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AN EMPIRICAL STUDY TO MEASURE THE EFFECTIVENESS OF SCENARIOS TO AID SHARED UNDERSTANDING OF FUNCTIONAL REQUIREMENTS

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1. Introduction

Design is described as "*a problem of resolving tension between what is needed and what can be done*" [Conklin 2006]. In this paper, the word "need" is used in the same sense as Ulrich and Epinger [Ulrich and Eppinger 2004]. That is to label any attribute of a potential product that is desired by the end user, for whom the product is designed.

During the engineering design process, the design team transforms the end user needs into a set of product specifications, a measurable detail of what the product has to do in order to satisfy them. Ulrich and Epinger state that "*product specifications do not tell the team how to address the customer needs, but they do represent an unambiguous agreement on what the team will attempt to achieve in order to satisfy the customer needs*". In order to define the product specifications, functional analysis might be used. Functional analysis builds a standard language to enable designers to share their viewpoints about needs and constraints. In functional analysis, the functional requirements refer to the needs and constraints. Product specifications are then the list of the defined functional requirements.

However, in the early stages of the new product design process, the end users are not always defined sufficiently well enough to clearly identify their needs or for them to be involved in the design process. Moreover, at the early stages of the design process the final product does not yet exist. What does exist are the intermediary objects which help designers to represent, manipulate and translate the product idea on which they work; such as sketches, diagrams, written specifications etc. [Boujut and Blanco 2003]. Even for contract projects it may be difficult to gain access to a client who is busy or located geographically at distance. Additionally, the designers generally work under time pressures, which makes it difficult to access end users to get data or integrate them to the design process. Furthermore, researchers, who undertake market and user research, are not typically the design actors, and the results very often comprise ambiguities, uncertainties and gaps that the designer have to manage.

Consequently, in the case that the information about the users is not available at the right time or difficult to understand or to remember, each design actor may interpret the end user needs differently and become sensitive to different product constraints. This lack of shared understanding of end users and of their needs, between design actors, may cause difficulties in defining product specifications and cause non-convergent design processes [Hey et al. 2007]. To overcome this, support methods might be used in order to define the end users and their needs in order to improve shared understanding of functional requirements between design actors. However, the appropriateness and effectiveness of the various methods is unknown.

In the literature, personas [Cooper 1999] and scenarios [Carroll 2000] are used in order to define end users and their needs. Their usage is becoming more and more popular, especially in Software and System Engineering and Human Computer Interaction (HCI). Our hypothesis is that scenarios and personas might be used to develop and improve shared understanding of functional requirements between design actors. In order to test their effectiveness in terms of developing shared understanding, an empirical study has been undertaken. It follows that the contribution of this paper is to present and evaluate the protocol of this study and discuss the primary analysis of the results.
The paper is organized as follows. In the next section the theoretical background of the research is explained in detail. Section three discusses how the empirical study was designed and conducted. Some of the findings gathered from the study are presented and discussed in section 4. The future direction of the research is explained in the last section.

2. Theoretical Background

2.1 Shared Understanding Between Design Actors

In a design process, design actors bring with them their own beliefs, responsibilities, language, interests, jargon, and knowledge to the design team. As a result of this, each actor might see the design object differently. Detienne [Détienne 2006] highlights the importance of creating negotiation mechanisms and grounding activity in order to manage the multiple perspectives in design groups.
The notion of common ground represents the knowledge that actors have in common and they are aware of this uniformity. Clark and Brennon [Clark and Brennan 1991] state that effective communication requires grounding activity. The grounding activity helps design actors to co-create the shared representation of the current situation of the problem, solutions, etc. Different mediums of communication might be used for accomplishing this purpose, such as, conversation, sketching etc. For example, in conversation, the aim is to ensure that what has been said has been understood.
On the other hand the notion of a negotiation mechanism describes the way that the design actors reach agreement. The negotiation is based on argumentation [Détienne 2006]. By argumenting, designers try to "*convince themselves and their peers of the sense and validity of a particular solution, or of the necessity to respect a particular constraint related to the problem*" [Prudhomme et al. 2007]. As Detienne mentions, negotiation does not force a person to accept an argument but the conversation makes it possible to get an agreement.
The term shared understanding is used in this paper to state the management of multiple perspectives and on the agreement of ideas and relevant actions in a design team. However, how to measure the shared understanding and its evolution within a design team is problematic. Visser [Visser 2008] defines the design process as the construction of representations. In this paper, the representations are considered as the external representations, which means "*the artefacts (text, diagram, sketch) that provide an interface to a person's internal mental models. They are things that have meanings but that exist outside the mind"* [Eng et al. 2008].Thus, our hypothesis is that the shared understanding might be evaluated by focusing on the designer's external individual representation and how this evolves over a design process.

