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WHAT REPRESENTATIONS DO DESIGNERS BUILD OF THE FUTURE USERS OF THEIR DESIGN?

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Abstract

This paper reports on an ergonomic study carried out during the design of the cutting station of the composite material for carbody parts casting. The design process was led by a group of designers. During this process, the majority of users' needs were inferred by the designers on the basis of their knowledge of the users' activity and their representation of the use of the new device. These representations – correct or false, rich or poor, partial or complete – play a decisive role in the choice of a solution. The aim of the study is to identify the particularity of these representations. Analyzing 7 technical meetings, we have extracted all statements referring to the users and highlighted that users are considered either as subsystems or basic design principles or elements of an imagined scenario. We have shown that these representations are linked to the types of technical meetings held during the process. Accordingly, a diversification of the types of meetings should be fostered by the project leader, so that designers multiply their points of view of the operators. The perspectives that this study opens up are to improving project management techniques for taking better into account the operators' point of view.

Keywords: user-centred design, project management, cooperative design

1. Objective

The design of a product is carried out through cooperation between players from a variety of professional fields (automation, mechanics, design, computing, ergonomics, etc.). The persons for whom this product is intended, the future users, are rarely involved in the design process. Collective decisions regarding design choices are usually made by teams of designers during technical meetings at which the future users themselves are seldom present. The future needs of the users are simply 'imagined' through representations that the designers make of the users and the probable ways in which they will use the device. These representations underpin the functional analysis of the product, guide technical decisions and therefore have a considerable influence on the design of the device.

The aim of this study is to identify the particularity of the mental representations that the designers build of the future users and of how they will use the device. We wish to understand how designers, during technical meetings, evoke the role, the function and the place of the future users.

It should be pointed out that, as far as we know, no previous ergonomic or mechanical engineering studies have been carried out on this subject. The integration of operators' points of view during the design cycle is generally tackled from the aspect of participatory design. In this perspective, taking users into account comes down to defining the best conditions in which to implement participatory design activites according to the local industrial context. Studies along these lines are numerous and serve to show that taking into account the future usage of a product is a central element in the design of work systems ([1], [2], [3], [4], [5], [6]).

But it should not be forgotten, however, that there will always be parts of the design process in which the future users will only be present in the minds of the designers. It is during these phases that integrating the users' points of view will have to be supported by methodologies for managing meetings whose aim is to promote a user-centered approach to design. The results we present in this paper are intended to contribute to the development of such methodologies, in the hope that they will promote the integration of richer and more varied representations of the operators during the design process.

Our study focuses on a particular design situation : the designers are methods engineers, and the future users are the manufacturing operators who will use the devices designed by the engineers in the workplace. In this design process, the methods engineers are to some degree familiar with the context in which the devices will be used : the jobshops are located quite near the methods office, and participatory design actions may encourage the operators to express their needs. However, it is very frequently the case, if not the rule, that technical design meetings are held without the operators who could voice their needs.

2. Industrial context

The study has been carried out in the field of carbody parts casting. The industrial context is the revision of the cutting process of the composite material (SMC) which is to be cast. The cutting operation, which up to now has been done manually by manufacturing operators using a craft knife and following the lines of a cutting table, is now to be performed automatically on a cutting station. The design process lasted two years and is described in details in [7].

This design process was led by a technical group in charge of writing the specifications and designing the system. This technical group was made up of three distinct subgroups : (i) the *steering group*, consisting of the persons responsible for the running of the project, namely the project leader, the mechanical engineer, the ergonomist and the scheduling manager; (ii) the *specialists group* (maintenance, mechanical engineering, control, computing); (iii) the *global design team*, made up of the systems engineers.

This design process was partly user-centered since the manufacturing operators were asked to give their point of view concerning the device they would have to operate. Once a month, a group of operators met with the project steering group and, on the basis of scenarios of use, identified some users' needs which were to be passed on to the technical group [8]. However, the vast majority of the users' needs were inferred by the designers themselves on the basis of their knowledge of the users' activity and their representation of how the manufacturing task is likely to be performed with the new device. These representations – correct or false, rich or poor, partial or complete – play a decisive role in the choice of a solution.

