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Usefulness and needs construction process in innovative software: an exploratory study of designers' viewpoints

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Abstract
Virtual Reality(VR)-based software, as any software, implies multidisciplinary teams composed of engineers in computer science, graphic designers and ergonomists. These designers with heterogeneous and various backgrounds have to dialog together to satisfy users' needs in the software design. This depends on their representations and viewpoints. This paper explores how the usefulness and needs construction (phases, methods, tools and stakeholders) are currently considered in design literature and by different designers' profiles through their viewpoints. Semi-structured interviews were performed with 10 designers and collected verbal data were qualitatively and quantitatively analyzed. Qualitative analysis used *verbatims* from the corpus. Quantitative analysis was based on a discursive analysis with TROPES and a geometrical analysis using a principal component analysis. Results suggest that 1) viewpoints are often specific to a designer profile because of specialized literature, professions and background; 2) some viewpoints are common to several designers' profiles probably because of experiences and their former integration in multidisciplinary projects. These findings allow us to advocate some recommendations to project leaders (e.g. prioritize an interdisciplinary relationship and organize frequent meetings between these three profiles in order to share these viewpoints, through various tools and methods of collaboration) and to suggest a scientific perspective for future study on intra-group variability.

1. Introduction

Usefulness and needs are considered as major criteria in software design (Nielsen, 1993; Berander & Andrews, 2005) together with other important criteria such as usability, accessibility or acceptability. Yet, the lack of usefulness has been often stressed in the context of innovative software, that is the existence of a mismatch between the goals of the user and those made possible by the artifact (Blandford & Green, 2008). Designing useful VR-based software mobilizes stakeholders with different expertise fields have to dialog together on usefulness and needs. But, how is the usefulness currently considered by these different design stakeholders? To answer this question, the present study aims at analyzing designers' viewpoints (also called representations) about processes as well as concepts related to usefulness, with a specific focus on how they define it, the methods and tools they mobilize in needs construction process and the way they represent the users and the other stakeholders. Because designers profile and role related to users can have an effect on the way usefulness is apprehended, we have contrasted three profiles of designers: engineers, graphic designers and ergonomists.

De Vries and Masclet (2013) explain that representations in the field of design studies can be individual or collective. Individual representations refer to "viewpoints" which specify the content of individual representations that appears to be specific to a design domain, a discipline and a social situation (Détienne et al., 2005), while collective representations can be illustrated by the concept of "boundary objects" which is an "entity used by several different communities but viewed or used differently by each of them" (Star & Griesemer (1989) as cited by De Vries & Masclet (2013), p. 48). In addition to the distinction between individual and collective representations, these authors distinguish:

- Internal representations which are 'entities in the mind' (p. 48): for example, mental models are individual internal representations and social representations are collective internal representations;
- External representations which refer to entities in the environment allowing one 'to interact with the objects, relations and phenomena relevant for solving a problem' (p. 48): typically, intermediary objects such as texts and mock-ups are both individual and collective external representations.

In design, collective representations involve individuals with different backgrounds and then different internal or external viewpoints. The "thoughts" (which we describe as "points of view") of the different designers are specific to their discipline and education (Santos et al., 2020). However, user-centered design requires a "multidisciplinary design approach" (Mao et al., 2005). Aoussat et al. (2000) refer to a transversal discipline between different designers that could be interpreted as transdisciplinarity. In order to clarify this, Jantsch (1972) proposes a hierarchy of disciplines: multi, pluri, inter and transdisciplinary. The last would be the ultimate level of integration where work is done at all levels of the structure. Multidisciplinarity and pluridisciplinarity occur at the bottom of the pyramid. Although there may be some interaction, these two relationships are not coordinated towards a common goal in contrast to interdisciplinarity. For this reason, we will use the term of viewpoint in the paper.

This article is organized as follows. In the second section, we describe the theoretical framework on usefulness and needs satisfaction in design and empirical studies regarding designers' viewpoints on the consideration of the needs in design. In the third section, we describe our methodology based on a discursive analysis, a geometrical analysis and a qualitative analysis of verbalizations produced by designers during semi-structured interviews. In the fourth section, we present the results. To finish, we discuss and conclude on some recommendations for project leaders in design of innovative software and on perspectives for future studies.

2. Designing for usefulness: from users' needs elaboration to their satisfaction by the way of the designed artifact

From our view, usefulness refers ultimately to the artifact's quality of providing supports to actual users' goals, and specifically those required and (spontaneously) expected. As part of a usefulness-centered approach, the question is first to understand when, by whom, on what basis of information and how needs[1] are treated in order to be transformed into a list of functions and non-functional properties, so that a real benefit in a contextualized situation exists for the user, compared to what already exists. To provide some answers to these questions, it is necessary to provide definitions of key concepts, review the various fields of literature about the methods and tools advocated by people involved in design, relatively to their profile, as well as viewpoints of usefulness and the consideration of the needs in design.

2.1. Design for usefulness: main definitions and framework

1 In this article, needs are explicitly assimilated to user needs (Anastassova et al., 2007), while requirements are specified by the designer (Rolland et al., 2004).

2.1.1. A framework for analyzing usefulness issues in design

The notion of usefulness is discussed in various disciplines implicated in design and concerned with the needs construction: ergonomics, requirements engineering, software engineering, industrial design, etc. Obviously, there are multiple definitions for usefulness and, in the same manner, there are several terms that refer to some aspects of usefulness like utility, needs satisfaction, etc. A framework to account for the process and the various steps of activity that emerge from comparing themes and approaches specifically dedicated to usefulness in these different fields have recently proposed (Loup-Escande et al., 2011). Issues related to usefulness can thus be analyzed by combining two axes representing 'what' is referred to when speaking about usefulness, and the steps of activity related to its 'reification' during the design process, as shown in Table 1.

Table 1. Dimensions of the usefulness and phases of the process of centered-usefulness design.

	Prospective universe: production of hypotheses on	Decision and implementation	Retrospective universe: measurement and evaluation
Utility-purpose of the artifact	Features, services, and possible dialogues; Possible non-functional properties;	Prioritization and decisions about features, services, interfaces and dialogues to develop	Measurement of the choices relevance; Identification of the failures
Usefulness-value for the end-user	Expected benefits (qualitative and quantitative hypotheses)	Selection and operationalisation of hypotheses privileged in terms of benefits and advantages	Measurements of the benefits and the advantages

'What' refers here to the (list of) description of functionalities and properties of the software artifact (often referred to as 'utility' or 'purpose'), and to the extent to which a proposed solution responds satisfactorily to the 'needs' of users, namely the significant advantage associated for their concrete users ('value' for user). The reification process is composed of three steps/activities that do not necessarily imply a strict sequential cutting (Table 1). The first set of activities concerns the production of 'needs' and the generation of candidate specifications. The second set concerns the decision-making with regard to a considered range of options and the formalization of the specifications which will serve to the basis for implementation. The third set of activities represents those related to the measurement and the evaluation of the usefulness associated specifically with the use of an existing artifact in the situation.

The three sets of this process have been introduced to represent the developmental dimension of design (Schön, 1983; Bucciarelli, 1994; Rabardel & Beguin, 2005). We see this process as a constant dialectic between a prospective universe (representing what is imagined by design participants in terms of potential goals, needs and situations of uses) and a retrospective universe (representing what can be actually experienced with existing artifact(s) at each moment) throughout the design process. This dialectic starts before the implementation and the realization of the artifact to be designed, where the usefulness, as the form and the details of the software, remains vague and hypothetical, to the phase after the implementation where the final shape is experienced and continues to evolve in use (Rabardel, 2005). The emphasis of both worlds comes from the idea that the real usefulness of software is largely determined by how these two worlds are explored in detail and how this exploration is carried out with a strong articulation between the various designers' contributions (Tichkiewitch, & Brissaud, 2000) and users' contributions (Muller et al., 1997; Reich et al., 1996; Von Hippel, 2005) to the design. Do not build and explore one of these two worlds, or do it partially or superficially, could induce the risk to define a new software artifact providing little or no improvement of the existing solution, regarding constraints, the failures observed and assistance to the objectives pursued by users. Even if there is an improvement, another risk is that improvement relates to functional or non-functional aspects with low value for users. It is possible also that the utility (purpose) of the software does not match any (actual) purpose or needs of users, resulting in the best case in the creation of a new use without necessarily responding to the needs that exist before.

Additionally, the analysis of the literature based on this framework enables us to emphasize the heterogeneity of prescriptions and covered thematic across disciplines in the way they consider issues related to usefulness, in terms of approach, key actors, methods and tools. This is briefly reviewed in the next section.

