A longitudinal study of participative construction of requirements in real innovative projects: the case of a virtual reality software for product design

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A longitudinal study of participative construction of requirements in real innovative projects: the case of a virtual reality software for product design

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Abstract - **This paper aims at increasing knowledge on how participative design (i.e. an approach where final users are considered as co-designers) actually works in the context of highly innovating technology like Virtual Reality, relying on a longitudinal study of a real project. The project deals with the design of a 3D real-time software to support people to validate concepts for new products. We present a review on knowledge and models related to the construction of requirements. Then, we report on a field study carried out among participants of the design team. The empirical data are compared with theoretical data in the third part. To conclude, we emphasize the research and industrial perspectives.**

Keywords - virtual reality, 3D real-time, longitudinal studies, user requirements, participative design, product design

I. INTRODUCTION

A. Objective

This paper reports on a longitudinal study[1] of 2 years of an innovative design project. Based on the method of participant observation[2], the focus of our analysis is on the distributed actions and contribution of various actors in a Virtual Reality project to the process of requirement elaboration.. The objective is to provide a clear account of this process and the way users and designers participate in the context of a real project.

The project concerned by this study is a Virtual Reality Software for Product Design. It deals with the specification and design of a virtual reality system to assist users and designers in validating concepts for brand-new products (see Figure 1). The design approach chosen in this project is the participative design.

Participative design, i.e. an approach where final users are considered as co-designers (see e.g.[1]) is usually seen as the best mean to ensure a continuous and mutual cross-fertilization of engineering-design knowledge with user's knowledge of uses. The specific context of emerging and very innovative technologies generates however several difficulties for users to actually participate in the co-elaboration of requirements (see e.g. [2, 3]). Furthermore, there are only few evidence regarding which methods can be best support participative design as well as how participative elaboration of requirements actually works in such a context of highly innovating technology.

As an expert from a domain, each participant has his own role and contributes to different parts of the project [4]. This approach is based on the parallelization of tasks of different actors, without them necessarily being aware of others or their activities. This method requires everyone feels involved in his area of expertise and seeks both to achieve a personal goal as well as a group objective [5]: design participants regularly exchange and cooperate through their workspace [6]. This method involves concessions on the part of each participant and does not satisfy them completely. However, it often leads to creative and original solutions [7].

In this approach, we consider potential users or prospective users of the system like designers: we call them co-designers. They have a dual role: firstly, to speed up the design of the new tool in devising solutions and evaluating the proposals made by developers or by other co-developers; secondly, they have to play the role of future users who have to be interested and trained to the use of the future tool.

[1] Study which is conducted by measuring an event with a group of persons at various moments.
[2] The participant observation refers to becoming a member of a group to take part completely in its activities.

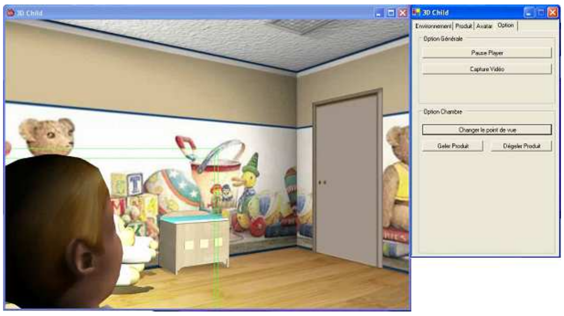

Figure 1. 3D scene viewed by an avatar

This study takes place in the field of ergonomics studies of design (see e.g. [8]) where the aim is to deepen our knowledge and understanding of the design activity, in order to propose more adequate tools and methods to design participants. There are few longitudinal studies on the activity and the process of construction of requirements within a real design community and project (see e.g. [9, 10]).

Moreover, these studies focus on analysis of some design meetings, design reports or a short formal phase (e.g. creation of « Special technical terms and conditions »).

