SPARK

D1.2

RESULTS FROM THE EXPERIMENTAL ACTIVITIES AND PRESENTATION OF THE RESEARCH METRICS FRAMEWORK

Approval Status

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1. EXECUTIVE SUMMARY

This report describes the activities and analysis completed for Tasks 1.3, 1.4, 1.5 and 1.6 of the SPARK project. The overall aim of these activities was to build an in-depth understanding of the nature of co-creative design sessions and the way they are conducted today and then use this understanding to inform the development of the SPARK platform.

The main objectives of this deliverable were to:

- Characterise the types of interactions that occur within co-creative design sessions between participants and with artefacts (both tangible and digital).
- Understand what design practitioners perceive to be the most important impacts and affordances of design representations used in co-creative design sessions.
- Gather input from a broad range of design practitioners about the challenges they currently experience with their use of design representations and the opportunities they see for SAR technology within the context of co-creative design sessions.
- Highlight important findings from all of the above in order to support the definition of priorities and requirements for the SPARK platform in Task 1.7.

Within Tasks 1.3 and 1.4 co-creative sessions were organised between the industry partners and the case study clients. These were normal working sessions that in each case formed part of an on-going project. The only difference to a normal session was that cameras and microphones were placed in the room to allow the interactions and discussions to be recorded. At Artefice the sessions were both related to packaging design: the first concerning the design of packaging for a range of premium biscuits and the second concerning the brand identity of an ice cream brand. At Stimulo the sessions were both focused on product design: the first concerning the redesign of a personal locator beacon and the second concerning the design of a gas barbecue. This range of products and sessions were chosen to reflect the variety of activities undertaken within the 'creative industries' that could be attractive markets for the SPARK platform.

The analysis of the recordings was completed using a variety of different methods. The general approach consisted of defining types of behaviour (gesture), activity or topic of the discussion that was of interest and then 'coding' the recordings to identify when these behaviours/activities/topics occurred within the session. One example of the findings from this analysis was that typically 90% of interaction time involves the use of some kind of design representation or artefact. This is an interesting finding for the SPARK project as it shows the important role played by design representations during co-creative sessions.

Other examples of findings from the analysis include:

- Both designers and clients use both digital (renderings or CAD models presented on a computer monitor etc.) and tangible (sketches on paper, foam models, working

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prototypes etc.) design representations extensively, although clients seem to prefer tangible design representations where they are available.

- Participants sometimes resorted to hand gestures that appeared to interact with 'imaginary artefacts' as a way of communication when the design representations they had available were not sufficient to express what they meant.
- In product design sessions, the most commonly discussed modifications to the design were related to: size change, change to the number of instances of an item, position change, and shape change.
- In packaging design sessions, the most commonly discussed modifications were: colour change, look change, position change, and change to the number of instances of an item.

These insights have helped to confirm the relevance of the SPARK platform and provide useful guidance for its development.

Within Task 1.5, the overall aim was to look at co-creative design activities from the perspective of design practitioners. Two main activities were completed. First, interviews were conducted with some of the participants of the observation sessions completed in Tasks 1.3 and T1.4. This activity provided a complementary approach to analyse the results of the observation sessions. Whereas the analysis in Tasks 1.3 and 1.4 focused on the direct observation of gestures and speech during the session, the analysis conducted in Task 1.5 focused on the reflections of the participants after the completion of the session. Key findings from this activity included:

- Design representations tend to be accurate and/or realistic representations of design concepts, the similarities that the representations share with real products mean that they can be used to explore physical or digital manifestations of particular design elements of interest related to the product as they would be in the real world.
- For co-creative session, design representations can offer a way of facilitating collaboration between the participants, allow for quicker decisions to be made and improve time efficiency.
- If the affordances associated with a design representation are not aligned with the goals of the session, the use of the representation can cause participants to lose focus.

The second activity within Task 1.5 involved interviews with external organisations that have experience of co-creative design practice. This activity was designed to engage design practitioners from outside the SPARK consortium and thereby broaden the analysis to include the perspectives of practitioners from a large variety of relevant organisations (primarily design consultancies and manufacturers of consumer goods). Key findings from this activity included:

- A better understanding of the basic characteristics of co-creative sessions (who, when, where, why).
- A better understanding of how designers decide what type of design representation to use within a session.

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- Insights into the types of challenges faced by designers in their use of design representations within co-creative sessions.
- A proposal for the potential application scenarios for the SPARK platform?
- Insights into the main requirements designers have for the SPARK platform.

Within Task 1.6, the findings from across the various research activities were reviewed in order to identify the insights that could inform the development of the SPARK platform. Key insights included the observation that clients often struggle to understand and provide useful feedback on a design representations unless they are very detailed and accurate (low level of abstraction) but making such design representations can limit the scope for creativity because the client then sees the idea as 'fixed' and 'complete'. A summary of the challenges and opportunities for SAR technology was compiled in order to highlight some of the doubts and concerns expressed by practitioners about the SAR technology and to propose ways in which these could be addressed during the development of the SPARK platform. Finally, an initial, basic roadmap for the development of the SPARK platform was proposed based on the insights, observations and conclusions from the preceding analysis.

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2. INTRODUCTION

2.1. SCOPE OF THE ACTIVITIES AND OF THE DELIVERABLE

This report describes the activities and analysis completed for Tasks 1.3, 1.4, 1.5 and 1.6 of the SPARK project. The overall aim of these activities was to build an in-depth understanding of the nature of co-creative design sessions and the way they are conducted today and then use this understanding to inform the development of the SPARK platform.

The main objectives of this deliverable were to:

- Characterise the types of interactions that occur within co-creative design sessions between participants and with artefacts (both tangible and digital).
- Understand what design practitioners perceive to be the most important impacts and affordances of design representations used in co-creative design sessions.
- Gather input from a broad range of design practitioners about the challenges they currently experience with their use of design representations and the opportunities they see for SAR technology within the context of co-creative design sessions.
- Highlight important findings from all of the above in order to support the definition of priorities and requirements for the SPARK platform in Task 1.7.

Section 3 describes the results of Tasks 1.3 and 1.4 in which four co-creative design sessions involving design practitioners working with their clients were observed. The rich data recorded from these sessions is analysed using complementary gesture and verbal analysis methods in order to understand and characterise the types of activities and interactions that occur within co-creative design sessions. Much of the analysis presented in this section makes use of the evaluation criteria of co-creative design sessions defined in deliverable D1.1'Case studies and evaluation criteria'.

Section 4 describes the results of Task 1.5 in which interviews with participants of the observed co-creative design sessions and with design practitioners from outside the SPARK consortium were completed. By analysing the thoughts and reflections of these design practitioners the analysis tries to give some insight into the practitioners' perspective of co-creative design sessions including the challenges they face today and the potential applications of SAR technology that they can envisage.

Section 5 describes the results of Task 1.6 which brings together the insights and key findings emerging from the preceding tasks and uses these to help set priorities and provide recommendations for the development of the SPARK platform. These recommendations will be used to define the requirements for the SPARK platform within Task 1.7, the results of which are presented in D1.3 'Final design specification for the SPARK platform'.

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3. OBSERVATION STUDIES ON INTERACTION WITH PROTOTYPES (T1.3/T1.4)

3.1. Objective of Task 1.3 and task 1.4

In SPARK one of the main underlying hypotheses is that tangible artefacts (e.g. mock-ups, products, etc.) have a positive influence on co-creativity in design sessions. This is why the project aims at developing a spatial augmented reality platform that will allow tangible and digital object to co-exist in the same environment. Therefore we proposed in this first phase of the project to concentrate on the interactions between designers or between clients and designers that involve tangible and/or digital artefacts. The objective of tasks 1.3 and 1.4 is to analyse team interactions with digital and tangible artefacts in the everyday design activities of our industrial partners. The expected outcome of these tasks is the collection of evidence that will contribute to the consolidated elaboration of the needs (Task 1.6) and highlight important features derived from the interaction analysis that allow the definition of priorities for the development of the SPARK platform.

Analyses have been performed with dedicated software (Transana) that allows a multimedia qualitative analysis mixing verbal and visual data. Observational activities have been carried out at the end users' premise (i.e. Artifice and Stimulo consulting companies). We concentrate on activities involving co-creative design activities and focused on a set of two case studies in each location that involved end customers of the products or clients of the consulting companies. While being involved in a creative design task the designers and their clients (or customers) are exposed to digital artefacts (e.g. CAD representations, digital visualisations of the packaging, etc.) or tangible artefacts (e.g. physical prototypes, 3D printed objects, card board mock-ups, etc.). Academic partners have monitored their activity during these real co-creative design sessions that we call "case studies". We have then selected a subset of relevant episodes within the recordings and carried out complementary analysis among the academic partners in accordance with the criteria, the objectives and analysis framework previously defined (see D 1.1).

3.2. Brief description of the case studies

What we call "case study" is a design session where the designers work with their customers (for example Alce Nero's case in Artefice) or clients. We call customer the people who buy the products in the shops and client the representative of the companies that manufacture and sell the products. Because most of them involve predominantly work with a client, these participants will be called 'clients' from here onwards. The typical format of a meeting is the following: 1) the designers present their work and their proposals to the clients, 2) the designers collect the client's feed-back, 3) there is a joint discussion on the evolutions, possible improvements of the ongoing proposal. During this process they use different instruments such

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as paper/pen/pencil, screenshots, laptops, projections, mock ups, catalogues of the brand, post-it for evaluation, etc. We have been able to record four case studies that we will now briefly describe in order to introduce the context of this work (see table below). A more comprehensive description is given in Appendix I.

Companies	ARTEFICEGROUP BRANDLANGUAGEDESIGN		stimulo	
	Company 1		Company 2	
Project names	Organic Biscuits	Ice Cream	GEO Device	Gas BBQ
Design phase	ATEGY > CREATIVITY > OUT IDEAS PRODUCTION IDEAS DEVELOPMENT IDEAS E		sign Lab D Definition Technical Approach	
	Case study 1	Case study 2	Case study 3	Case study 4
Description of the sessions	The session is dedicated to the evaluation and feed-back from customers on proposition validated in previous meetings by the client. 4 package designs are presented, discussed and evaluated. And finally one concept is revisited and modified following the customers comments	This session is dedicated to the evaluation of the visual identity of 9 design suggestions based on physical prototypes. The proposals were discussed and customers remarks were recorded on post its.	The meeting is dedicated to the review of ideas elaboratd in a previous meeting. The ideas have been implemented into several prototypes and presented to the client. Emphasise is given to the material aspect and color.	The meeting is dedicated to the review of ideas previously discussed about target users, cost and assembly issues. Several parts of the BBQ are reviewed and real products are displayed in a show room so that the participant can manipulate them and compare on real objects.

Figure 3.1. Description of the cases studies

Artefice is a consulting company specialised in branding design and communication. The products designed by Artifice are mainly packaging for food industry.

Stimulo is a consulting company specialised in product design. The products designed by Stimulo are manufactured products for all kind of industry ranging from small start-ups to international groups.

3.3. Terminology: From virtual and physical prototypes to digital and tangible artefacts

The terminology used in the SPARK project definition highlights two different categories of design representations: sketches and 3D CAD models displayed on screens, or tangible shapes produced for example with additive technologies or cardboard mock-ups. Following the results of deliverable D1.1, we chose to use the terms digital and tangible to qualify the representations that are used by the stakeholders during the case studies. Then a **digital**

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representation may be 2D or 3D computerised representation, a picture, an image, a concept rendering, everything that is displayed on a digital screen, like a computer or HD television. A **tangible** representation will be object that helps to the creation, the understanding, the explanation, of the concepts, as long as it is tangible. Example includes hand sketches on paper, printed 2D drawings, 3D physical mock-ups, printed photos, etc. Our observations led us to create a new category that we call **imaginary** representation and that we will explain further in the document. Basically, an imaginary representation is a representation externalised by gestures and words but that has no tangible reality at the moment the participants make reference to it.

Design representation: we use several names to describe the objects used by the participants of the design sessions. Prototypes, objects, representations, elements, resources are all different terms involving different level of genericity or particularity, describing a set or sub-set of objects of the world. Our observations show two main categories of elements that are used by designers: elements dedicated to the description of the designed object and elements dedicated to the description of the environment, the context of the designed object. We propose to consider two categories: design representation and external resource. The category design representation is used later in the description of the interviews of task 1.5 and most of the elements of this category are based on the work of Pei (2009). Therefore, for the analysis of the design sessions, in order to reduce the ambiguity, we chose to include all these elements in the same category. We propose the term **Artefacts**. Each externalisation used during a design session is then considered as an artefact (figure 3.2).

In our analysis, we will consider **Artefacts** that are either **digital**, **tangible** or **imaginary**, according to the classification proposed above.

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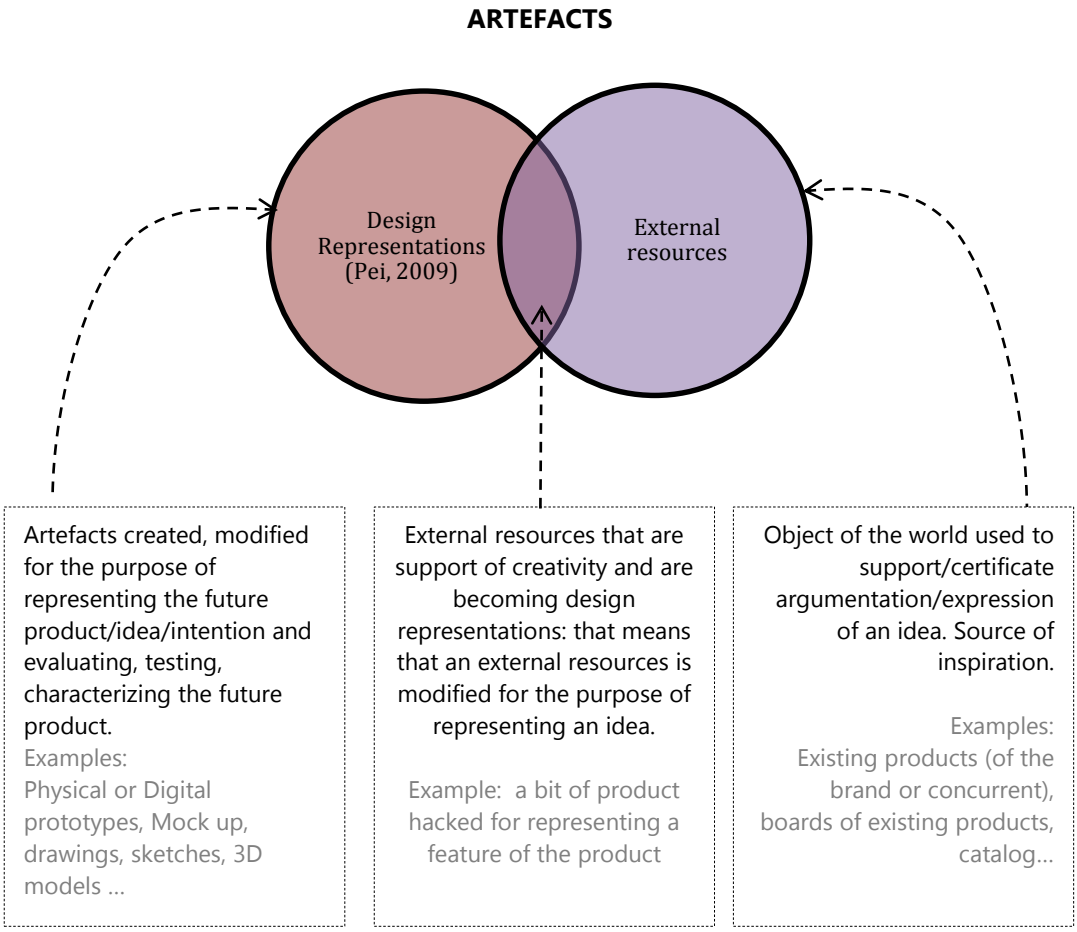

Figure 3.2. Categories of artefacts

3.4. Definition of the level of observation and the analysis frameworks

3.4.1. Interaction analysis framework based on gestures

3.4.1.1. Justification of the use of verbal and gesture interactions analysis

As we raised in D1.1, the interactions with artefacts in design sessions have been studied in the literature by means of protocol analysis based on the analysis of verbalisations and/or the analysis of gestures associated with verbalisations. Observing and analysing these practices is an important level of analysis in order to understand the needs for interaction in co-creative sessions and anticipate future needs for the SPARK platform. The aim of our observations is to capture these interactions in natural setting. **An interaction** is defined as an action that a person performs towards someone or something that is present in his environment. It could be an interaction between a client and a designer for example, supported or not by an artefact, but also an interaction between a client and a physical mock-up when he manipulates or observe it. An interaction can therefore be verbal or physical. Studying interactions is an objective way of observing a design session. This type of observation has already been used by other researchers studying design (Watts et al., 1996), (Brereton & McGarry, 2000), (Lund, Prudhomme and Cassier, 2009).

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In our study, we first concentrated on gesture interactions involving artefacts and our aim was to evaluate the importance of these interactions. We focused on gestures as a first level of analysis, since gestures are the first and observable feature of a design session. Gesture analysis does not require the full transcription and translation of the verbal interactions and is less subject to interpretation from the researcher.

In a second time, we carried out analysis of verbalisations and is presented in Sections 3.4.2 and 3.8. It is an important level of analysis that allows to access to some information on the content of the exchanges. Then we can distinguish more accurately if the interactions are related to the structure of the product or to its behaviour or to the functional aspects of the solution. This is very helpful to distinguish what aspects of the case studies are relevant for the SPARK platform or not, as well as a deeper investigation allowed to recognize the specific items elaborated within the design process and their transformations.

3.4.1.2. Definitions and typology of gesture interactions

As postulated for the gesture analysis in deliverable 1.1 and depicted in Figure 3.3, we considered three different actors/items for the gesture analysis: the client(s), the designer(s), and the artefact(s), and we defined 8 different categories of possible interactions that are detailed in Figure 3.4 below.
The analysis distinguishes two sublevels (1.1 and 1.2).

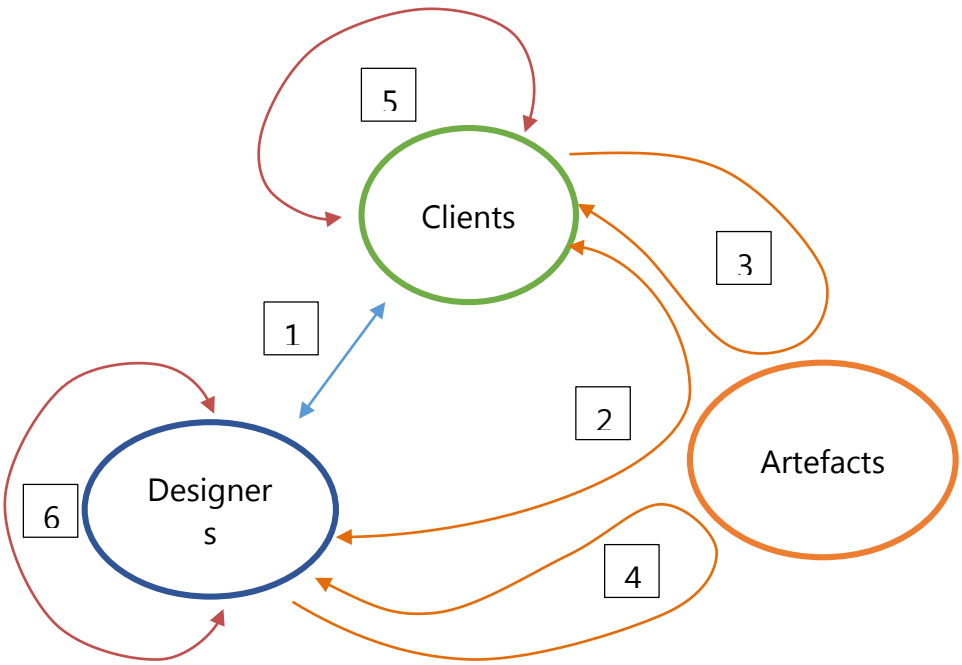

Figure 3.3. Structure of the analysis framework.