2.1.2. Heterogeneity and specificity of disciplinary viewpoints about usefulness

Design frameworks, methods and tools recommended in the literature are heterogeneous. Depending on the discipline, there are specific emphases on some issues related to usefulness as well as it appears specific gaps in covering some other issues. For example, the engineering and ergonomics literature deals with the issue of needs production more broadlythan the industrial design literature. The key actor related to the production of needs also depends on the discipline. In engineering, needs identification is usually based on the backers' requirements (e.g., Alenljung & Persson, 2008; Aurum & Wohlin, 2003). This is in contrast with ergonomics recommended approaches, where needs identification is based on task and activity analysis of (real/future) end-users (Mollo & Falzon, 2004; Anastassova et al., 2005b; Kujala, 2003). In industrial design, some needs which are 'unexpressed' by users are anticipated with specific methods and tools which allow to extend the field of the possibilities and even to be creative (e.g., Bruseberg & McDonagh-Philip, 2002; Bonnardel & Zenasni, 2010; Bouchard et al, 2008). Such a creative dimension of design has been far less seriously considered in ergonomics and user-centered design (but see Gero, 2010).

Prioritization and selection of needs in design are only addressed in engineering and ergonomics literature. These two disciplines differ mainly about the user involvement in this selection process: when engineering recommends the selection and prioritization of needs by the designers themselves (Ma, 2009; Berander & Andrews, 2005; Lehtola & Kauppinen, 2004), ergonomics recommends the contribution of users to the decision phase (e.g., Plos et al., 2007, Loup-Escande & Christmann, 2013).

Finally, there are a variety of methods to assess the usefulness in the engineering, industrial design and ergonomics literatures. In engineering, functionalities of concurrent software are evaluated to judge those that can be reused for the design of future software (e.g., Richir et al., 2016). In industrial design, evaluation is usually realized by the graphic designers themselves, who play the role of users. To a lesser extent, graphic designers ask real end users to assess non-functional prototypes; but this evaluation comes down to 'it's well' or 'it isn't well' (Hasdogan, 1996). In ergonomics, evaluation of prototypes is made by end users who can propose new functionalities and measure the benefits of the software in comparison with the reference situation (Anastassova et al., 2007). The huge variety of these definitions, frameworks, methods and tools suggests different viewpoints of the utility, usefulness and needs construction among designers having different disciplinary backgrounds.

2.2. Methods, tools and procedures advocated in the design disciplines

Some methods and tools are specific to each discipline of design and to each phase of the design process. For the production phase of hypotheses about the purpose and the expected benefits, the engineering literature advocates tools such as the needs document (Alenljung, 2005; Aurum & Wohlin, 2003; Macaulay, 1996) or the functional specifications document (Richir et al., 2016). These documents - which formalize backers' requirements - describe the purpose of the artifact, while the industrial design has more tools (e.g., tool TRENDS which is a content-based information retrieval system for designers, Bouchard et al., 2008) and methods (e.g. brainstorming) to promote the invention of new features, properties and uses of the artifact (e.g., Bruseberg & McDonagh-Philip, 2002). Beyond this type of methods also recommended in the ergonomics literature, this discipline has methods (e.g., interviews, observations, allo-confrontation) and tools (e.g., activity patterns, task templates) based on the needs and the activity, which allow to construct hypotheses about the benefits and advantages of the application to design (e.g., Anastassova et al., 2005a; Mollo & Falzon, 2004).

For the decision and implementation phase, there are two kinds of methods and tools: those of prioritization and those of formalization. The methods for prioritizing needs, alternatives and assumptions are mainly represented in the engineering requirements literature (e.g., Berander & Andrews, 2005; Karlsson et al., 1998): in the nominal scales methods (e.g., Moscow which involves grouping requirements into four priority groups: requirements that the system [must/should/could/won't have] meet in a new version, (Ahmad et al., 2017)), requirements are assigned to different priority groups; ratio methods (e.g., 100 dollars which consists of asking users to allocate a sum of money to each need (Berander & Andrews, 2005) provide relative difference between requirements; ordinal scales methods (e.g., filing single) produce an ordered list of requirements. To formalize the requirements, engineers adopt a procedure of decomposition in functional subsystems (Dorfman, 1997).

The phase concerning the measurement and evaluation of the usefulness is performed on the basis of existing tools like technology scouting (Richir et al., 2016) and ergonomic benchmarking (Nogier, 2005), whose results sustain the prospective universe of the usefulness. The iterative evaluation by designers can be used during the design process. This assessment, called differently according to the disciplines of design, also has different objectives depending on the perspectives: self-modeling design is mainly the improvement of non-functional properties (Hasdogan, 1996), ergonomic inspection seeks to modify goals and qualities of the artifact so as they correspond to the user (Bastien & Scapin, 1993), while iterative tests in engineering aim to identify technical dysfunctions to correct them (Kruchten, 2007). Assessment methods involving end-users of the artifact (e.g., scenarios, use cases, personas) are used primarily in design and ergonomics (Carroll, 1995; Carroll, 2000; Cooper, 1999).

For each of these design phases, Kaulio (1998) explains that there are three types of user involvement: "design for" refers to an approach in which users are used to design technologies, "design with" is an approach using data on user needs as in a "design-for" approach, but also includes users reactions to different proposed solutions, and "design by" denotes an approach in which users participate in the design of their own technology.

2.3. Empirical studies of designers' viewpoint about usefulness and the best way to satisfy users' needs

Few studies deal explicitly with viewpoints concerning usefulness and the best way to satisfy users' needs.

As far as we know, two studies have focused on designers' viewpoints on the users' needs but not specifically in software design (Darses & Wolff, 2006; De La Garza & Fadier, 2005). A third study (Alenljung & Persson, 2008) has been focused on how the designers represent themselves their own contribution to the process of needs construction. The fourth study (Loup-Escande et al., 2014) is an analysis of the activity and the process of requirements construction within a real design community and project.

The study by De La Garza and Fadier (2005) was situated in the domain of printing machine design. The authors were interested in how users' needs in terms of safety were taken by designers into account in the design process. The authors combined two approaches. The first one was to analyze design documents in order to observe how users' needs related to safety are actually presented; the second approach was to analyze the content of designers' viewpoints with different profiles (i.e., project managers, generalist engineers, specialist engineers, project designers) on the topics related to the design of safe machines (e.g., security or known risks in relation to health and safety of future users). The authors performed a systematic content analysis of designers' verbal data collected through semi-structured interviews. The results show the specificity of designers' viewpoint related to user's safety needs depending on their professional profile. The specialist engineers have a machine-centered representation of safety, while the generalist engineers and project designers tend to take into account the environment and the users of the machine. The authors also point out that designers, whatever their profile, have an incomplete and extremely partial mental representation on the users' needs and equipment uses. This can be explained by a model of the machine in which the user is absent (integral automatic functioning), and in which the intervention in case of failure doesn't pose a safety problem because the machine is stopped.

Darses and Wolff (2006) investigated the designers' viewpoints about users' needs, in the design of a cutting machine of composite bodywork elements. The authors analyzed seven design meetings involving designers. A thematic analysis of these verbalizations was conducted. The results emphasize some of the factors explaining a low relevance of designers' representations about users and their needs. The results indicated three main ways of integrating users and their activity in the representations observed during these meetings. Most frequently, designers represent users as "subsystems" of the main system: their needs are examined only regarding their interactions with the technical system. In this case, designers seek to know what actions users would make in the overall system. A very less frequent mode is to consider the users' needs through an imagined scenario in which the designers try to adopt the user's perspective, simulating their actions and their reasoning. The designers then imagine how future users will perform their tasks. A third (even less frequent) method is to consider users' needs through general principles concerning the human element. This study highlights that the needs are essentially anticipated by the designers based on their own representations of users' "ordinary" behavior, and not through data collected from users.

Alenljung and Persson (2008) conducted a study on the viewpoints that the requirements engineers have on their own contribution to the needs construction process. The methodology is based on interviews and a focus group session. The results show that engineers' viewpoint of their own participation to the needs construction process concerns essentially two phases: (1) identification of requirements and (2) management of need changes. They consider users' needs identification as the identification of backer's requirements and the analysis of existing solutions in order to reduce the space of possibilities and finally to evaluate and select alternative solutions. This phase is seen by engineers as an activity which requires creativity and teamwork. The second phase is more individual and refers to managing requirements changes during the whole project.

