representation of the bar in the little lounge while Louis is starting to work on a lift, Marie abandons the bar without any explicit formulation to this respect. Louis who continues on the lift is, first, joint up with by Charles, and afterwards also by Marie. The bar stays in abeyance. Later on, while Louis and Charles are still elaborating the lift, Marie initiates another issue, that is, office enlargement.

6 DISCUSSION

In this final section of the text, we are starting a discussion of differences between representations, going beyond the material offered by the examples presented. We discuss a certain number of aspects of collaborative designers' different representations: the resolution of differences between representation, their causes, issues related to their implicit character and to their level, amongst which the question of collaborating designers leaving implicit the concurrence or divergence of their colleagues' representations with their own.
We conclude by some first ideas concerning consequences of our analysis for design tools.

In a paper on "bringing different points of view together", Fischer [34] writes:

> Because complex problems require more knowledge than any single person possesses, communication and collaboration among all the involved stakeholders are necessary; for example, domain experts understand the practice, and system designers know the technology. Communication breakdowns are often experienced because stakeholders belonging to different cultures (Snow, 1993) use different norms, symbols, and representations. Rather than viewing this *symmetry of ignorance* (Rittel, 1984) (or "asymmetry of knowledge") as an obstacle during design, we view it as an opportunity for creativity. The different perspectives help in discovering alternatives and can help uncover tacit aspects of problems. (p. 3)

Different stakeholders, having different expertise, will indeed hold different representations—which, generally, are supposed to be complementary. They may be, but in order to take advantage of this complementary nature, one needs to know (1) that a colleague holds another representation, and (2) the nature of this representation. It may be more difficult to realise that colleagues who have the same culture may have different representations of the "same" object, than that stakeholders belonging to different cultures hold different representations.

Differences of representation are not necessarily "solved". Differences passing unsolved may depend on the granularity of the difference. Analysis of a MOSAIC-meeting protocol fragment concerning the layout performed elsewhere identified five [16] or six [33] different versions of the layout (researchers may also represent their data differently). These rather global representations included many particulars. At the end of this part of the meeting covered by the fragment, the three architects agreed on a particular version—that is, they did not continue the discussion—, but their personal representations of all details of the agreed-upon layout probably were not identical.

Differences between representations may have various causes. They may be due to different persons interpreting differently the same data and/or making a different selection among the same data. The example of the two representations of the linen room may be analysed as Marie and Louis interpreting differently the same constraints.

Causes of differences between representations remaining implicit may be various. Positive evaluation often remains implicit—it can be so without any problem. Negative evaluation has often been inferred—by cognitive design researchers, but probably also by design partners—from a colleague formulating an alternative proposal.
Notice that "evaluation" as it is used in cognitive design studies is a rather generic term, which covers both (1) expression of opinions and (2) reviews or assessments leading to acceptance or rejection of a design proposal as an intermediate state or (part of) the definitive artefact specifications. The negative evaluation that we inferred from alternative-solution proposal in our analysis of software technical review meetings [23] was the second type of evaluation.
The analysis of alternative-proposal formulation as—amongst other things—expressing negative evaluation of the original proposal does not imply that every negative evaluation of a colleague's proposal is made explicit—through an alternative proposal or another modality. One thing is to have a different representation of an object, another is to generate—and possibly verbalise—an alternative proposal.

In an analysis of various forms of articulation between graphico-gestural and verbal modalities in parallel interactions between the designers involved in the MOSAIC meeting, we distinguished designers proceeding in alignment from designers being disaligned [35]. Designers are aligned when they focus on the same object. Disalignment occurs when one or more designers do not focus on the same object as their colleague(s). Designers who are disaligned do not necessarily have different representations at the level of the artefact specification (the lowest level). They may hold different representations at a higher level: for example, they may focus on different objects (e.g., because they consider that another than the current object is more relevant); or they may consider that specifying the artefact is not relevant (at the moment in question), but that one should replan the meeting, for example.