This study is original for two reasons. First, it was followed for a long time with an access to all data which makes possible to do a fairly thorough analysis of all productions. The second originality of the study presented here lies in the choice of the point of view of the participant observer; the person who analyses the data from the field is also a member of the collective design. This regular presence on the ground allowed to maintain a coherent overview of the situation: to attend all project review meetings and in-house meetings, to follow through the effects of decisions, to observe tests of intermediate representations and changes of objectives [11].

B. Outline

The article is structured as follows. At first, we set out the knowledge and models for the construction of requirements from the literature. The next section describes the field study conducted among participants of the new design tool. Then, a discussion reviews the contributions of the ergonomic approach adopted, by confronting the scientific data from the field. Finally, the conclusion summarizes the perspectives of this work.

II. REVIEW ON PROCESS OF REQUIREMENTS CONSTRUCTION

The construction of requirements differs according to discipline. This section will allow us to draw up a review of these problems in the fields of industrial engineering, ergonomics and requirement engineering.

A. *Requirements construction in industrial engineering*

In industrial engineering, identification of requirements is usually before the design [12], with partners or end users. These requirements are described in a functional specification, in terms of functions the system has to perform [13]. This entry in the specifications requires prior validation or rejection of the requirements identified previously. The implementation of validated requirements is punctuated through various mediums of representation of the product, such as sketches, models or prototypes [12].

B. *Requirements construction in ergonomics*

In ergonomics, requirement analysis can be made during the design process or after it.
Indeed, this analysis is often conducted simultaneously with the specification or with the detailed implementation rather than in the earlier phase of the project. Specification and assessment/validation phases are linked as advanced refinement requirements [14].

If conscious requirements may emerge before the design, they will change (i.e. will be specified or invalidated) and other ones will be born during or after conception. This approach of a design which continues during use had been addressed by [15, 16]: the development of artefacts and is similar to a design process by the user. The model of "design loop" [15, 16] represents the registration process of instrumental genesis in the entire cycle of the design of an artefact. In other words, features designed by the subjects and implemented patterns of use will be articulated in the design and will form respectively new constitutive functions and new operating procedures for a later version of the artefact.

The literature considers three types of “requirements”. Requirements explicitly expressed by the (future) users, that is “conscious” [17]. Conscious requirements are generally incomplete or out of step with the real requirements, and especially since they are treated carelessly at the request - which rarely comes to the actual user. Subconscious requirements [17] result of several possible factors. A primary factor is the lack of opportunity offered to users to reflect about their current activity. A second factor is the lack of understanding by the users of properties and potentialities of the chosen technology, preventing matching this potential with the critical properties of the task and the targeted activity. Another major factor is the non-verbalized nature of some requirements, such as a great deal of automation in the activity. Some automatic reflexes may also have been developed to get around or minimize difficulties for the current activity.

Requirements in the “latent” state (Sperandio, 2001) are characterized by their nature not yet proven or “undreamed” (Robertson, 2001). This third type of requirement is an important issue for emerging technologies, still under development in laboratories, and thus constantly evolving. However, anticipating promising technology and applications is one of the challenges of the intensive innovation.

C. Requirements construction in requirements engineering

Requirements Engineering aims to formalize a “systematic process of developing requirements through an iterative cooperative process of analyzing the problem, documenting the resulting observations in a variety of representation formats, and checking the accuracy of the understanding gained” [18], p. 3. This quote justifies the dominance of this part in the review.

1) The process of requirements construction as a process of making decisions

The overall process has been formalized by [19]. It is an iterative process that begins with the statement of requirements and ends with their validation through a phase of analysis and negotiations between the participants of the design, followed by the formalization of requirements in documents. The determinants of this process are the existing systems (systems to improve or competing systems), user requirements, proposals of designers and standards of ergonomic design. The selected requirements and system specifications are the output of this process.

The process of construction of requirements are analyzed in terms of process of making decisions [20, 21]. They consist of three phases [21]. The identification phase [22] aims to conduct research on existing tools, of which some characteristics can be applied to the future tool. The development phase [22], also called “problem analysis phase” [23], consists of identifying all the alternatives for the future tool. The result of identification and development phases is what we call in the following sections a set of stated requirements. The selection phase [22] corresponds to the action to reject or validate design alternatives. This means assessing the costs and benefits of each alternative and to conduct a detailed requirements analysis in order to formalize the validated requirements in a document [23]. [24] adds the implementation phase to these phases; the result is the state of implemented requirements.

