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Using Annotations in a Collective and Face-to-Face Design Situation

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Abstract. Allowing a group of users to produce and transmit some annotations in common digital documents is nowadays a major issue for groupware systems. In this paper, we report a psychological and ergonomic study carried out on this topic in the mechanical design domain. We observed a collective design process that took place in a series of face-to-face meetings attended by the members of a design team. Our results show the minor role played by textual annotations, contrasting with the great number of figurative annotations. We also highlight that the function of annotations is not to develop parts of the solution but to provide the team members with contextual descriptions of the problem and the solution. These results are a first step towards a model of annotations in a collective face-to-face situation. They also provide interesting tracks for elaborating specifications of annotations in mediated situations.

Introduction

One of the current research objectives in CSCW and engineering design (Computer Assisted Design - CAD systems) is to develop digital annotation functionalities for groupware tools (Cadiz, Gupta & Grudin, 2000; Koivunen & Swick, 2001; Boujut, 2003). The aim is to allow the users of such systems to draw up, transmit and use annotations that are traditionally produced on paper and

created spontaneously during individual or groupwork. Most of the research concerns the field of digital documents, the idea being to use the properties of annotations to make web-based information retrieval more efficient. Studies are also being carried out in the field of CSCWriting (Cerratto & Rodriguez, 2002 ; Weng & Gennari, 2004) in order to provide tools to assist the collective drafting of texts. As regards the field of engineering design and architectural design, the use of annotations is a very frequent process in non-mediated activities. On the other hand, digital annotations provided by certain CAD systems, remain little used, as there are not well suited to the action goal of the designers.

Whatever the field concerned, it can be seen that most of these studies have adopted a psychological and ergonomic analysis of the cognitive process of annotation. Our study aims to contribute to such an approach. On the basis of a state of the art, we have built a framework for defining annotations. Using this framework, we carry out a psychological and ergonomic study in the mechanical design domain. The design process that we observed took place in a series of face-to-face meetings attended by all the members of a designers' team. The results that we obtained take into account the role that annotations play when made in such meetings, and indicate some interesting functions that mediated annotations could meet.

The Use of Annotations in Collective Elaboration of Documents

Computerization has modified the status of a document: whereas this status was previously acquired when the drafting and editing of a text had been completed, the status of "document" is nowadays attributed to texts that are still being drawn up, and whose degree of completion may vary greatly from one situation to another. Annotations that are mediated and shared play a vital part in the progressive breaking down of a hard and fast division between the "completed document" and "document in progress", as they are one of the vectors for the continuing evolution of texts.

Many research studies (Denoue, 2000; Wolfe, 2002; Jacobs Reimer, Brimhall, Cao, & O'Reilly, 2009) aim to improve the use of annotations made on texts in the framework of individual activities by one (or several) readers: processing the information contained in the document, obtaining an automatic summary and information retrieval being the most widely examined functionalities. Yet annotations are increasingly being used in group situations as, due to the digitalization of annotations and their widespread diffusion, the document becomes both the object of the collective work as well as the collective workspace itself. By examining the few studies that have analyzed real-life situations where annotations

are produced and used, we have identified several objectives that are pursued in this direction.

Reducing the cost of reading a document — A text can be read more quickly thanks to annotations made by another reader (Marshall, Price, Golovchinsky, & Schilit, 1999). This presupposes that both readers have the same reasons and context for using the document.

Reducing the individual workload for processing the information — The members of a group can pool the resultants of their documentary research. Making the information jointly assimilable is done by indexing the documents and will increase the field of knowledge open to all (Koivunen & Swick, *op.cit*. ; Denoue, 2000). In this case, and in contrast to the point raised above, the benefit is an increase in information for each person involved.

Assisting decision-making — It has been stated (Marshall, Price, Golovchinsky, & Schilit, *op.cit*.) that annotated passages are the most discussed collectively Thanks to annotation zones (underlining for instance), it would then be possible to identify areas of consensus or divergence on the importance of parts of the text.