We formulated the conjecture that without any proof of the opposite, people attribute their own representation of things to their partners. Clark and Brennan [1] notice that many accounts of language use assume that negative evidence is all that people need to look for, in order to check for common ground with their interlocutors (p. 131). The authors claim, "in fact, people ordinarily reach for a higher criterion". Their "contribution model" says, "people ultimately seek positive evidence of understanding". (p. 131) The three most common forms of positive evidence proposed by the authors are interlocutors' acknowledgments (e.g., "uh huh", "yeah"), initiation of "relevant next turns", and continued attention, the "most basic form of positive evidence" (p. 133).
Notice that Clark and Brennan [1] are concerned with mutual understanding, as they work on communication in conversation, not on a goal-oriented, professional task, such as the design of an artefact. In the case of collaborative design, instead of mutual understanding, the issue may be compatibility of the representations constructed—not only the internal ones, but also the external ones translating the specification of the artefact under design.
In the detailed analysis of one design-proposal elaboration during the MOSAIC meeting [145 verbal turns, taking 4 minutes and 13 seconds, see 33], we observed several cases of architects starting to work in

parallel. We distinguished six sub-proposals; four out of them were initiated in parallel with the sub-proposal that preceded them—rather than to follow this proposal, once its elaboration was complete. The two cases that we presented above (see Ex. 4 and 5) were two other examples of designers proceeding in parallel (in these examples, the proposals had a finer grain than the four sub-proposals distinguished).

We conclude this paper by some preliminary ideas concerning consequences of our analysis for design tools. In our analysis of design collaboration in the industrial, aerospace design project [12], we underlined the difficulties met by designers working in co-operation due to unawareness of certain information needs and to memory limitations (which we supposed augmented compared to individual design situations). We attributed some of these difficulties to new information elements coming from colleagues, references to knowledge one did not have, or use of different evaluation criteria. We noticed that the situation is complicated when information one person has, or uses, remains implicit for others. As noticed already, because sharing an external representations is no guarantee for shared interpretation of the underlying presentation, drawings, plans, and other external representations can rarely do without comment—even if they do not either automatically warrant "correct" interpretation: ambiguity may remain [36]. The fact that it is only "sometimes" that "a diagram is …worth 10,000 words" [37] has often been overlooked!
Tools—methodological and/or computer tools—that request designers to make explicit their accord or disagreement with their colleagues' proposals may be costly. This cost, however, has the positive side-effect of making designers process proposals at a "deeper" level [38, 39]. As additional value can be obtained if not only proposals, accords or disagreements are made explicit, but also the underlying evaluation criteria and justifications. Through this deeper processing, such reflexive—and other explicitation—activities will, generally, not only lead to additional "individual" knowledge and, through more inter-comprehension, to more shared knowledge, but also to more robust choices and decisions—results probably worth a certain investment of time—and thus money.

7 REFERENCES

[1] **Clark, H.H. and Brennan, S.E.** Grounding in communication. In Resnick, L., Levine, J.-M. and Teasley, S.D., eds. *Perspectives on socially shared cognition*, pp. 127-149 (American Psychological Association Press, Washington, DC, 1991).

[2] **De Terssac, G. and Chabaud, C.** Référentiel opératif commun et fiabilité [Operative frames of reference and reliablity]. In Leplat, J. and De Terssac, G., eds. *Les facteurs humains de la fiabilité dans les systèmes complexes [Human factors of reliablity in complex systems]*, pp. 111-139 (Octarès, Paris, 1990).

[3] **Hoc, J.-M. and Carlier, X.** Role of a common frame of reference in cognitive cooperation: Sharing tasks between agents in air traffic control. *Cognition, Work, & Technology*, 2002, **4**, 37-47.

[4] **Détienne, F.** Collaborative design: Managing task interdependencies and multiple perspectives. *Interacting with Computers*, 2006, **18**(1), 1-20.

[5] **Hoc, J.-M.** Coopération humaine et systèmes coopératifs [Human cooperation and cooperative systems]. In Boy, G., ed. *Ingénierie cognitive. IHM et cognition [Cognitive engineering. HCI and cognition]*, pp. 139-187 (Hermès, Paris, 2003).

[6] **Hoc, J.-M.** Towards a cognitive approach to human-machine cooperation in dynamic situations. *International Journal of Human-Computer Studies*, 2001, **54**, 509-540.

[7] **Détienne, F. and Traverso, V.** Présentation des objectifs et du corpus analysé [Presentation of the objectives and the analyzed corpus]. In Bastien, J.M.C., ed. *Actes des Deuxièmes Journées d'Etude en Psychologie ergonomique-EPIQUE 2003 (Boulogne-Billancourt, France, 2-3 octobre)*, pp. 217-221 (Institut National de Recherche en Informatique et en Automatique, Rocquencourt, France, 2003).

[8] **Visser, W.** *The cognitive artifacts of designing*. (Lawrence Erlbaum Associates, Mahwah, NJ, 2006).