[20] propose a process of construction of requirements, detailing the contribution of the design group in a continuum between user requirements and system requirements. The user requirements analyzed by the project leaders, engineers and marketers, are reformulated in more general system requirements. These are then detailed by engineers, marketers and requirements engineers.

2) The approach of creativity for the stage of statement

[25] propose a technique called “EPMcreate”. This technique of creativity, based on the elementary pragmatic model (EPM), is an editor of requirements that produces a set of possible responses to two points of view of participants in the design. From combinations of these views, new views can be generated and creative ideas can arise.

3) The discrepancy approach for the analysis and negotiation stages

[26] provide a tool (AGORA tool - Attributed Goal-Oriented Requirements Analysis Tool) which aims to identify discrepancies between the different project members in terms of requirements. They define the discrepancies based on three criteria:

- Missing: person A has a need that person B does not have;
- Inconsistency: person A wants a red button while person B wants it to be blue;
- Discordant: if two people interpret a need differently or their evaluation in terms of preference of a need is different.

4) The approach of decision making for the stage of formalization

From [23, 27], there are three types of requirements documents. Market requirements documents are necessary when developing a product for a potentially large number of customers. User requirements documents describe the nature of the design problem, the general constraints (e.g. cost and time) and the desired functionality of the system (e.g. acceptance criteria, quality attributes, technical constraints). Software requirements documents contain detailed system description (i.e. specification) for design and implementation (e.g. detailed functional description, representation of system behaviour, indication of performance requirements and design constraints).

III. A LONGITUDINAL STUDY FROM THE VIEWPOINT OF THE PARTICIPANT-OBSERVER : 3D CHILD PROJECT

A. *The 3D Child project*

This study was conducted on the industrial project 3D Child. This project, led by a group of companies specializing in producing accessories for children, was divided into two parts. The goal of the first sub-project, called "measurement campaign", was to obtain morphological and anthropometric data of 0 to 5-year-old children. The second sub-project, directly related to the first was entitled "3D environments and places; the aim was to design a virtual reality tool for three SMEs (companies A, B and C) to help them to assess their future products. This resulted in the presentation of interactive 3D scenes composed of future products in which human characters modelled in 3D (using data from the campaign of measurements) could move (see Figure 2).

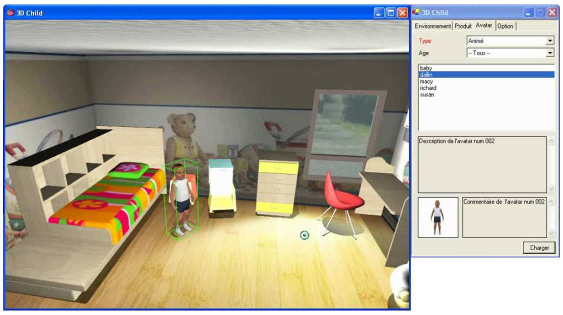

Figure 2. Avatar in the 3D scene "bedroom"

The work presented here reflects the work of the "Presence & Innovation" LAMPA team, which focused its research on the "places and 3D environments" sub-project only. In the end, this collaborative tool will aim to help teams to design new products and to reduce time and cost of designing industrial products especially in the preliminary phases of design.

The virtual reality system is a software made for decision support in industrial design. Two environments have been developed: a "room" environment and a "car" environment.

B. *Methodology*

1) *Participants*

Participants in this study were designers (LAMPA team), co-designers (designers and users working in 3 companies involved in the project) and the holders of the project. This study involved 10 designers, 25 co-designers and 2 project leaders. The data of participants (age and experience) are summarized in Table 1.