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Level 1.1	Level 1.2	interaction	definition
X	1a	Interaction from the client to the designers, WITHOUT artefact	The client will explain/show something to the designer without using an artefact
Y	1b	Interaction from the designers to the client, WITHOUT artefact	The designer will explain/show something to the client without using an artefact
X	2a	Interaction from the client to the designers, THROUGH an artefact	The client will explain/show something to the designer by using the artefact
Y	2b	Interaction from the designers to the client, THROUGH an artefact	The designer will explain/show something to the client by using the artefact
X	3	Interaction of the client with an artefact	The client will use/manipulate the artefact for himself
Y	4	Interaction of the designers with an artefact	The designer will use/manipulate the artefact for himself
X	5	Interaction between the clients, WITHOUT artefact	The client will explain/show something/talk together without using an artefact
Y	6	Interaction between the designers, WITHOUT artefact	The designer will explain/show something/talk together without using an artefact

Figure 3.3. Interactions framework level 1

3.4.2. Interaction analysis framework based on speech content

Still with the purpose of exploring the dynamics of collaboration in design, the analysis of speech protocols was completed by the research team in order to grab further relevant elements to support the identification of needs and expectations the SPARK platform aims at satisfying. Beyond what stated in Deliverable 1.1, for what concerns the metrics to be applied for the analysis of interaction, the consortium agreed to explore the SAR-related issues that occurred during the collaborative design sessions with a deeper attention. This required focusing the scope of the already defined metrics in order to provide meaningful evidences and priorities for the identification of relevant content. The outcomes of this investigation also aim to support the definition of requirements and use cases for the management.
To this purpose, we have developed tailored metrics using the analysis of the recordings carried out during the preparatory observations at the end users' premises (e.g. Milan, March 7th-8th- 2016). The coding scheme developed for the above analysis aims to measure the duration of episodes in which SAR-relevant content is mentioned. We structured the coding scheme according to three different layers in order to grab different facets that might be relevant for the development of both the SAR and the information modules of the SPARK platform.

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Layer 1. Relevance of the content and interaction for the development of the SPARK platform (5 mutually exclusive categories the nature of design items with reference to their usability on the mixed prototype "to-be")

Layer 2. SAR-related topic emerging from the discussion (8 different mutually exclusive categories describing the what the items are)

Layer 3. Distinctive features of the topics considered and coded at layer 2, with reference to the characteristics the designer would like to change or keep (9 different features describing the features to be changed or kept in the proposed design).

For what concerns Layer 1, the five mutually exclusive categories are as hereafter:

A. SPARK directly related items such as textures, logos, images, textual elements…

B. Items drawn "ex novo" within the session that would be nice to have on the design object (e.g. in SPARK they could be scanned from paper and projected on the prototype, or sketched on a tablet)

C. Stylized items drawn within the session to share directions/thoughts with other designers/participants for the development of the design object, but not to be directly reused as content to be projected on the prototype (draft sketch for concepts to be searched/produced elsewhere); Imaginary artefacts may fall in this category

D. Further sketches not to be reused on the prototype, but concerning other aspects of the development process (schemes on strategic decision,…))

E. Discussion not related to design elements, usually relating to the project as whole: strategy, timing, knowledge, data, etc (with no support of sketches or drawings).

We expect that the co-creative design sessions for Task 1.3 and 1.4 can be characterized by means of the above classification. It is also worth mentioning that, depending on the specific stage of the development process undergone in the creative industry, some of these categories might be not frequent in the planned observations, despite they all appeared in some preliminary tests run before the start of Task 1.3 and Task 1.4. Therefore, the classification, for Layer 1 will be kept as it is presented above in order to have a sufficient degree of generality that makes it applicable also along the next steps of the project (WP4 and WP5).

We have developed Layer 2 for its application on the recorded segments classified by the letter A, even if it can potentially apply also to the segments classified with different letters. Layer 2 considers the specific design items identified in Layer 1. It is organized in:

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	Statements referring to …
Texture	…background motifs/patterns
Logo	…brand distinctive graphics
Image	…a computer generated picture
Photograph	…a photograph of a real object
Text	…the part concerning words
Icon	…icons/symbols that do not belong to the brand
System Part	…something not pertaining to the whole object but one of its sub-system (tangible).
Whole	…the product as a single entity

For each of the above items, the focus of the discussion on the distinctive feature identified by the classification developed for Level 3, whose nine different features are as follows:

	Statements referring to features of the items characterizing the…
Position	…geographical dislocation with reference to the whole design proposal
Orientation	…degree of rotation
Size	…length and/or width and/or depth
Number	…the amount of items
Look	…collective indications of qualitative features of the content such as morphology, shape, geometry etc.
Colour	…chromatic content
Content	…information directly communicated
Material	…the substances composing the design proposal
Presence	…introduction or removal of items.

Additionally, the partners involved in T1.3 and 1.4 also agreed on mapping the speech also according to the FBS framework (Gero, 1990), whose variables have been adapted and generalized for this specific purpose. The interpretation of the three FBS variables is as below reported:

	Whatever relates to…
Function	…the intentions of the design representation (tangible or virtual)
Behaviour	…the communication and interpretation mechanism behind the design proposal
Structure	…the structural characteristics of the design idea under discussion.

This is done with the purpose of creating an additional layer of codification. It serves purpose of having the data codified according to one of the most common coding schemes used in literature. This makes possible comparing different existing sessions in the future, possibly also recorded beyond the SPARK project, and gain further insights about the cognitive

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dynamics within collaborative sessions in the remaining part of the project (e.g. WP4), for which these recordings can be benchmark sessions that describe 'normal' practice.

3.5. Data acquisition and processing

3.5.1. Introduction

A lot of design activities and prototypes can be used during a design and/or co-creativity session. In the project, we use mainly two complementary research approaches. One based on interviews and one based on video analysis. In this section, we will describe the video acquisition and management process.

The active involvement of our partners Stimulo and Artefice was a very helpful added value which stimulated the team and improved the efficiency and the success of the process: they provided us with the room meeting plans, the disposition of their clients, designers and information of the use of specific session tools (TV, whiteboard, heavy materials...) so that the recording could be planned well.

3.5.2. Equipment / settings

Video

The video recording process requires heavy material: we filmed the scene with **4 High resolution cameras**, fixed on professional tripods, covering at best the entire scene and taking into consideration specific requirements of the session, mentioned by our partners.

These cameras were plugged in a **Tricaster**, which is a professional device for the creation and broadcast of live High definition video content for professional TV broadcast.

In agreement with our industrial partners and in order to be non-intrusive as much as possible, we installed the Tricaster outside of the meeting room and we streamed and follow the session from a monitor in a different location.

Audio

Concerning the audio, we provided participants with personal **lapel-microphones,** when it was possible, in order to have a good audio quality and a separate recording channel for each participant. The microphones were plugged on a Tascam audio multichannel device, which is a professional audio recorder that allows the recording and synchronization of 8 simultaneous audio tracks. We also installed an ambient microphone to cover the whole room.

3.5.3. Protocol of observation

Here is the description of the observation's process:

1- Setting up material: Before the beginning of the session, the research team installs the observation equipment.

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2- Inform participants: The participants have been informed of the protocol and invited to sign the consent to participate (see appendix II).
3- Record the meeting. During the sessions the observing team sits apart in another room.
4- Interview: Post session interview have been carried out with selected participants.
5- Post process and data storage (including synchronisation, formatting, etc.)

First of all, before the beginning of each case study, we asked for the agreement to record the session from the participants. For this purpose, a document describing the observation protocol has been provided (see appendix II), including the methods and the equipment used for the recordings, the data processing and of course the confidentiality of the data. At the end of the document, the participants signed consent to participate to the experiment.

During the capture, we also recorded some basic information: the date and the time, the project name and the goals of the meeting (usually given by our design partners before the session), the language of the session, and the context of the session (where the activities we observed took place in the design process of the company). We noted also the participants' function. For example, among the clients, there were some creative or marketing directors, and some other people who gave an expert vision. We also drew a map of participant's position, of the artefacts used, and of the camera and furniture present in the room. All this has been summarised in Appendix II.

3.5.4. Post-processing

After collecting data at our partners' premises, we had to post-process the raw data in order to combine audio and video inputs, synchronising them to have a result which facilitates the analysis of the sessions.

Option of filming with professional equipment guaranteed an excellent result but it required a time-consuming procedure. The overall amount of data gathered for the four sessions was 1.9 TB, the main contributor being the raw video data which is 1.4 TB. The final exported video files are compressed down to 12 GB.

Data processing

In this step we mainly used Sony Vegas Pro which is a video editing software package. The principal motivation of choosing this tool is that Sony Vegas Pro manages exporting High definition video. We used Audacity to manipulate the audio files as well.

The post-processing includes the following tasks:

- Importing files:

Sony Vegas pro import and read files frame by frame before letting the user operate them. This is a time consuming task, for example for G7 (company 2) case study, importing 4 video and 2 audio files takes approximately 77 minutes.

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- Manipulating files:

Once the video file is imported, we can adjust it as needed, by cutting extra parts, and synchronising with audio files and deleting the camera sounds to improve the final result.

- Exporting files:

The final step is to set the full High definition Image parameters and the multitrack audio option and then run the exportation. This is the most time consuming task of the whole process: for example, exporting a project with 4 videos that initially last 3 hours can take approximately 18 hours 45 minutes. We had to do that for the four case studies and a substantial number of times, as we had to fine-tune the parameters, particularly the synchronisation of the video and the sound.

3.5.5. Transcriptions of the recordings

In order to manage the data and accessing the speech related content more quickly and efficiently, the recordings of the two collaborative design sessions carried at Artefice have been transcribed with some excerpts of Stimulo's sessions that were representing relevant episodes. The relevance has been decided collectively based on the intensity of the interactions and the topics addressed. These were used in the interaction analysis introduced in 3.4.2. Full transcriptions of the other two sessions are also being completed for the use by various partners.

3.6. Gesture interactions Analysis level 1.1

As presented in section 3.4 our coding framework addresses different levels of interactions and for this first level of analysis we addressed gesture analysis along the entire duration of the four sessions.

3.6.1. First analysis Strategy

The objectives of the first-level analysis were:

- To quantify the time ratio where designers or clients use or don't use artefacts to support their interactions during the co-creative sessions observed.
- To characterise who (designers or clients) use artefacts and which types of artefacts were used (digital or tangible).

For this first-level analysis, we considered all the four recorded sessions. For the Stimulo cases studies, it was manageable to code the totality of the video, because they last 1h20 and 1h40. Artefice cases studies last 3h30 and 2h50. In order to ensure a consistent time frame for the four coded sessions, we choose to select different episodes of different step of the Artefice's meetings. For example, for the Case study 1 meeting we selected one of the four packages they considered during the meeting (figure 3.5, dark green cells on the top of the figures). The same procedure has been applied for case study 2 and the two sets of episodes are displayed on

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figures 1.5 and 1.6 along the sessions' timelines. In both cases, the video selected for the analysis has been reduced to approximately 1h30mn.

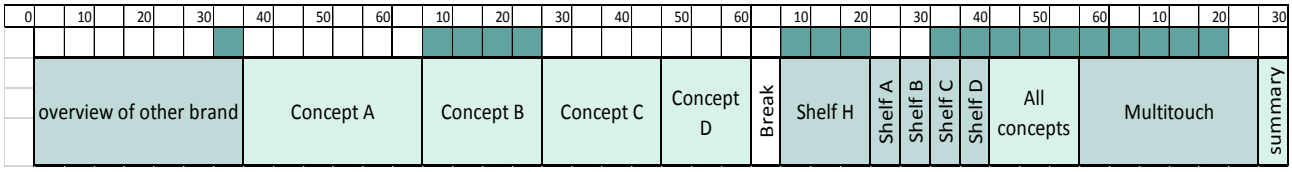

Figure 3.4. Selection of the moments to analyse: case study n°1

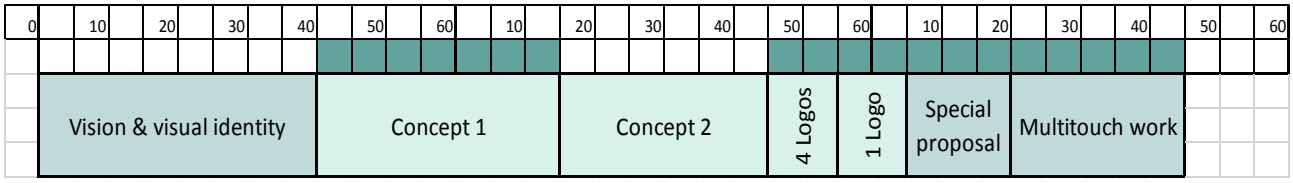

Figure 3.5. Selection of the moments to analyse: case study n°2

3.6.2. Gesture Analysis framework level 1.1

The first level of coding analyses the gesture interactions <u>with</u> or <u>without</u> artefacts. Every time a person interacts with an artefact we encode X or Y the duration of the interaction with this artefact (see figure 3.7).

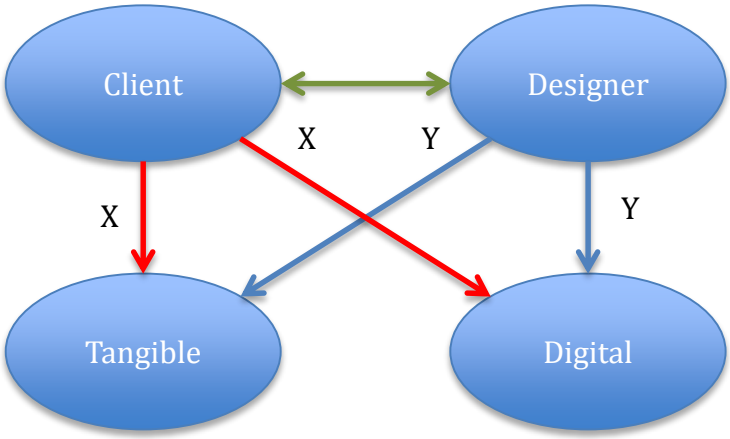

Figure 3.6. Types of interactions

Interactions of type X can be:

- Interaction between the client (s) and the artefact (s) (whether digital or tangible)
- Interaction from the client (s) to the designer (s), through the artefact (s) (whether digital or tangible)

Interactions of type Y can be:

- Interaction between the designer (s) and the artefact (s) (whether digital or tangible)
- Interaction from the designer (s) to the client (s), through the artefact (s) (whether digital or tangible)

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We run these analyses with Microsoft office Excel 2013 using tables shown figure 3.8. We choose to code second by second.

		time line	00:00:10	00:00:11	00:00:12	00:00:13	00:00:14	00:00:15
DIGITAL	X (client)		X	X	X	X	X	X
TANGIBLE								
DIGITAL	Y (designer)							
TANGIBLE								

Figure 3.7. Example of a coded episode.

In order to have consistent results, we established a **coding book** where we can find the coding rules and some examples of application.

For example:
Rule 1: We do not differentiate the clients between them, or the designers between them. If several designers are participating to the session, either the designer 1 or the designer 3 that interact, we will code the same way: interaction of the "designer i with artefact" -> Y.

Rule 4: There may be sequences where are coded several interactions simultaneously. Several causes are possible. In that case, we listed all the possibilities where this may happen and we code in parallel simultaneous events on the timeline.

The aim of this coding book, is to enable anyone to code the video and obtain the same results.

3.6.3. Results and discussion on the level 1.1

Here we present the level 1.1 analysis using four types of graphic:

- The first graphic displays the breakdown of interactions with or without artefacts. This highlights the predominance of artefacts (digital and tangible) in the communication during the design sessions.
- The second pie chart displays **what type of artefact** (digital or tangible) is the most solicited among the participants, designers and customers combined. This analysis aims at supporting the hypothesis of a predominance - or at least the significant presence - of tangible artefacts compared to digital, in the exchanges among the participants.
- The third pie chart lets us see **what type of artefact** the **clients** use the most.
- The fourth pie chart lets us see **what type of artefact** the **designers** use the most.
- Combined with a summary of both designers and clients we can analyse if the clients or the designers tend to use significantly more artefacts.

Breakdown of interactions with or without artefacts

Thanks to the first level of analysis, we obtained several interesting results. In the following graphs, we can see the distribution of the time when participants (clients and designers

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combined) are using artefacts or not. During the sessions, on average, we have approximately 90% of time where people are using, pointing, manipulating, annotating, sketching, or just simply talking about[1] artefacts (figure 3.9). This confirms that artefacts played a very significant role in the co-creation sessions observed.

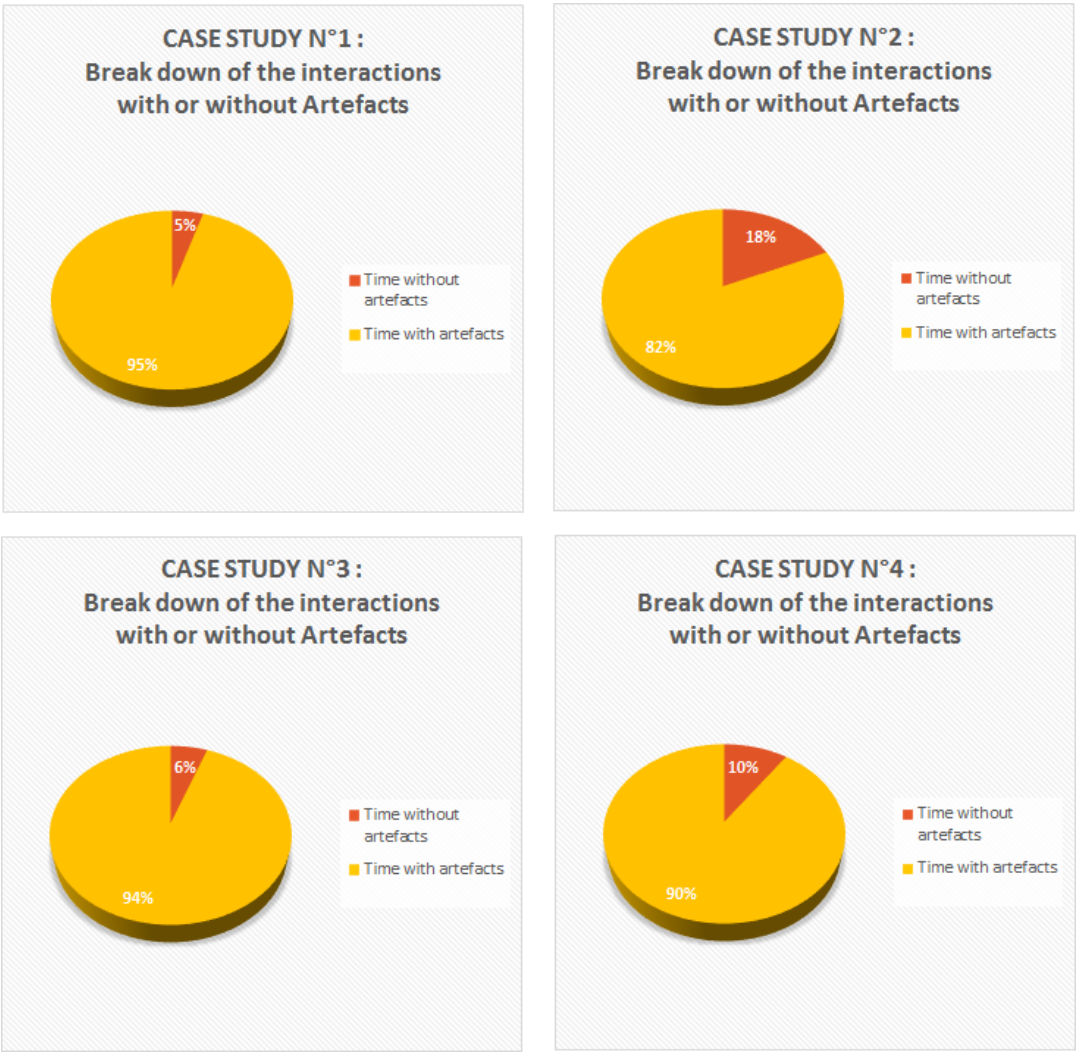

Figure 3.8. Distribution of time with and without artefacts

Breakdown of interaction X(client) and Y(designer) with artefacts during the meeting

The first group of pie chart displays (figure 3.10), of all the interactions with artefacts, which ones involve the **clients or the designers**.

[1] These verbal interactions have been identified just as the other interactions we just could "see" they were talking but we did not listen to what they were talking about.

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Figure 3.9. Breakdown of interactions with artefacts for clients and designers.

We note that in Artefice's case studies (n°1 and 2), the breakdown between clients and designers is reasonably equal. On the contrary, the breakdown in Stimulo's cases studies (n°3 and 4) is more 63% for the designers and 37% for the clients.

In the following, we point out some facts that may explain the differences in the results. However, this should be investigated further in order to get a reliable result based on the observation of more cases:

- Firstly we notice that the design phase considered in Artefice and Stimulo is different.
    - In Artefice, we are in the creativity phase of the design process, The concept was not frozen and the designers were still trying to get feedbacks from the client. Therefore more interactions may be necessary to get a shared understanding or clarify the clients' opinions.

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- In Stimulo, we were at the end of the ID Definition. That means that the concept's structure was almost frozen. We are approaching the end of the design process and the participants are working on the colours, materials and finishes, therefore we may consider that they need less interactions in order to come to an agreement as they have had the time to build a shared understanding during the previous design phases.

- Secondly, we notice that the objectives of the session are not the same in Artefice than in Stimulo. Which may also be a factor that influences the results:
  - In Artefice, the goal of the session was to get the clients feedbacks. They ask customers to evaluate each concept with positive and negative aspects. This is potentially a reason why there is a greater number of interactions from the clients than for Stimulo.
  - In Stimulo, the goal of the session was mostly to present the updates which have been done since the previous meeting. Of course the clients were very welcome to comment on the proposal, but it was not the main aim of the session.