[9] **Visser, W.** Designing as construction of representations: A dynamic viewpoint in cognitive design

research. *Human-Computer Interaction, Special Issue "Foundations of Design in HCI"*, 2006, **21**(1), 103-152.
[10] **Simon, H.A.** *The sciences of the artificial (3rd, rev. ed. 1996; Orig. ed. 1969; 2nd, rev. ed. 1981)*. (MIT Press, Cambridge, MA, 1969/1996).
[11] **Visser, W.** Use of episodic knowledge and information in design problem solving. *Design Studies*, 1995, **16**(2), 171-187. Also in N. Cross, H. Christiaans & K. Dorst, eds. *Analysing design activity*, pp. 271-289 (Wiley, Chichester, England, 1996).
[12] **Visser, W.** Collective design: A cognitive analysis of cooperation in practice. In Roozenburg, N.F.M., ed. *Proceedings of ICED 93, 9th International Conference on Engineering Design*, pp. 385-392 (HEURISTA, Zürich, Switzerland, 1993).
[13] **Visser, W.** Conception individuelle et collective. Approche de l'ergonomie cognitive [Individual and collective design. The cognitive-ergonomics approach]. In Borillo, M. and Goulette, J.-P., eds. *Cognition et création. Explorations cognitives des processus de conception (ch. 14) [Cognition and creation. Cognitive explorations of design processes]*, pp. 311-327 (Mardaga, Bruxelles, Belgium, 2002).
[14] **Cahour, B.** Interprétation affective en situation de travail collectif. Méthode et processus [Affective interpretation and collective-work situation]. In Battistelli, A., Depolo, M. and Fraccaroli, F., eds. *Actes du 13è Congrès de Psychologie du Travail et des Organisations de Langue Française [CD-Rom]* (CLUEB, Bologna, 2005).
[15] **Cahour, B.** Les affects en situation d'interaction coopérative. Proposition méthodologique [The affects in cooperative interaction situations. A methodological proposal]. *Le Travail Humain*, 2006, **69**(4), 379-400.
[16] **Baker, M., Détienne, F., Lund, K. and Séjourné, A.** Analyse épistémique et argumentative de la conception collective en architecture : Etude des profils interactifs [Epistemic and argumentative analysis of collective architectural design: A study of interactive profiles]. In Détienne, F. and Traverso, V., eds. *Méthodologies d'analyse de situations coopératives de conception : Le corpus MOSAIC [Methodologies for analysing cooperative design situations: The MOSAIC corpus]* (Presses Universitaires de Nancy, Nancy, France, in press).
[17] **D'Astous, P., Robillard, P.N., Détienne, F. and Visser, W.** Quantitative measurements of the influence of participant roles during peer review meetings. *Empirical Software Engineering*, 2001, **6**, 143-159.
[18] **Von Glasersfeld, E.** Piaget's legacy: Cognition as adaptive activity. (http://srri.nsm.umass.edu/vonGlasersfeld/onlinePapers/html/245.html, 1997).
[19] **Schmidt, K. and Wagner, I.** Coordinative artifacts in architectural practice. In Blay-Fornarino, M., Pinna-Dery, A.M., Schmidt, K. and Zaraté, P., eds. *Cooperative systems design: A challenge of the mobility age (Proceedings of the Fifth International Conference on the Design of Cooperative Systems, COOP 2002)*, pp. 257-274 (IOS Press, Amsterdam, 2002).
[20] **Boujut, J.-F. and Laureillard, P.** A co-operation framework for product-process integration in engineering design. *Design Studies*, 2002, **23**, 497-513.
[21] **Star, S.L.** The structure of ill-structured solutions: Heterogeneous problem-solving, boundary objects and distributed artificial intelligence. In Huhns, M. and Gasser, L., eds. *Distributed artificial intelligence*, pp. 37-54 (Morgan Kaufman, Los Altos, CA, 1988).
[22] **Falzon, P.** Dialogues fonctionnels et activité collective [Functional dialogs and collective activity]. *Le Travail Humain*, 1994, **57**(4), 299-312.
[23] **D'Astous, P., Détienne, F., Visser, W. and Robillard, P.N.** Changing our view on design evaluation meetings methodology: A study of software technical review meetings. *Design Studies*, 2004, **25**, 625-655.
[24] **Bucciarelli, L.** An ethnographic perspective on engineering design. *Design Studies*, 1988, **9**(3), 159-168.
[25] **Kunz, W. and Rittel, H.W.J.** Issues as elements (Working Paper No. 131) (1970, July; Reprinted 1979, May).
[26] **Olson, G.M., Olson, J.S., Carter, M.R. and Storrosten, M.** Small group design meetings. An