TABLE 1. PARTICIPANTS INVOLVED IN THE DESIGN OF SOFTWARE

		Designers	**Co-designers**	**Leaders**
Size		10	25	2
Age	μ	29,8	41	*Data not available*
	E.T.	8,8	8,7	
Experience	μ	3,9	19,5	
	E.T.	6,3	9,7	

To perform the analysis presented below, we grouped the 35 participants in 3 categories according to their profile (engineer, designer, marketer). These three categories are crossed with status in the project (developer or co-designer). The 25 co-designers were divided among three companies A, B and C. We put together the two leaders of the project in a specific category.

2) *Data collection procedure*

In this study, data were collected by the analyst throughout the project development. The collection was facilitated by the fact that the analyst participated in the design community as a designer-ergonomist and as project manager of the module "places and 3D environments". The data collected are:

- the official documents of the project recording the changing of the requirements through the design choices (specifications, presentations of project reviews);
- the reports of internal meetings, the progress reports of the designers;
- the different versions of the software.

Moreover, as human factors engineer, the analyst has collected data through ergonomic methods aiming at supporting the process of requirements analysis:

- transcripts of brainstorming and discussions, particularly on the integration of the tool in practice situation;
- recordings of usage scenarios of the software by "users";
- recordings of situations of software course;
- questionnaires.

3) *Data analysis*

The analysis of the data collected is based on a fine classification of the extracted requirements, according to several axes. These are outlined in the next section.

a) Data collected and requirements extracted from the documents

We consider a requirement as, "a statement, in natural language plus diagrams, of what services the system is expected to provide and the constraints under which it must operate. It is generated using customer-supplied information" [28] (p. 64).

142 expressions of requirements have been collected during the period from 10/01/2007 to 09/30/2009.

As far as possible, every requirement is characterized by different elements: its statement, the date it has appeared / has been mentioned the first time, by who, the methodology support and its status in the project (validated, rejected, in progress - expressed but neither rejected nor validated till the end of October 2009 - and implemented in our virtual reality tool) (see an example in Table 2).

TABLE 2. EXTRACT OF THE SUMMARY TABLE OF REQUIREMENTS

Module "bedroom"		
Requirement (example)		***To give ergonomic postures to 3D models***
Elicited	***When***	October 2007
	By who	Marketer LAMPA
	Means	Meeting
Validated ~~Rejected~~	***When***	November 2007 – ~~June 2008~~
	By who	Engineer + Designer + Marketer A Engineer + Marketer B Designer C ~~Engineer LAMPA~~
	Means	Questionnaire - ~~Meeting~~
Implemented	***When***	/
	By who	/
	Means	/

b) Coding of the characteristics of the collected requirements

The following coding scheme was applied to the 142 requirement

Each elicited requirement was dated relatively to the design process and associated with a type of participant who changed the state of the requirement. We also noted the source behind these requirement states.

We identified three phases in the design process: before, after and parallel. The phase before the design applies to the clarification of objectives and project milestones (Legardeur (2004) in [29]), the characterization of the current situation (modelling of the design process currently spread out in the three partner companies) and some requirements [30]. Phase parallel to the design concerns detailed specifications [14], choices and technological developments of models and prototypes [29] and the emergence of previously unconscious requirements [31]. The stage after the design applies for tracking of the product in its use situations [14], in which latent requirements arose.

The contribution of the 11 participant profiles has been studied: LAMPA engineer, LAMPA designer, LAMPA marketer, A engineer, A designer, A marketer, B engineer, B designer, B marketer, C designer and holders (D).

c) Dissection of the requirements into basic units of construction activities

The 142 characterized requirements were then dissected further into basic units of action. A basic unit corresponds to each possible action (to elicit, to validate, to reject, to implement) observed for a specific need (e.g. "allow a 3D character to have an action on an object") and is associated with an actor (e.g. B engineer, B marketer, A designer). Thus, the same action (e.g. to draw the requirement "allow a 3D character to have an action on an object") is divided into three action-units if this requirement was elicited by three actors (B engineer, B marketer and A designer). Moreover, if the designer had elicited two other requirements, for example "to develop a desktop environment" and "to have an avatar of a 4-year-old child in the database", we counted three acts for the A designer. In total, 576 actions-units were counted.

d) Statistical analyses

A preliminary statistical analysis based on relative sizes consisted of studying the distribution of construction actions according to the state of the requirements and the design phase among the three groups of participants (e.g. designer, co-designer of project leader).