3. Principles of the data analysis

To identify and to model the mental representations that designers build of the future users of their design, we have taken up a cognitive approach which theoretical and methodological principles are the following. Mental representations are seen as operative knowledge, enabling people to act and to solve problems in a situated context. The methodological tools required to elicit this knowledge are CTA (Cognitive Task Analysis) tools [9] among which we have chosen protocol analysis for its efficiency in inferring operative knowledge.

3.1. Selecting and characterizing seven design meetings

We followed the entire design process, during which the technical group held 15 meetings. Of these, we selected 7 meetings due to the quality of interaction, as well as the theme of the meeting (e.g. certain meetings, dealing with totally automated components of the system, contained no references to the operators themselves). These meetings, described in the table below, were initially characterized according to 5 aspects:

- the name of the technical meeting (functional analysis, review of technical progess, steering committees, etc.);
- the subject matter discussed during the meeting (e.g. evaluating a tender made by a supplier, assessing a design principle such as fully-automated control of the station versus semi-automated control, presenting a flow model, etc.);
- the intermediary objects (plan, text of a tender, document, filmed demonstration, etc.);
- the course and progress of the meeting, its phases and the issues raised;
- the forms *of collaboration* that the participants employed (e.g. conflict negotiation, the seeking of an agreement, establishing a common frame of reference, etc.).

WG	**Name of meeting**	**Subject dealt with**	**Intermediary objects**	**Progress of the meeting**	**Form of collaboration**
2.	Presen-ting a tender	Examining the tender from Polymatic	Plan Text of the tender	*Information meeting* - The project leader presents the tender - The participants react by asking for further details	Participation essentially consists of :(i) understanding the project, and (ii) seeking further information, then (iii) reformulating
8.	Conver- -gence meeting	- Presenting the material flow simulation model - Discussion on the feasibility of a completely automated running of the station	Conceptual model of the flow simulation program	- Discussing basic issues : the presentation of the model is supposed to prove the facts - Drifting away from the main subject : presenting the automation program, problems with the interface, operating modes	Confronting antagonistic points of view about the automatic or semi-automatic running of the station; (ii) conflict over the feasibility of a totally automated system
10.	Function-al analysis meeting	- Functioning of automated devices managing the pressing/cutting interface - Central interface	Specifica-tions written on the paper-board	*Functional analysis* Formulating the specifications	- Seeking consensus - Establishing common representations
12.	Present-ing a tender	Evaluating the first detailed plans proposed by the systems engineers	Plan Prototype of the cutting system	*Information meeting* - The project leader presents the tender - The participants react by asking for further details	Collaboration consists of (i) understanding the project (ii) seeking further information, then (iii) making constructive hypoth.

13.	Conver--gence meeting	Automatic or manual management of the cutting station	Joint document for/against	Discussion led by the head of the methods office	Negotiating the choice between automatic or semi-automatic Negotiating basis previously worked on
14.	functional analysis meeting	Managing the materials scheduling	Written document recording the design hypotheses	Discussion of various hypotheses Common definition of the operating mode of the station	Work meeting aiming to better define the content Seeking consensus
15.	Technical meeting	Verifying the function/structure compatibility of the subsystems	Plan	Chronological review of the process, phase by phase, with the global designers	Integrating points of view

Table 1 Description of the meetings analyzed

3.2. Analysis methodology

The designers' meetings were recorded in full using video and/or audio tapes, and then transcribed [7]. In these transcriptions all explicit or implicit statements referring to the operators were selected, as for instance: 'I don't want the operator to command the containers or the material, that must be automatic or else it'll be a disaster' (project leader's statement). They are referred to as 'operator-references' in the rest of the text. Note that a sentence or phrase is considered to be an operator-reference when the operator is mentioned explicitly : 'the operator', 'he', 'you (meaning the operator)', etc.