Assisting the synthesis of documents read by different persons — It has been observed by Denoue (2000) that the various passages that are annotated by several persons could form a sound basis for producing a synthesis or a summary.

Increasing the relevance of the results of information retrieval — Combining the annotations made by different persons makes it possible to index the document on the basis of unanticipated objectives for using the document (Champin, Prié, & Mille, 2000).

Cognitive and operative synchronisation of the members of a work group — Annotations are used as a means of coordination, as stated in Denoue (*op.cit*. and Marshall, Price, Golovchinsky & Schilit (*op.cit*.): establishing what the members have already read, allocating tasks, planning goals, etc.

Nonetheless, these mediated practises of collective design, based on the sharing of annotations, have a certain number of limitations:

- The annotations that are exchanged are more helpful for coordinating tasks than for joint and direct cooperation of a common artifact, such as text, mechanical artifact, etc. (Cerratto & Rodriguez, *op.cit*.; Churchill, Trevor, Bly, Nelson, & Cubranic, 2000).
- Personal annotations – made by an author for himself – are generally confused with annotations that are intented for the group (Cerratto & Rodriguez, *op.cit*). This often makes the exploitation of annotations too costly.
- The widespread diffusion of annotations partly diminishes their social, informal and sometimes confidential nature. Some authors consequently limit their annotations and thereby impoverish the content of the exchanges, as stated in Cadiz, Gupta & Grudin (2000).

The Use of Annotations in the Particular Case of Product Design

The documents used in product design are mainly three-dimensional digital representations and geometric in nature. In contrast, the constraints of the work are mainly expressed in a non-geometric way (the nature of a material, the manufacturing process, etc.). The digital transfer of these annotations is not currently possible, as available CAD tools only allow for annotations as simple pointers. One can point out two major properties of the annotations produced and exchanged in the field of design, which must not be impaired by becoming digital and mediated: annotations are "boundary objects" and they support the cognitive synchronization.

Annotations as "boundary objects" — Annotations provide intermediary representations that serve as common frames of reference to support communication between the various actors (and professions) involved. This role is due to the fact that they do not function as closed objects (which cannot be acted upon as, for example, plans) but rather as open objects that are not completely prescriptive. They play the role of "boundary objects" (Star, 1988) - or cooperation entities (Boujut & Laureillard, 2002). Their function is to present the various points of views, specific to each profession and each background, and to provide the members with the means to take part in and support discussions concerning these differences in such a way that a shared understanding may be achieved (Boujut & Laureillard, *op.cit.*).

Annotations as mediums for mediated cognitive synchronisation — Some phases of collective design are not conducive to being mediated, mainly due to the subsequent impairment of the possibilities of oral explanations about certain solution elements on which the designers are focusing. In Blanco & Gardoni (2001), it has been suggested using annotations to make up for the loss of such verbal exchanges. This would, in particular, allow the entire code of the technical drawings to be transmitted. The mediated manipulation of three-dimensionnal objects should thus become operative, allowance being made for the constraints of the design task.

Defining a Framework for Annotations

Although there is not a universally accepted definition of annotations, it is nonetheless possible to establish a number of their characteristic elements, brought to light from the previous state of the art as well as by Azouaou, Desmoulins, & Mille (2003) as well as in Bringay, Barry & Charley (2004). These characteristic elements are summarized in the following figure and discussed below.