These three studies suggest that designers have only a partial and variable viewpoint on the users' needs according to their profession. However, they do not explicitly deal with the usefulness of the artifact and they give no information about the means used to take into account the needs and usefulness in the design. Another limitation is that only engineer's profile is involved in these studies, whereas other stakeholders (e.g., users) and design disciplines are also involved in the consideration of the needs through design models and processes. For example, in their study concerning the design of a virtual reality software, Loup-Escande and al. (2014) describe the acts of construction of needs, the dynamics of construction of needs and the contribution of each stakeholder to these processes. The methodology is based on the participant observation and longitudinal study. The results show that users contribute more than designers and backers to the needs design process, in particular during the production and evaluation phases. The degree of user involvement in the process is both a factor and a consequence of the representation that the designers have about the design and usefulness of an artifact. But, even if this study describes the effective contributions of stakeholders to the design process, it does not deal with them viewpoints which could explain or justify these observations.

2.4. Aims and originality of our study

Our study aims at providing an investigation of viewpoints of different designer's profiles (i.e., engineers, graphic designers and ergonomists) about the usefulness and needs construction during the design process.

This study is interesting and original for three reasons. First, focusing on a specific criterion for software product design (i.e., usefulness), it is provided an empirical evidence to a statement mentioned very / too often without real justification. Second, it is described how the criterion "usefulness" is understood, implemented and used in the design. Third, the results about common and specific viewpoints described are a basis that allows designers to exchange between us, to construct a better mutual understanding of usefulness in design and to promote a better integration of usefulness in the design process. This last point is particularly important since the design teams are often multidisciplinary.

3. Methodology

3.1. Participants

Ten designers were involved in the study. They were three different background and profession profiles: two graphic designers, four engineers and four ergonomists. The two graphic designers work on innovative artifacts, the four engineers are specialists in computer science and the four ergonomists work on technological research projects. As described in Table 2, participants have 39 years in average (Min = 27; Max = 53 years; S.D. = 10 years). They had between 1 and 25 years of experience (average = 12 years; S.D. = 8 years).

Table 2. Profiles of the interviewed designers.

Designer profile	Age	Experience	Gender	Occupation
Graphic Designer	34	10	Woman	Consultant designer and teacher
Graphic Designer	51	17	Man	Consultant designer and teacher
Engineer	31	1	Man	Engineer in computer science
Engineer	37	13	Man	Assistant professor in computer science
Engineer	29	3	Man	Engineer in computer science
Engineer	53	25	Man	Assistant professor in computer science
Ergonomists	45	22	Man	Professor in ergonomics
Ergonomists	51	16	Man	Ergonomists
Ergonomists	27	2	Man	Researcher in ergonomics
Ergonomists	32	7	Woman	Researcher in ergonomics

To recruit participants, an email describing the context and the overall purpose of the interview was sent to a list of people, who have an experience recognized in the field of design of new technologies (e.g., virtual reality). This list was established based on background and profession of potential participants (e.g., software engineering, ergonomics and innovative design), their position (e.g., practitioner) and when relevant their research areas identified in relation to their publications (e.g., prospective ergonomics, requirements engineering). All persons who answered positively have participated in an interview.

3.2. Semi-structured interviews

Semi-structured interviews were conducted individually by the first author. After having collected biographical data about the interviewees (current position, past positions and experiences, background, age), the interviewer asked the designers to focus on their past incremental innovation projects and to explain and illustrate how they processed in order to take into account the needs and the criterion of usefulness at different moments of the design process of the software artifact. For that, the interview began with a general question (e.g., *"By basing yourself on past and experienced projects, I would like you explain how you have managed to gather needs?"*), and some specific questions (e.g., "*What methods have you deployed?, What people have you met?"*). And, four other specific topics related to the role of creativity (e.g., *"Always based on real-life projects, I would like you to explain how you went about generating ideas about possible uses of the product or alternative solutions?, Have you ever used creativity methods during the needs gathering phase, or during the specifications definition phase?"*), the way needs have been formalized (e.g., *"How did you go about formalizing these needs? Who formalized (one or more people, profession)?, Did the formalization require a new needs assessment?"*), the conversion of needs into specifications and / or functionalities (e.g. *"How did you go about transforming these needs into specifications?, What methods* *were used?, Who made this transformation (one or more people)?, Which people were brought together (number, profile)?, How did you go from an analysis of the activity to a specification?, What was the role of business modeling in this transition?, What was the role of business modeling in this transition?"*), the usefulness evaluation (e.g., *"How did you evaluate the usefulness of the device being designed or already designed?, What methods have you deployed?, What people have you met?, Who evaluated?, At what point in the process did this take place (before, during or after use)?"*), were processed. The order of topics could change according to the interview progress and the more or less spontaneous introduction of the themes of the interview guide.

3.3. Collected data

The interviews lasted 40 minutes in average (Min = 26; Max = 77 minutes). The total duration represented 6 hours and 50 minutes. All interviews were transcribed verbatim. A corpus of 34 923 words representing 2344 lines of text after having deleted interviewer's questions and optional interventions, was obtained.

3.4. Verbal data analysis

The method to analyze the recorded interviews was twofold. Firstly, a categorical content analysis, whose basic principle is the grouping of similar objects under a common category (Strauss & Corbin, 1998) was carried out. For that, the TROPES software was used, this is based on semantic analysis of textual corpus and allows cognitive analysis of a discourse[2] using dictionaries of "reference worlds" (called "scenario") composed of "semantic equivalents" (e.g., Wolff et al., 2005). The scenario used for analysis was manually adapted by the analyst, according to the objectives of the study.

Secondly, verbal excerpts specifically associated to main categories and observed associations between categories and profiles were extracted from the corpus. This qualitative analysis enables us to clarify and illustrate the results based on projects and situations elicited by participants during the interviews.

3.4.1. Definition of the TROPES scenario used in our analysis

The scenario for analysis has been elaborated to observe the main themes (Table 2) related to the several dimensions of usefulness and needs processing in the participants' discourse. These main themes have been selected on the basis of our framework, because there are five issues associated with usefulness in design and can explain heterogeneity and specificity of disciplinary viewpoints:

- Utility-purpose and usefulness-value;
- Usefulness as a response to needs;
- Needs construction phases;
- Tools of the needs construction process;
- Stakeholders explicitly associated with the needs construction process.

These five main themes are decomposed into fifteen subthemes associated to our scenario. Some subthemes are decomposed in sub-subtheme. Each subtheme or sub-subtheme has semantic equivalents. Semantic equivalents correspond to the sense units directly associated with a subtheme (e.g., "benefit", "advantage" and "activity" for the subtheme "usefulness-value") or with a sub-subtheme (e.g., "choice", "choose", "decision", "selection", "select" for the sub-subtheme "selection acts"). Subthemes, sub-subthemes and their semantic equivalents represent a hierarchical decomposition which corresponds to an increasing level of detail in our analysis (i.e., the total number of sub-subtheme for a subtheme is equal to the total size for this subtheme). This hierarchical decomposition is presented in Table 3.

Table 3. Main theme, subtheme, sub-subtheme and semantic equivalent.

Main theme	Subtheme	Sub-subtheme	Semantic equivalent
Utility-purpose and usefulness-	Utility-purpose	Function	Functionality
		Concept	

2 For a detailed description, see (Ghiglione et al., 1998).

value		Service	
		Specification	Recommendation, solution
		Requirement	
		Constraint	
	Usefulness-value	Activity	
		Advantage	Benefit
		Need	Lack, expectation, request
Phases of needs construction process	Prospective universe	Collection/identification acts	Collect, emerge, expression, express, inference, infer, collection
		Imagination acts	Imagine, anticipate, guess, ideation, imagination, exploration
	Needs formalization	Rewording acts	Reword, transform, reformulation, transformation
		Formalization acts	Formalize, model, formalization, modeling
	Needs selection	Selection acts	Choose, select, choice, decision, selection
		Priorization acts	Priorize, priorization
	Retrospective universe	Reuse acts	Reuse
		Correction acts	Correct, modify, improve, improvement, correction, modification
		Evaluation acts	Evaluate, adequacy
Tools and methods	Needs production tools	Needs collection/identification tools	Interview, classical analysis of work, activity analysis, self-confrontation, theoretical model, ergonomic models, observation, appointments, meeting, actor schema
		Tools and methods of creativity	Brainstorming, focus group, persona, creativity, scenario, script
	Needs formalization tools		Task models, activity models, specifications report, task model in computer, production tools of needs
	Needs evaluation tools	Artifact representations	Prototype, model, drawing, draw, prototype, prototyping
		Evaluation methods	Usability testing, longitudinal study, carnet de bord, film, retour d'expérience, vidéo
Stakeholders	Designers		Software developer, ergonomist, graphic designer, engineer, designers, team, ergo, student, graphic designer, computer, information system division, specializing in human computer interaction
	Backers		Director, representative, association, customer, backer, company, association, steering committee, decision maker, industrial organization, partner, non-disabled person, person without disabilities, work division, responsible, contractor
	End-users		User, operator, blind, business, community, consultant, child, expert, people with low vision, business, parent, senior citizen, disabled person, salesperson

Finally, the Tropes scenario was validated by a third person.