2.2 Scenarios for Shared Understanding of Functional Requirements

Despite their popularity, there is no common definition of what the term "scenario" means, their use also varies widely in different design contexts. In this paper, the term scenario is used in the same sense with Carroll [Carroll 2000], stories about people and their activities. Each scenario includes the setting, agents/actors who have specific goals/objectives and sequences of action and events. In the early stages of the design process, talking about the end users and their actual activities allow designers to elaborate their needs, analyse and prioritize them. They also guide the projected scenarios, which explains the future activities, after the creation of the new product. In that way the designers evoke new views on defined needs and define new ones. In other words, scenarios are used to help designers to focus on end users and their activities and how these activities may be changed because of a new design. They serve as a communication tool between designers.

In the literature, even if the focus is on end users and their needs, some researchers prefer to use vague definitions of end users while building scenarios. For example, in Carroll's scenarios, we do not see the detailed description of the users; generally just a name or the job description. However, Cooper [Cooper 1999] argues that by focussing on the behaviours and the goals of specific end users, the designers can satisfy a particular class of users with similar goals. Cooper proposes the utilization of personas -representative user archetypes-, to provoke common sense of categories of end users. Personas are fictional people who have names, details, and goals. They may be presented in their working and/or living environments and tied to particular activities that they are practicing. Cooper's "goal-directed design" focuses the design effort for achieving persona goals, which covers the goals of the target market. Cooper points out that, once personas have been created then scenarios can be constructed around them. They are used to improve the power of scenarios. Grudin and Pruitt [Grudin and Pruitt 2002] argue that scenarios are less engaging and difficult to memorize when not built on personas. They also mention that personas help to prioritize functions for a product development cycle and facilitate decision-making process.

2.3 Design Observatory

The design researchers focus more and more on observing and understanding design activity in order to develop effective tools and methods that would support the overall process [McDonnell and Lloyd 2009]. The audio and video capture has been used for the observation.

Hicks et al. [Hicks et al. 2009] proposes a process model in order to realise a structured observation. This is an iterative approach that involves five main phases: 1) Monitor 2) Capture 3) Analyse 4) Prepare and 5) Intervene. In the monitoring phase the researchers define what will be monitored during the design activity: the actors, their interaction, the objects, etc. The technology and the tools that will be used for monitoring are also prepared in this phase. The inputs, outputs, content and relationships between activities and interactions are then captured in the second phase. In the third phase the data is analysed and interpreted. The last two phases are respectively the preparation of new tools or methods that will have the impact on the activity and ensuring that those interventions are beneficial.

However, as Hicks et al. mentions in order to realise more robust observations the design situation that will be worked on has to be defined. According to Prudhomme et al.'s model [Prudhomme et al. 2007] a design situation contains four main elements: task, actor, object and environment. A design task expresses a goal and the conditions in which work should be realized, whereas the design object, or the product is the entity on which designers work. The design actors are the people who are involved into design process. Finally the environment element is described by the industry, the available technical means and the project organization. This model gives a macroscopic view of a design situation. By taking this model as a reference, the relevant considerations that have to be addressed in an observational research can be defined.

In this research we realised an empirical study in a laboratory environment, which is based on the Hicks et al.'s process model. The detail of this study is discussed in the next section.

3. Design of the Empirical Study

The discussions in section 2 presented the premise for a hypothesis that scenario and persona usage might encourage a shared understanding of functional requirements within a design team. In order to test this hypothesis two questions are posed:

- How to test if the design actors converge through a shared understanding of the requirements during a design meeting?
- How to evaluate if the scenarios and personas are effective in creating shared understanding between design actors?