The analysis was also used as a basis for a statistical analysis whose aim was to identify correlations between phases (e.g. before, in parallel, after) and state of the requirements (e.g. elicited, validated, rejected, implemented). We used the Cramer's V2[3] and relative deviations[4].

e) Analysis of evolution of construction of requirements

[3] Cramer's V2 is calculated by dividing the phi by the phi 2 max. The phi 2 max is the smallest dimension in the Table less 1. Phi 2 is the average of the Relative Deviation in the Table. Between 0 and 1 the link is considered strong for Cramer > 0.16, weak for Cramer <0.04 and intermediate between the two.

[4] The Relative Deviations (RD) are the discrepancies relative to independence. They are obtained by comparing between the data observed and those which would have been obtained if the two factors studied were independent. There is attraction when the RD is positive and repulsion when it is negative. The attraction is said to be remarkable for a RD ≥ 0.25.

The second analysis, clearly, was focused he number of requirements for each dynamics construction of the requirements. A “dynamics construction of requirements” is characterized by a series of actions at different stages. In others words, dynamics represents a sequence of actions associated to several requirements and falling within a specific temporality related to the 3 phases. We listed eighteen dynamics in which we divided the 142 elicited requirements (see Table 3).

TABLE 3. OBSERVED–DYNAMICS IN CONSTRUCTION OF REQUIREMENTS : DESCRIPTION, FREQUENCY AND PROPORTION

N°	Dynamics construction of requirements	Freq.	%
1	Elicited and validated before *(the design stage)*	4	2.8
2	Elicited before and validated in parallel	37	26.1
3	Elicited before and validated after	3	2.1
4	Elicited and rejected before	1	0.7
5	Elicited before and rejected in parallel	15	10.6
6	Elicited and validated before and rejected in parallel	3	2.1
7	Elicited before, validated and rejected in parallel	1	0.7
8	Elicited before, rejected then validated in parallel	1	0.7
9	Elicited and validated before then re-validated in parallel	6	4.2
10	Elicited before, validated in parallel then re-validated after	2	1.4
11	Elicited and validated in parallel	23	16.2
12	Elicited in parallel and validated after	1	0.7
13	Elicited and rejected in parallel	1	0.7
14	Elicited in parallel and not yet analyzed	10	7.0
15	Elicited and validated in parallel then rejected after	1	0.7
16	Elicited and rejected in parallel then validated in parallel	1	0.7
17	Elicited and validated after	2	1.4
18	Elicited after and not yet analyzed	30	21.4
	Total	142	100

This second analysis was used to support a statistical analysis based on the frequencies and percentages; the aim was to study the distribution of the different dynamics of evolution of requirements. For better understanding, we illustrate each dynamics with examples of requirements concerned by from the project (see Table 4). Moreover, each dynamics construction is decomposed into refined dynamics: we integrate the actors who initiated actions of expression, validation, rejection and “in progress”.

TABLE 4. LIST OF EXAMPLES FOR EACH DYNAMICS OF CONSTRUCTION OF REQUIREMENTS

N°	Example
1	Integrate 3D anthropometrics human characters
2	Choose between day and night ambiance
3	Save 3D scene as a film
4	Propose a car environment
5	Propose a shop environment
6	3D Avatars can adopt ergonomics positions
7	3D Avatars can interact with objects
8	Propose a kitchen environment
9	Change arrangement of objects in environment
10	Integrate our tool with a design software
11	Create 3D models acceptable by Virtools
12	Permit design validation
13	Integrate security norms and potential risks
14	Choose between seasons of a year
15	Simple and easy to use
16	To be able to slide a chair under a desk
17	To create an interface for accessing the database
18	To be able to load the software from network

C. Results

1) Analysis of construction activities

a) Intermediate link between states of requirements and phases of design

As shown by Table 5, the parallel design phase is the most important phase in the process of requirements: it represents more than half of the collected actions (306/576, i.e. 53%). “Before design phase” (211/576, i.e. 37%) and especially “after design phase” (59/576, i.e. 10%) are less important. The two main subset of requirements states were ones validated (239/576, i.e. 41%) and ones enonced without decision yet corresponding to the "enonced" category (179/576, i.e. 31%). Beyond these two main sets, 72/576 (i.e. 13%) were implemented requirements at the time we collected the data, and 86/576 (i.e. 15%) were rejected.