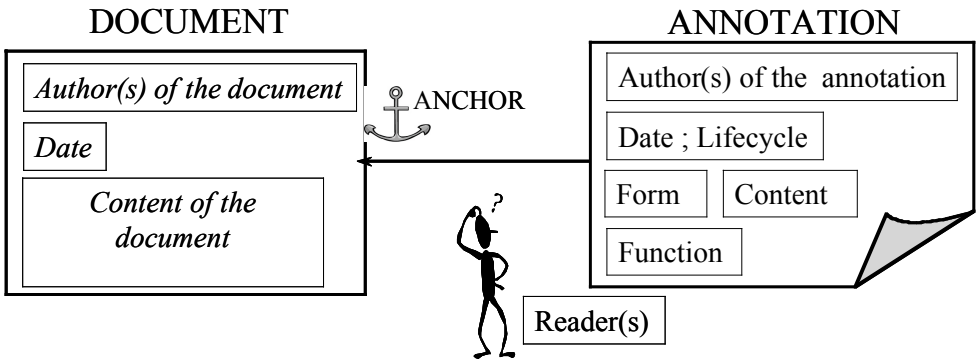

Fig. 1. Characteristic elements of an annotation: a synthesis drawn up from the literature.

- *The document is the target* to which annotation refers. This may concern the document as a whole on only a part of it. The annotation may or may not be physically distinct from the document it refers to. For example, a footnote is integrated in the document whereas a "post-it" sticker is distinct from the document it refers to.
- *The content of the annotation* corresponds to the information that is transmitted. It may be transmitted in various forms (text, icon, graphics, etc.), which are more or less shared by the annotators.
- *The anchor of the annotation* is the informational point to which the annotation is attached. In the example of a "post-it" sticker, the anchor is the place where the "post-it" is stick, the annotation being the information written on it.
- *Annotations are private or public*, depending on whether or not they are produced in a shared work document and/or made available to a group, or whether they are intended for personal use.
- *The life-span of an annotation* may be of varying lengths: short-term as in the case of a "post-it" sticker saying where to file a document, or permanent such as the footnotes of a document.
- *The annotator and the reader of the annotation may or may not be the author of the document*. For example, a footnote may be produced by the author himself or by his translator. When an annotation is produced, its writer may or may not know the persons to whom he will transmit the message. A teacher who annotates homework knows his student but an editor drawing up a commentary of a book, on an Internet site, is not intending this annotation for any particular person.

Objectives of the study

The functions of annotations in collective design processes are variously considered in current studies. They are characterized more by an intuitive perception of the needs than by a systematic and thorough ergonomic approach. Our study aims to examine this issue in greater detail.

Data relating to annotations were gathered during a collaborative design situation for a product intended for the general public (a bicycle trailer). Four mechanical engineers had to define a manufacturing solution of the product in face-to-face meetings. The meetings were filmed and all documents were collected in order to analyze the annotations produced during the collaborative sessions.

Method

Design Task

The project involved designing a bicycle trailer to carry children (see Fig. 2a). The designers were required to produce the manufacturing and marketable solution of this artefact. Their task was therefore to work on the CAD modelling of the trailer parts, the complete plans and nomenclature of the product, the costs and supplier estimates, together with an implementation strategy. The designers were provided with a file containing the findings of a preliminary study which included a functional analysis of the product, a proposal for a technical solution and some detailed plans of partial solutions.

The design process took place over four weeks. All four designers attended a two-hours meeting each week. Between two meetings, a week was set aside for individual work, during which the designers could only communicate with each other using e-mail. A preparatory meeting was held so that the designers could become familiar with their allocated role and the preliminary study that had already been carried out. After this meeting, and to ensure that the designers could use the CAD tool ProEngineer effectively and had analyzed the architecture proposed, each of the designers had to model parts of the product before the first work meeting. Finally, a review of the project was planned for a week after the last work meeting so that the team could present their work to the client.

Designers' Profile

The project team was made up of four recently qualified mechanical engineers who knew one another but had never worked together. They had experience designing in a workplace setting, and were paid for their participation to this specific design project. They were allocated clearly defined roles: a project leader-

coordinator, an ergonomist-designer, a designer responsible for the connecting parts, a chassis designer. Before the first meeting, the designers received a job description of their roles, together with details of the aims of the project. The project leader was in charge of ensuring the consistency of the solution and the work schedule. The ergonomist-designer was responsible for the products' usability. The two other designers were responsible for the technical and industrial aspects of two separate parts of the product: the chassis and the connecting parts.