In this section, the framework, which is adopted to answer these questions, is first explained. Secondly, the design situation which will be worked on is presented, based on the previously mentioned design situation model [Prudhomme et al. 2007]. Finally, the process model [Hicks et al. 2009] of the study is discussed. However, because the study is under progress, the last two phases of this model are not considered in this paper.

3.1 Framework of the Empirical Study

As mentioned previously, in this paper the representations of designers are accepted as indicators to evaluate the shared understanding between them. Thus, in order investigate if they converge through a shared understanding of the requirements during a design meeting, their individual representations before and after the design meeting might be analysed.

On the other hand, a control group, which won't use the scenarios and personas as a method during the meeting, might be used. Comparing the results of the control group (refered as group A) and experiment group (refered as group B) might help us to evaluate the effectiveness of scenarios and personas.

Consequently, three main steps were defined for the empirical study (see figure 1):

- Individual representation of the product specification
- Design meeting: During this stage the subjects elicit the functional requirements collectively. While experiment group B is asked to use scenarios and personas, the control group is free to choose their methods.
- Individual representation of the product specification: The same representation media has to be used with the first step to allow comparison.

In addition to the three steps, the subjects have to be informed about the tools and methods that they will use during the study. A preliminary training step is then required in order to train the subjects.

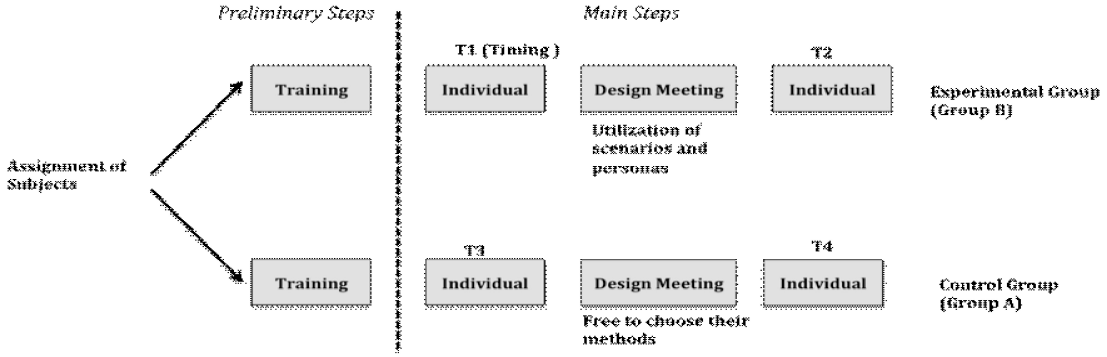

Figure 1. Framework of the Empirical Study

3.2 The Design Situation

3.2.1 Actors

In this paper, the design actors are the subjects who participated in the study. Because our focus is to analyse the collective activity, we had to use more than one person. Studies showed that in functional analysis teams with more then 5-6 people, tend to be divided into small informal groups with only a core of 3 to 4 people doing real work [Fowler 1990]. So, we decided to use 4 subjects in each of the two groups (group A and B). The composition of the groups was configured to be as similar as possible using PhD students and postdoctorals with engineering degrees and similar levels of experience. All subjects were volunteers and were not remunerated. They were not informed about the aim of the project. They were told their collective activity would be observed and recorded (video and audio) as a part of the study. However, after the experiment a presentation was given to explain the research context and answer to the subjects' questions.

3.2.2 Task

The focused domain of the project is industrial design. We chose to construct a design meeting typical of the early stages of the new product design process, during which design actors elicit functional requirements of a new product.

Before the design meeting subjects were given some time to think individually about the product idea. They were asked to represent the product idea in the form of a 5W table (When, Why, Who, What and

Where), which provided information concerning their individual perspectives about the product specifications. The question How was eliminated from the original 5W1H table because it could possibly focus the subjects on the technical possibilities and constraints by limiting their perspectives. However, the aim of this step was to focus subjects on generating alternative solutions not creating a specific one (divergence). The same representation media is used after the design meeting in order to get individual perspectives of the subjects.
During the design meeting, they are asked to elicit the functional requirements collectively in the form of a Function-Criteria-Level (FCL) table. As mentioned before, while the group A was free to use any method(s) they felt appropriate for defining the functional requirements, the group B was required to use the scenarios and personas.