- Finally It should be noted that during the Artefice sessions, we have around 3-4 designers and 6-7 clients, whereas during the Stimulo sessions there were 3 designers and 1 client. This also can be a reason for the predominance of the clients interactions in Artefice.

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Breakdown of interactions with digital or tangible artefacts (X+Y)

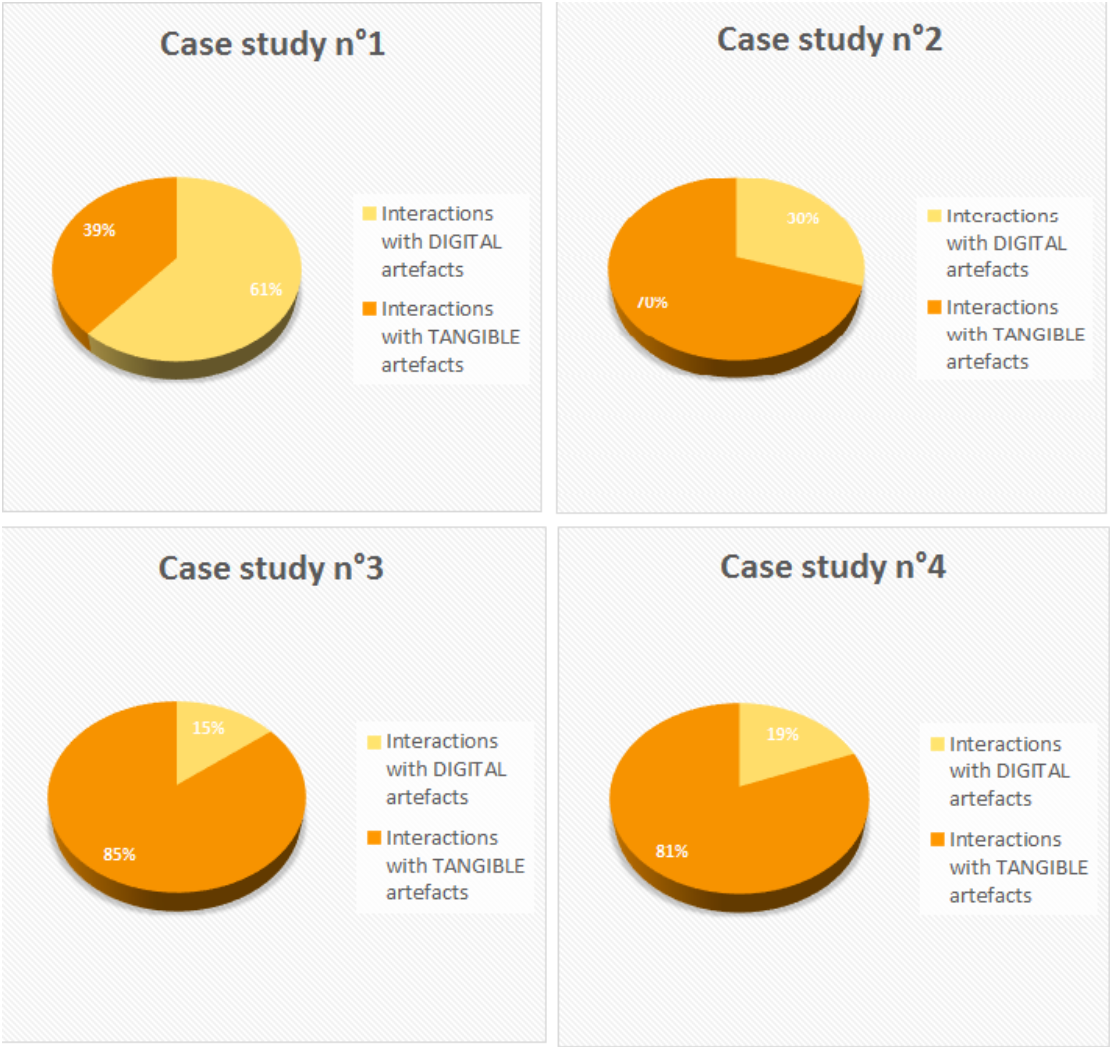

Figure 3.10 : Breakdown digital vs. tangible for clients+designers interactions

For this analysis, we took the portion of time where participants were using artefacts, and we distinguished, the distribution of tangible artefacts versus digital artefacts.
We clearly observe that in three of the four cases the participants use mostly tangible artefacts. We mention that during the sessions, we usually found several tangible artefacts (paper, post-it, mock-up, catalog etc) and only one or two digital ones (computer or tv screen).

However in case study n°1 we see the opposite phenomenon. We have more interactions with digital artefacts than with tangible ones. In fact, during this session, the designer realised that the mock-up available was not corresponding to the digital representation. The colour of the packaging was not exactly the same that the one projected on the screen. Because of this issue the designer prefered to remove and hide the mockup and rely on the digital one. The clients had only the digital representation and printed concept to evaluate the proposals. Furthermore, during case study n°1, the designers used a multitouch screen which enable the live modification of the concepts. These could be the main reasons behind the result of this case study.

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Breakdown of Digital / Tangible artefact used by clients (X)

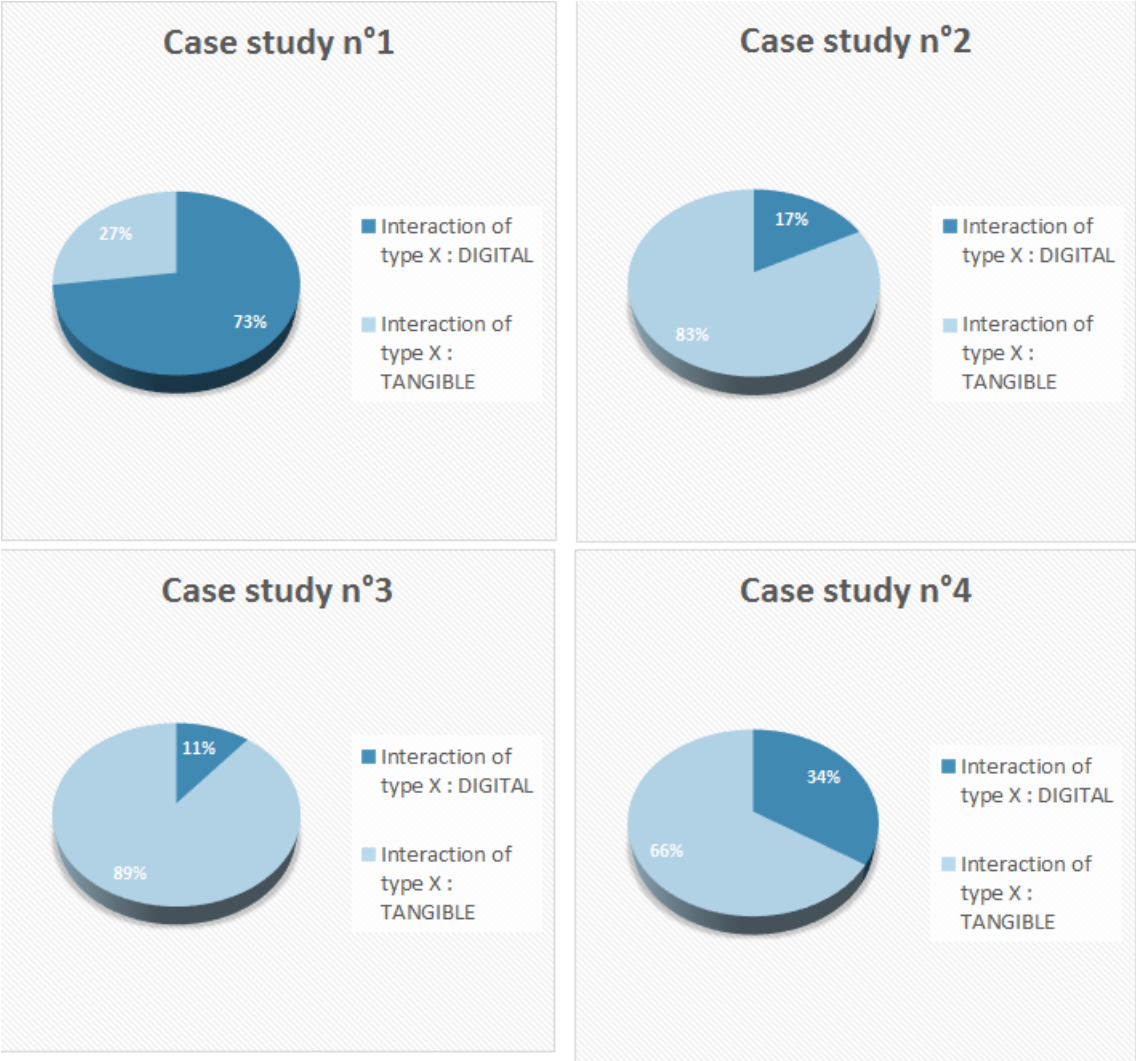

Figure 3.11. Breakdown digital vs. tangible for clients' interactions.

For the analysis displayed figure 3.12 we took the portion of time where clients were using artefacts, and we distinguished, the distribution of tangible artefacts versus digital artefacts. For the same reasons than for the previous case, we find out that globaly clients were using more tangible artefacts than digital ones, excepted in case study n°1.

In case study n°4, we observe that we have slightly more interactions with digital artefacts. In fact, during this session, the only digital representation was displyed through the client's laptop.

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Break down of Digital / Tangible artefacts used by designers (Y)

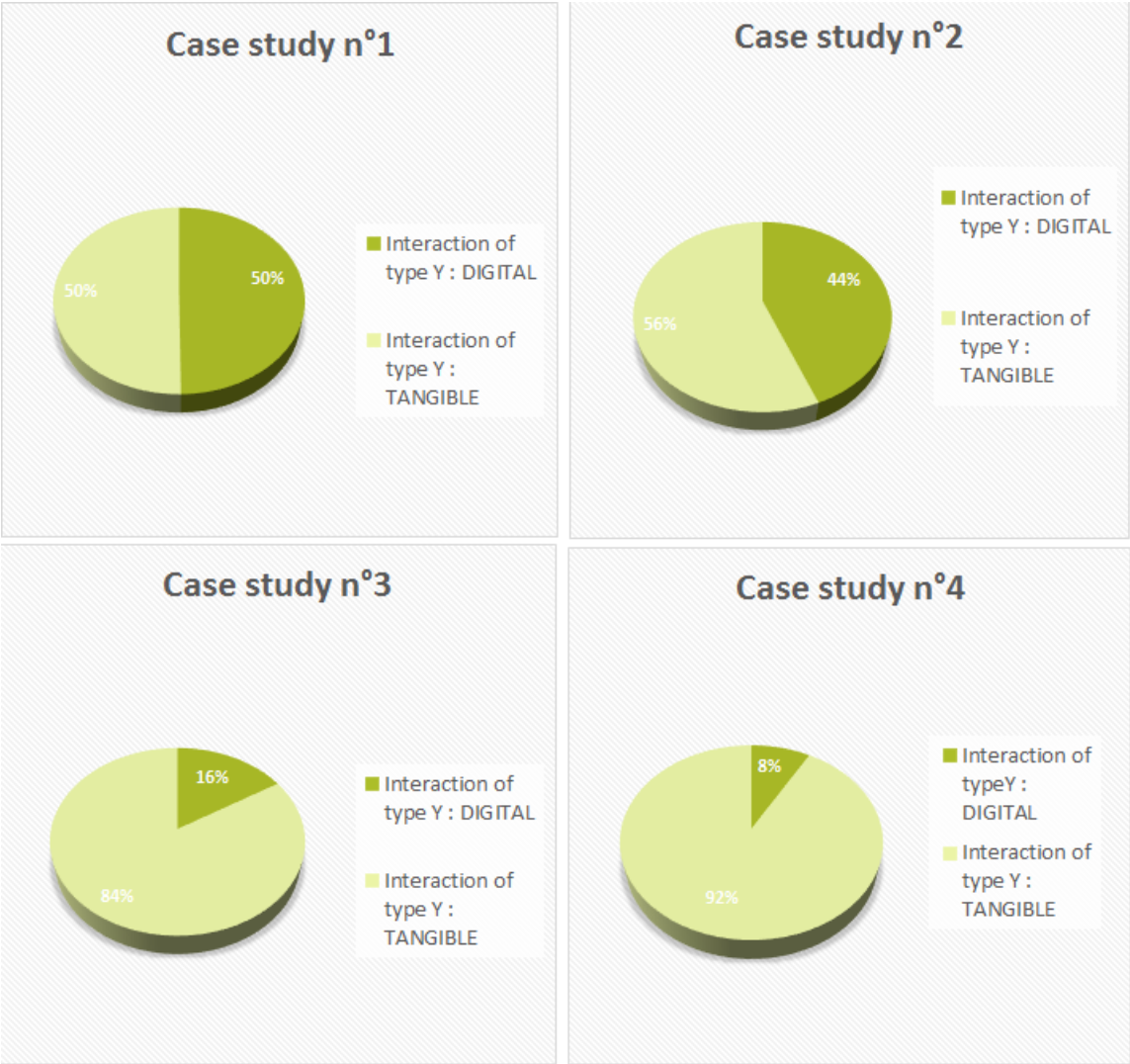

Figure 3.12. Breakdown digital vs. tangible for designers' interactions.

In this results, we took the portion of time where designers are using artefacts, and we distinguished, the distribution of tangible artefacts and digital artefacts.

Comparatively to the previous pie graphs (clients), we see that the designers from Artefice use more digital artefacts. This is due to the fact that they are using a multitouch screen, which requires some knowledge. In the case study n°2, the multitouch screen had some troubles, so they used the macintosh screen and the designer was forced to do the live modification directly on photoshop.

In Stimulo, in case study n°1, they are using only a TV screen in order to project a powerpoint presentation, and a laptop to simulate electronic features. In case study n°2, they used the client's laptop sporadically to watch video, pictures, or to refer to an email. These are the reasons why we have mostly interactions with tangible artefacts.

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3.6.4. Conclusion on level 1.1 analysis

From this level 1.1 analysis, we saw that the vast majority of the interactions were carried out through artefacts or with artefacts and that both tangible and digital artefacts are involved in these interactions (figure 3.14). We therefore conclude that a suitable environment for co-creative sessions must enable participants to interact with each other *through* and also directly *with* digital artefacts and tangible artefacts.

It seems that customers and clients are more likely to use tangible artefacts when available and use digital ones if no other option is at hand. This hypothesis is worth being investigated further. Additionally the client's participation ratio (Client vs. designers) (figure 3.14) depends a lot on the objective of the meeting. For example, in case study 1 and 2 the sessions were dedicated to customer feedback therefore we have a greater participation of the clients compared to case study 3 and 4 where we had a more classical design meeting.

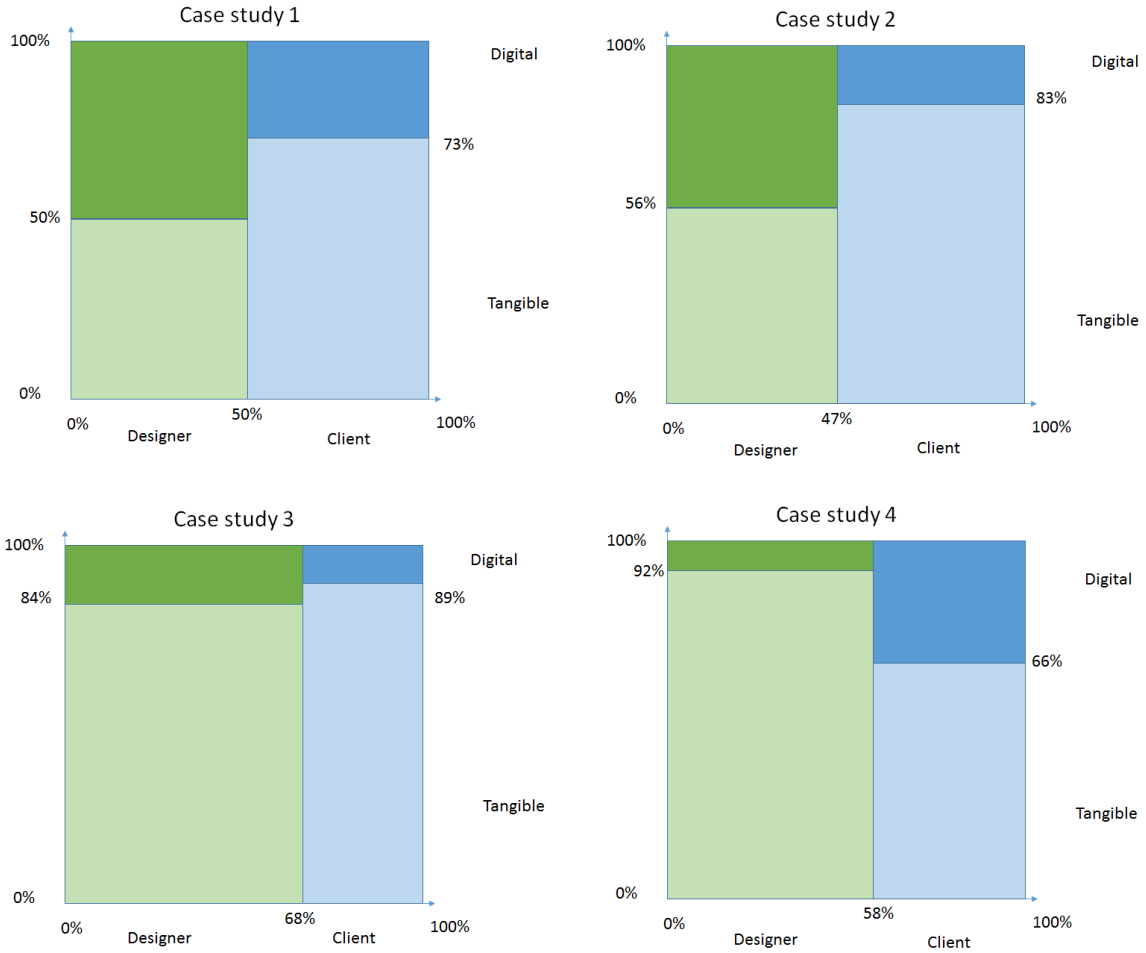

Figure 3.13. Summary chart showing breakdown by designer vs client and tangible vs digital

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3.7. Gesture and interaction analysis level 1.2

3.7.1. Data studied

The level 1.1 data processing gave some global information about designers' and clients' use of artefacts along the four different case studies we analysed. The objectives of the level 1.2 analysis is to provide a deeper gesture analysis on selected episodes. Our criteria for selection are the following:

- ✓ The episodes were based on interaction with tangible or digital prototypes, being interesting for a better understanding on how artefacts were used during interaction,
- ✓ They put forward the use of more than one type of artefact at the same time, for example imaginary and tangible. Such interactions might feed the requirements for the future SPARK platform,
- ✓ They included 'simulation with hands', highlighting the lack of support to convey ideas or to interact with others. Once again, such lacks could be addressed by the future platform.

We chose four different episodes from case study 4:

- ✓ Episode 1, From 17:38 to 27:20
  This episode shows a sequence of two distinct phases: in the first half of the sequence digital representations are used (videos visualized on a laptop) while tangible artefact (real Barbecues) were used in the second half.
- ✓ Episode 2, From 29:34 to 34:18
  This episode features a lot of hand gesture during interactions between the client and the designers, while other artefacts used are mainly paper and sticky notes.
- ✓ Episode 3, From 1:08:55 to 1:13:17
  In this episode, designers mainly use Post-It notes (representing temperature gauge or labels) which they stick on top of the barbecue to help give an indication of what the finished barbecue product might look like.
- ✓ Episode 4, From 1:17:38 to 1:22:36
  This episode is particular because actors are manipulating spare parts of the BBQs (knobs and a handle). Designers and client manipulate knobs, put them in situation on the real barbecue and on the design representation of the new version of the barbecue that is displayed on a pin board.
  The handle is also used by the designer and client working together to simulate what it might feel like to operate the handle.

3.7.2. Data processing

The initial analysis framework, Level 1.2 analysis (see figure 3) was enriched by differentiating interactions according to the nature of the artefact involved during the interaction: digital (d), tangible (t) and imaginary (v). Digital and tangible have the same meaning as in the previous analysis (see section 3.3). We added a new category we call "imaginary" for characterizing interactions where designers and/or clients are using gestures with hands as we will qualify as

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'gesture in the air' for interacting together. This 'gesture in the air' can be communication oriented, but also used for simulating a shape of a part or simulate the manipulation of the product.