We do not deal with those parts of the dialogue where the operator is clearly the subject under discussion without being mentioned explicitly. For example, some time may be spent discussing the design of the device for attaching the material to the automatic roller, an operation that is carried out entirely by the operator, without ever introducing the operator as a 'reference element' in the discussion. This methodological choice may lead to a certain underestimation of the operator's position during the design. But this choice may be justified on the grounds that the issue we wish to address is not so much the extent to which the operators are represented in the design meetings, but rather to know *how* they are represented : what are these representations, which roles and functions are attributed to the operator, how is the operator supposed to interact with the technical system and on what principles do the designers, depending on their specialist field and involvement in the project, base their point of view of the operator?

The results presented below therefore bear on this last point. Are there identifiable classes of references in the corpus of operator references? And if so, what are their distinguishing features? Is there a link between the type of design meeting and the use of a particular type of reference? Firstly, we will show that representations of the operators evoked by the designers are of three different types. Then we will show that there is indeed a link between the type of meeting that the designers take part in and the way in which they represent the operators. These results lead to a description, as a conclusion, of the prospects for transforming and modifying methodologies for managing meetings in a design project.

4. Result 1 : How are the operators spoken of?

On the basis of the data described in the previous section, we found that the designers speak of the operators in three different ways, thereby considering their role and place in the work system in three distinct ways : (1) *operators are considered as subsystems,* (2) *operators are considered according to basic design principles,* (3) *operators are elements of an imagined scenario*.

4.1. Operators are considered as subsystems of the human-machine system

In this first, relatively frequent case the operators are represented as one of the *elements of the human-machine system.* Here, the role of the operator is evaluated according to the interactions that he has with the technical system. The designers agree on the actions that the operator will have to carry out as an element of the human-machine system. The future actions are formulated along various lines : Which actions will the operator be allocated, and which actions will be carried out by the device itself? How much leeway should the operator have when performing these actions? Which skills and abilities must the operator have in order to be able to carry out a particular action? What exactly are these actions and these operating modes? Four sub-categories realting to these various points, were identified :

- Task allocation
  In a certain number of cases, the designers foresee which actions the operator, in his role as a subsystem, will be able to carry out, in conjunction with the actions of the machine. This would be the case, for instance, for 'I don't want the operator to command the boxes or the material, that must be automatic, or it'll be a disaster.'
- Leeway
  The designers establish how much leeway the operator may be allowed in his actions and decisions An example is '…can we foresee the possibility of the operator being allowed to stop the material folding process while it is in operation?'
- Abilities
  The designers attempt to find out whether the operator has the necessary abilities and information for the task. For example '…well, the operator must know how to do this manipulation to command the material.'
- Operating modes
  The designers establish the future operating requirements. For example, '…the foreman will firstly have to enter a certain amount of data, and then maintenance will have to change the parameters of the program.'

4.2. Operators are referred to as basic design principles

Here, the designers introduce the representation of the operators in their discussions by stating general principles when taking the operators into account in the design of the system. They speak of the operator in general terms, as a ''generic''operator, whose roles and functions are abstract in the sense that they could equally apply to projects other than the one in hand. For example : *'…it's necessary to decide between two options for the machine : either a completely automatic mode, or a semi-automatic mode* ***where the operators must always take priority over the machine.'***

By evoking the roles and functions of the operators in this general way, the co-designers aim to specify 'values' regarding the place of the operators in the system, in order to reach agreement on the role they will be given in the design of the future system.