3.2.3 Object

The industrial product to be worked on was a "digital calendar". The product idea was chosen from an open innovation platform: Crowdspirit (www.crowdspirit.com). This site allows its visitors to submit new product ideas, commit arguments, make commentaries about product ideas. The aim is to design a new product collectively on an internet platform. We have three reasons for choosing this design object: 1) We have already an independent corpus on this project obtained from the internet site for testing the acceptability of the experiment; 2) As subjects had limited time for achieving the design task, materials had to be simplified. So, we have chosen a product idea that they may feel familiar with and contribute to easily; 3) The idea was cited as the most popular on the site, and hence we thought that it would be interesting for the subjects to work on.

3.2.4 Environment

As mentioned in section 2.3, the environment element is described by the industry, the available technology and project organisation. In this research, because the study was realised in a laboratory layout, the industry was not considered.
The available technology in the dispositions of the subjects during the design meeting, was limited with the supplied facilities. During the before and after steps of the design meeting, in order to realise their individual tasks, each subject was provided with a computer. The previous research on sketches shows that they play an important role in design process. As Ferguson [Ferguson 1992] states: "*Many features and the qualities of the objects that a technologist thinks about cannot be reduced to unambiguous verbal descriptions: therefore, they are dealt with in the mind by a visual, nonverbal process*". Thus, the subjects were also supplied with some draft papers and pens in each step, in order to allow them to sketch or write freely.
During the design meeting, both of the groups were provided with a computer for completing FCL table. Group A was also provided with a whiteboard and boardmarkers that they might use to apply their methods, while as the group B was supplied with another computer in order to create the personas and scenarios in Powerpoint format. Because they had a limited time, group B was asked to use media which is easy to create and manipulate such as text or storyboards. Thus, they were also supplied with a set of pictures selected randomly from google's image library (which were rooms of a house, an office and a selection of faces) that might be used for scenario and persona creation.
In terms of the project organisation, within each group, one of the subjects was proposed as the manager of the design meeting according to his/her previous experience of managing. His/her role was to manage the time, ensure that the tasks would be realised and organize the relationship between the subjects. The choice of a manager may have positive or negative effects, which is not behind the scope of this paper. Otherwise, all the subjects had all equal rights during the meeting. The subjects were trained before the experiment with the aid of preprepared material. This included a document containing the explication of the tools and methods (in additional to the informations supplied to group A, the group B was informed about scenarios and personas), and examples of their usage. A formation document was also prepared for the manager in order to explain his/her responsibilities. Both of the documents were sent to subjects three days before the experiment via e-mail.

3.3 Process Model

3.3.1 Monitor

The design meetings of the subjects were video and audio taped. Therefore, an observatory room was prepared, equipped with video and audio recording facilities. A voice recorder (placed on the table) and three movie cameras recorded the design activity (see figure 2). The movie cameras were installed to capture different views: a closer view of the subjects when sitting at the table 2) the whiteboard and 3) overhead view of the table. They were fixed and were not moved or repositioned during the session for not disturbing the subjects. The experimenter and the recording equipment were situated in a neighbouring room that the subjects could not see. For group B the same experiment layout was used with the difference that one movie camera was removed, which was recording the whiteboard.