In order to enable the use of our final scenario for the analysis, the corpus is prepared by indicating some expression structures in order to enable TROPES to count these expressions as a whole. For example, the term “specifications report” has been represented as “specifications_report”.

3.4.2. From a discursive analysis to a geometrical analysis

The statistical analysis is based on the counting of the frequencies of our coded categories as they are observed in each individual discourses. These frequencies are calculated directly by TROPES software. A total of 1732 units for all participants were obtained. The units have been counted by theme for each participant. Two analyzes follow.

On the one hand, these numbers of occurrences for each theme and for each designer's profile were added: engineers, ergonomists and graphic designers. The result is a data table which crosses themes and designer's profiles (Table 4).

Table 4. Main themes *vs.* designer's profiles: frequencies.

	Engineers (N =4)	**Ergonomists (N=4)**	**Graphic designers (N=2)**	**All**
Utility-purpose and usefulness-value	69	110	34	**213** (13%)
Usefulness as a response to needs	184	147	15	**347** (20%)
Design phases	115	114	16	**245** (14%)
Tools used	59	166	58	**283** (16%)
Stakeholders involved	183	316	145	**644** (37%)
All	**611** (35%)	**853** (49%)	**268** (16%)	**1732** (100%)

On the other hand, the data table obtained from the frequencies of occurrences is composed of 10 rows (10 speakers) and 15 columns (15 subthemes). For each row (participant), a qualitative marker called structuring factor (for a detailed description, see Le Roux & Rouanet, 2004) was added to index the profile of each interviewee (engineer, graphic designer, ergonomist) in order to interpret the participants' speech.

This table, composed by 15 numeric variables, was used to perform a standard Principal Component Analysis. PCA is intended to summarize and to visualize the important information of a dataset by extracting multivariate data and by creating a set of new variables or principal components (Jolliffe and Cadima, 2016). Five axes were selected for this analysis (which represents 80% of the variance). Two clouds were then elaborated: the cloud of the variables and the cloud of the barycenters which was constituted from the factor "profile of the designer" (engineer, graphic designers, and ergonomist).

3.4.3. Qualitative analysis

For a more detailed analysis (e.g., the distinction between "collection acts" and "imagination acts" in phase "prospective universe"), a qualitative analysis was performed in order to clarify and to explain the use by an interviewee of special attributes related to a category or a subcategory. This qualitative analysis is illustrated with examples of sense units extracted from the analyzed corpus.

4. Results

4.1. General results

4.1.1. Qualitative analysis Global results about participants' contributions and themes distribution

The amount of verbalizations differed depending on the profile of participants (Table 3). Ergonomists produced the most units in the speech related to our themes (853/1732; i.e. 49%) followed by engineers (611/1732; i.e. 35%) and by graphic designers (268/1732; 16%) who were only two, so they are underprivileged in all frequency tables.

The most represented theme in the designers' discourse concerned "stakeholders involved in the design" (37% of the units; i.e. 644/1732). It is followed by references to "needs" (20%; i.e. 347/1732). The three following categories were less evocated: “tools” (16%; i.e. 283/1732), “design phases” (14%; i.e. 245/1732), and references to “utility-purpose or usefulness-value” (13%; i.e. 213/1732).

4.1.2. Global results about participants’ contributions and subthemes/sub-subthemes distribution

As presented in Table 5, ergonomists are those who talk the most about usefulness: they produced more than half of the collected discourse (110/213; i.e. 52%). They are followed by engineers (69/213; i.e. 32%) and by graphic designers (34/213; i.e. 16%). The discourse of participants was quite focused on utility seen as a purpose for use (186/213; i.e. 87%, e.g. *“there are needs transformed in functions”*) rather than on usefulness seen as a value actually brought to users (27/213; i.e. 13%; e.g. *“we will describe this activity”*). This difference can be explained by a dominance in design of utility limited to the functionalities of a software artifact, whereas usefulness in the sense of value measuring the appropriateness of these functions to the user's goals and the contexts in which use takes place are still only apprehended today in user-centered design approaches.

Table 5. Definitions of utility/usefulness vs. designer’s profiles: frequencies

	Utility-purpose	**Usefulness-value**	**All**
Engineers	67	2	**69**
Ergonomists	87	23	**110**
Graphic designers	32	2	**34**
All	**186**	**27**	**213**

As presented in Table 6, those who evoke the most the usefulness as a response to needs are engineers (185/347; i.e. 53%) and ergonomists (147/347; i.e. 42%). The graphic designers used few terms associated with this definition of usefulness (15/347; i.e. 4%). Usefulness is mainly evoked in the speeches by the word “need” (215/347; 62%; e.g. *“an expression of needs”*). Other words are less frequently used: “requirements” (83/347; i.e. 24%; e.g. *“these specifications, these formalized requirements, by taking into account the technical possibilities”*), “request” (28/347, i.e. 8%; e.g. *“there is a request”*), “constraint” (13/347, i.e. 4%), “expectation” and “lack” (respectively 4/347, i.e. 1%).

Table 6. Usefulness as a response to needs vs. designer’s profiles: frequencies

	Need	**Lack**	**Expectation**	**Constraint**	**Request**	**Requirement**	**All**
Engineers	96	1	0	4	1	83	**185**
Ergonomists	114	3	4	0	26	0	**147**
Graphic designers	5	0	0	9	1	0	**15**
All	**215**	**4**	**4**	**13**	**28**	**83**	**347**

As presented in Table 7, those who evoke the most about the phases of needs construction process are engineers and ergonomists (respectively, 115/245; i.e. 47% and 114/245; 47%), followed by graphic designers (16/245; i.e. 7%). The prospective phase (i.e. which corresponds to the needs production) was largely present in the analyzed speeches (92/245; i.e. 38%; e.g. *“we try to imagine a lot of things concerning the product”*), followed by the artifact evaluation phase (66/245; i.e. 27%; e.g. *“end users are present to evaluate the product”*) and needs selection phase (50/245; i.e. 20%; e.g. *“we must make a decision”*). The phase of needs formalization was the less evoked by the participants (37/245; i.e. 15%).

Table 7. Design phases vs. designer’s profiles: frequencies

	Prospective phase	**Needs formalization**	**Needs selection**	**Retrospective phase**	**All**

Engineers	24	19	36	36	**115**
Ergonomists	6	17	11	26	**114**
Graphic designers	8	1	3	4	**16**
All	**92**	**37**	**50**	**66**	**245**

As shown in Table 8,the ergonomists evoked many tools and methods of needs construction (166/283; i.e. 59%), followed by engineers and graphic designers (respectively, 59/283; i.e. 21% and 58/283; i.e. 20%). The trend is different if we compare these numbers to the size of each designer's group: ergonomists are those who have evoked the most of units (49%) but are followed by graphic designers (34%) and engineers (17%). Needs production tools and methods are those the most evoked (168/283; i.e. 59%; e.g. "*activity analysis*", "*meeting*", "*brainstorming*", "*scenarios*"), followed by needs formalization methods (62/283; i.e. 22%; e.g. "*task models*", "*specifications report*") and needs selection methods (62/283; i.e. 19%).

Table 8. Tools and methods vs. designer's profiles: frequencies

	Tools of needs production	Tools of needs formalization	Evaluation tools	All
Engineers	36	20	3	**59**
Ergonomists	121	11	34	**166**
Graphic designers	11	31	16	**58**
All	**168**	**62**	**53**	**283**

As suggested in Table 9, those who evoke the most of units related to stakeholders involved in needs construction are ergonomists (316/644; i.e. 49%). Engineers (183/644; i.e. 28%) and graphic designers (145/644; i.e. 23%) evoked fewer units. The trend is different if we compare these numbers to the size of each designer's group: Ergonomists and graphic designers are those who tend to be more talkative about the stakeholders involved (respectively, 79/197.3; i.e. 23%). More units evoked are related to the end user (330/644; i.e. 51%; e.g. "*senior citizen*", "*user*", "*operator*"). It was followed by units referring to designers (157/644; i.e. 24%; e.g. "*software developer*", "*team*", "*ergonomist*") and backers (157/644; i.e. 24% e.g. "*contractor*", "*backer*").