This 'gesture in the air' may have two purposes:

- ✓ Gestures to support oral communication, emphasizing the speech. It usually falls into the body language category. We'll refer to them as "communication gestures".
- ✓ Gestures for simulating usage of whole or part of the product. It can also depict the shape of parts that do not exist yet. We'll refer to them as "technical gestures".

However, we decided to code these two kinds of gesture in a unique interaction set called "imaginary artefact".

The interaction framework used to code interactions of the selected moments can be described as follows:

1a *Client to designer without artefact*
1b *Designer to client without artefact*
2ad Client to designer with digital artefact
2at Client to designer with tangible artefact
2av client to designer with imaginary artefact
2bd Designer to Client with digital artefact
2bt Designer to Client with tangible artefact
2bv Designer to Client with imaginary artefact
3d Client (to client or with himself) with digital artefact
3t Client (to client or with himself) with tangible artefact
4d Designer (to designer or with himself) with digital artefact
4t Designer (to designer or with himself) with tangible artefact
5 *Client to client without artefact*
6 *Designer to designer without artefact*
7 Other

We add a category 'Other' for interaction that could not be coded inside the 14 first proposed categories.

For example:

Example 1: Designer 1 pushes the chair out
Example 2: Designer 1 and Client come back to the desk

We deliberately discarded 3v and 4v categories as we considered that opportunities to witness actors making gestures in thin air for themselves would not occur.

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We also add a marker we called **'multiple'** to point the fact that more than one artefact is handled simultaneously. This is the case when for example imaginary artefact (gesture) is used during interactions with tangible artefact. This is also the case when a tangible artefact is used at the same time as another tangible artefact, provided that these two artefacts are considered in relation to each other. For example, when an actor considers knobs that have been disconnected from the barbecue and they compare and observe these knobs in relation to the barbecue, we recorded the double artefacts as 'multiple' (knobs and barbecue). But on the other hand when people extract a drawer from a barbecue and then discuss it, we do not consider this as 'multiple'.
We used the TRANSANA Software to perform the coding of the chosen episodes (figure 13).

TRANSANA enables to simultaneously view:

- the four camera angles captured in the video (upper right corner),
- the transcript (That was constructed gradually during the analysis) of the interaction expressed in terms of gesture (bottom left corner)
- and the collections of interactions we associate to the same keyword (bottom right corner)

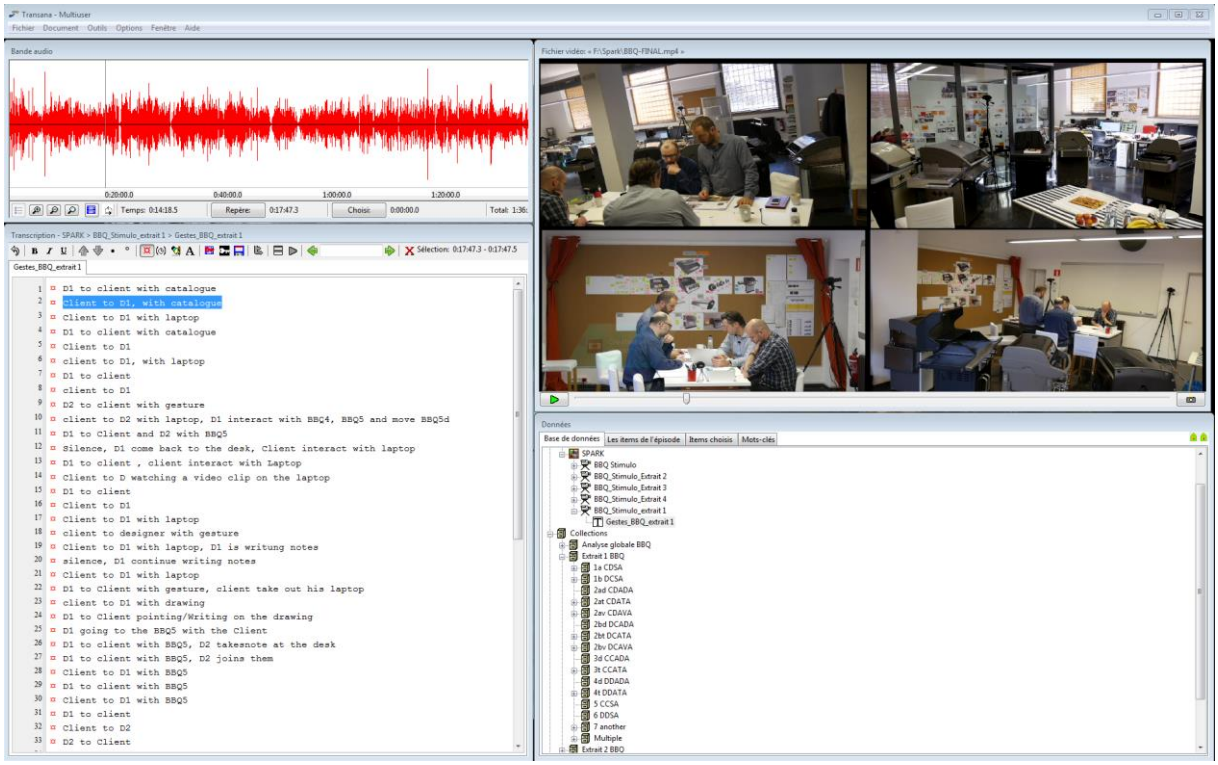

Figure 3.14 : Transana screenshot

Two researchers did the first coding activities together. During this activity, they collectively built a **coding book** based on decisions made about the way to code ambiguous interactions in which they did not agree on coding in the first instance.
For example:

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1. *When a client or designer B is not "obviously" attentive (but maybe listening), while his interlocutor A speaks to him, we code the interaction between A → B and we add another interaction describing the interaction B is doing in parallel.*

2. *Artefacts can be digital (laptop video, CAD model, slides on TV screen...), tangible (everything that can be touched, seized, grasped...) or imaginary*

3.7.3. Results of gesture interactions level 1.2

The results we obtained are available in Appendix III. For each episode studied, you can find a timeline showing the result of the coding of the interaction and a representation of the breakdown of the interactions according to the interaction framework defined above.
We describe in the following the main findings and analysis of the episodes.

Results for the first episode

Interaction types		**% of time**
1a	Client to designer without artefact	6
1b	Designer to client without artefact	5
2ad	Client to designer with digital artefact	11
2at	Client to designer with tangible artefact	12
2av	client to designer with imaginary artefact	10
2bd	Designer to Client with digital artefact	0
2bt	Designer to Client with tangible artefact	27
2bv	Designer to Client with imaginary artefact	2
3d	Client (to client or with himself) with digital artefact	4
3t	Client (to client or with himself) with tangible artefact	7
4d	Designer (to designer or with himself) with digital artefact	0
4t	Designer (to designer or with himself) with tangible artefact	15
5	Client to client without artefact	0
6	Designer to designer without artefact	0
7	Other	2

Figure 3.15. Results of episode 1.

Noticeable elements

This episodes last about 10 minutes.
Digital artefacts were proposed by the client during the first half of this episode. 11% of interaction time is coded as client to designer with digital artefact (the client laptop was used for displaying a video clip). Designers did not use digital artefacts to interact with the client. They suggested to the client to directly interact with a tangible artefact during the second half of the episode. In the largest percentage of time (27%), designers were interacting with the client with tangible artefacts. The client also interacts a significant amount of time (12%)

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with the designers with such tangible artefact.

An interesting phenomenon appears around the 20th minute (see Appendix III, Episode 1) when the client interacts with the designers through a digital artefact, and around 24th minute when the client interacts with the designers through a tangible artefact: in both cases the client uses gestures with his hands. This type of gesture represents 10% of the interaction time, which is strictly comparable to the client's interaction with tangible or digital artefacts. This observation was the motivation for eliciting a new type of artefact we named ***imaginary artefact***. The existence of such gestures suggests that there is a lack of support in the existing environment. Investigation at a lower level (taking into account speech utterances) should provide a better insight on the rationale for those kinds of gestures.
Another interesting lesson learned from this analysis is the time ratio (22%) client and designers spent interacting for themselves with the tangible artefacts. We can add that several individual artefacts (typically a BBQ) were used for a short time. It means that the variety of products available was necessary for these types of interactions.

Results for the second Episode

Interaction type		**% of time**
1a	Client to designer without artefact	7
1b	Designer to client without artefact	0
2ad	Client to designer with digital artefact	0
2at	Client to designer with tangible artefact	17
2av	Client to designer with imaginary artefact	28
2bd	Designer to Client with digital artefact	0
2bt	Designer to Client with tangible artefact	11
2bv	Designer to Client with imaginary artefact	6
3d	Client (to client or with himself) with digital artefact	0
3t	Client (to client or with himself) with tangible artefact	6
4d	Designer (to designer or with himself) with digital artefact	0
4t	Designer (to designer or with himself) with tangible artefact	23
5	Client to client without artefact	0
6	Designer to designer without artefact	0
7	Other	2

Figure 3.16. Results of episode 2.

Noticeable elements

This episode lasts around 5 minutes.
It was chosen because we observed a lot of gestures. The quantification shows that 34% of interactions are coded as interactions between client/designer with an imaginary artefact. This percentage could be even higher if we didn't take into account interactions that one of the designers has in parallel with tangible artefact from 29:45 to 31:15 (see 4t on the timeline of

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appendix III, Episode 2). One interesting thing is that imaginary artefacts are called up during interactions either in same time (8%, see the multiple characteristics), or alternately with tangible artefact. The fact that imaginary artefacts are used lead us to assume that client and designer need another mode of expression to interact. Of course, further analysis could help us to dissociate communication gestures from technical gestures.

Results for the Third Episode

Interaction types		**% of time**
1a	Client to designer without artefact	0
1b	Designer to client without artefact	0
2ad	Client to designer with digital artefact	0
2at	Client to designer with tangible artefact	21
2av	client to designer with imaginary artefact	0
2bd	Designer to Client with digital artefact	0
2bt	Designer to Client with tangible artefact	72
2bv	Designer to Client with imaginary artefact	0
3d	Client (to client or with himself) with digital artefact	0
3t	Client (to client or with himself) with tangible artefact	5
4d	Designer (to designer or with himself) with digital artefact	0
4t	Designer (to designer or with himself) with tangible artefact	2
5	Client to client without artefact	0
6	Designer to designer without artefact	0
7	Other	0

Figure 3.17. Results of episode 3.

Noticeable elements

This episode has been studied because 93% of the interaction time includes tangible artefact. What is striking in this episode is the ratio of multiple interactions: 73% of interactions are multiple interactions involving artefacts of the same nature (tangible). Here, it is mainly due to the use of stickers on the topside of a BBQ. They are stuck, unstuck and dragged to another location, annotated and even removed from the panel. This episode is also typical of a phase where designers and clients try to evaluate the best layout for inserting components in the structure.

Results for the fourth episode

Interaction types		**% of time**
1a	Client to designer without artefact	1
1b	Designer to client without artefact	3
2ad	Client to designer with digital artefact	0
2at	Client to designer with tangible artefact	23

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2av	client to designer with imaginary artefact	0
2bd	Designer to Client with digital artefact	0
2bt	Designer to Client with tangible artefact	40
2bv	Designer to Client with imaginary artefact	1
3d	Client (to client or with himself) with digital artefact	0
3t	Client (to client or with himself) with tangible artefact	12
4d	Designer (to designer or with himself) with digital artefact	0
4t	Designer (to designer or with himself) with tangible artefact	5
5	Client to client without artefact	0
6	Designer to designer without artefact	0
7	Other	15

Figure 3.18. Results of episode 4.

Noticeable elements

In this episode a majority of interaction (63%) were done with tangible artefact. 39% are multiple interactions. They are mostly due to the use of knobs and a handle, which concentrates interactions made in relation with tangible representations of the BBQ.

Global Results from this detailed gesture analysis

The four episodes analysed above have not been carefully chosen. They were selected because the interactions with the artefact were either particularly intense or different to the types of interaction seen in the other episodes. Hence, we are not surprised by the fact that more than 90% of the time is dedicated to interactions with artefacts. However, the main outcome from this second level analysis is twofold.

Importance of the multiple interactions

It is important to notice that in this case study (case study 4) it was not expected that there would be any digital artefacts used during the meeting (the session was not prepared for that). However, the client brought his laptop to the meeting leading to some interactions with digital artefacts. Multiple interactions (i.e. interactions with several artefacts at the same time) exclusively concern tangible artefacts, or a mix of imaginary and tangible artefact (c.f. episode 2) but not any mixed tangible and digital interactions.

Importance of imaginary artefact

At several occasions, we observed "gestures in the air" in various contexts. At this stage of our analysis, we cannot conclude on the motivation for such gestures with imaginary artefact. However, they are made spontaneously and seem to fill the gap between the available artefacts and the intentions that actors wanted to express. We must consider this faculty as a natural way of communication and try to support or develop it in our future co-creative environment (see https://www.tiltbrush.com/ for example which allows users to draw and paint in a 3D space using virtual reality).

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Next step

The next step is, undoubtedly, to analyse verbal interactions for a deeper understanding of the rationale behind the interactions. According to literature on intermediary object (Boujut, J.F, Blanco, E., 2003) (Vinck, D, 2011), the artefacts are supporting the knowledge building and exchange. The next step is to analyse the speech, which remains a major communication channel.

3.8. Analysis of interaction with artefacts using speech protocols

Consistently with the metrics described in Section 3.4.2, the following part presents the analysis of specific segments of the different recordings carried out for the activities of Task 1.3 and 1.4.

3.8.1. Analysis strategy

Four different collaborative design sessions have been recorded at the end users' premises and, as stated before, their duration significantly varies according to the specific kind of design proposal to be developed. In order to explore the needs and expectations emerging in sufficiently varying design episodes (good coverage of possibly different dynamics) and keep the analysis thorough on the specific elements to be codified (meaningful detail level of the analysis), we have decided to focus the attention on two out of four recordings. This decision is also partially constrained by the need of providing early but robust information to the team members working in parallel on the development of the SAR modules for the SPARK platform (WP2).

The two recordings are representative of the two example contexts of design sessions the SPARK project has access to: packaging design (co-design session at Artefice with Company 1 – case study 1) and product design (co-design session at Stimulo with Company 4– case study 4).

For what concerns the analysis of case study 1 on biscuits packaging, four thematic phases (A to D) have been identified in the recordings; overall durations in bold.

1. Evaluation of existing biscuit packages (Organic Biscuits and non-organic biscuits): 0' to 35'
2. Presentation and review of the 4 alternative design variants: 35' to 2h 01' 40'
    a. Package variant #1 – Concept A: 35' 14'' to 1h 04' 32''
    b. Package variant #2 – Concept B: 1h 04' 33'' to 1h 23' 24''
    c. Package variant #3 – Concept C: 1h 23' 25'' to 1h 43' 16''
    d. Package variant #4 – Concept D: 1h 43' 17'' to 2h 01' 40''
3. Shelf evaluation (as the 4 variants declined on the whole product range) 2h 01' 40'' to 2h 44' 50''
4. Collaborative re-design session starting from the previous evaluations 2h 44' 50'' to 3h 30'

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For what concerns the analysis of case study 4, the collaborative design session on the product barbecue has been characterized in terms of themes, each of them focusing on a specific subsystem of the whole barbecue. As above, durations in bold.

1. Preparation of the session: 0' to 02'39''
2. Focus on the BBQ parts: 02'40'' to 1h 35' 41'
    a. Theme «Supports for the grill of the barbecue»: 02'40'' to 08' 12'
    b. Theme «Fat tray»: 12' 21'' to 33'17''
    c. Theme «Burners and top»: 35' 21'' to 1h 03' 31''
    d. Theme «Thermogauge»: 1h 07' 23'' to 1h 16' 33''
    e. Theme «Knob»: 1h 16' 41'' to 1h 20' 00''
    f. Theme «Handle»: 1h 20' 20'' to 1h 21' 56''
    g. Theme «Gasket»: 1h 22' 23'' to 1h 24' 45''
    h. Theme «Reversible Grill»: 1h 25' 26'' to 1h 29' 56''

In this specific case, the missing time in between the different themes is the time required to shift the theme to a new one (e.g. by taking drawings, stickers, tangible parts…).
Considering what was already discussed in Section 3.2 on the nature of the design activities of the four case studies, it is not surprising that they present differences with each other. Comparing the two above described sessions with each other, it clearly emerges that the "packaging design" session more easily enabled the direct modification/refinement of previously developed design proposals. This chance to directly apply the changes suggested by participants' feedback was probably due to the "mostly-virtual" nature of the largest part of the contents there handled. Phase number 4 of case study 1, thus, can be identified as a creative review session, according to the classification proposed in Deliverable 1.1. This segment represents a good selection for carrying out the speech analysis, considering that the SPARK platform aims at addressing exactly a scenario of such a kind, shifting the application of SAR technologies beyond the simple design review practice.
On the other hand, Phase 2 of case study 1 can be considered as a more "typical" design review session, where the participants are asked to express their judgement on design proposals in order to clarify if a specific solution is worth of further development, if it deserves major/minor changes or if it has to be completely rejected. Considering the alternative nature of this phase (with reference to phase 4, mentioned above) its analysis can provide meaningful insights on the main differences between the two phases, showing the gap the SPARK platform should aim at filling. Phase 2 of case study 1 is significantly longer than phase 4. In order to keep a similar amount of time for the two segments, two out of the four proposed concepts have been selected: Concept A and Concept B. This decision is also motivated by the fact that the first two proposals (A and B) are the ones that received more comments that, if applicable also to other concepts, did not have to be repeated in the remaining part of the collaborative design session.
The collaborative session of product design (case study 4) is similar in dynamics and purpose to the design review session of case study 1, even if it deals with a completely different topic

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and nature of the discussion. The customer participating in the collaborative design session at Stimulo, indeed, was mainly asked to provide feedbacks about the different design proposals the Stimulo design team had prepared for barbecue components. The participants (both designers and their client), indeed did not ask for any specific change or modification. The design review nature of this session makes the explored themes good candidates for carrying out comparisons between product and package design, specifically for what concerns reviewing solutions. Still with reference to the similar durations of the recording segments to be analysed, we had to select some of the themes discussed during case study 4. The choice of the themes for the analysis has been done taking into account the overall purpose of WP1, which is providing meaningful information to WP2 for the development of the SPARK platform modules. After the complete analysis of the case study 4, we recognized three themes as candidates for providing the analysis with more various insights. Moreover, the following three themes are also the ones that by nature fitted the potential application of a SAR-based platform better:

- the Burners and the devices to place on top for cooking (Theme 3)
- the Thermogauge (Theme 4)
- the Knob (Theme 5)

Within this section we will refer to the segments of the recording selected for the analysis as follows:

- **Package review:** Case study number 1, biscuits. Two concepts proposed along phase 2 (overall duration → 2890 seconds, approx. 48 minutes)
- **Package ideation:** Case study number 1, biscuits. The whole phase 4 (overall duration → 2834 seconds, approx. 47 minutes)
- **Product review:** Case study number 4, barbecue. Themes: Burners and top, Thermogauge, Knob (overall duration → 2890 seconds, approx. 45 minutes).

3.8.2. Approach for data processing

As for what carried out within the analysis of gesture-based interactions, we have coded the selected design episodes considering seconds as the elementary time unit, to capture occurrences and durations more precisely.

The analysis, also with the purpose of ensuring the compatibility and interchangeability of data with the partners carrying out the coding with different schemes, has been done using spreadsheets. This also facilitated the definition of automatic procedures for the calculation of results useful for the discussion.

Each second of considered segments of the recordings has been classified similarly to what depicted in Figure 3.20. The specific coding has been determined according to the interpretation of the speech content by one coder. Further studies that go beyond the purpose of this deliverable will also clarify to what extent the metrics enable a sufficient inter-coder reliability.

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	00.35.21	00.35.22	00.35.23	00.35.24
Classification				
Layer 1 (A/B/C/D/E)	A	A	A	A
Layer 2	System part	System part	System part	System part
Layer 3	Position	Position	Position	Position
FBS	S	S	S	S

Figure 3.19. Example of coded episode.

Considering the different levels of the analysis, we decided to explore the results from two complementary perspectives. Each of them will support the definition of specific needs and expectations from the end users' side that will have to be translated into a prioritized set of requirements for steering the development of SPARK modules and platform.
The first approaches the analysis of results by separately taking into account the different levels of coding (decoupled analysis). Figure 3.21 summarizes the target conclusions we aim to draw out with reference to the different levels of investigation.

Table 1. Objectives of the investigation with reference to the application of the metrics: layers separately analysed.

Results from segments coded with	**Objectives of the investigation (for the development of the SPARK platform)**
Layer 1 (A/B/C/D/E)	1. Pertinence of a SAR-based platform for design in a collaborative design environment 2. Priorities for the development of the SAR and/or the information management module
Layer 2 (SAR-related topic)	1. Implications for the information management system of the SAR platform 2. Differences between topics addressed in sessions having different purposes (product vs packaging design)
Layer 3 (features of the SAR related topic)	1. Characterization of the main actions (functions) to be carried on the prototype/design representations
FBS	• Differences in cognition when dealing with different design tasks (or phases)

The second approach, conversely, considers both the second and third coding level at the same time (coupled analysis). Figure 3.22 summarizes the research objectives for this investigation.