4.3. Operators as elements of an imagined scenario

Very frequently, the designers evoke the *operators as elements of an imagined scenario* : in this category, the designers figure out how the future users are supposed to perform their tasks. They describe and simulate task sequences which are to be carried out on the future device. The designer adopts the point of view of the operator in his work situation, and simulates his actions and reasoning. For example : '[with this interface] you can change a command, you can choose to shunt, you can switch from line 1 to line 2,… '

5. Result 2 : Effect of the type of meeting on the designers' representation of the operators

As was specified in section 3.1 (see table 1), each technical meeting has specific objectives and takes a particular form : some meetings are dedicated to evaluating tenders from subcontractors, others aim to deal with very specific technical points, and others again are called by the management to resolve conflicting issues, etc. We are going to examine whether it is possible to find a link between the type of meeting on the one hand, and the representations that the designers build of the operators, on the other hand. Our hypothesis is that certain types of meeting encourage certain types of representation, to the detriment of others. If this hypothesis holds, our recommendation will be to improve the management of these types of meeting in order to generate a richer and more diverse view of the operators.

5.1. Identifying three types of meetings

Technical working groups	**WG** Type **A**				**WG** Type **B**		**WG** Type **C**
% (nb)	**WG2**	**WG 12**	**WG 13**	**WG 14**	**WG 10**	**WG 15**	**WG 8**
Principles	**7** (1)	**13** (6)	**27** (32)	**35,5** (8,5)	**6** (2)	**0,3** (1)	**57** (16,5)
Sub-systems	**79** (11)	**83** (39)	**61** (71)	**60,5** (14,5)	**94** (31)	**97,7** (324)	**13,7** (4)
Allocation	**38** (5)	**40** (19)	**34** (39)	**29** (7)	**79** (26)	**52** (172,5)	**7** (2)
Leeway	**23** (3)	**4** (2)	**19** (22)	**10** (2,5)	**3** (1)	**3,7** (12,5)	**3,4** (1)
Abilities	**0** (0)	**6** (3)	**5** (6)	**21** (5)	**12** (4)	**8** (26)	**3,4** (1)
Operating modes	**15** (2)	**32** (15)	**3** (4)	**0** (0)	**0** (0)	**34** (113)	**0** (0)
Imagined scenarios	**14** (2)	**4** (2)	**12** (14)	**4** (1)	**0** (0)	**2** (6)	**29,3** (8,5)
TOTAL	100 (14)	100 (47)	100 (117)	100 (24)	100 (33)	100 (331)	100 (29)

Table 2 Identifying three classes of meetings characterized by the distribution of the number and proportion of operator-references of each category.

An analysis of table 2 makes it possible to compare the proportion of operator-reference categories formulated during the various meetings, and reveals strong similarities between certain meetings, leading to a classification into three distinct types of technical meetings.

- Type A technical meetings : WG2, WG12, WG13 and WG14

- Type B technical meetings : WG10 and WG 15
- Type C technical meetings : WG 8

Let’s look in more detail what leads to this classification :

- **Type A technical meetings**: This class is distinguished by a distribution of the three categories of operator-references : during these meetings the designers make mainly ‘subsystem’ operator-references – about 70% - (particularly due to the ‘allocation’ subcategory), but do not hesitate to invoke principles regarding the operators’ involvement in the system – about 20% - and, if necessary, to simulate the operators’ tasks – about 10%.
- **Type B technical meetings**: Examining the Type B column shows that this type of meeting is characterized by an almost exclusive use of ‘subsystem’ representations. Among these representations, the use of the ‘allocation’ subcategory is predominant (65.5%) : this means that the representations that the designers evoke are essentially used to decide upon the distribution of tasks between the system and the operator.
- **Type C technical meetings**: The characterization of this class should be qualified by the fact that it is based on only one occurrence (one meeting). It is essentially made up of operator-references as general design principles (57%). The designers also use imagined scenarios (30%), probably to back up the formulation of the principles they stated.