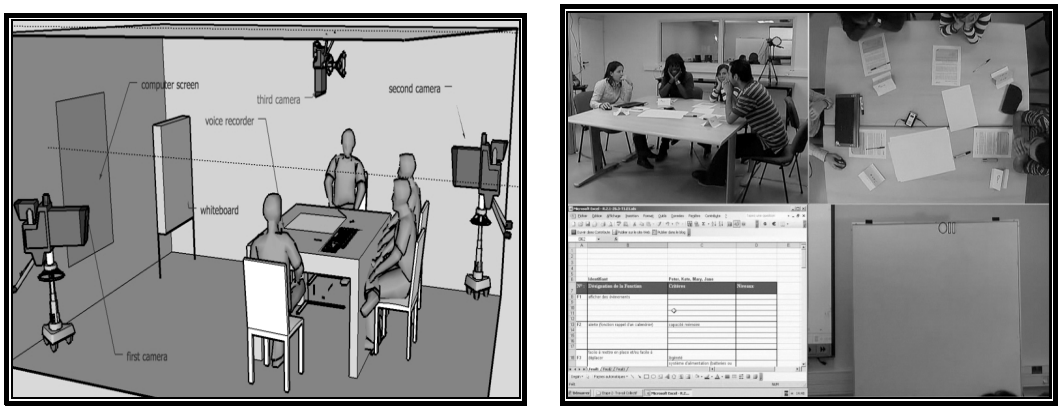

Figure 2. (Group A) Observatory Room view and 4-PIP

3.3.2 Capture

Figure 3 summaries the documents furnished to the subjects (inputs), the tasks, the timeline and expected outputs for each step of the empirical study for the group A. The outputs of the each step were captured for the analyse phase. The same process was also followed for group B with the exception of step 2. The steps of the empirical study:

- Step 1 (20mn): The 5W tables and the sketches, the written texts etc. produced on the draft papers were captured in this step.
- Step 2 (1h 30mn): During the meeting the three camera views and the computer screen were recorded and mixed into one 4-PIP (four pictures in picture) combined view (see figure 2). A time stamp of the date, the time in hours, minutes and seconds was included in the video image. The group B 4-PIP combined view contained two computer screens and two camera views. The group B was also delivered the created scenario and persona. All produced documents were also captured in this step.
- Step 3: This step consisted of three sub-steps:
    - Step 3-1 (5mn): In this step the subjects are asked to rank the 5 most important requirements from the FCL table that they created collectively in step 2. The aim was to identify if the subjects of a same group would assign the same importance to the defined requirements. The individual ranking tables of the subjects were captured.
    - Step 3-2 (10mn): New vision of the problem: A new empty 5W table is completed individually by the subjects were captured.
    - Step 3-3 (10mn): In last step the structured open question interviews [Coolican 1999] were realised with the subjects. There were three reasons for conducting these interviews: 1) to verify if the subjects were in agreement with the group results - i.e. to gather subjects' individual perspectives on the FCL table completed collectively; 2) to understand the argumentation behind their ranking table; 3) to get some commentaries and critics on the design tools used during the experiment. The interviews were audio recorded.

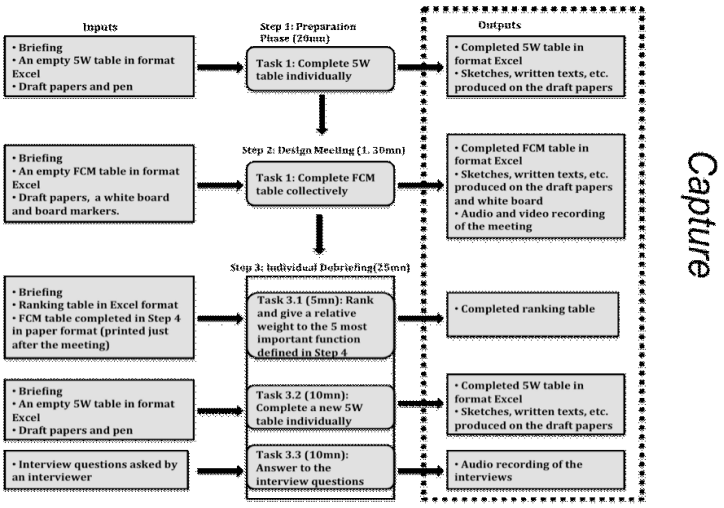

Figure 3. Experiment Steps-Group A

3.3.3 Analyse

As mentioned previously, the aim of the preliminary study presented here was to evaluate and redesign the experiment protocol, which will be used for the future studies that are going to be carried out. Bryman [Bryman 2001] mentions three main criteria in order to test the validty of a social research: replicability, reliability and validty.