analysis of collaboration. *Human-Computer Interaction*, 1992, **7**, 347-374.
[27] **Herbsleb, J.D., Klein, H., Olson, G.M., Brunner, H., Olson, J.S. and Harding, J.** Object-oriented analysis and design in software project teams. *Human-Computer Interaction*, 1995, **10**(2 & 3), 249-292.
[28] **Stempfle, J. and Badke-Schaub, P.** Thinking in design teams. An analysis of team communication. *Design Studies*, 2002, **23**(5), 473–496.
[29] **Karsenty, L.** Design strategies in database conceptual modelling. In Quéinnec, Y. and Daniellou, F., eds. *11th Congress of the International Ergonomics Association: Designing for everyone and everybody* (Taylor & Francis, London, 1991).
[30] **Olson, G.M., Olson, J.S., Storrotsen, M., Carter, M.R., Herbsleb, J.D. and Rueter, H.** The structure of activity during design meetings. In Moran, T.P. and Carroll, J.M., eds. *Design rationale: Concepts, techniques and uses*, pp. 217-239 (Lawrence Erlbaum Associates, Mahwah, NJ, 1996).
[31] **Klein, M. and Lu, S.** Conflict resolution in cooperative design. *Artificial Intelligence in Engineering*, 1989, **4**, 168-180.
[32] **Vermersch, P.** *L'entretien d'explicitation [The explicitation interview]*. (ESF, Paris, 1994).
[33] **Visser, W.** Co-élaboration de solutions en conception architecturale et rôle du graphico-gestuel : Point de vue de l'ergonomie cognitive [Co-elaborating architectural design solutions and the role of the graphico-gestural: The cognitive-ergonomics viewpoint]. In Détienne, F. and Traverso, V., eds. *Méthodologies d'analyse de situations coopératives de conception : Le corpus MOSAIC [Methodologies for analysing cooperative design situations: The MOSAIC corpus]* (Presses Universitaires de Nancy, Nancy, France, in press).
[34] **Fischer, G.** Symmetry of ignorance, social creativity, and meta-design [Internet version: Social creativity: Bringing different points of view together]. *Knowledge-Based Systems*, 2000, **13**(7-8), 527-537. Retrieved May 24, 2007, from http://l3d.cs.colorado.edu/~gerhard/papers/kbs2000.pdf
[35] **Détienne, F. and Visser, W.** Multimodality and parallelism in design interaction: Co-designers' alignment and coalitions. In Hassanaly, P., Herrmann, T., Kunau, G. and Zacklad, M., eds. *Cooperative systems design. Seamless integration of artifacts and conversations-Enhanced concepts of infrastructure for communication*, pp. 118-131 (IOS, Amsterdam, 2006).
[36] **Stacey, M. and Eckert, C.** Against ambiguity. *Computer Supported Cooperative Work*, 2003, **12**(2), 153-183.
[37] **Larkin, J.H. and Simon, H.A.** Why a diagram is (sometimes) worth 10,000 words. *Cognitive Science*, 1987, **11**, 65-100.
[38] **Mollo, V. and Falzon, P.** Auto- and allo-confrontation as tools for reflective activities. *Applied Ergonomics*, 2004, **35**(6), 531-540.
[39] **Falzon, P.** Les activités méta-fonctionnelles et leur assistance [Meta-functional activities and their support]. *Le Travail Humain*, 1994, **57**(1), 1-23.
[40] **Larson, J.R.** Modeling the entry of shared and unshared information into group discussion. A review and BASIC language computer program. *Small group research* 1997, **28**(3), 454-479.
[41] **Kameda, T., Tindale, R.S. and Davis, J.H.** Cognitions, preferences, and social sharedness: Past, present, and future directions in group decision-Making. A chapter draft to appear in S.L. Schneider & J. Shanteau (Eds.), Emerging perspectives on judgment and decision research. Cambridge: Cambridge University Press, 2003).

Contact: W. Visser
INRIA (National Institute for Research in Computer Science and Control)
EIFFEL2 (Cognition & Cooperation in Design)
bât. 23
Rocquencourt B.P.105
78153 Le Chesnay Cedex
France

Phone: + 33 1 39 63 52 09
Fax: + 33 1 39 63 59 95
email: Willemien.Visser@inria.fr
http://www-c.inria.fr/eiffel/documents/VISSER%20Willemien%20FICHE%20en.html