Table 9. Stakeholders involved vs. designer's profiles: frequencies

	Designer	Backer	End user	All
Engineers	33	55	95	**183**
Ergonomists	54	49	213	**316**
Graphic designers	70	53	22	**145**
All	**157**	**157**	**330**	**644**

4.2. Cloud of subthemes

For the interpretation of axes projected onto the cloud of subthemes, we retained variables whose relative contribution to the axis (column CTR) were greater than or equal to an average contribution (here, the average contribution is equal to 6.67%, which corresponds to 15 variables used). These variables are represented in bold in Table 10. Table 10 also highlights that all the variables are fairly well represented by the five axes, as QLT column indicates a value for some variables not far from 1. The variable backer is the least well represented by these five axes.

Table 10. Table of the factorial coordinates (#F), consinus consines (COR), relative contributions (CTR) and goodness of fit (QLT) of active variables (axes F1, F2, F3, F4 and F5)

Active variables	QLT	F1			F2		
		1#F	COR	CTR	1#F	COR	CTR
Utility-purpose	0.862	0.004	0.000	0.000	0.015	0.000	0.008
Usefulness-value	0.988	-0.360	0.130	2.808	0.537	0.288	**10.691**
Need	0.900	-0.504	0.254	5.491	0.115	0.013	0.488
Constraint	0.903	0.882	**0.778**	**16.853**	-0.094	0.009	0.328
Request	0.949	-0.399	0.159	3.451	0.513	0.263	9.775
Prospective phase	0.933	-0.698	**0.487**	**10.548**	-0.526	0.277	**10.289**
Needs formalization	0.943	-0.100	0.010	0.215	0.929	**0.863**	**32.030**
Needs selection	0.877	0.353	0.125	2.702	0.515	0.266	**9.866**
Retrospective phase	0.796	-0.446	0.198	4.298	0.021	0.000	0.016
Tools of needs production	0.949	-0.780	**0.608**	**13.157**	-0.274	0.075	2.781
Tools of needs formalization	0.932	0.852	**0.726**	**15.727**	-0.106	0.011	0.413
Evaluation tools	0.823	-0.208	0.043	0.935	-0.460	0.211	**7.843**
Designer	0.911	0.577	**0.333**	**7.199**	-0.564	0.318	**11.799**
Backer	0.752	0.505	0.256	5.532	-0.049	0.002	0.090
End user	0.911	-0.715	**0.512**	**11.083**	-0.311	0.096	3.581

Active variables	F3			F4			F5		
	1#F	COR	CTR	1#F	COR	CTR	1#F	COR	CTR
Utility-purpose	-0.363	0.132	5.032	0.810	**0.656**	**35.068**	-0.271	0.073	4.499
Usefulness-value	0.668	**0.447**	**17.074**	0.239	0.057	3.045	-0.258	0.067	4.100
Need	-0.325	0.106	4.037	0.630	**0.397**	**21.207**	0.361	0.130	**7.997**
Constraint	0.289	0.083	3.186	0.051	0.003	0.138	0.173	0.030	1.834
Request	0.616	**0.380**	**14.510**	0.281	0.079	4.225	-0.260	0.067	4.140
Prospective phase	0.203	0.041	1.583	-0.078	0.006	0.322	0.348	0.121	**7.425**
Needs formalization	0.248	0.062	2.355	-0.057	0.003	0.173	0.077	0.006	0.364
Needs selection	-0.090	0.008	0.308	-0.033	0.001	0.059	0.691	**0.478**	**29.336**
Retrospective phase	-0.435	0.189	**7.232**	-0.424	0.180	**9.609**	-0.478	**0.228**	**14.009**
Tools of needs production	0.434	0.188	**7.195**	-0.170	0.029	1.535	0.222	0.049	3.016
Tools of need formalization	0.243	0.059	2.266	0.330	0.109	5.814	0.161	0.026	1.592
Evaluation tools	0.712	**0.507**	**19.398**	0.097	0.009	0.500	-0.227	0.052	3.174
Designer	0.242	0.059	2.245	0.374	0.140	**7.491**	-0.248	0.062	3.788
Backer	0.585	**0.342**	**13.075**	-0.351	0.123	6.570	0.172	0.029	1.809
End user	0.115	0.013	0.504	0.282	0.079	4.245	0.459	0.210	**12.916**

The variables are represented in the geometric plane defined by factorial axes 1 and 2 (see Figure 1).

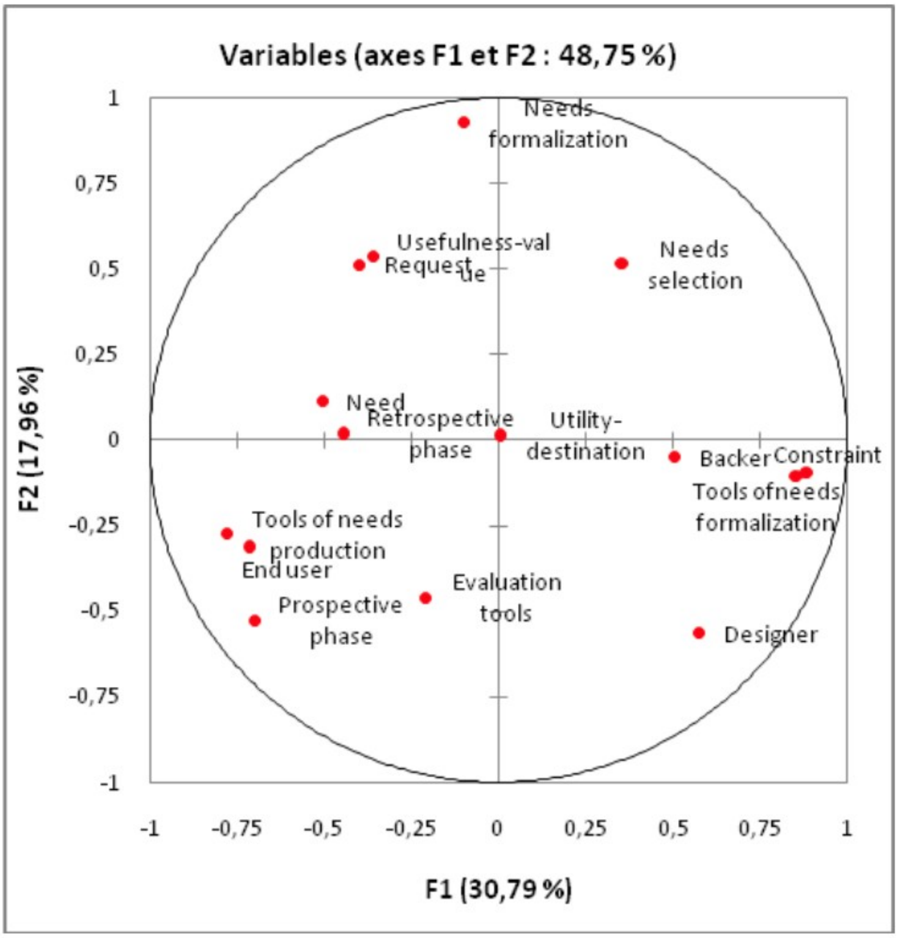

Figure 1. Cloud of subthemes; plane 1-2.

The F1 axis (horizontal) opposes evocations on “production tools”, “end users” and “prospective phase” (left on the graph) with those relative to the “constraints”, the “formalization tools” and the “designers” (right on the graph). The left area in the graph, represents discourse focused on co-production of assumptions about the possible functionalities, services, dialogues, properties and expected benefits, by means of the methods and tools dedicated to the collection and identification of needs as well as the methods and tools devoted to creativity ; they refer more frequently to end-users with terms like “users”, “operators” etc, and made references to activities associated with the prospective phase of the usefulness in terms of collection of needs (expression of needs, collect, infer, etc.) as well as in terms of creative production (guess, imagine, predict). At the opposite side of this axis, discourses most centered on formalization of the usefulness by participants through tools such as specifications reports were observed.