Work Space and Data Gathering

The design sessions took place in a meeting room (see Fig. 2b). The tools available to the designers were a Teamboard (an interactive whiteboard), a CAD tool (ProEngineer), a computer with a set of office software packages (Word, PowerPoint, etc.), an Internet connection, a scanner, and blank sheets of paper (A3) and felt-tip pens. The designers had a common storage zone for computer data. The various screen pages of the software packages were displayed on the Teamboard. The designers could interact with them, either by using the mouse or by using a touch screen. The Teamboard could also be used as a whiteboard on which the designers could draw sketches. The designers could draw or make annotations on the displayed pages.

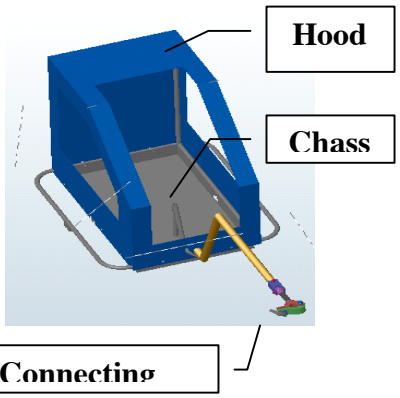

Fig. 2a. Drawing of the bicycle trailer.

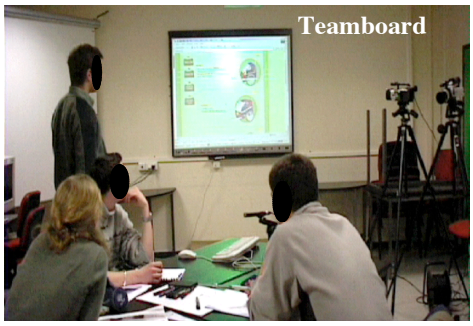

Fig. 2b. The work space.

Fig. 2. Design situation

The meetings were filmed with both wide-angle views and close-up shots of certain documents not only to have a global view of the collaborative design process but also to keep a record of the annotations at the time they were produced and to see how they were used. All the documents produced and used were gathered.

Data analysis

Differentiating Document / Sketch / Annotation

We have stated above that an annotation refers to a document. But while it is easy to identify an annotation made on a finished document, it is not so simple to locate an annotation on a document in progress (i.e. a document that is being drawn up). The confusion may, in particular, arise from the fact that certain documents under development, such as sketches, resemble annotations. Therefore, in order to categorize rigorously the various graphical and textual productions and to ensure a sound interpretation of the annotation processes, it was necessary to make a clear distinction between the various concepts prior to encoding the data.

Document. Following Chabin (1997) and Stern (1997), we define a document by its content (the information contained), its container (the medium) and the intentionality that led to its creation (the goal of the activity, the context of the task).

Sketch. This graphical production is a particular form taken at a given moment by a document (or part of a document). It has a context, a container and an intentionality (see Fig. 3) and it may be understood independently of any other document. Any subsequent modification made to a sketch but with the same intentionality is considered to be part of the development of the same document. These modifications (the adding of a line, the changing of a curve) are therefore not considered to be separate annotations.

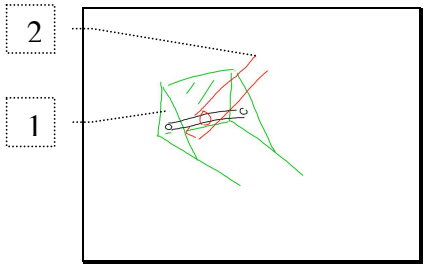

Fig. 3. An example of a sketch: a content, a container and an intentionality. The medium of this sketch is a blank sheet on the Teamboard (container). It represents a content: the connecting part [1] that joins the bars [2] to the chassis. The sketch was made by the teamleader to explain how the bars can be folded (intentionality).

Annotation. An annotation does not have an autonomous existence independently of the main document. It only reveals its informational content when linked to the document. Annotations rely on a different intentionality to that which led to the creation of the document, which is the medium of the annotation (see Fig. 4).