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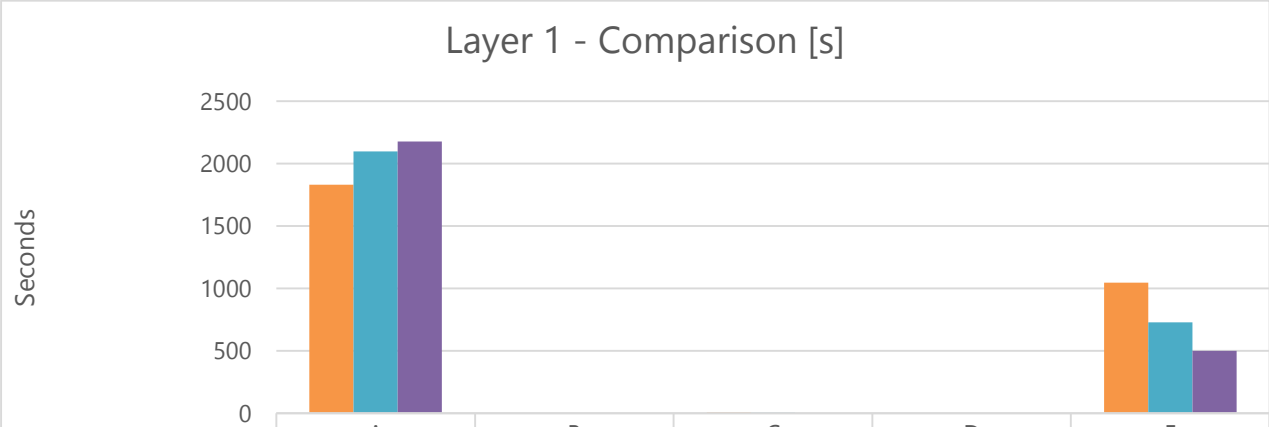
Table 2: Objectives of the investigation with reference to the application of the metrics: layers analysed together

Results from segments coded with	Target conclusions using the results (for the development of the SPARK platform)
Layer 2 and Layer 3 (SAR topic and its feature)	1. Prioritization of functions to be performed 2. Identification of specific use cases according to the nature of the session (product vs packaging design) 3. Preliminary identification of potentially relevant gestures (note: not based on gesture analysis) for performing functions to directly interact with the mixed prototype and the SPARK platform.

The next two subsections present graphs with both absolute and relative values in order to present both the magnitude and the relative weight of the occurring phenomena. All the data presented in the following graphs and tables are expressed with reference to durations measured in seconds. We do not see the investigation of occurrences necessary at this stage of the project.

3.8.3. Decoupled analysis: results and discussion



	A	B	C	D	E
Package Review	1833	0	9	0	1048
Package Ideation	2098	0	6	0	730
Product Review	2178	0	0	0	502

Figure 3.20. Coding Layer 1: Results of the three analysed segments of the recordings. Absolute durations [s]

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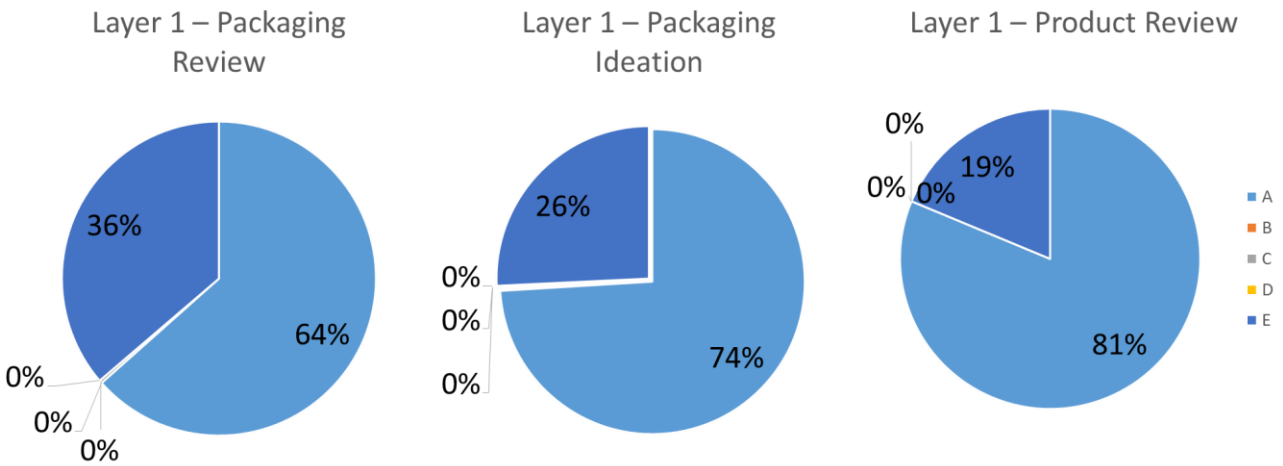

Figure 3.21. Coding Layer 1: Results of the three analysed segments of the recordings - relative durations.

Main results from segments coded (Layer 1)	Target conclusions using the results (for the development of the SPARK platform)
• Each of the three segments (approximately 45' each) addresses content that the SPARK platform can address via SAR module(s) for more than 30 minutes, which correspond to more than 60% of the co-design session. The average across the three cases is approximately 72%. (seconds coded A) • No seconds coded B or D for the observed sessions • Amount of seconds coded C is negligible for the observed sessions • The interactions among participants that are not relevant (on average 13-15 minutes) are coded as E.	• The predominance of A-coded seconds shows there is a clear opportunity for the introduction of a solution empowering and facilitating the interaction among participants • The predominance of A-coded segments shows the development of the modules for the management of SAR-related content and the related interactions between user and mixed prototype should be addressed with higher priority. • Modules addressing the needs underlying codes B, C, D will require the integration of modules for live generation of new content within the SPARK platform. For the first version of the the SPARK platform this can be addressed with a lower priority, but for future releases this is a promising opportunity.

Figure 3.22. Coding Layer 1 – Summary of the results and the related conclusions.

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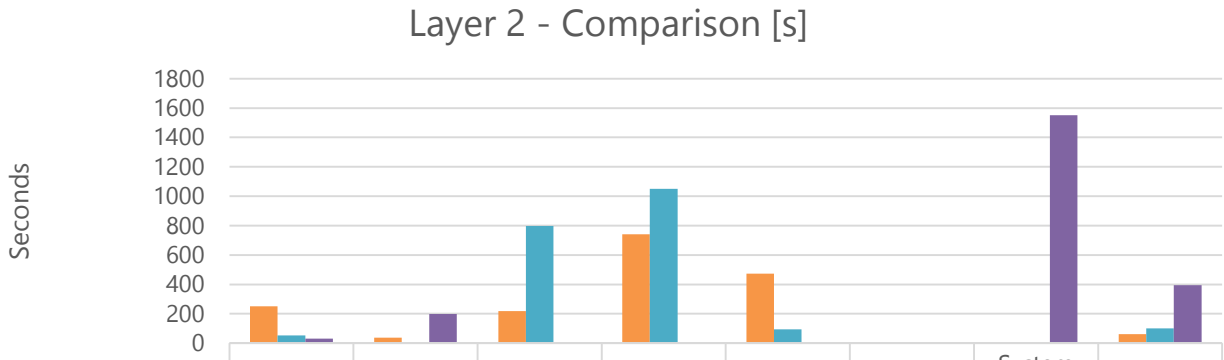

	Texture	Logo	Image	Picture	Text	Icon	System Part	Whole
Package Review	252	38	218	741	473	0	0	62
Package Ideation	52	3	797	1051	95	0	0	101
Product Review	32	199	0	0	0	0	1552	395

Figure 3.23. Coding Layer 2: Results of the three analysed segments of the recordings – absolute durations [s].

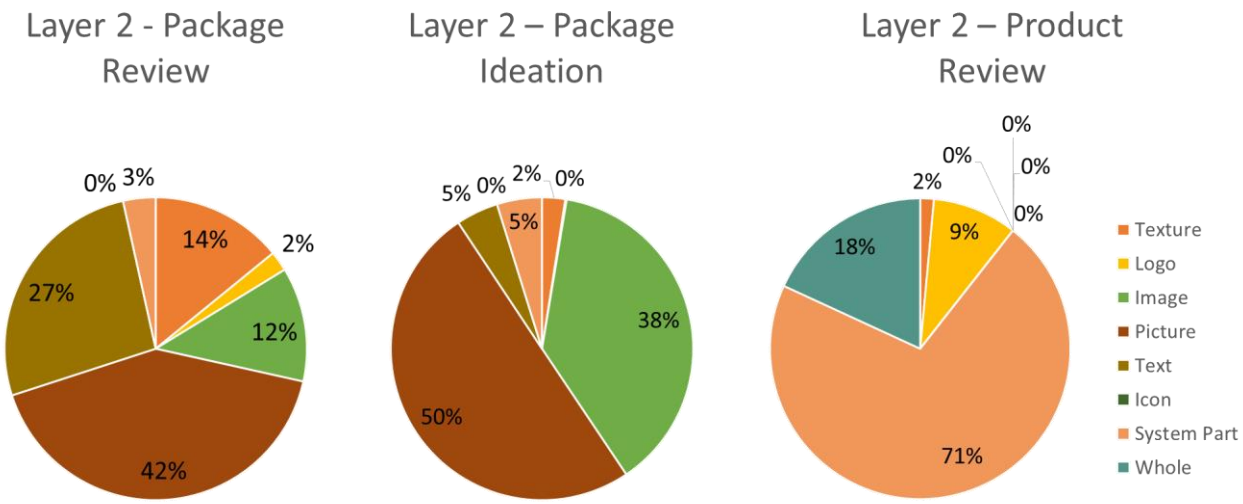

Figure 3.24. Coding Layer 2: Results of the three analysed segments of the recordings - relative durations.

The results shown in the above graphs about Layer 2 analysis highlight a highly polarized behaviour depending on the nature of the design session: speech content during packaging design appear to be mostly focused on the images and the pictures for the package, with no reference to the system parts. Conversely, the product design session mostly talks about the system parts without or very limited discussion of images or pictures, as one can expect.
The following two graphs still refer to Level 2, but the results concerning images, pictures, icons and system part have been clustered into a single category hereafter renamed "Visual/System part". This choice is motivated by the visual nature of the content the platform under development will be able to project: whether they are images on packages or burners on the top of a barbecue, there is no difference from the perspective of spatial augmented

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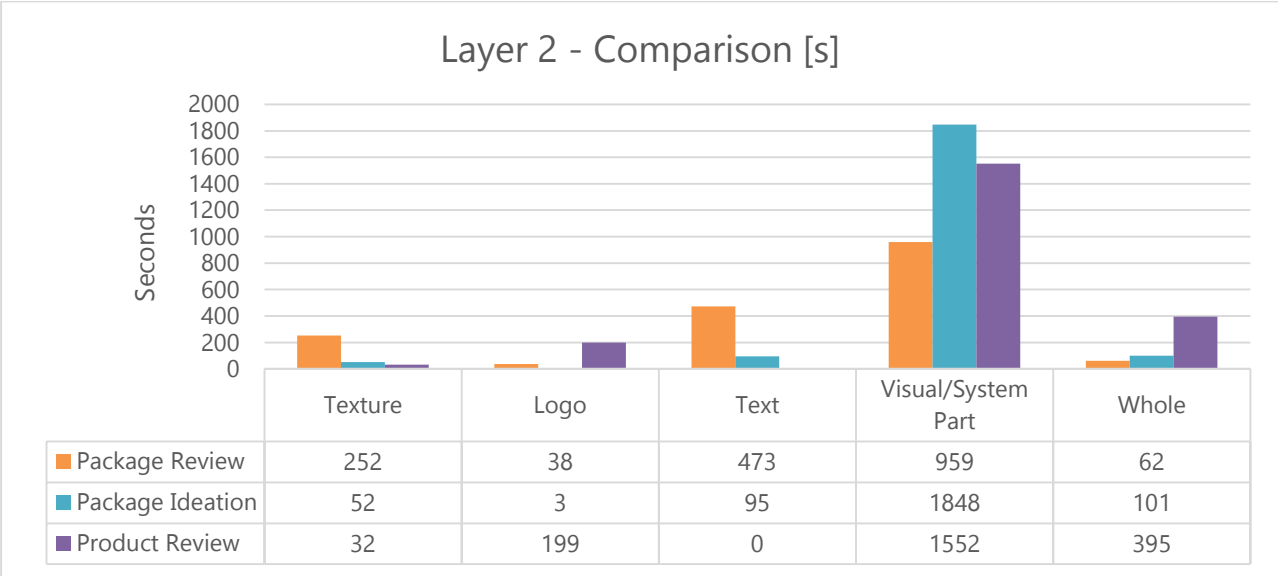
reality. The projection in both cases supports the direct identification of the item (image, picture or system part) and its relationships with the package/product they belong to.
The choice of keeping the logo as a separate item in this proposed re-clustering, despite it satisfies the above characteristics for aggregating the results, is motivated by the fact that the observed sessions did not address the need of re-designing the logo, which is here to be considered as an unalterable element of the design (except for its Layer 3 features).
Texture has been kept as a separate item, since it is usually referred as the background, which makes it different from the other type of items.
We keep this kind of clustering also for the coupled analysis presented in the next subsection.



	Texture	Logo	Text	Visual/System Part	Whole
Package Review	252	38	473	959	62
Package Ideation	52	3	95	1848	101
Product Review	32	199	0	1552	395

Figure 3.25. Coding Layer 2: Results of the three analysed segments of the recordings - absolute durations (with Picture, Image, Icon and System part clustered into the Visual/System Part category).

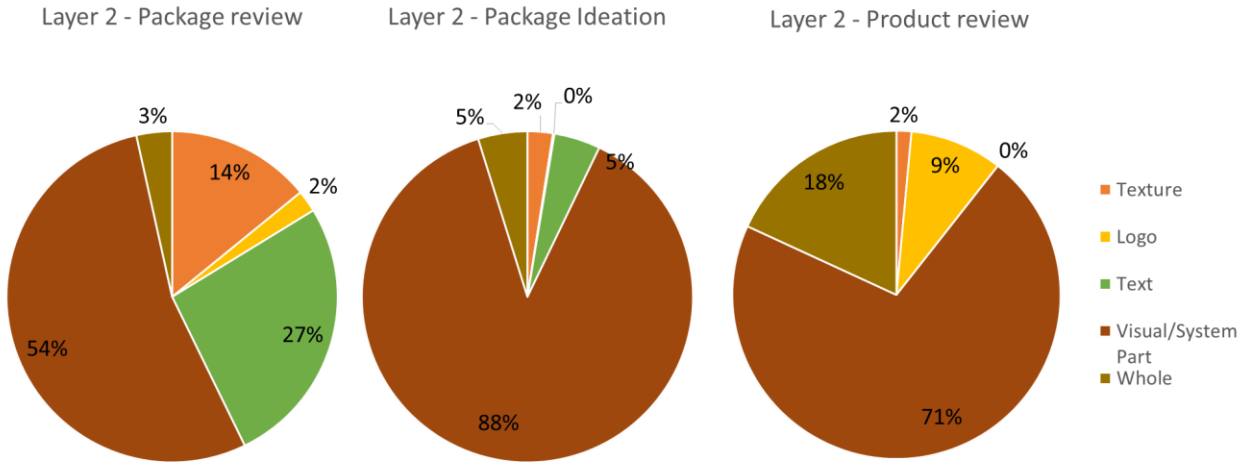


Figure 3.26. Coding Layer 2: Results of the three analysed segments of the recordings- relative durations (with Picture, Image, Icon and System part clustered into the Visual/System Part category).

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Table 3 Coding Layer 2 - Summary of the results and the related conclusions.

Main results from Layer 2 analysis	Target conclusions using the results (for the development of the SPARK platform)
• Strong polarization between product design and packaging design (System part vs Images and pictures) • The greatest amount of content to be projected for evaluation and modification during a session relates to images and pictures or system part (min: 54%, approx. 15'; max 88%, approx. 30'). • Text and texture plays a significant role in package design sessions while they revealed to be almost absent in the product design sessions we run. • The relationship between the theme of the discussion and the whole system to be developed occurs more frequently in product design sessions ("whole" ratio is one order of magnitude higher) • Design discussions regarding the logos in packaging design can be treated as other images to be projected.	• Product and packaging designer might look for different kind of files or information managed by the SPARK platform. The development should consider creating a universal interface that can be also customized for different user profiles or design conditions in order to make the interaction more efficient. • Both considering the quantitative results and the qualitative analysis of the speech as a whole, visible elements (images, pictures as well as system part) should be visualized on the prototype with a high degree of fidelity • For what concerns the management of information (files, ...) the platform can treat Images, Pictures and System parts as similar elements if this not affects the projection technology and its outcomes. • The SAR platform should be capable of supporting (co-)designers to refer the focus of their attention to the whole system (pack or product) as well as the design elements (?) under development.

Figure 3.27. Coding Level 2 - Summary of the results and the related conclusions.

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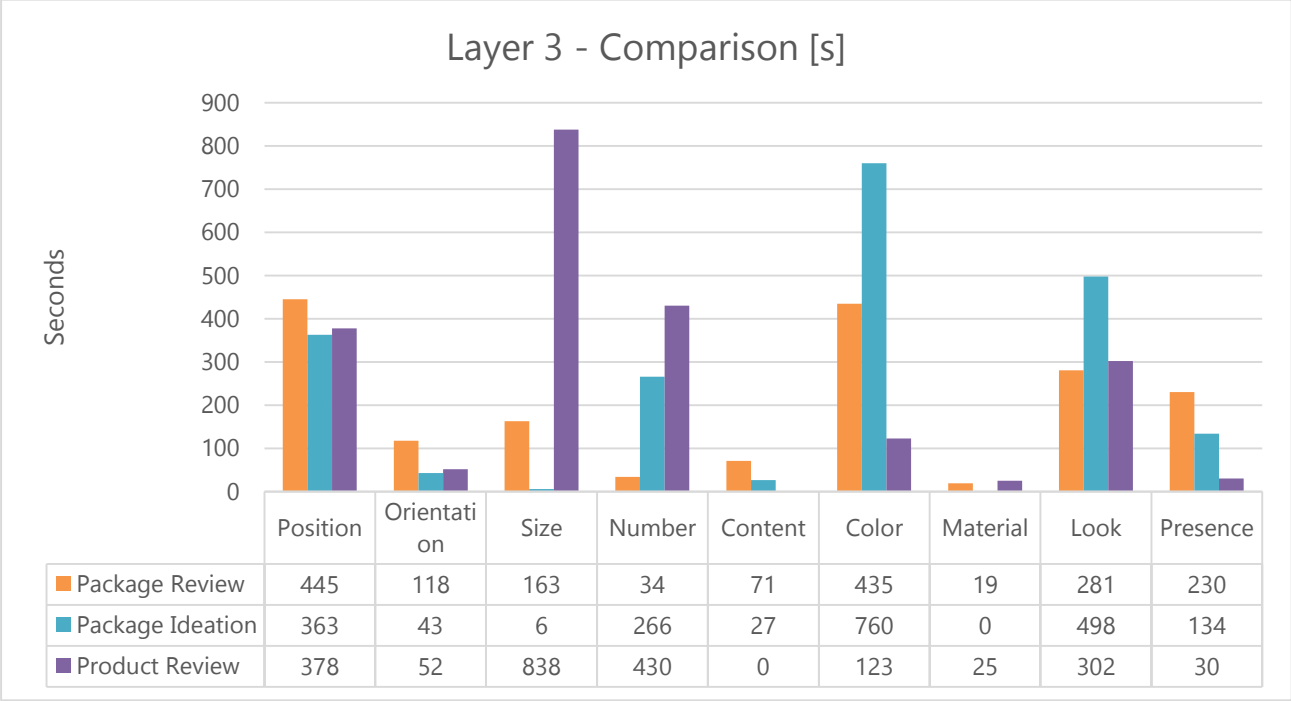

Figure 3.28. Coding Layer 3: Results of the three analysed segments of the recordings -absolute durations.