- Replicability: A study must be capable of replication. That means, the protocol of the study must be spell out in great detail, which will allow its repetition in somewhere else.
- Reliablity: is concerned with the question of whether the results of a study is stable or not. In order to gather the reliability the same study has to be repeated several times.
- Validty: is concerned with the integrity of the conclusions that are gathered from a research. The main types of validty are:
    - *Internal validity:* is concerned with the causal relationship between the variables and the gathered results. In this research, in order gather the internal validty, we have to be sure that the control group did not also use the scenarios and personas as a method, we analysed the creation and the usage of scenarios and personas in each group. Video recording of the collective activity (Step 2) of each group was analysed using the video annotation tool VCode [Hagedorn et al. 2008]. VCode helped us to define the time samples (the starting time of the event and the duration) during which the scenarios and personas were created and used. By creation we mean the construction process of the scenarios/personas, while utilization indicates the overarching process of discussing, expanding, revising, validating, documenting and rejecting scenarios/personas.
    - *Measurement validity:* The measures gathered from the analysing method has to be verified. In this paper in order ot test the hypothesis two questions were conisdered:
        - To answer the first question, we analysed and compared the individual 5W tables created before and after the collective sections.
        - In order the test the effective in terms of the creation of shared understanding of functional requirements, results gathered from each group were compared.

A code (a relative number) was given to each significative answer to each question in the individual 5W tables of the participants. These coded ideas were organised as a coding schema. This coding schema was provided to the two coders with the 5W tables (non coded version) of the participants. Afterwards, the coders checked the significative ideas on each 5W table individually and found the related code on the coding schema and noted the idea with its code. They were also free to add new codes to the coding schema if they believed the idea did not fit into an existing category. In that way we checked:

- The total number of ideas produced before and after the collective section,
- The number of ideas shared by all the subjects before and after the collective section,

- The total number of ideas shared by two or more subjects before and after the collective section,
- The total number of ideas generated and dismissed
- How many of the dismissed ideas were shared by all subjects and how many of them shared by two or more people,
- How many of the generated ideas were shared by all subjects and how many of them shared by two or more people,

In order to test the validation of the measurement, the coding results of each coder were compared using the Cohen's Kappa Calculations. Cohen's kappa coefficient is a statistical measure is used to quantify agreement between two raters for categorical items [Cohen 1960]].

- *External and ecological validty:* External validity is concerned with the question of whether the results of a study can be generalized beyond the specific research context. On the other hand, the ecological validty of the study is concerned with the questions if the fundings are applicable to people's every day settings.

4. Findings

The results gathered from the study are discussed in this section.

- Replicability: The empirical study, which is discussed in this paper was carried out in two different laboratories: laboratory G-SCOP (France) and IdMRC (England). In both of the laboratories the same protocol was respected. Thus, we can conclude that the study is capable of replication.
- Reliability: This paper is discussed the results of one of the empirical study. To address the question of reliability, the same experiment has to be undertaken several times.
- Validty:
  - *Internal validty:* The analysis showed that in group A a total of 5 min 33 seconds was spent on scenarios, while in group B 19 min 28 seconds were spent on scenarios and 20 min 4 seconds on personas.

In group B seven personas are created. While four of them were the members of a family: mother, son, daughter and grandfather, the other three were members of a workgroup that the mother is also a member of. For each persona a Powerpoint slide was created to describe the characteristics of each persona: his/her name, age, hobbies, job, etc. In total 47 fragments of scenarios were created during the meeting. These scenarios were generally the part of the detailed scenarios created around the personas. Some of them were short scenarios about unknown people, their selves or general user groups like as children, older people, etc. Even if many scenarios are created and used during the meeting, only very few of them are captured. There was no written trace of the scenarios, except some sketches done while discussing about the scenarios. They did not captured any of the created scenarios. We observed that one of the reasons might be the usage of the Powerpoint file, which was not ergonomic for scenario building. The other reason might be the absence of an animator (who is expert in scenarios and personas) in the meeting, who will be responsible for orienting the group in the creation and capture of the scenarios and personas. In future studies, more ergonomic tools might be supplied to the subjects, and/or an expert might animate the meeting.