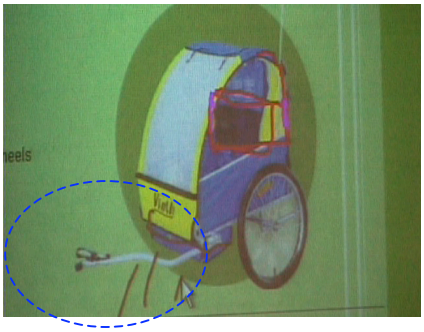

Fig. 4a.

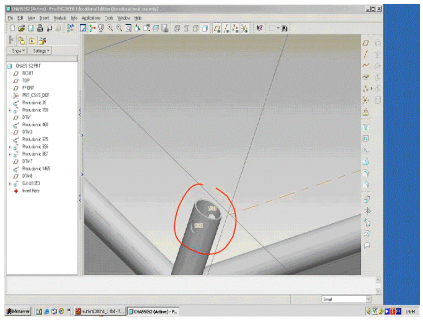

Fig. 4b.

Fig. 4. Examples of annotations, which are both made here on digital screen pages. On Fig. 4a, the annotation is the drawing of a throwing stone under the bicycle. On Fig. 4b, the annotation is the circle which focuses the attention on a sub-part of the chassis.

Analyzing the Data

We produced a chronological representation of the thematic development of each meeting. In order to characterize the medium of each annotation, we also record the way in which the designers used the documents and the various tools according to:

- *the location of the document used* :Teamboard or table;
- *the medium of the document*: type of application for electronic document (CAD, Internet, Word or Teamboard) or type of medium for paper documents (A3 sheets, print outs from Word or journals);
- *the documents' scope of use*: private use or public use.

In this way we obtained a corpus of 93 annotations created during the four design meetings. We also made transcripts of the verbal exchanges associated to the production of each annotation.

Results

Medium of Annotations: A Majority of Digital Mediums

The study revealed that the designers used no private documents, excepting their notebook, which is very often open for all on the table. Almost all documents take place in the collective arena.

It is worth to note (see table 1 below) that electronic documents (48,2%) slightly less than paper documents (51,8%). But two thirds of the annotations (63,4%) were made on electronic documents compared with a third (36,6%) on paper documents (see Table 2). In the study, digital mediums by no means hindered the designers from making annotations, but appeared, rather, to encourage them. This positive

effect of the digital environment on the production of annotations may be explained in two ways:

- *Computer tools are suited to "natural" production*: the digital annotations were produced using a touch pen (supplied with the Teamboard) which reproduces the same functions as a graphite pencil for making annotations: easy to draw with, fast to use. None of the annotations was made using the annotation functions provided by the CAD software, which are not well-suited to such easy manipulation.
- *Increasing use of digital documents downloaded via the Internet*: 32,3% of the annotations was made on documents that had been downloaded via the Internet. These documents concern solutions that are currently available on the market. This approach to design, based on reuse, comes as no surprise, reflecting, as it does, one of the main strategies used in the cognitive processes of design problem-solving highlighted by work on Case Based Reasoning. The hypothesis may be made that easy access to digital documents (via the Internet or Intranet) will encourage and increase the use of these reuse strategies.

Type de support	**Documents** **%** (number)		**Annotations** **%** (number)		**Ratio annot/doc**
Paper Documents					
Technical requirements	4,5 (5)	**51,8** (58)	3,2 (3)	**36,6** (34)	0,6
Product booklet published by competitors	6,3 (7)		0		0
Benchmarking documents	3,6 (4)		0		0
Sketches on paper	30,4 (34)		20,4 (19)		0,56
Sketches on personal notebooks	7,1 (8)		12,9 (12)		1,5
Electronic documents					
Digital representations (CAD)	12,5 (14)	**48,2** (54)	25,8 (24)	**63,4** (59)	1,71
Downloaded via the Internet (competing solutions)	20,5 (23)		32,3 (30)		1,3
Digital sketches on whiteboard	14,3 (16)		5,4 (5)		0,31
Technical requirements	0,9 (1)		0		0
		100 (112)		100 (93)	

Table 1. Production of annotations according to the type of the document

It is also worth noting that the solutions produced in the form of digital representations (CAD), although few in number (12,5% of the documents) gave rise to 25,8% of all the annotations, with a ratio of 1,71 annotation per document, whereas the solutions produced in the form of sketches (either on paper or digital sketches) have an annotation /document ratio of 0,56 on the one hand and 0,31 on the other hand.