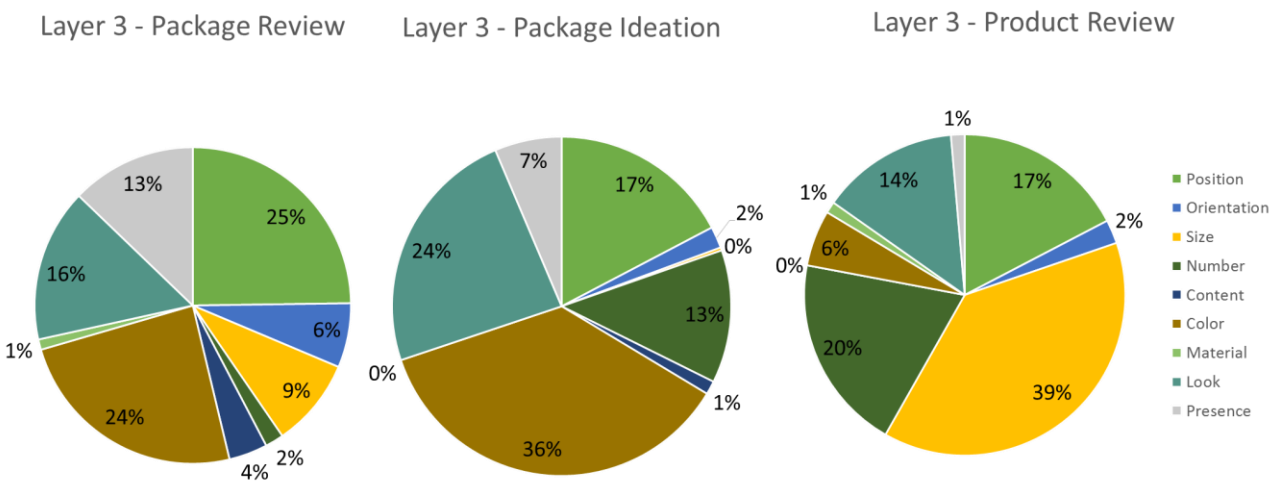

Figure 3.29. Coding Layer 3: Results of the three analysed segments of the recordings -relative durations.

Table 4 Coding Layer 3 - Summary of the results and the related conclusions.

Main results from Layer 3 analysis	Target conclusions using the results (for the development of the SPARK platform)
• The most frequent changes during the ideation of new solutions in packaging design deal with modifications of colour, look and position. Note: the combined results of "presence" and "number" correspond to 400 seconds in	• The most frequently occurring functions for the interaction with the prototype in packaging design sessions are: 1. Colour Change 2. Look change 3. Position Change 4. Number/Presence Change

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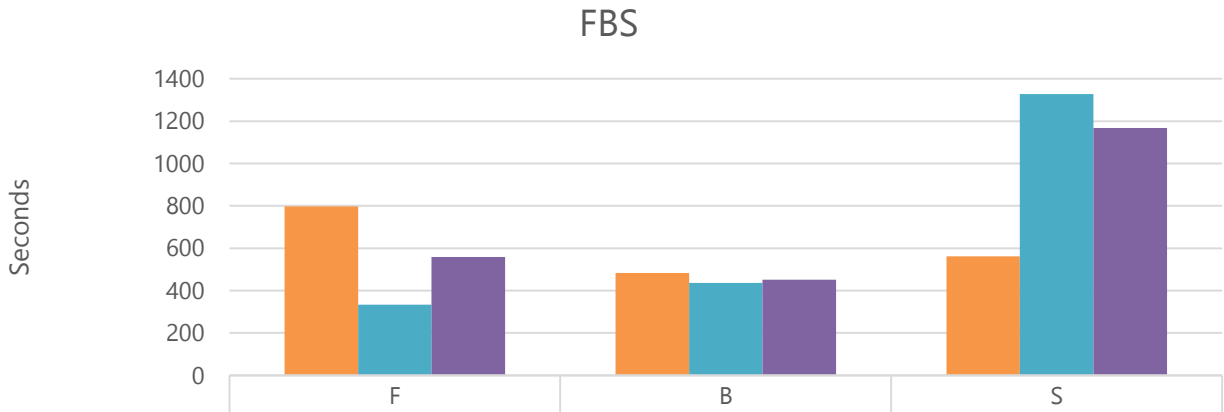
which the topic of the discussion regarded the removal, the introduction or the addition of similar items. This amount of time makes this kind of interaction as significant as position change. • The evaluations in both packaging design sessions focus on the same topic, even if with slightly different ratios. • Size appears not to be so relevant for package ideation (*note of the analyst: this is mostly due to the direct size adjustment carried out on imported content by the designer arranging new design proposal with the touch screen*). • The most frequent changes mentioned in product review sessions are about size (approx. 40%). • Content is never mentioned in the segment of product review. The reasons of this will be better catched with the combined analysis of layers.	Therefore the SPARK platform will need to allow its user to: ○ to select and change colour of items ○ access to image database ○ to superimpose items on top of the others • to add, remove or multiply items The most frequently occurring functions for the interaction with the prototype in product design sessions are: 1. Size change 2. Number change 3. Position change 4. Look change (usually meant as "shape" in the analysed session of product design) Therefore the SPARK platform should allow its users to: ○ modify one or more of the dimensions of the objects to be projected (i.e. length, width, depth) with the option to maintain the aspect ratio. • Size can be relevant for package design as well, even if the data suggests it is not. This might depend on the specific system (touchscreen) that the designer used to redesign the package on the fly.

Figure 3.30. Coding Layer 3 - Summary of the results and the related conclusions.



	F	B	S
Package Review	798	483	561
Package Ideation	333	437	1328
Product Review	558	452	1168

Figure 3.31. FBS Coding: Results of the three analysed segments of the recordings -absolute durations.

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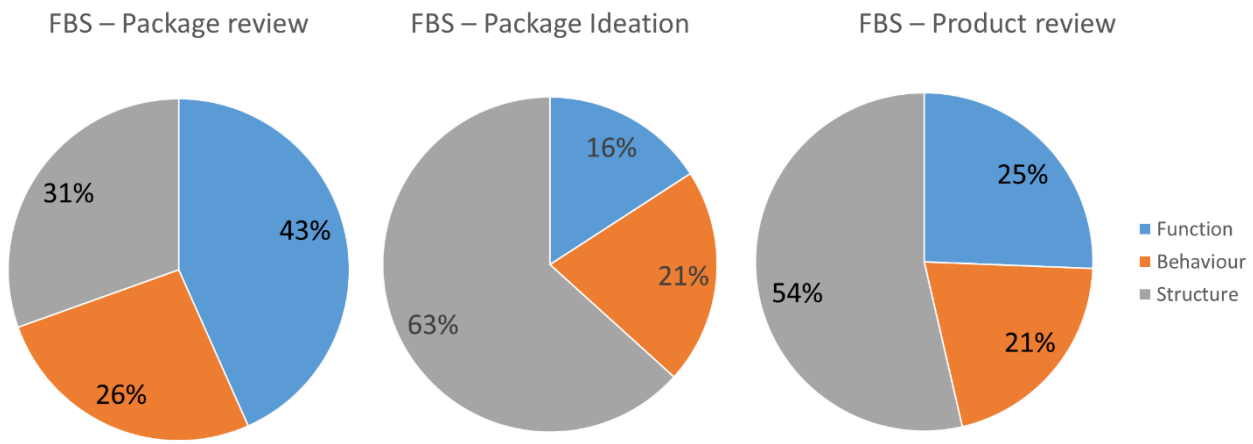

Figure 3.32. FBS Coding: Results of the three analysed segments of the recordings -relative durations

Table 5: FBS coding - Summary of the results and the related conclusions.

Main results from segments coded according to the FBS ontology	Proposed conclusions using the results (for the development of the SPARK platform)
• The review sessions present FBS variables more equally distributed in the three classes than in the ideation session. • The ideation session has a marked prevalence of structural variables discussed. • Functional variables are the ones less considered during the ideation session, while they appear to be more frequent during package review.	• Enabling modification of structural features during the ideation phase is a high priority. • SPARK's visualization of generated concepts (both on the prototype or on another visualization device) should enable the immediate evaluation of proposals both in terms of the mechanisms of communication (with reference to the Behaviour) and in terms of the intentions to be conveyed (with reference to the functions items play in the whole design proposal).

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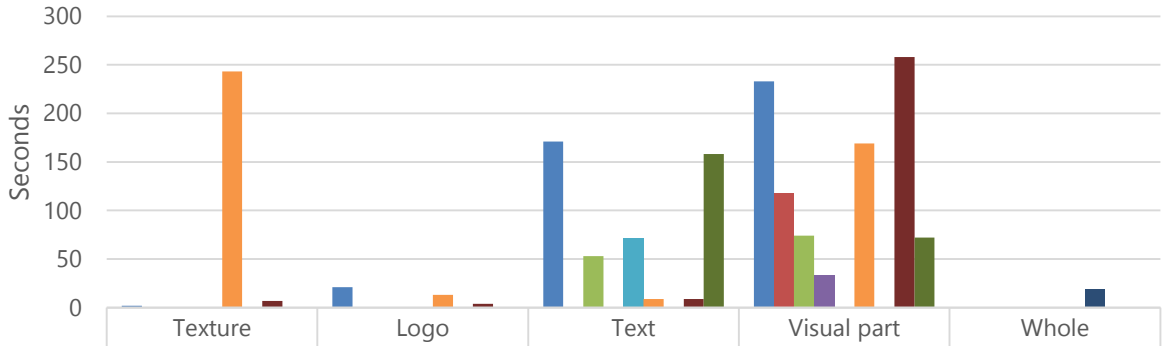
3.8.4. Coupled analysis: results and discussion



	Texture	Logo	Text	Visual part	Whole
Position	2	21	171	233	0
Orientation	0	0	0	118	0
Size	0	0	53	74	0
Number	0	0	0	34	0
Content	0	0	71	0	0
Color	243	13	9	169	0
Material	0	0	0	0	19
Look	7	4	9	258	0
Presence	0	0	158	72	0

Figure 3.33. Coding Layers 2 and 3: Results of the three analysed segments of the recordings - absolute durations of package review

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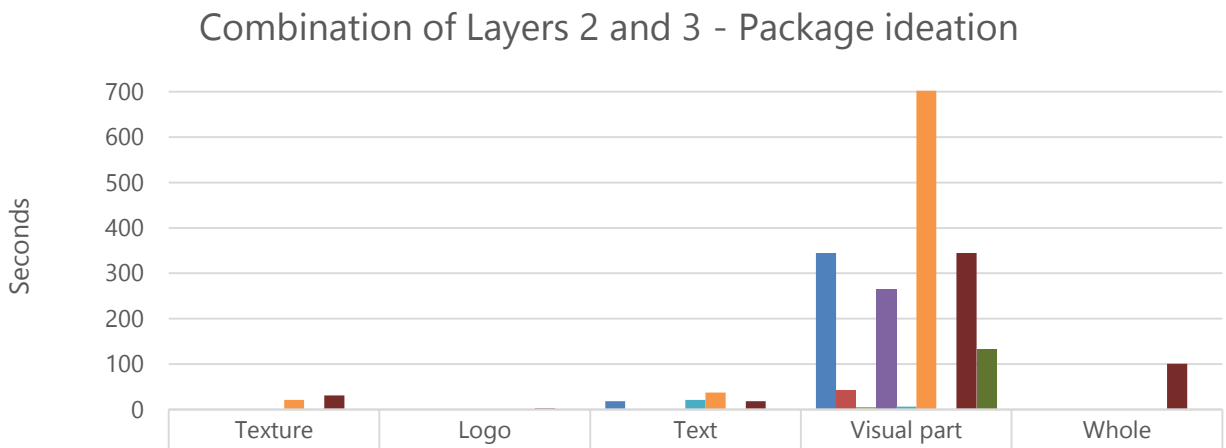

	Texture	Logo	Text	Visual part	Whole
Position	0	0	18	345	0
Orientation	0	0	0	43	0
Size	0	0	0	6	0
Number	0	0	0	266	0
Content	0	0	21	6	0
Color	21	0	37	702	0
Material	0	0	0	0	0
Look	31	3	18	345	101
Presence	0	0	0	134	0

Figure 3.34. Coding Layers 2 and 3: Results of the three analysed segments of the recordings - absolute durations of package review.

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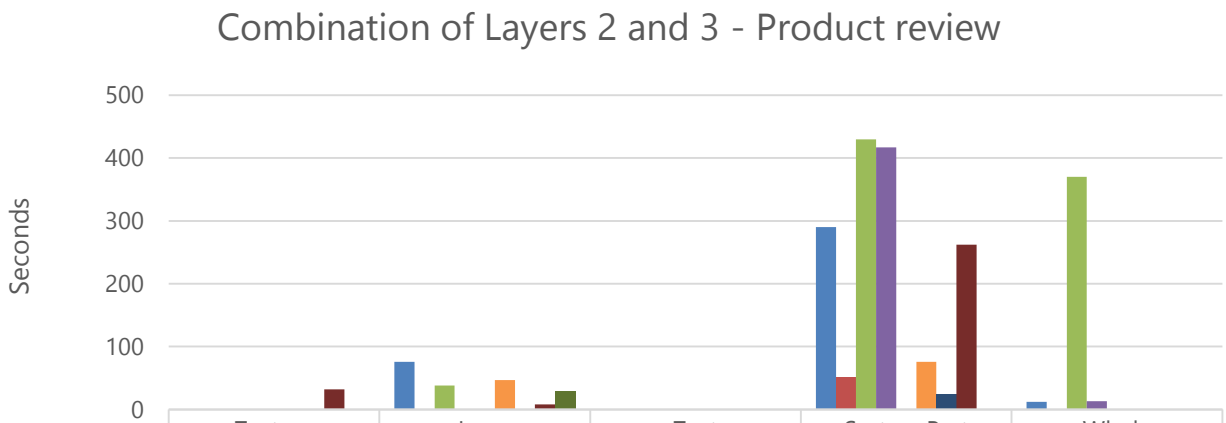

	Texture	Logo	Text	System Part	Whole
Position	0	76	0	290	12
Orientation	0	0	0	52	0
Size	0	38	0	430	370
Number	0	0	0	417	13
Content	0	0	0	0	0
Color	0	47	0	76	0
Material	0	0	0	25	0
Look	32	8	0	262	0
Presence	0	30	0	0	0

Figure 3.35. Coding Layer 2 and 3: Results of the three analysed segments of the recordings - absolute durations of package review.

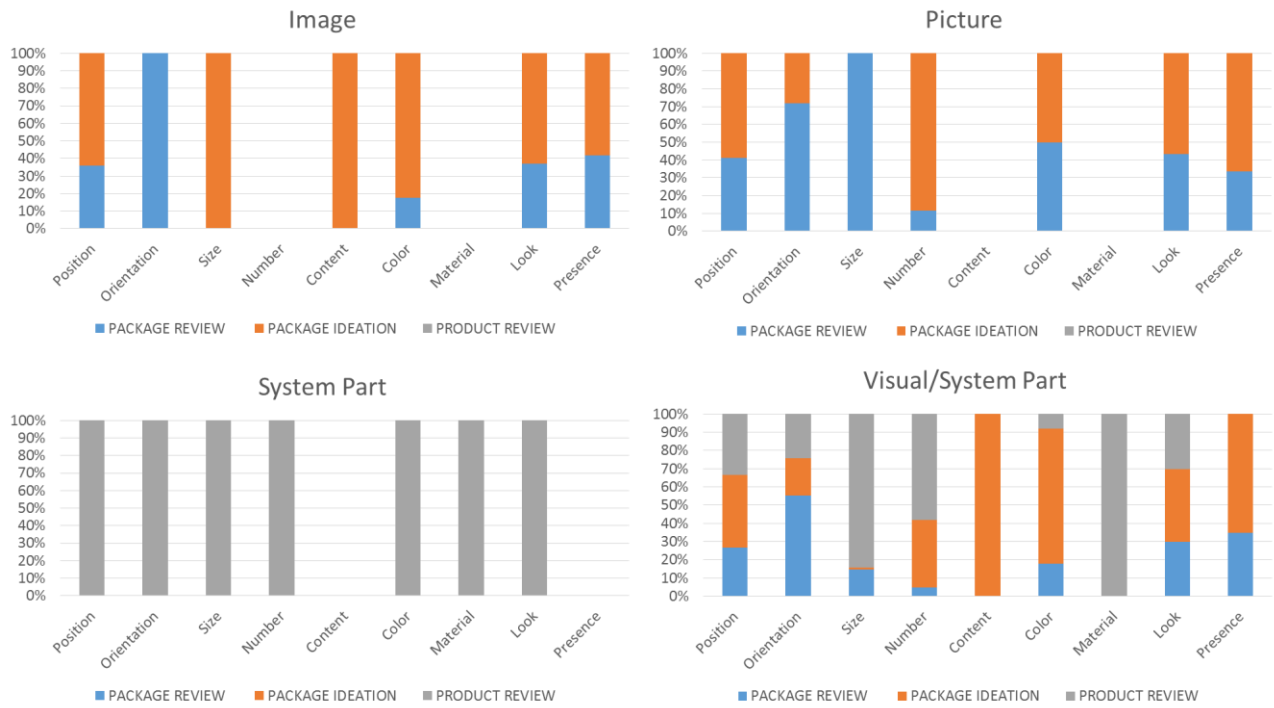

Figure 3.36 Coding Layers 2 and 3: Results of the three analysed segments of the recordings. Relative durations of Package review – Topics: Visual/System Part (low right) and what composes that cluster (the remaining three diagrams, Icon not shown because of null contribution).

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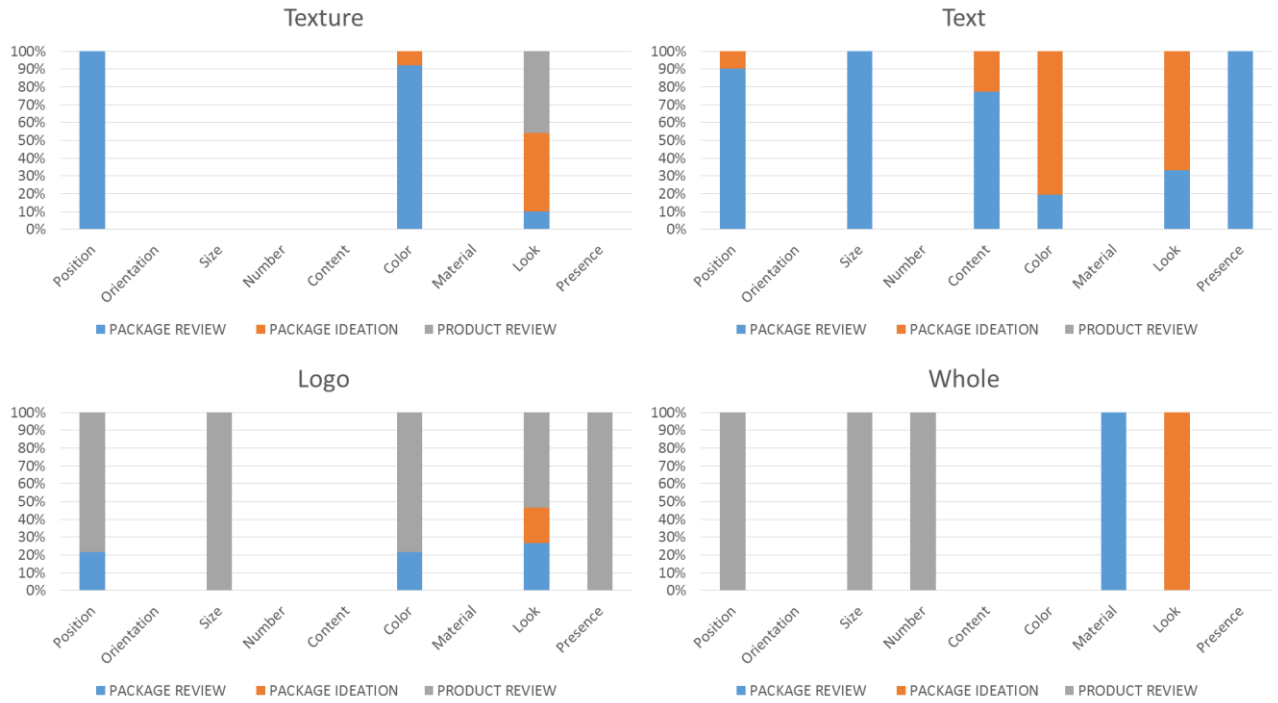

Figure 3.37. Coding Layers 2 and 3: Results of the three analysed segments of the recordings - relative durations of Package review

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Table 6: Combined analysis of layers 2 and 3 - Summary of the results and related conclusions.