The F2 axis (vertical) opposes semantic worlds “needs formalization”, “needs selection” and “usefulness-value” (on the top of the graph) with evocations relative to “designers”, “prospective phase” and “evaluation tools” (on the bottom of the graph). The upper area represents discourses expressing a desire to link the phase of selection and the phase formalization of the usefulness with the meaning of appreciation or value of an artifact to the user, which is primarily mentioned in the speech by the term activity. The low area represents discourses that consider usefulness as a predictable element (evocations concerning the prospective phase) by designers from knowledge or a previous evaluation of existing tools (typically, references to inspection methods of concurrent artifacts to predict the usefulness of the artifacts being designed).

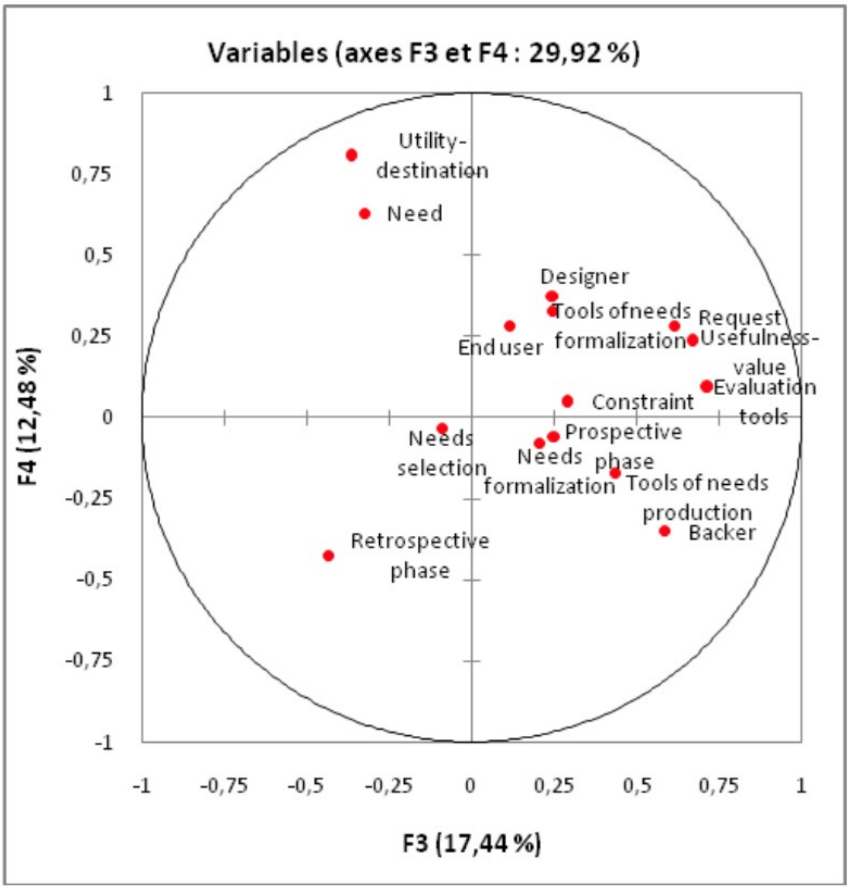

Figure 2. Cloud of subthemes; plane 3-4.

The F3 axis (horizontal; cf Figure 2) opposes verbalizations about the “prospective phase” to those concerning “evaluation tools”, “usefulness-value”, “request”, “backer” and “tools of needs production”. In the first case, the discourses show that usefulness can be achieved through the measurement of how relevant design choices are, the identification of the failures and the measurement of benefits and advantages. At the opposite side, it is observed discourses that are more focused on the process to design for usefulness by invoking tools to support the elaboration of needs and usefulness assessment by the backers.
F4 axis (vertical) opposes the semantic worlds “utility-purpose”, “need” and “designer” to evocations concerning the “retrospective phase”. The upper area represents discourses that define utility as the “purpose of the artifact according to the designer and as a response to needs”. The low area represents discourses that define usefulness as the measurement of the choices relevance, the identification of the failures, the measurement of benefits and advantages.

Axis F5 (not shown on the previous figures) is representative of the opposition between the “needs selection phase”, “end user”, “need” and “prospective phase” on one hand and the “retrospective phase” on the other hand. On the one side, the speeches show a tendency to link the phases of the production of assumptions about the functionalities, services, dialogues, properties and expected benefits and the phase of needs selection in order to meet the needs of the end-users. On the other side, the speeches deal with the phase of measurement and evaluation of the usefulness.

4.3. Cloud of barycenters related to designers’ profile

Complementary to the previous section, this part focuses on local analysis between these main themes and these designer’s profiles, using standardized scores (Table 9). This appears to be relevant also because data analysis has shown a significant effect of profiles on the distribution of subthemes found in the discourse (Khi2 =41.38; ddl= 28, p<. 0.0001).

The clouds of barycenters related to designers' profiles (Figures 3 and 4) are interpreted using relative contributions to the axes, and using the table of standardized scores (Table 11). Variables with a higher relative contribution than the average contribution were retained.

Table 11. Standardized scores (Z scores) according to the exerted function (active variables)

M	Utility-purpose	Usefulness-value	Need	Constraint	Request	Prospective phase	Needs formalization	Needs selection
Ing	0.18	-0.58	0.42	-0.07	-0.58	-0.25	0.68	1.12
Erg	0.90	1.15	0.72	-0,96	1.15	1.10	0.47	-0.33
Des	-1.08	-0.58	-1.14	1.03	-0.58	-0.85	-1.15	-0.79

M	Retrospective phase	Tools of needs production	Tools of needs formalization	Evaluation tools	Designer	Backer	End user
Ing	0.86	-0.35	-0.07	-0.94	-1.04	0.87	-0.16
Erg	0.24	1.13	-0.97	1.05	0.09	-1.09	1.07
Des	-1.10	-0.78	1.03	-0.11	0.95	0.22	-0.91

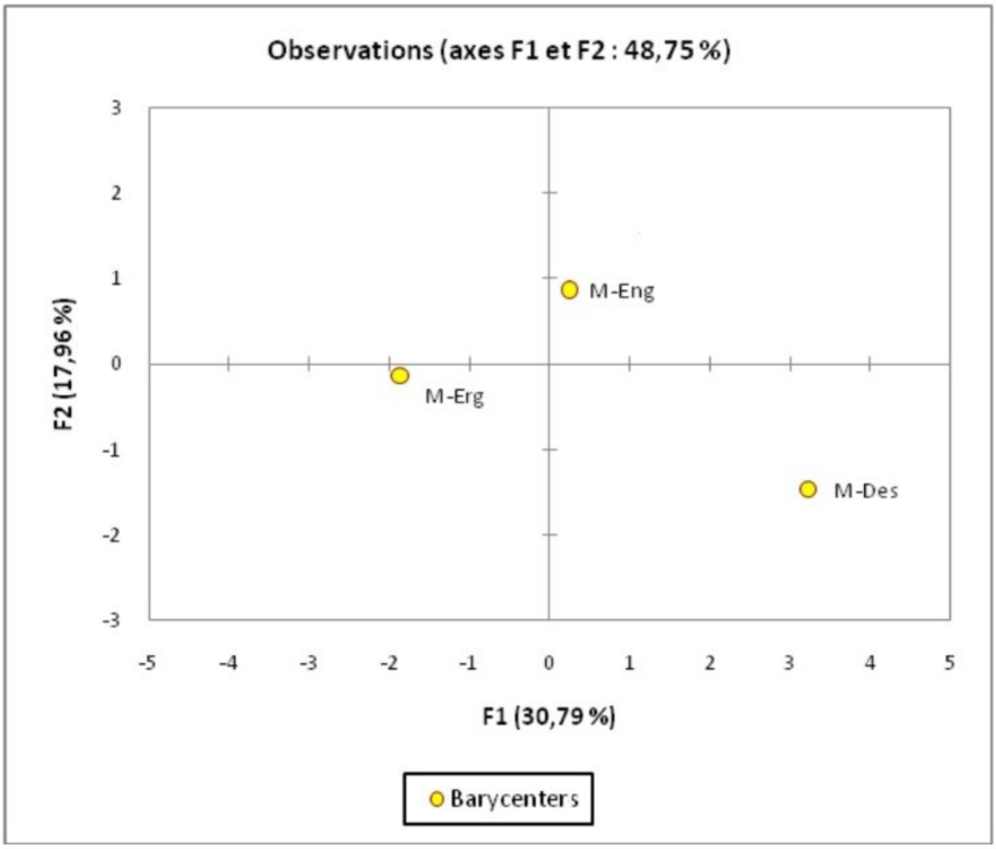

Figure 3. Derived cloud of the profiles' barycenters; plane 1-2. M-Erg (ergonomist), M-Eng (engineer) and M-Des (graphic designer).