TABLE 5. STATES OF REQUIREMENTS VS. PHASES OF DESIGN: FREQUENCIES

	Before	**Parallel**	**After**	**All**
Elicited	102	44	33	179
Validated	99	120	20	239
Rejected	6	77	3	86
Implemented	4	65	3	72
All	211	306	59	576

The analysis of data shows an intermediate global link (Cramer’s V2=0.13) between the two variables “state of requirements” and “phase of design”. To go a step further, we look at local attractions between the two variables.

The analysis of RD shows that the “before design phase” is characterized by a strong attraction with elicitation of requirements (RD=+.56). Logically, a repulsion is observed with the state of rejected requirements (RD=-.81) and implemented requirements (RD=-.85).

The “after design phase” is similarly characterized by a strong attraction with the state of elicited requirements (RD=+.80). Conversely, a repulsion is observed with the states of validated requirements (RD=-.18), rejected requirements (RD=-.66) and implemented requirements (RD=-.59).

The analysis of RD shows the “design phase” is characterized by a strong attraction with the states of rejected requirements (RD=+.69) and implemented requirements (RD=+.70). Conversely, repulsions are observed with the state of validated requirements (RD=-.05), and more with the state of elicited requirements (RD=-.54).

b) Intermediate link between kind of participants and states of requirements

As presented in Table 6, co-designers have very much participated in the process of requirements: they represented more than half of the collected actions (318/576, i.e. 55%), followed by designers (225/576, i.e. 39%) and by holders (33/576, i.e. 6%). The distribution of « states of requirements » was analyzed in part a). However, it is presented in Table 6 for the sake of consistency.

TABLE 6. STATES OF REQUIREMENTS VS. KIND OF PARTICIPANTS: FREQUENCIES

	Designers	**Co-designers**	**Holders**	**All**
Enonced	53	125	1	179
Validated	65	154	20	239
Rejected	35	39	12	86
Implemented	72	0	0	72
All	225	318	33	576

The analysis of data shows an intermediate global link between the profile of participants and the state of requirements (Cramer's V2=0.14). In the following part, we focus on local attractions between the two variables.

The analysis of RD shows the state of elicited requirements is characterized by a strong attraction with co-designers group (RD=+.26). Conversely, a repulsion is observed with designers group (RD=-.24), and still more with holders group (RD=-.90).

Validated requirements are characterized by a strong attraction with holders group (RD=+.46), and a repulsion with designers group is observed (RD=-.30), while co-designers group contribute proportionately lower (RD=+.17).

We observed a strong attraction between holders group with the state of rejected requirements (RD=+1.44), while designers group (RD=+.04) and co-designers group (RD=-.18) seem less contributed to the rejection of requirements.

Implemented requirement are strongly attracted by the designers group (RD=+1.56), and conversely repulsed by co-designers group (RD=-1.00) and holders group (RD=-1.00).

c) Intermediate link between kind of participants and phases of design

The distributions of « phases of design » and « kind of participants » were analyzed in parts a) and b), respectively. With a view to being consistent it is presented in Table 7.

TABLE 7. KIND OF PARTICIPANTS VS. PHASES OF DESIGN: FREQUENCIES

	Before	**Parallel**	**After**	**All**
Designers	59	161	5	225
Co-designers	149	115	54	318
Holders	3	30	0	33
All	211	306	59	576

The analysis of data shows an intermediate global link (Cramer’s V2=0.08) between the variables “kind of participant” and “phase of design”. To go further in the analysis, we look at local attractions between the two variables.