Results from Layer 2 and Layer 3 combined analyses	Target conclusions using the results (for the development of the SPARK platform)
• Within what coded as "visual parts" the results significantly differ in product and package design: "size" and "materials" are preferentially changed within product design, while "presence" "colour" and "orientation" in package design. • The change of position of visual items is transversally relevant. • The reorientation of visual items is a typical feature of packaging design and occurs less frequently in the observed product design sessions • Texture appears to be relevant to product design just for what concerns the look, while in package design it also matters in relation to its position and colour. • Text is relevant just to the packaging design segments even if with different intensity. Colour and Font (look) appear to be especially relevant during the ideation. • Material for what concerns the projection is mentioned just with reference to system parts in the product design case.	• The duration of topic concerning the size of items confirms the previous conclusions. This also suggests introducing in the platform easy and not intrusive solutions for the interaction (one option the developers can take into account is the use of gestures to interact with the prototype and bring the required changes). • The same applies to the management of colour for the image used for the projection. Furthermore, the qualitative analysis of speech suggests the palette should be easily managed and the verisimilitude of the final colour has to be visualized on the prototype or on a different device. • The management of textual elements has to include the possibility to change: a. its size b. its font c. its colour • Material rendering can become relevant in projections for product design, this need hasn't emerged yet in package design. • The different durations of interactions between product and package design allows for the identification of user profiles for an improved user experience

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4. INTERVIEWS WITH CREATIVE PEOPLE ABOUT CO-DESIGN EXPERIENCES (T1.5)

4.1. Overview of Task 1.5

The overall aim of T1.5 was to look at co-creative design activities from the perspective of design practitioners. This is important because design practitioners will be the primary user group for the SPARK platform. By interviewing design practitioners about their experiences of co-creative design activities our specific objectives were:

- To understand what design practitioners perceive to be the most important impacts and affordances of the design representations used in the observation sessions.
- To gain insights into current co-creative design practices from a broad range of design practitioners.
- To identify the challenges that design practitioners perceive with their current use of design representations within co-creative design sessions.
- To understand the requirements for the SPARK platform driven by design practitioners' perspectives.

To fulfil these objectives two main activities were completed. First, interviews were conducted with some of the participants of the observation sessions completed in T1.3 and T1.4. This activity provided a complementary approach to analyse the results of the observation sessions. Whereas the analysis presented in Section 3 focuses on the direct observation of gestures and speech during the session, the analysis conducted here focuses on the reflections of the participants after the completion of the session.

The second activity involved interviews with external organisations that have experience of co-creative design practice. This activity was designed to engage design practitioners from outside the SPARK consortium and thereby broaden the analysis to include the perspectives of practitioners from a large variety of relevant organisations (primarily design consultancies and manufacturers of consumer goods).

Together these two activities, and the subsequent analysis, help to provide the 'practitioners perspective' that can be used to inform the definition of requirements for the SPARK platform.

4.2. Impact of Design Representations on Observation Sessions

The work described in this section is related to the co-creative observation sessions that were carried out at the case companies, Artefice and Stimulo. A summary of these companies and the sessions that were observed is available in Section 3.2; Appendix I: Descriptions of the Case Studies contains detailed descriptions of the case studies.

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Constituting the second approach to analysing the observation sessions, the first being the video analysis based approach detailed in Chapter 3, the impact of design representations on the observation sessions were analysed based on the perceptions of the designers who were involved in the sessions. The research components - research aim, research question and research objectives that drove this study of the impact of design representations are outlined in Table 4.1

Table 4.1 Research Aim, Question and Objectives

RESEARCH AIM	Explore the impact of design representations on the observation sessions as perceived by designers in order to understand their best practices.
RESEARCH QUESTION	What was the impact of design representations on the observation sessions?
RESEARCH OBJECTIVES	RO1: Establish which design representations were reported as used during the observation sessions RO2: Establish how design representations were reported to be used during the observation sessions RO3: Establish what affordances were perceived to be associated with design representations during the observation sessions RO4: Establish what challenges were perceived to be associated with design representations during the observation sessions

Through this study, informed by the perspective of the involved designers, a better understanding of the best practices related to the impact of design representations during the observation sessions was sought. The outputs of this study will provide further insight for the interpretation of the experimental evidences in T1.6.

4.2.1. Methodology

The type of question being asked ultimately determines the type of approach necessary to complete an accurate assessment of the topic at hand. As a study primarily concerned with finding out the 'what' of and event (e.g. what impact do the design representations used have on the observation sessions?), the qualitative descriptive approach was adopted. Qualitative description is the least theoretical of qualitative approaches and is especially amenable to obtaining straight and largely unadorned (i.e., minimally theorized or otherwise transformed or spun) answers to questions of special relevance to practitioners (Sandelowski, 2000). Qualitative descriptive research studies are typically an eclectic but reasonable and well-considered combination of sampling, and data collection analysis, and re-presentational techniques (Sandelowski, 2000); Table 4.2 presents the research approach for this study, it outlines the elements of the research approach and provides details that are specific to the study.

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Table 4.2: Qualitative Descriptive Research Approach for the Study

		RESEARCH DESIGN AND STUDY SPECIFICS
RESEARCH DESIGN ELEMENT	PHILOSOPHY	PRAGMATIC APPROACH: Methods which appeared best suited to the research problem were used without getting caught-up in philosophical arguments about the best approach.
	SAMPLE	PURPOSEFUL SAMPLING: The sample in study was composed of four observation sessions. The observation sessions were carefully selected for inclusion in the research project for various reasons (See D1.1). The sessions were deemed reasonable and information-rich for the purposes of this study in particular. Due to the varied nature of the observation sessions, no two had identical goals, the sampling was akin to maximum variation sampling. Through maximum variation sampling researchers can explore the common and unique manifestations of a target phenomenon across a broad range of varied cases (Sandelowski, 1995). This allows for a broad insight into a subject and was particularly relevant as ultimately a better understanding of the best practices of designers relating to design representations was being sought.
	DATA COLLECTION	SEMI-STRUCTURED OPEN-ENDED INTERVIEWS: Individual and focus group pre- and post-observation session interviews were undertaken with designers involved in the co-creative sessions. The interviews focused on the 'what' as they sought to ascertain the participants' perceived impact of design representations on the sessions.
	ANALYSIS	QUALITATIVE CONTENT ANALYSIS: Mainly taking the form of in-vivo coding, the qualitative content analysis used modifiable coding systems that corresponded to the data collected while staying close to the data, the level of interpretation or extrapolation needed was low, thereby making the analysis inherently robust QUASI-STATISTICAL ANALYSIS: As a supplement to the qualitative content analysis, where appropriate, numbers were used to summarise data through descriptive statistics.
	DATA RE-PRESENTATION (OUTPUTS)	DESCRIPTIVE SUMMARIES: The analysed data was re-presented as straight descriptions of the data organised in a manner fitting the data. This took the form of a descriptive summary of the participants' perceived use and impact of design representations within the individual observation sessions (the summary refers to each of the cases individually) and a descriptive summary of the participants' perceived impact of design representations on the observation sessions in general (the summary refers to all the cases together).

As an output, this study presents a comprehensive summary of the participants' perceived impact of design representations in terms of the observation sessions that were carried out the case companies. By adopting a descriptive qualitative approach, the researchers stay close to the data and the surface of words and events as described by the designers.

4.2.2. Study Cases, Data Collection and Processing

The data collection, taking the form of interviews, was directed towards discovering the 'what' impact of design representations during the co-creative sessions that were observed at the

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case companies based on the experiences of the designers that were involved. Each of the four observation sessions, two at each of the two case companies, formed a study case. Table 4.3 contains short summaries of the observation sessions; details on the case companies and more detailed descriptions of the study cases can be found in Appendix I: Description of the Case Studies.

Table 4.3: Summary of Study Cases

STUDY CASE 1	STUDY CASE 2
COMPANY: Artefice PRODUCT: Organic Biscuits DESIGN PHASE: Idea Production > Idea Development SESSION DESCRIPTION: Evaluation and feedback from customers on client validated product proposition.	COMPANY: Artefice PRODUCT: Ice Cream DESIGN PHASE: Idea Production > Idea Development SESSION DESCRIPTION: Evaluation, with customers, of brand visual identity.
STUDY CASE 3	**STUDY CASE 4**
COMPANY: Stimulo PRODUCT: GEO Device DESIGN PHASE: ID Definition > Technical Approach SESSION DESCRIPTION: Review, with client, of previously elaborated ideas about product look and feel.	COMPANY: Stimulo PRODUCT: Gas BBQ DESIGN PHASE: ID Definition > Technical Approach SESSION DESCRIPTION: Review, with client, of previously discussed ideas about target users, cost and product assembly.

The interviews were directed by an interview protocol that was developed specifically for the purpose of helping the researcher answer the research question. The interviews were carried out face-to-face at the site of the observation sessions in two forms: pre-session interviews that were carried out before the observation session and post-session interviews that were undertaken upon completion of the session. Through the pre-session interviews, the main goals and activities to be undertaken relating to the upcoming session were established and through the post-session interviews the impacts of used design representations were explored.

Table 4.4 contains details of the designers that acted as interview informants and the duration of the interviews that were undertaken. During the interviews, audio recordings were made, this audio formed the raw data before it was transcribed verbatim; the transcriptions formed the dataset to be analysed.

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Table 4.4: Informants and Duration of Pre- and Post-Observation Session Interviews

		Pre Observation Interview		Post Observation Interview	
		Informants	Duration	Informants	Duration
Company 1	Case No. 1	3 x Designers 1 x Creative & Art Director	16:25	2 x Designers 1 x Creative & Art Director	1:02:39
	Case No. 2	1 x Designer	11:23	2 x Designers 1 x Creative & Art Director	58:19
		1 x Designer 1 x Creative & Art Director	17:23		
Company 2	Case No. 3	1 x Business Developer	08:12	1 x Business Developer	53:05
	Case No. 4	1 x Business Developer	08:10	1 x Designer	32.48

4.2.3. Data Analysis and Results

The data analysis mainly took the form of qualitative content analysis, the strategy of choice in qualitative descriptive studies (Sandelowski, 2000). Qualitative content analysis is a dynamic form of analysis of verbal and visual data that is oriented toward summarising the informational contents of that data (Altheide, 1987; Morgan, 1993). The qualitative content analysis took the form of coding, where data were systematically searched to identify and/or categorise specific observable actions or characteristics of interest. The coding was not used to determine themes in the data but rather as a way of categorising the data, simplifying the coding process. While the data analysis was mainly concerned with understanding the manifest content of the data (i.e. a descriptive account of the data; this is what was said, but no comments or theories as to why or how), it also sought to gain a low level understanding of the latent content of the data (i.e. interpretive analysis that is concerned with the response as well as what may have been inferred or implied).

A bespoke method of identifying and coding data was developed to account for the fact that no system for pre-coding exists. The coding was divided into two coding cycles as recommended by Saldana (2013); during the first coding cycle which focused on the manifest level, the coding of interview transcripts occurred and then in the second cycle which focused on the latent level the outputs of the first cycle were analysed.

The first coding cycle took the form of holistic in-vivo coding; a single code was applied to each large unit of data in the corpus to capture a sense of the overall contents, the code assigned to that unit of data was made up of words that were taken from the data itself. As recommended by Miles and Huberman (1994) the coding process was kick-started by a provisional 'start list' of categories; this provisional 'start list' is available in Appendix IV: Start List for Categorisation. As the coding process progressed, codes were added until all data of interest in the interview transcripts were assigned a code.

The results of this coding cycle were as follows:

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- A case based meta-matrix that outlines the design representations that were used in each of the study cases and presents manifest level codes associated with how the design representations were used and their impacts (categorised into affordances and challenges). The meta-matrix is available in Appendix V: Manifest Level Case Based Meta-Matrix.
- A holistic list that brings together manifest level codes from across all four observation sessions and groups them into the following four categories: use of representations, design representation affordances, design representation challenges and best contributor to session. This list is available in Appendix VI: List of Holistic Manifest Level Codes.

Pattern codes, defined as explanatory or inferential codes that identify an emergent theme, configuration or explanation, were identified during the second coding cycle. The codes generated during the first cycle were analysed and re-categorised based on emergent patterns and assigned codes that described the latent content within the data, this represented a low level interpretation of the analysed data. The result of this cycle was a holistic list that brings together latent level codes from across all four observation session and groups them into the following four categories: use of representations, design representation affordances, design representation challenges and best contributor to session. This list is available in Appendix VII: List of Holistic Latent Level Codes.
To supplement the qualitative content analysis, descriptive statistics were also used to summarise the data were appropriate. The data was quantitatively analysed in different ways that stayed close to the data, descriptive statistics resultant from this analysis are available in Appendix VIII: Observation Session Descriptive Statistics; some of the results are as follows:

- Total number of design representations reported by participants
- Reported frequency of design representation use across cases
- Number of activities reported by participants within the observation sessions

4.2.4. Research Outputs: Data re-presentation

In accordance with the methodology, there was no mandate to produce anything other than a descriptive summary of the participants' perceived impact of design representations during the observation sessions, organised in a manner that best contains the data collected and is most relevant to the audience for whom it is written. Resultantly, the outcome of this descriptive qualitative study was a straight descriptive summary of the informational contents of the data organised in a way that best suits it. This was done through the following two types of descriptive summaries from the interviewees' opinions:

1. Use and Impact of Design Representations per Observation Session: a description of the design representations that were used in each of the individual observation sessions, what they were used for and their impact (the summary refers to each of the cases

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individually).

2. Impact of Design Representations on Observation Sessions: a description of what design representations were used for across the observation sessions and their impact (the summary refers to all the cases together).

Use and Impact of Design Representations per Observation Session

The descriptive summary of the use and impact of design representations for the individual observation sessions is presented in Table 4.5; for each of the cases, the summary is sectioned as follows:

- First Section: Details the main goal, participants and activities (and their importance) related the observation session. The importance of session activities was numerically scored by the creative participants; the evaluation is presented out of 1.0.
- Second Section: Outlines the design representations that were used and the impact they had on the session activities. As with the importance of session activities, the impact on session activities as scored by participants is a numerical evaluation presented out of 1.0.
- Third Section: A description of what the design representations were reported as used for during the observation session and the affordances and challenges associated with their use. The affordances and challenges serve as qualitative descriptions of the participants' perceived impacts of the design representation use.

Table 4.5: Descriptive Summary of the Use and Impact of Design Representations per Observation Session

CASE NO.1	
MAIN SESSION GOAL: Determine graphic approach & graphic treatment for packaging. SESSION PARTICIPANTS: Designers x 3 Client x 2 Customers x 5 ACTIVITIES IN SESSION AND THEIR IMPORTANCE: Communication Design Information = 0.9 Evaluation and Selection = 0.6 Identifying or Completing Project Tasks = 0.6 Idea Generation = 0.4	USED REPRESENTATIONS AND THEIR IMPACT ON SESSION ACTIVITIES: Physical Model (Mock-Up) Communication of Design Information = 0.5 Evaluating and Selecting = 0.4 Post-It Notes Evaluating and Selecting = 1.0 Idea Generation = 0.2 PC + Monitor Evaluating and Selecting = 1.0 2D Images Evaluating and Selecting = 1.0 Idea Generation = 0.4
SUMMARY OF USE AND PARTICIPANTS' PERCEIVED IMPACT OF DESIGN REPRESENTATIONS ON SESSION:	

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During this observation session, four different types of design representations were utilised. Physical models, or mock-ups, were used to show the different graphical treatments of the packaging that was the focal point of the session. The mock-ups were realistic, to-scale physical representations of the final product. There were multiple mock-ups used, all physically similar but with different graphical treatments. Through these mock-ups, the designers were able to accurately communicate the design of graphical treatments with the rest of the participants; they were a realistic representation of what the finished final product could look like. Due this realism, the non-creative participants took the mock-ups to be not just a realistic representation but also an accurate one; they mistook the mock-ups for the final product. However, because the focus was on the graphical treatment given to the packing and not the packaging itself, the materials, textures and finishes of the mock-ups were not the same as those of the final product. The designers had urge the other participants to focus on the graphical treatment and emphasise that the materials, textures and finishes associated to the finished product would be different. The designers found that the presence of mock-ups that were so realistic and fully formed tended to hamper idea generation as the other participants found it hard to think outside of what was presented in front of them. The designers also used 2D images of the packaging graphics in various side by side arrangements to show how they could be arranged and presented on a shelf. Post-it notes were used during the evaluation sections of the session, through them the customers' evaluations and views of the presented concepts were captured. The designers chose to include digital interactivity into the session, this was accomplished through the use of a PC and monitor with Adobe Photoshop and Adobe Illustrator software packages. Through the use of the PC and monitor, the designers were able to explore a new approach to co-creative sessions as they did not normal use it. They were able to implement in real time simple changes to the graphics that were suggested by the other participants. Not only did this make them feel like their inputs were being valued and that they were an important part of the process, it also allowed them to see what implications their suggestions would have.

> *"It is useful to have something physical, but to also have the possibility to show the final result of their indication because what is in their mind when they are asking for something is not what will be the final result."*

However, it was essential that one of the designers implement the suggested changes, the customers could not do so themselves and only one suggested change could be implemented at one time. The practitioners expressed how there is value in being able to have the other participants personally implement changes individually and simultaneously. Upon reflection, the designers selected the PC and monitor as the best contributor to the session. While they admit that they did not use it to its fullest potential because they used various other design representation, it was deemed to be the one that could have replaced all the other design representations and be used alone while still allowing them to meet the goals of the session.

CASE NO. 2	
MAIN SESSION GOAL: Determine brand vision, concept and visual identity (i.e. brand building) for product. SESSION PARTICIPANTS: Designers x 4 Client x 3	USED REPRESENTATIONS AND THEIR IMPACT ON SESSION ACTIVITIES: Text Whole Session = 1.0 Evaluating and Selecting = 0.8 Communication of Design Information = 0.4

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Consultants x 2 ACTIVITIES IN SESSION AND THEIR IMPORTANCE: Evaluation and Selection = 1.0 Communication Design Information = 1.0	Mood Board Whole Session = 0 Physical Model (Mock-Up) Whole Session = 1.0 Evaluating and Selecting = 1.0 Communication of Design Information = 1.0 PC + Monitor Whole Session = 1.0 Evaluating and Selecting = 1.0 Communication of Design Information = 0.2

SUMMARY OF USE AND IMPACT OF DESIGN REPRESENTATIONS ON SESSION:

During this session, four different types of design representations were utilised. The designers used text (words printed on card) and mood boards, to communicate different brand visions with the other participants. Through the use of these two design representations, they were able to set the context surrounding the brand vision and capture the feelings and sensations that the other participants had towards the presented visions. The text also served the purpose of giving the participants inspiration and allowed them to imagine what type of graphical treatments would personify the various brand visions that were being described. Despite being used in the session, the mood boards added some flavour to the context setting, but because they did not represent any concepts the designers did not deem their presence to be pertinent. The physical models, or mock ups, were used to show different graphical treatments applied to the packaging of the product that was the focal point of the session. Multiple mock-ups were used, physically the same but with different graphical treatments; they were a realistic representation of what the finished final product could look like. Through them, the designers were able to accurately communicate the design of graphical treatments with the rest of the participants. As they were very realistic representations of the final product, the other participants mistook them to be accurate representations of the final product. However, the designers had anticipated this and dealt with it accordingly. Allowing them to explore a new approach to co-creative sessions, the designers employed the use of a PC and monitor with Adobe Photoshop and Adobe Illustrator software packages which allowed them to add an interactive digital element to the session. This was their first time using such a design representation and it proved to be a welcome departure from the way in which they usually conduct co-creative sessions. Through the PC and monitor, they were able to implement in real time simple changes to the graphics that were suggested by the other participants, allowing them to see what implications their suggestions had.

"The real time aspect is awesome."

As a result, there was quicker feedback on the suggested changes that came up during the session; there was no need to reconvene at a later date to evaluate the suggested changes after the designers had gone away and implemented them. The use of the PC and monitor also posed some challenges for the designers. For the interactivity to work as desired, it was necessary to have an extensive database to as input in anticipation of the different types of changes that could be suggested. The changes that they could implement in real time were limited not only to the pre-prepared materials in the database, but also in the time and effort it took to implement certain changes. When the changes were simple and straight forward (e.g. colour, font or size changes)

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they could be made in real time, however more complex changes (e.g. make graphic more artisanal) could not be executed in real time. The designers found that the real time interactivity sidetracked them and made them lose focus. Due to the goal of the session, it was not important for them to see the impact of implementing small changes to the presented concepts. Additionally, there were technology-based issues associated with the use of the PC and monitor that had to be solved during the session. Upon reflection, the designers came to the conclusion that no one design representation could be dedicated as the best contributor to the session. They reached the consensus the design representations *"all worked together as a system; what worked was the process itself."*

CASE NO. 3	
MAIN SESSION GOAL: Finalise product structure (internal and external), packaging and user interaction feedback for product. SESSION PARTICIPANTS: Designers x 3 Client x 1 ACTIVITIES IN SESSION AND THEIR IMPORTANCE: Evaluation and Selection = 1.0 Communication Design Information = 0.75	USED REPRESENTATIONS AND THEIR IMPACT ON SESSION ACTIVITIES: 3D Rendered Images Whole Session = 0 Physical Model (Mock-Up) Whole Session = 1.0 Evaluating and Selecting = 1.0 Communication of Design Information = 1.0 Sketching Whole Session = 0.75 Communication of Design Information = 0.75 Digital Simulation Whole Session = 1.0 Evaluating and Selecting = 1.0

SUMMARY OF USE AND IMPACT OF DESIGN REPRESENTATIONS ON SESSION:

During this session, four different types of design representations were used. During the session, a presentation that included 3D rendered images of the products of interest was given to set the context. While the images were adequate for this purpose, they were not used for any other purpose the digital images differ from physically real representations. Instead, the designers employed the use of physical models, or mock-ups, as the focal point of the co-creative session. The mock-ups were used to show the feel, look and configuration of the product and packaging design. The mock-ups were realistic physical representations of proposed designs and through them the designers were able to accurately communicate various design aspects. In addition to being realistic, the mock-ups were also accurate in terms of the physical configuration, materials, textures and finishes. This allowed these aspects of the proposed designs to be explored during the session. Being able to see various accurate and realistic representations allowed for quick decisions to be made during the session. Through the mock-ups, physical conflicts within the configuration of various aspects of the product which did not appear in the digital design became apparent, some of the parts did not fit together properly. The participants of the session were also able to test how potential users would be able to physically interact with the product as the use it (e.g. positioning of buttons and feel of product in your hand). At certain points during the session, sketches were created as a means of roughly illustrating ideas related to the internal configuration of the product.