On the F1 axis, an opposition between graphic designers and engineers (on the right side of the graph) and ergonomists (on the left side of the graph) is observed, suggesting an opposition between "techno-centered" (engineers and graphic designers) and "user-centered" (ergonomists). Engineers and even more graphic

designers evoke in their discourse the designers, the constraints and the tools to support the formalization of needs, while ergonomists' discourse is much oriented towards verbalizations about the prospective phase, the tools to support the identification of needs. Also, this discourse is characterized by much emphasis on end-users than on designers in this phase of the design process, as is the case in user-centered design. Engineers as well as graphic designers' discourses are addressing needs' entries mostly in terms of constraints which is consistent with a techno-centered approach. These can be general constraints associated with the object to be designed, like "*technical constraints or very strong constraints related to a brand*". This can also be constraints as they are given by the backer; for example, one participant explained that "*what we have to do at the beginning is to tell him [the backer]: give me all your constraints, all the ones you think, then those that you don't dare to think or imagine*". Designers also focused on tools and activities related to the formal viewpoints of needs to proceed them toward design solutions and implementation (e.g., "*after the selection of a concept, we wrote a prospective specifications_report*"). To formalize these needs, graphic designers integrate designers into the design process; this is reflected in their speeches in which designers are evoked (e.g., "*to consult an industrial designer, a graphic designer, an engineer for some elements to help to transcribe the specifications report*"). Ergonomists tend to discuss the prospective phase through the attribute "collection and identification of needs" (e.g., "*It is indeed an expression of needs*"), or in terms of inference from the analysis of the situation and the existing activity (e.g., "*It's also a way to collect needs*", "*Infer needs and thus define the basis for a usefulness*"). This is consistent with the evocation of need production tools through the use of terms referring to the tools for collecting and identifying needs like "*Data collection by interview, but also data collection by observation*", "*Performing an analysis of existing activity*". Ergonomists also evoke end-users in their discourse: "*showing different versions of prototypes to users to help them to elicit their needs*".
On F2 axis, engineers, who tend to evoke needs formalization phase, needs selection phase and usefulness-value are in contrast with ergonomists and graphic designers, who share a common view on the designers, the prospective phase and evaluation tools (bottom of the graph). On the one side, ergonomists and graphic designers (even though these last ones have discussed these terms in a lesser extent) mention in their speeches the prospective approach of the usefulness through references to the imagination acts such as: "*we prefer to guess what they will do in a real situation, rather than create false situations*" or "*we try to imagine a lot of things concerning the product*, to *make analogies with existing and competing products*", "*we must be able to predict what will happen*"). This approach of the usefulness as a predictive and imaginable dimension is consistent with references to designers, because they are asked to specify systems in the early stages of design. Ergonomists and graphic designers also referred to evaluation support (e.g., prototype, model, drawing). An ergonomist has explicitly linked the evaluation supports or acts with the production of new needs (e.g., "*it is expected that new data emerge during the product evaluation*"). One graphic designer evoked the fact that "*if you ask people in the street what they think about the Walkman, they have not necessarily the ability to imagine what it could be otherwise. So in fact, prospective surveys among the general public are not working very well. Because they cannot immediately say: what we would like to see that or that inside. Once that is thought and when we put the two products side by side, there is no problem and it's pretty accurate. They can tell you: I prefer this one for some reason; I am ready to put such a price for such a solution. It works well*", this confirms the interest, for ergonomists and graphic designers, of the evaluation of an artifact being designed to anticipate new uses. On the other side, engineers evoke in their discourse the needs selection and formalization phases (e.g., "*prioritize goals*" or "*every time we have alternatives, [...] we must make a decision and make a choice*"). Some engineers interviewed have worked in project teams involved ergonomists. For those, making choices involve a description of the activity with the meaning of a task which can be formalized (e.g., "*a hyper detailed process model which describes a range of activities*") and assumes that the system designed by the designers will be beneficial to the end-user in terms of ease of use (e.g., "*necessarily the more you do something which is complex, the more the design is expensive, but it is often for the benefit of users who avoid a huge labyrinthine system*").

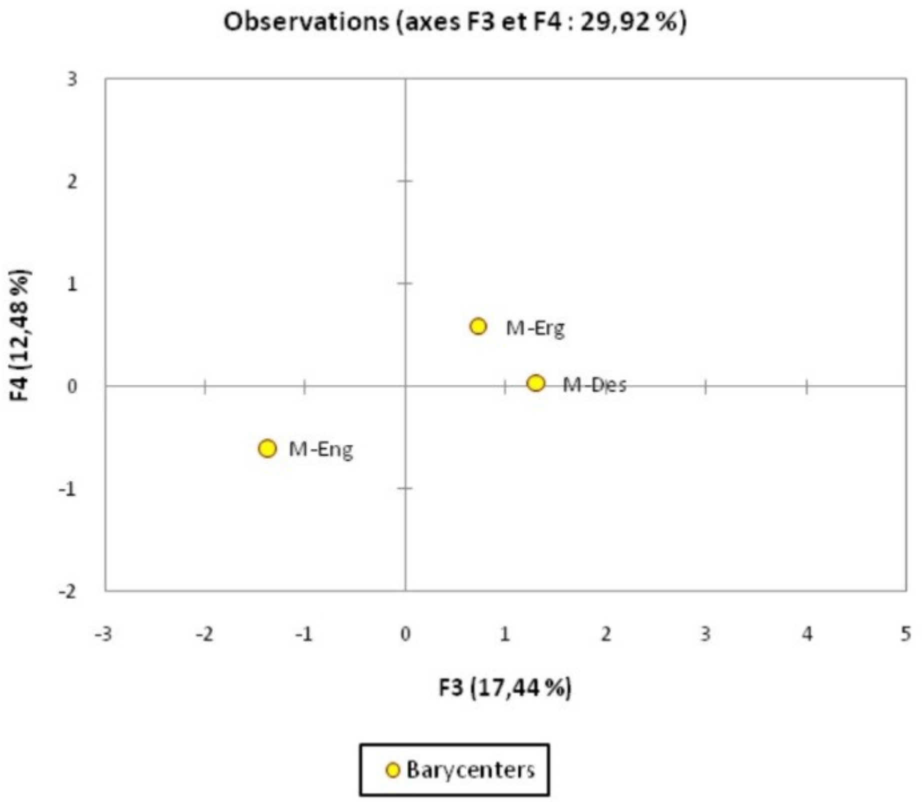

Figure 4. Derived cloud of the profiles' barycenters; plane 3-4. M-Erg (ergonomist), M-Eng (engineer) and M-Des (graphic designer).

On the F3 axis (Figure 4), it exists a conflict between graphic designers and ergonomists on the one hand and engineers on the other. While graphic designers and ergonomists tend to discuss the evaluation tools, usefulness-value, request, backer and tools of need productions, engineers tend to refer to the retrospective phase. When they refer to this phase, engineers use the terms "correction" and "test" referring to actions of system debugging which are linked to iterative and incremental models of software engineering (e.g., *"validation cycles with corrections"*). Graphic designers and ergonomists share the same views on the analysis to perform and tools to use in order to design an artifact that adds value to the end user, starting from a request from a backer (e.g ., "*if I take the example of the Ipod. He will say I want a small device, I can put into my pocket, which is autonomous, which not need to be connected to the mains, or I can easily change a piece of music. [...] My competitor is the Walkman with a cassette: when I want to go from the third piece to the tenth, I have to move the cassette. Do I can find new solutions for all this? It is the demand*", "*the principle with a needs expression is that at a moment, there is a* *<u>request</u>*"). The speech of these two kinds of designers includes evocations of production tools and assessment tools to anticipate and predict the usefulness value, with references to the activity in a macroscopic way for the graphic designers (e.g., *"complete changing of sector of activity?"*) and conversely, focused on the ergonomists (e.g., "*we will describe this activity in order to try to identify [...] what we could change or add to help it. It is from this point that we can make this evocation of need*"). In these speeches, evaluation tools allow to identify needs (e.g., *"evaluation of prototype with building of scenario"*).