The analysis of RD shows the “before design phase” is characterized by a strong attraction with co-designers group (RD=+.28), and conversely a repulsion with designer group (RD=-.28) and even more with holders group (RD=-.75).

The “design phase” in characterized by a strong attraction with holders group (RD=+.71) and with designers group (RD=+.35), while co-designers contribute lesser (RD=-.32).

We can observe that co-designers participate strongly after design (RD=+.66) and designers participate lightly (RD=-.78), and the holders group don’t contribute at this phase (RD=.-1).

2) Analysis of construction dynamics

The frequency and proportion data (see Table 3.) show most of the dynamics (61.3% of all) with a basic schema of construction like elicitation followed by validation (49.3% of requirements) or elicitation and rejection (12% of requirements).

This data shows other dynamics of construction of the more complex requirements (10.5% of total dynamics): 5.6% of requirements were elicited and validated and re-validated, 3.5% of the requirements were elicited then validated then finally rejected and 1.4% of the requirements were elicited then rejected then finally validated.

This data also highlights construction dynamics of requirements which proceeded for one phase, two phases or three phases. Thus, 22.5% of dynamics proceeded within one phase, 47.9%

proceeded across two phases and a very small subset 1.4% proceeded for three phases.

IV. DISCUSSION

In participative design, users (or co-designers) imagine solutions before design, evaluate suggestions proposed by designers or by other co-designers during design phase, and play the role of future users who would utilise the future artefact [11]. Our study confirms that designers and co-designers contribute to the process of construction of requirements with elicitation, rejection, and validation acts. A strong attraction is observed between co-designers and state of elicited requirements. Conversely, designers contribute more to the implementation of requirements. The holders contribute mainly to validation and rejection acts.

In industrial engineering, the identification of requirements [22] is associated with the before-design phase [12, 13]. Previous ergonomics studies have suggested that these states are associated with before-design phase but also during the design and after-design phases [14-16].

Our study confirms that the requirements are mostly elicited during before-design phase and during after-design phase, and less in the design phase

The states of validated requirements and rejected requirements characterize one of the approaches of the “requirements engineering” which regards the process of construction of the requirements as a process of decision making [20, 21]. This selection is made during design process in “requirements engineering”, while is made before design phase in industrial engineering [12, 13]. Our study confirms that findings and highlights a strong correlation between design phase and state of rejected requirements.

The state of implemented requirements was approached by [24]. The realization is intrinsic at design process [12, 14, 24], but it can continue after design [15, 16]. Our study only shows truthfulness of the first approach: requirements are implemented during design phase.

The process of construction of requirements begin with elicitation and end with implementation, while passing through validation and rejection [19]. Our study provides new evidence on the implementation of dynamics of construction of basic requirements: requirements are elicited and validated or elicited and rejected. We also highlighted some more complex dynamics of construction of requirements; they are:

- elicited and not yet analyzed at the current state of progress
- elicited and doubly validated
- elicited and validated and then rejected
- elicited, first rejected and then validated.

V. CONCLUSION AND PERSPECTIVES

The objective of this paper is to deepen current knowledge on participative design. The method used was participant observation during a longitudinal study of 2 years. The artefact designed is a Virtual Reality Software for Product Design. The virtual reality systems can reduce costs and design time by facilitating decision making. This study describes the acts of construction of requirements, the dynamics of construction of requirements and the contribution of each participant to these processes.

From the point of view of research, it appears interesting to carry out a detailed analysis of the construction of the requirements before design. Our study shows the importance of integrating the component "users" in the design’s methods of virtual reality systems for which the resolution of technological problems remains a priority.

From the industrial point of view, the results of this study are invaluable to continue the design of our virtual reality tool in order to adapt the initial version to other users. Some requirements are elicited during and after design. So, it seems appropriate to incorporate similar software to raise awareness of the constraints and technological potentialities, with the future users in order to give birth to new requirements. It would be interesting to put to test the current version of the software in the companies potentially interested in our virtual reality system and not having been involved in the process of design.

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