We interpret this result as being due to the different natures of the solutions in either case. A digital representation describes a solution at a fairly complete level of detail. A consensus among the group has already been reached regarding the solution in question, even if it may be modified subsequently. Any modifications will be marked (pointed out) by annotations. On the other hand, sketches (on paper or digital) represent ideas for solutions, about which the group has made no decision. A modification of such solutions is more easily made by drawing a new sketch than by marking critical points (by means of annotations) on the existing sketch.

The Form of the Annotations: Beyond Simple Deictics

In table 2 below, it is stressed that, of the 93 annotations that the designers produced during the four meetings, only 3 (3,2%) were textual in form (measures, question marks), while 6 (6,5%) were mixed. All the other annotations (90,3%) were graphical. The high number of graphical annotations shown here is not in line with certain proposals for tools to assist mediated design, which are primarily based on textual annotations (in the form of comments). Such is the principle adopted by Naveiro, Brézillon & Soares (2002) in the SISPRO system which enables designers working on civil engineering projects to exchange texts, via a chat room, of all their annotations concerning building plans and design constraints. Our results suggest that such a text-based approach should be enhanced by including graphical annotation facilities.

The graphical annotations produced during the design situation that we studied are presented either as figurative forms (55,9%) or else as deictic (34,7%) – see Table 3. The figurative annotations represent:

- *representation of mechanical parts* (for instance, the position of the seat on the chassis will be roughly annotated on the digital representation of the chassis);
- *pictural representation* expressing problem constraints (the position of the passenger, the throwing up of a stone by the bicycle wheel, etc.)
- *arrows,* which are figuring various elements (the movement of an object, the behaviour of the chassis, the space between the chassis and the ground, distances that must be respected, etc.).

The existence of two types of graphical annotations (figurative and deictic) is an interesting result. Only deictic annotations are available in currently available CAD tools. Our results, on the other hand, show the importance of figurative annotations in the design process. We make the assumption that the rich semantic content of this category plays an important role in the project memory and in the problem solving process, whereas deictic annotations can only have a short-term and shallow role. This being the case, deictic annotations should be completed by

libraries of figurative annotations. The deictic annotations – which account for 1/4 of the annotations – are mostly pointers that serve to highlight certain elements of the problem or of the solution.

Type of annotation	**Form of annotation**	**Semiotic function of the annotation**	**%** (number)
Textual	Text / numbers only	*complementing*	3,2 (3)
Mixed	Combination of textual and graphical		6,5 (6)
Graphical deictic	Crossing out	*erasing / correcting*	4,3 (4)
	Combination (Crossing out + component delimitation)		2,2 (2)
	Highlighter	*hightlighting*	**18,3 (17)**
	Cercle, point, cross, stroke, arrow	*pointing*	9,9 (9)
Graphical figurative	Movement	*simulating*	2,2 (2)
	Distance		4,3 (4)
	Component	*figuring*	**46,2 (43)**
	Scene		3,2 (3)
			100,00 (93)

Table 2. Distribution of the annotations according their forms.

It is also interesting to note the large number (46,2%) of annotations that represents mechanical parts. Our encoding has clearly established that these annotations are distinct from elements of the solution: they do not represent a development of the solution, but they direct the focus of attention towards a subproblem to be dealt with. We therefore make the assumption that this category of annotations serves to represent the subproblem to be dealt with in a broader context.

The Collective Function of Annotations in Problem-Solving

All of the annotations produced during the four design meetings were created in the workspace, shared and produced by the group. They were public in nature, almost all made on group documents (92%) rather than on private documents (8%), the latter being made available in the shared workspace as soon as an annotation was made on it.