On the F4 axis, there is an opposition between graphic designers and ergonomists on the one hand and engineers on the other. Graphic designers and ergonomists tend to evoke the semantic worlds "utility-purpose", "need" and "designer", while engineers tend to refer to the retrospective phase. On the one side, in these speeches, ergonomists and graphic designers consider the usefulness of the artifact regarding the function that it is supposed to accomplish (e.g., "*sometimes, there are 2 or 3 possible options to realize a* *function, and when we progress in the project, we will say oh no it is still this one which is the most interesting*"), the concept of the product (e.g., "*a concept, it is a promise of the future product; we say the product will be moving in this way*" or "*the concept, it is like initiating a unique response to a need*") or with the meaning of how to achieve this goal (e.g., "*there are functional specifications, so there are needs transformed in functions. [...] A specification report where was such button, where to put it, other stuff like that… and then technical specifications*"). Beyond this consideration for the utility-purpose, these two types of designers tend to evoke the usefulness as a response to a need. This need comes from the field or from the backer (*"it is often the client who comes or I will say it's a commercial approach which means that it comes a time when he has a need"*). Ergonomists also evoked a second category of needs ("*those that we will emerge*") and thus make a reference to the needs construction. On the other side, engineers tend to evoke the retrospective approach of the usefulness with the term "*ecological evaluation*". This engineer explained that he was trying to "*do a user-centered design*" and "*regularly assess either concepts or parts of the system [...] and then regularly [...] with people*". Among these, tools very specific to ergonomist's profile have been cited by engineer's profile. This is the case of self-confrontation usually used by ergonomists and yet evoked by an engineer: *"it was a first phase where [...] we also did a self-confrontation at home with a voluntary person; that means we filmed this person for a day using the system to carry out what he wanted to do*". The fact that an engineer evokes in his speech references to the retrospective approach of the usefulness, not in terms of iterative cycles of testing techniques and validations, but more in terms of user involvement in the assessment in order to match the value of the artifact with user feedbacks, is surprising. The presence in the engineers' speech of evocations *a priori* specific to ergonomists shows that this is not only the background of the designers that determines their points of view on the usefulness and its consideration in the design, but they depend on the experience acquired in projects involving collaborations with other designer's profiles.

On the F5 axis (not represented here), an opposition was observed between the ergonomists and graphic designers who share the same point of view on the end user-centered evaluation on one hand and engineers who integrate the production , selection and formalization of backers' requirements on the other hand. Ergonomists and graphic designers tend to evoke evaluation acts, but to a lesser extent, to improve the artifact in terms of usefulness and usability with the idea that end users are able to judge and to make a choice between two alternative solutions (e.g., "*they can tell you: I prefer this one for some reason, I am ready to put such a price for such a solution*"). Engineers tend to integrate the usefulness as a response to needs (e.g., "*For me, the need is a vague notion [...], you may have a need that is not clearly formalized on paper*") coming from a backer (e.g., "*The needs collection is generally done during a formal or informal meeting, during the discussions with the companies in which needs exists and become clearer in the course of time*") and to which they answer by formalizing specifications of the artifact (e.g., "*I just try to imagine the product functionalities that could meet these specifications, these formalized requirements, by taking into account the technical possibilities*").

5. Discussion

When designers are prompted to speak about the way(s) they take into account the usefulness in design, from their own experience in past projects, there is an effect on the viewpoint.

Viewpoint can be common between two designer's profiles. Indeed, graphic designers and engineers define usefulness of an artifact as a dimension which is formalized through their own constraints, while ergonomists tend to consider usefulness as a dimension which is defined with identification tools of user needs. These perspectives are complementary in terms of design because if we need to identify the characteristics and expectations of users, it is also necessary to deduct and to formalize the associated constraints. Graphic designers and ergonomists have a common interest in the question of usefulness. This is reflected in their discourses in that they dealt with utility-purpose, usefulness-value and usefulness as a response to a need, conversely to engineers. Moreover, graphic designers and ergonomists share a number of tools to assess the utility-purpose. Finally, graphic designers have common viewpoints with engineers and with ergonomists. That suggests they can be seen as intermediaries between engineers and ergonomists.

Our results indicate that viewpoints can also be specific to a designer profile as Z scores suggest it. Engineers mention mainly the backers, the needs and the formalization, selection and retrospective phases. These results are consistent with the literature which suggests that engineers contribute strongly to the needs selection phase (e.g., Alenljung & Persson, 2008; Aurum & Wohlin, 2003) according to a “design for” approach (Kaulio, 1998). And, the predominance of the phase’s theme can be explained by the fact that the main design process models are advocated by the literature in software engineering, requirements engineering and industrial engineering. Ergonomists tend to mention utility-purpose, needs, request, prospective and formalization phases, production and evaluation tools and end-users characterizing a “design with” approach (Kaulio, 1998). The references to the usefulness-value are found mainly in the discourse of ergonomists. The usefulness-value corresponds to the benefits and advantages of the artifact for the user. It appears consistent that the usefulness-value is mainly addressed by the designers who evoke mainly end users as co-designers as suggested in “design by” approach (Kaulio, 1998). Ergonomists are clearly intermediaries between designers and users. This “value for user” is a central objective for ergonomics science and justifies the relevance of the activity analysis to achieve its.

Even if usefulness-value is less frequently evoked in the discourses of engineers and graphic designers, some references are present. This observation is consistent with a wide dissemination of the ideas, objectives and methods of “user-centered design”. In addition, this study shows that graphic designers consider designers and backers as the main stakeholders involved in design process, with little consideration for end users. This last result confirms an observation stemmed from our state of the art on the low involvement of the end user in engineering and in industrial design, due to the feeling of the graphic designers that they have sufficient experience to imagine what the user might need (Hasdogan, 1996). Another explanation is that the graphic designers consider users as too conservative (Bruseberg & McDonagh-Philip, 2002). This weak consideration for the end user suggests the necessity to take actions to bring together the engineering sciences (e.g., software engineering) and social sciences (e.g., ergonomics) in the learning, in the practice and in research. These actions can be, for example, an awareness of the importance of the role of ergonomists in design projects, or training in concepts and methods of ergonomics to take into account the end user in the design.

A final point is that our results suggest that the profession and the background of the designer are not the only determinant of these viewpoints. Indeed, an engineer has used the term “self-confrontation” which is a method specific to ergonomics. This kind of observation suggests that the experiences and the former integration of the designers in multidisciplinary teams determine the viewpoints they have about the usefulness and the needs construction process. This involved the learning of a common vocabulary between the other fields. Numerous authors (e.g. Tichkiewitch & Brissaud, 2000; Pei et al., 2010) agree that it is necessary to have a common language to improve the quality of the collaboration. However, it is necessary to build a relationship of trust to set up this collaboration (Dirks, 1999).

6. Conclusion

This study shows that, if viewpoints are often specific to a designer profile, some viewpoints can be shared between at least two designer’s profiles. This suggests that specific literature, profession and background are not the only determinants of these viewpoints. Indeed, the experiences and the former integration of the designers on multidisciplinary teams are also pertinent determinants for explaining these common viewpoints. This observation suggests two main concerns: some recommendations can be advocated to project leaders, and a scientific perspective for future research can be evoked.

Concerning recommendations to help project leaders in the design process of innovative artifacts like VR-based software, engineers, ergonomists and graphic designers must be involved in the first phases of design process. This would ensure to prioritize an interdisciplinary relationship as opposed to the multidisciplinary relationship often mentioned (Brown, 2009, p. 28). In a multidisciplinary approach, each trade defends its field and negotiations lead to compromises during pilot committee. At the opposite, interdisciplinary approach leads to mutual transformations between fields (Hamel, 1997, p. 190) because they share the responsibility of their ideas (Brown, 2009, p. 28). Frequent meetings between these three profiles have to be held in order to dialog and share these viewpoints not only on usefulness definitions, phases, tools and methods used in design but also on stakeholders to imply (e.g., users). Indeed, several tools and methods of collaboration already exist (e.g. Barré et al., 2018; Riboulet, Marin, & Leon, 2002). Barré et al. (2018) have for instance developed a method (Logical Thinking) based on an engineering method (EPMcreate) combined with an ergonomic method (personas). Riboulet et al. (2002) have developed an online collaborative environment (CoDVS) allowing the management of data that are processed by the different actors. Thus, it would be relevant to continue to develop more tools and methods in order to support and improve these collaborations between the different designers. Moreover, this weak consideration for the end user suggests the necessity to take actions to bring together the engineering sciences (e.g., software engineering) and social sciences (e.g., ergonomics) in the learning, in the practice and in research. These actions can be, for example, an awareness of the importance of the role of ergonomists in design projects, or training in concepts and methods of ergonomics to consider the end user in the design.

Concerning perspective, an intra-group variability is observed according to previous experiences of interviewed designers. So, a larger sample of interviewees for each profile would allow to study this intra-group variability and to assess to what extent the experience of former projects modulates their viewpoints of usefulness and needs construction process.

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