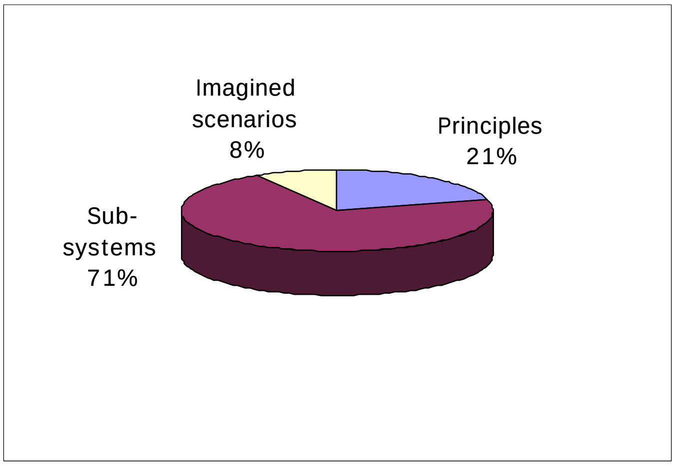


Figure 1. Distribution of the different types of operator-references in the Technical Meetings of TYPE A

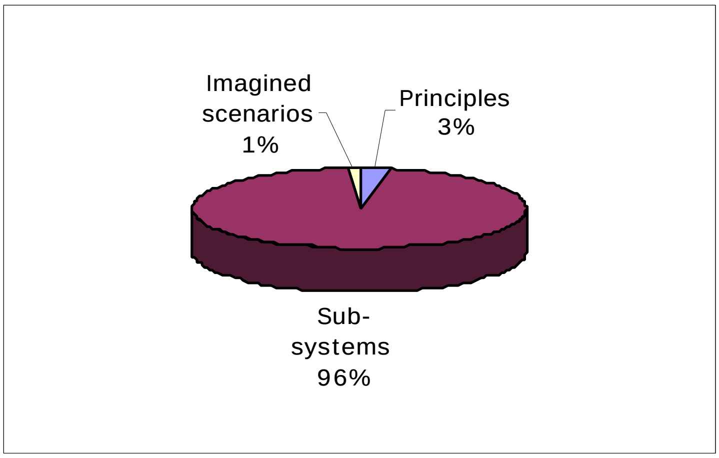
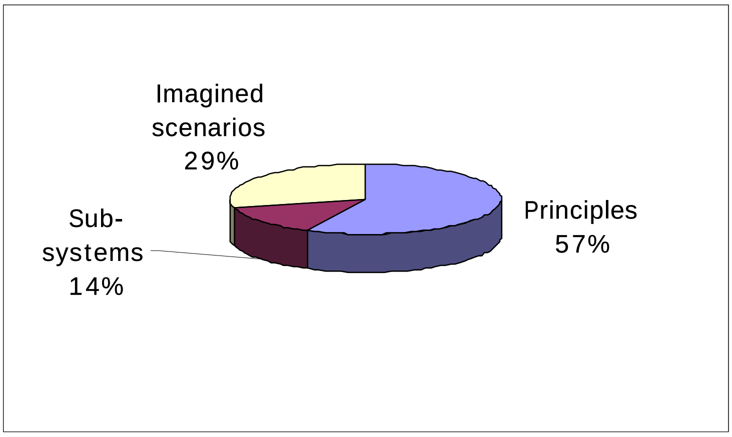


Figure 2. Distribution of the different types of operator-references in the Technical Meetings of TYPE B

Figure 3 Distribution of the different types of operator-references in the Technical Meetings of TYPE C



5.2. Characterizing the three types of meetings according to their internal features

We carried out a qualitative interpretation of the data to examine whether the distinction between the 3 types of meetings could be explained by the internal features of meetings concerned. We can see from the table 3 that the factors *« course and progress of the meeting »*, « *subject discussed* », and « *name of the meeting* » all vary independently of the 3 types of meetings. It is the characteristic « *form of cooperation*» that distinguishes them more clearly.