Since most of the annotations are created in and for the group, their function must be understood regarding the collective problem-solving process. To do so, we encoded the annotations in order to interpret them from the collective problem-solving viewpoint. We analyzed the annotations in the problem-solving context on the basis of the verbal exchanges that accompanied the production of the annotation. These exchanges were transcribed, and a chronological depiction of their topic was done (see figure 5 below). The problem-solving nature of the

exchange was also characterized, either as aimed at *generating* a solution or *informing* partners about contextual data related to the problem to be solved.

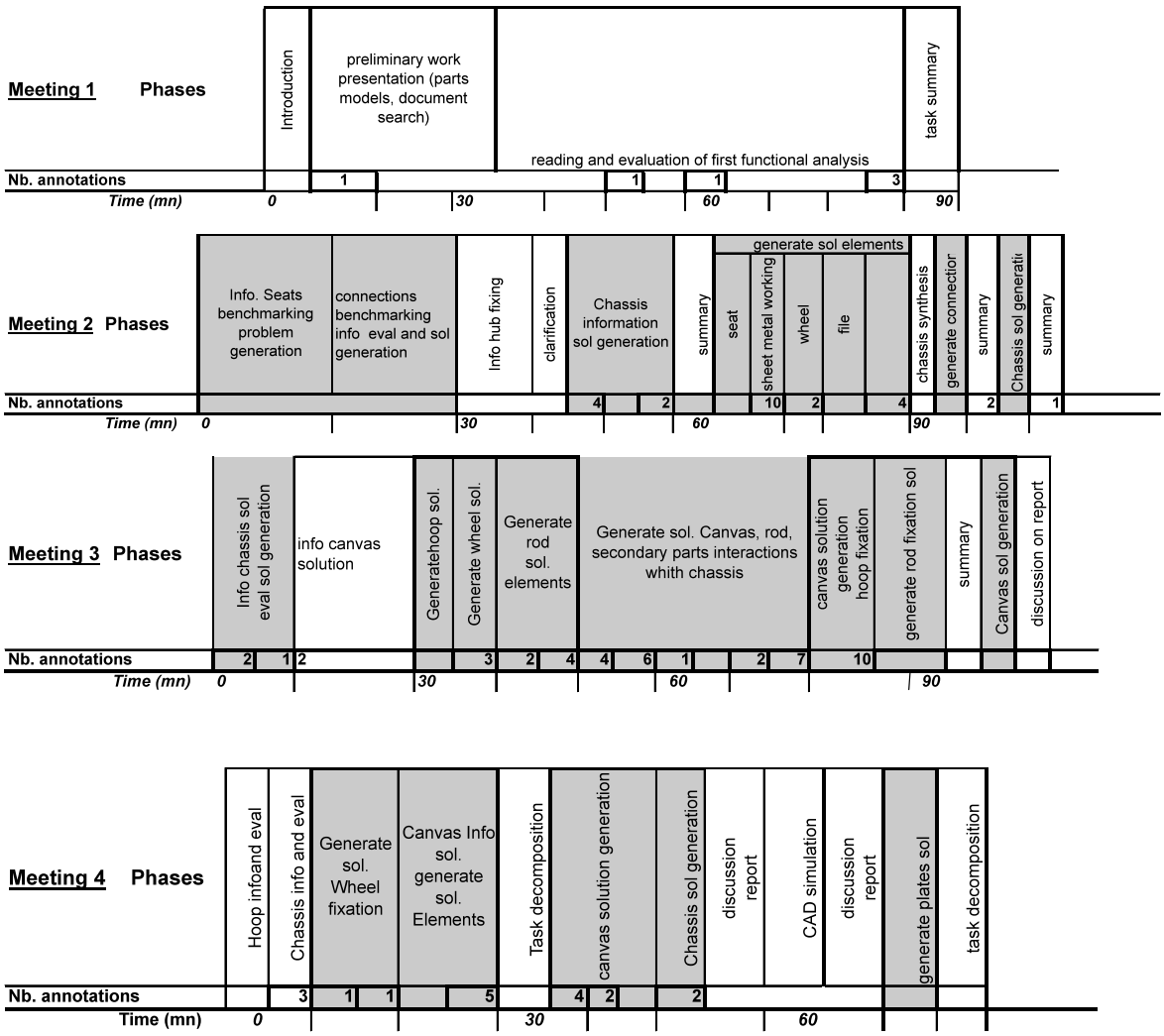

Fig. 5. Distribution of the annotations according to the problem-solving phase during which they are expressed: *Generation* problem-solving phases are figured in shadowed segments. *Information* problem-solving phases are figured in white segments

It was then indicated when – and how many - annotations were formulated along these various phases of the problem-solving process. Results are presented in table 3. It can be seen that most of the annotations (85%) are produced in order to support the process of *generating* a solution. Only 15% of annotations are produced to *inform* the team members about the problem or solution data.

This means that annotations are produced in order to elaborate the solution itself, rather than for establishing a shared context about the problem to be solved and its data. This is an exciting result to be investigated further, since it contradicts some previous studies (Salembier & Zacklad, 2007; Naveiro *et al., op.cit.*) claiming that

annotation is mostly dedicated to an evaluation function in a collective problem-solving process.

Function in the collective problem-solving process	To inform about a solution	To generate a component
Meeting #1	6	0
Meeting #2	3	22
Meeting #3	2	42
Meeting #4	3	15
TOTAL 93 *(100%)*	14 *(15%)*	79 *(85%)*

Table 3. Distribution of the annotations according of their problem-solving function

Discussion and Conclusion

The results presented here are remarkable in several ways. First, they represent the first psychological and ergonomic study that, to our knowledge, has been carried out on the use of annotations in a collective product design situation in which modern digital tools were used. An initial finding is the major role that electronic documents on the Internet play in the problem solving process, compared to paper documents. We put forward the assumption that access to electronic documents encourages analogical and case-based reasoning. We have shown that the production of annotations is stimulated by this availability of analogical solutions. This finding, if it were backed up by studies made in other collective design situations, would confirm the need to provide designers with powerful annotation functionalities.