On the other hand, in the group A a total of 24 scenarios were created. They didn't create any personas. The scenarios were only created around the unknown people, their selves or general user groups like as children, older people, etc. The scenarios were discussed just in short time periods and they didn't re-discussed about a previously created scenario.

The results showed that the corpus was convenable for the analysis, because group B was using scenarios and personas remarkably more than the group A.

- *Measurement validty:* The results of the analysis showed that in group A, before the collective activity, a total of 45 ideas were noted on the 5W table and only 11 % of them were shared by all the subjects and 42 % were shared by two or more subjects. However, after collective activity there were totally 40 ideas noted and 5% of them were shared by the all subjects and 28 % of them shared by two or more people. That means after collective meeting the percentage of shared understanding was decreased, which is contradictory with our attending. However, in group B, before

the collective activity a total of 49 ideas were noted on the 5W table and only 8 % of them were shared by all the subjects and 41 % were shared by 2 or more subjects. After the collective activity 30 ideas were recorded and 17 % of them were shared by the all subjects and 53 % of them shared by two or more people. We can conclude that group B was more effective compared to group A in terms of the level of shared understanding of the functional requirements.
On the other hand, in each group there were less number of ideas noted in 5W tables after the design meeting. That might be because the subjects were tired after the design meeting or they eliminated the ideas consciously after the collective section. The reason might be understood analysing the rest of the data gathered. If necessary, for future studies the duration of the design meeting might be reviewed, in order to gather more reach data in after step.
The coding results of the two coders agreed moderately according to Cohen's Kappa Calculations. Table 1 shows the Kappa Indexes calculated for each double coding of 5W tables before and after collective sessions. The results show that the coders has to get together and clarify the reasons of the differences in their coding. A more robust coding schema might be then created, which will be tested by new coders.

Table 1. Kappa Indexes of the double coding

	Cohen's Kappa Index		**Cohen's Kappa Index**
Group A (Before)	0,62	**Group B (Before)**	0,57
Group A (After)	0,56	**Group B (After)**	0,45

- *External and ecological validty:* The study presented in this paper is ongoing. In this paper we discussed the results of just one study and the limited sample size prevents the generalisation of the results. Further, the subjects were not professional designers and hence are unlikely to be representative of experienced design actors. The laboratory environment might also have an influence on the gathered results.

5. Conclusion and Next Steps

In this paper we have presented only the results gathered from the initial analysis of the outputs of the before and after steps of the design meetings. The aim was to test if we could gather some indicators about the design meetings by analysing the just before and just after steps, which could be an alternative to the analysis of the whole corpus which is much more time consuming. We can conclude that even if some insight can be gathered, more detailed analysis of the whole corpus needs to be undertaken in order to gather more robust findings. Once again, the sample size of the study also needs to be increased for the generalisation. For the external validity, the same study was conducted with industrial partners. The results will be discussed in future papers.
Furthermore, during the video analysis, it was observed how the use of personas brought about a marked behavioural change. For example, persona usage reinforced the empathy in group B, who rather than discussing whether or not they were interested in a function, focussed on whether the persona would be interested. Hence, the design team was more conscious of the possible contradictory needs of the intended users, which was not observed in group A. They mentioned several times that a function which might be desirable for a persona, might be undesirable for another. In order to examine other effects of persona usage in a design situation a more detailed analysis of the video recordings will be undertaken in the future.
It was also observed during the video analysis that many different forms of scenarios were used such as: fragments of scenarios, detailed scenarios, scenarios created around personas (or unknown people), etc. So, we have found ourselves debating the meaning of the term "scenario". Moreover, we could not find a common agreement in the litterature. Thus, detailed analysis of the scenarios created in both groups will be the subject future work, in order to determine the different classes of scenario and the way that they are used during the meetings.
Lastly, as mentioned before, any of the discussed scenarios were captured in group B, despite that the subjects were asked for. One of the reasons might be the tool that we furnished to them was not enough flexible for the scenario creation and the capture. This highlights the compromise between a controlled experimental protocol (i.e. the design team was not allowed to choose their own tools), and

the necessity to research the tools that should best facilitate the utilisation and the capture of the scenarios. For future studies, we will focus on more flexible mediation tools that might be supplied to the subjects.

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