Analysis of Type A technical meetings

The subjects discussed during these four meetings varied greatly. These were in information meetings (presenting tenders from systems engineers) as well as in convergence meetings, the subjects being supported by lively debate (e.g. about the automated or semi-automated management of the cutting station). The aims of the participants were both to gain information about on-going projects, and to discuss hotly contended and potentially conflictual issues. The diversity of aims explains the diversity of operator-reference types formulated during the meetings : the operators are sometimes referred to design princimples, sometimes as elements in an imagined scenario, and very frequently as a reflection of task-allocation within the human-machine system.

Analysis of Type B technical meetings

The objectives of the meetings in this class are homogeneous : they all aim to define functional specifications. It therefore comes as no surprise that the operator-references evoked by the designers are essentially of the 'sub-system' type. Indeed, the formulation of specifications traditionally tends to focus on specifying what the technical system will be able to handle, and identifying the role of the operators in the running of the system.

Analysis of Type C technical meetings

The theme of this meeting was particularly sensitive for the steering group as several antagonistic viewpoints were in conflict regarding major decisions about the future functioning of the system. It is likely to be these disagreements that generated a rather large number of statements about the place of the operator in the system, and an equally large number of imagined scenario formulations.

	WG	Name of meeting	Subject dealt with	Progress of the meeting	Form of collaboration
TYPE A	2.	Presen-ting a tender	Examining the tender from Polymatic	*Information meeting* The project leader presents the tender The participants react by asking for further details	Participation essentially consists of (i) understanding the project, and (ii) seeking further information, then (iii) reformulating
	12.	Presen-ting a tender	Evaluating the first detailed plans proposed by the systems engineers	*Information meeting* The project leader presents the tender The participants react by asking for further details	Collaboration consists of (i) understanding the project (ii) seeking further information, then (iii) making constructive hypotheses
	13.	Conver--gence meeting	Automatic or manual management of the cutting station	Discussion led by the head of the methods office	- Negotiating the choice between automatic or semi-automatic - Negotiating basis previously worked on
	14.	Functio-nal analysis meeting	Managing the materials scheduling	- Discussion of various hypotheses - Common definition of the operating mode of the station	Work meeting aiming to better define the content Seeking consensus
TYPE B	10.	Functio-nal analysis meeting	- Functioning of automated devices managing the pressing/cutting interface - Central interface	- Functional analysis - Formulating the specifications	- Seeking consensus - Establishing common representations
	15.	Techni-cal meeting	Verifying the function/structure compatibility of the subsystems	Chronological review of the process, phase by phase, with the global designers	Integrating points of view
TYPE C	8.	Conver--gence meeting	- Presenting the material flow simulation model - Discussion on the feasibility of a completely automated running of the station	- Discussing basic issues : the presentation of the model is supposed to prove the facts - Drifting away from the main subject : presenting the automation program, problems with the interface, operating modes	Confronting antagonistic points of view about the automatic or semi-automatic running of the station; (ii) conflict over the feasibility of a totally automated system

Table 3. Characterisation of the three types of meetings according to their internal features.

6. Conclusion

This study has brought to light two points which we believe may improve the taking into account of the users during the design process. The first contribution is to have identified the various representations that the designers of a technical system evoke of the future users of this system : some are functional (distributing tasks and roles between the user and the system), others are evoked in scenarios of future usage (the designers envisage how the users will behave when using the system), and other representations are of a general nature, evoking design principles which should guide the designers (the role and place of 'human factors' issues in technical systems).

The second contribution of this study is to have shown that this diversity of representations of operators is not expressed in the same way depending on the type of design project meeting. Thus, purely technical meetings, such as functional analysis meetings, encourage a functional view of the users, but are less inclined to evoke general principles on the place that the operators should have in the system.

A better understanding of how designers represent the operators according to various types of meetings that are held throughout the design process should make it possible for the steering groups of a project to diversify the structure of these meetings. This diversification should help the designers to multiply their points of view of the operators, and to enrich their technical proposals in ways that are better suited to the operators' needs. The perspectives that this study opens up therefore lend themselves to improving project management techniques for taking into account the operators' point of view.

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