The analysis that we made of the various forms taken by annotations provides particularly interesting perspectives for the future. Firstly, the minor role played by textual annotations, as observed in our study, undermines the importance that is generally placed on this category of annotation. Textual annotations are supposed to make up for the lack of verbal exchanges that occurs when an activity is mediated. Our results suggest, at least as far as mediated design activities are concerned, that this principle is not sufficient to support the complexity of the activity. Textual annotations will have to be completed by graphical annotations whose semiology is better suited to the work of designers and which provides a less costly manipulation. Secondly, we have brought to light the wide variety of graphical annotations. Although they were traditionally considered as pointers, our study shows the crucial part that figurative annotations play in describing constraints of the problem and the solution. As we have shown, the function of annotations is not to develop parts of the solution, but to provide the team members with contextual descriptions of the problem and the solution, by specifying which data and constraints should be taken into account. Therefore, we do not recommend trying to integrate, in CAD systems, annotations in the digital model of the artifact being

designed: the annotation must be distinct from this model. Its role is to improve the designers' understanding regarding the artifact by specifying the representation of the problem and the solution.

Our study should be taken further in order to examine the possible effect of the function of the designers and the social organization of the group on the production of annotations. It would appear that the more questions regarding the designers' workload are discussed, the more annotations are produced. Testing this hypothesis would require complementary methodological developments. If it were verified, it would be possible to assert that the designers' roles would be an important piece of information to include in the widening of annotations. This possible link between the production of an annotation and the function of its producer must surely be influenced by the social organization of the design project, in which roles sometimes emerge that do not conform to the functions that were attributed at the outset of the project. Nevertheless, such a result would confirm the importance of a multi-viewpoint indexing of annotations.

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