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Through the sketches, the participants were able to communicate and explore spontaneous ideas quickly, graphically and in real time.
During the session, user interaction feedback of the product was also illustrated and tested through the use of a digital simulation of the feedback. The participants were able to see the different types of digital feedback that the user could receive after interacting with the product – the feedback to take the form of different types of flashing lights on the product. The simulation was an accurate and realistic representation of the feedback back and there was scope within the simulation to preview various presentations of the feedback based on suggestions by the client. This allowed for quick decisions to be made regarding what the best way to give the user digital feedback would be. Upon reflection, the mock-ups were selected as the best contributors to the observation session as they were an accurate and realistic representation of the product that the session participants could interact it with.

"You can touch; you can see."

CASE NO. 4	
MAIN SESSION GOAL: Sharing progress and making decisions regarding architecture and design of product. SESSION PARTICIPANTS: Designers x 3 Client x 1 ACTIVITIES IN SESSION AND THEIR IMPORTANCE: Idea Generation = 1.0 Evaluation and Selection = 1.0 Communication Design Information = 1.0	USED REPRESENTATIONS AND THEIR IMPACT ON SESSION ACTIVITIES: 3D Rendered Images Whole Session = 0.5 Technical Drawings Whole Session = 1.0 Sketching Whole Session = 0.5 Physical Products Whole Session = 1.0

SUMMARY OF USE AND IMPACT OF DESIGN REPRESENTATIONS ON SESSION:
During this session, four different types of design representations were used. 3D rendered images were used to create a visual map of the various product functions and features that were of interest during the session. They provided a visual representation of the space that was to be explored during the session, allowing the session participants to systematically go through and discuss areas of interest regarding the product, the visual map ensured that they could keep track of the areas that they had covered and to also see everything in once place. When discussing particulars based on the direction dictated by the map, relevant technical drawings were referred to. The technical drawings were accurate and detailed representations of the concepts in a form that was familiar to the client; they formed the focal point for discussion and were used to primarily derive discussions regarding the product architecture. A wide range of drawings were used, covering whole products as well as specific features and functional areas. At certain points during the session, sketching was used as a means of roughly illustrating various types of ideas. Through the sketches, the participants were able to communicate and explore spontaneous ideas quickly, graphically and in real time. Sketching was also used in tandem with the technical drawings as the participants occasionally sketched directly onto the technical drawings. An array of physical products was also available during the session, these were competitor products and through them, in addition to being able to see what the competition had to offer the market, the participants has access to real

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life solutions to certain issues related to the product. They could isolate different product functions and features, as directed by the 3D rendered image map, and see in detail how they manifested in alternative products. Upon reflection, the technical drawings were chosen as the biggest contributor to the session due to their representativeness, high level of detail and ability to be easily annotated in real time by all participants. *"… because they show everything that you need to show."*

Impact of Design Representations across Observation Sessions

The descriptive summary of the participants' perceived impact of design representations on observation sessions is presented in Table 4.6; the summary is in three sections under the following headings: use of representations, design representation affordances and design representation challenges. Each of the sections contains key descriptive statistics – mainly in the form of frequencies – and a qualitative description. Note that 'unique' denotes that appearance of the same factor across all cases only counted once (e.g. if design representation use appears in 3 different cases, it is only counted once) and 'cumulative' denotes that all appearances of a factor across all cases are counted (e.g. if design representation use appears in 3 different cases, it is counted three times).

Table 4.6: Descriptive Summary of the Impact of Design Representations on Observation Sessions

REPORTED USE OF REPRESENTATIONS
Total Number of Unique Design Representations Types Used Across Sessions: 11 Total Number of Design Representations Used per Session: 4 Total Number of Unique Uses of Design Representations Across Sessions: 10 Cumulative Number of Uses of Design Representations Across Sessions: 25 Most Frequent Use of Design Representations Across Session: Visual Aid x 6 Total Number of Design Representations Used as Visual Aids Across Sessions: 4 Highest Number of Unique Uses Across Sessions: Physical Model (Mock-Up) x 2, Mood Board x 2 Highest Number of Cumulative Uses Across Sessions: Physical Model (Mock-Up) x 3 Most Used Design Representation Across Sessions: Physical Model (Mock-Up) x 3
During the observed sessions, while design representations were used in a number of different ways, they were generally used either as communication/presentation aids or to enhance the process that was undertaken during the co-creative session. The design representations were used as visual, tactile, emotional expression, idea expression, context setting or mapping aids, or a combination of them. The most versatile of the design representations was the physical model, or mock-up, which was used as a process enhancer, a visual aid and tactile aid. See Appendix VII: List of Holistic Latent Level Codes for elaborations on the aids.
DESIGN REPRESENTATION AFFORDANCES DESCRIBED BY PARTICIPANTS
Total Number of Unique Design Representation Affordances Across Sessions: 23 Cumulative Number of Design Representation Affordances Across Sessions: 97 Most Prevalent Design Representation Affordance Groups Across Sessions: ▪ Facilitates design communication with non-designers' x 12 ▪ Similarities between representation and real product x 11

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- Accurate and/or realistic representation of concept x 11
- Allows for focus on a specific area or element x 11

Most Prevalent Individual Design Representation Affordances Across Sessions:

- Accurate communication of design x 3 – Physical Model (Mock-Up)
- Realistic physical representation x 3 – Physical Model (Mock-Up)

Highest Number of Unique Affordances Across Sessions: Physical Model (Mock-Up) x 8
Highest Number of Cumulative Affordances Across Sessions: Physical Model (Mock-Up) x 12

Through the use of design representations during the observation sessions, designers were able to present accurate and/or realistic representations of design concepts of interest to varying degrees. This was in part due to similarities between the design representations and the real products. Some of the used representations were physical or digital manifestations of particular areas or elements of interest related to the product as they would be in the real world (e.g. materials or finishes). Through the use of physical representations, the designers were able to avoid some of the limitations that are associated with using digital representations for physical products (e.g. colours appearing different on a screen and in print).
Design representations also played a key role in facilitating design communication between the designers and other session participants.

> *"Because client haven't the imagination about a vision … if they could touch its product and view a mock up and view the colour and view the details and view how it is on the shelf, it is easier to then discuss about that because it is not easy to create a vision on your mind if you are not a designer." – Case 2, Designer*

This was particularly beneficial to the observation sessions due to their co-creative nature, they aided the process of collaborating with non-professionals. In some cases, the use of design representations resulted in improved session efficiency, as decisions were made quicker, improvements to the approach to co-creative sessions and the creative outputs of the session, as the participants were able to explore various ideas in real time.

DESIGN REPRESENTATION CHALLENGES REPORTED BY PARTICIPANTS

Total Number of Unique Design Representation Challenges Across Sessions: 11
Cumulative Number of Design Representation Challenges Across Sessions: 22
Most Prevalent Design Representation Challenge Groups Across Sessions:

- Limited usability x 6
- Differences between representation and real product x4

Most Prevalent Individual Design Representation Challenges Across Sessions:

- Mock up mistaken for final product x 2 – Physical Model (Mock-Up)

Highest Number of Unique Challenges Across Sessions: PC + Monitor x 6
Highest Number of Cumulative Challenges Across Sessions: PC + Monitor x 6

The use of design representations posed some challenges during the observation sessions. As representations and not the actual product, there were cases where the apparent differences between the two were undesirable as the representation was not representative enough of the elements of interest or was wrongly perceived by clients/end-users to be an accurate representation of the final product. Differences between digital and physical representations of the same thing (e.g. colours appearing different on a screen and in print) also posed some challenges. Some of the design representations had usability limitations, these were related to a number of different factors

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including what they were able to represent, the effort and resources required to use them and how participants could interact with them.

4.2.5. Conclusion

Upon completion of the study, it is put forward that the descriptive summary of the impact of design representations on observation sessions presented in Table provides an answer to the research question that drove this part of task 1.5. The impacts design representations had on the observation sessions are understood through the use of design representations, design representation affordances and design representation challenges as perceived by the designers involved in the co-creative sessions. Some key findings from the summary are as follows:

- Design representations tend to be accurate and/or realistic representations of design concepts, the similarities that the representations share with real products mean that they can be used to explore physical or digital manifestations of particular design elements of interest related to the product, as they would be in the real world.
- For co-creative sessions, design representations can offer a way of facilitating collaboration between the participants, allow for quicker decisions to be made and improve time efficiency.
- If the affordances associated with a design representation are not aligned with the goals of the session, the use of the representation can cause participants to lose focus.

Ultimately, design representations are not the real product and they have various usability limitations. Typically, design representations are selected by aligning their strengths with what is trying to be achieved through their use; when these are not aligned an undesirable result will be achieved as the representation is not representative enough of the elements of interest. To ensure the best opportunity for co-creation, the design representations used during sessions have to achieve a balance between being too defined (limiting creativity) and not being representative enough (leading to misinterpretation).

This study was undertaken with the aim of exploring the impact of design representations on the observation sessions, as perceived by designers in order to understand their best practices. Resultantly, the following are some of the key insights that were gleaned into designers' best practices regarding design representations:

- For co-creative sessions that include non-professional participants, designers adopt the use of design representations that best facilitate design communication amongst the participants.
- Designers view the best contributor to a session to be dependent on the goal of

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the session; it is the typically the one that provides a realistic and/or accurate representation of element of interest in the simplest form possible.

- Designers typically utilise multiple design representations during a co-creative session, with the different design representations used in ways that exploit their strengths.
- When using physical models, or mock-ups, during co-creative sessions, designers isolate the elements they want to focus on and represent those as accurately as possible while making sure that the other elements are adequate but not necessarily accurate.
- When using design representations with digital interactivity, designers are limited to only making simple changes during the co-creative, as they are limited by the materials they pre-prepare and the time and effort it would take to implement more significant changes. To mitigate this, when preparing for the session the practitioners try to anticipate the changes that the participants will suggest and aim to have materials prepared that can allow them to implement them.

Through this study, designers shed light on their experiences with design representations during the observed co-creative sessions, this allowed for straight descriptions of the impact of design representations used during the observation sessions to be attained. This lead to a better understanding of practitioner best practices; the outcomes of this process provide further insight for the interpretation of the experimental evidences in T1.6.

4.3. Interviews with external organisations

4.3.1. Methodology for interviews with external organisations

Company selection and recruitment

To company selection and recruitment process involved first identifying relevant companies to target before inviting them to participate. In keeping with the objectives of the SPARK project, the main target was companies within the creative industries, including both consultancies and manufacturers. No limit was placed on the size of the company but preference was given to SMEs. Specific companies within this target group were primarily identified from the existing UK contacts of the University of Bath research team and Belgian contacts of the AMS (formerly FIS) research team. Additional relevant companies were identified through web searches. The companies were contacted via email. A one-page overview of the SPARK project was provided to give some context to the interview request.

Development of the interview protocol

The interview protocol was developed by first specifying the aims of the interviews, which were:

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- To understand the types of co-creative session that currently take place across the New Product Development process.
- To understand the types of design representation currently used within these co-creative sessions.
- To understand the challenges that practitioners face with their current use of design representations
- To gather opinions from practitioners as to how they might use the SPARK platform and what their requirements would be.

A series of interactive activities and discussions were then planned to address each of the aims. The main activities were split into three parts:

Part 1: Capture the current design process, co-creative sessions and design representations

Interviewees were asked to sketch out the main phases of their design process on a large sheet of paper. They were then asked about the types of co-creative sessions that occur during the process and the type of design representations used in each of those sessions. This information was noted on the same diagram as the design process overview. To facilitate discussion and avoid misunderstandings a 'design representation chart' was created that showed 14 types of commonly used design representation, based on the work of Pei (2009). For each design representation a name, an example, and a brief description is provided - an example is shown in Figure 4.1. The full chart is provided in Appendix IX. Finally, the interviewees were asked about the challenges they experienced in their current use of design representations.

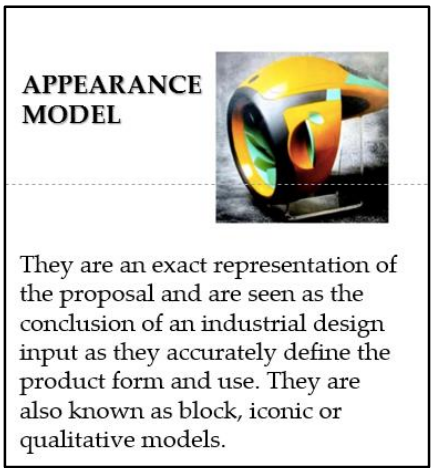

Figure 4.1. Example from the design representation chart.

Part 2: Introduction to SAR technology

Interviewees were shown a two-minute video, showing examples of SAR technology in use. The video featured a variety of different products including a car sear, a shoe, and some cosmetic products. These clips were specifically selected so as to represent a range of products that companies in the creative industries might have experience of designing. An example was also shown of somebody using a very basic, generic user interface created with SAR technology. At the end of the video the participants were asked to provide their initial impressions of SAR technology and had an opportunity to ask questions about what they had seen.

Part 3: Requirements discussion and ranking

The interviewees were asked to describe how they might use SAR technology in their own work and what requirements they would have of the technology. This gave the interviewees the opportunity to talk freely about how the topics that immediately came to mind for them.

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They were then presented with a pre-determined list of requirements, which they were asked to rank in order of importance. The list of requirements was generated with input from the technical experts from WP2 responsible for the SPARK platform development.

A pilot interview was conducted with a design consultancy that has connections to UBATH. This pilot interview was useful for testing the effectiveness of the protocol in eliciting the right types of information from the participants and was also used to check duration of the protocol was less than one hour. Several changes were made to the protocol based on an internal review of the pilot interview. The data from the pilot interview was not included in the results.

Conducting the interviews

Four of the interviews were completed with Belgian companies and a further seven were completed with UK companies. The first five interviews were conducted with two researchers, with the remainder conducted by one researcher per interview.
An audio recording was taken of every session. The diagrams created by the interviewees showing their design process was captured in photos. The requirement ranking exercise was completed using a PowerPoint slide in which the interviewees could position each of the requirements in the rank order they wanted and then save the slide.
The interviews were generally completed face-to-face, at the premises of the company with between one and four participants. In one company, two out of the three participants joined the interview via a web conference. Further details about the companies and the interviewees that participated can be found in the results section. All the interviews were conducted in English.

Data processing and analysis

The audio data from each interview were first transcribed and then coded using the qualitative data analysis software package NVivo.
The coding scheme was developed by reviewing the aims of the interview along with topics and questions considered most interesting by the partners involved in the SPARK platform development. This led to a first iteration of the coding scheme. Modifications were made to the coding scheme throughout the early stages of coding. Changes included adding new types of design representation mentioned by the interviewees for which no suitable category was available. The final coding scheme is provided in Appendix X along with a summary of the coding completed.
The coded data were analysed using several complementary approaches. First, by simply examining the number of references to a code and the number of companies mentioning a code. Secondly, by reviewing the content coded against a particular code and trying to identify common themes across the companies. Thirdly, by making use of the more complex, compound queries supported by NVivio, such as identifying instances where an interviewee mentioned challenges in obtaining feedback from a client. Examples of the quotes on which the analysis was based are available in Appendix XI.

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4.3.2. About the participating companies and interviewees

Eleven companies and 15 practitioners participated in the interviews. Table 4.7 provides an overview of the main characteristics of the companies and the practitioners (interviewees). The companies agreed to participate in the research on the condition of anonymity. Therefore no identifying features of the companies or participants are provided. Companies A to G were UK-based participants interviewed by the University of Bath. Companies H to K were Belgian-based companies interviewed by AMS-FIS.

Company background	Typical products	Interviewees job title
Company A Global consultancy specialising in product design of consumer goods and branding	Fast-moving consumer goods Packaging	Creative Director
Company B In-house consultancy providing design services to various business units within a large manufacturer of FMCG products as well as external clients	Fast-moving consumer goods Packaging	Designer
Company C Small-medium sized research, design and innovation consultancy with experience of product design and product development	Packaging Medical equipment Military equipment Consumer goods	Design Director Head of User Experience Design
Company D Small industrial design consultancy	Professional equipment Industrial machinery	Industrial Designer (Owner)
Company E Small product innovation consultancy with a strong focus on the front end innovation activities	Consumer goods Packaging	Designer FMCG Designer
Company F Small consultancy specialising in structural packaging design	Packaging	Creative Director Designer
Company G Large manufacturer	Household electronics	Principal Industrial Design Engineer Principle Design Engineer Product Design Engineer
Company H Small design consultancy	Toys Consumer goods	Design manager Senior designer

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Company I Medium-sized consultancy offering research, design and innovation support services	Professional equipment Furniture Display equipment	Co-owner
Company J Large manufacturer	Luggage	Design Director - Europe
Company H Small-medium-sized consultancy offering design and innovation services	Industrial machinery Furniture Electronic equipment	Head designer/Owner

Table 4.7. Overview of the companies and people that participated in the interviews.

4.3.3. About the nature of co-creative sessions that they participate in

This section provides some insights into the nature of co-creative sessions in terms of who is involved, where they take place, and the types of design representation used.

Who is involved?

Co-creative sessions can involve the design team (whether this is a consultancy or in-house team), representatives from a client, end users and, occasionally, other value chain partners. Figure 4.2 shows the number of references made to each of these types of participant (in red) and the number of companies (out of the total of eleven companies) that mentioned that type of participant at least once (in blue). Around 44% of all references mentioned participants from the client organisation. It is not possible to conclude from this that 44% of all co-creative sessions involve participants from the client organisation (not least because two of the companies where in-house design teams that do not work with 'clients'). However, it does suggest that co-creative sessions do frequently involve clients.

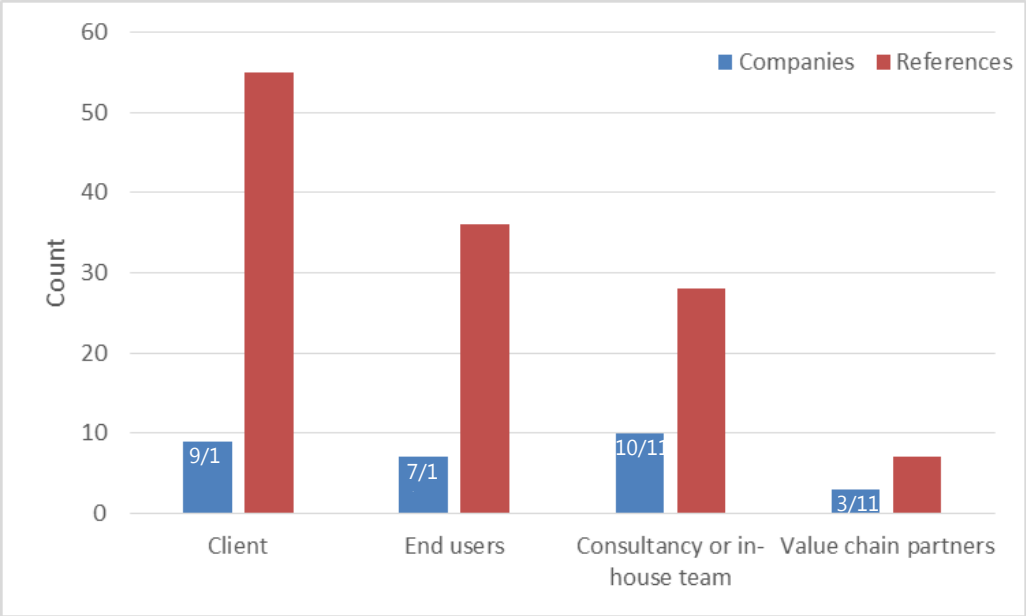

Figure 4.2. Overview of the types of participants in terms of their position in the value chain.

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Figure 4.3 provides some insight into the types of business function represented within co-creative session. 'Other functions' included a variety of functions including model makers, innovation team members and even a 'pitch doctor' (somebody who helps to prepare and perfect the presentation of a concept to the client).

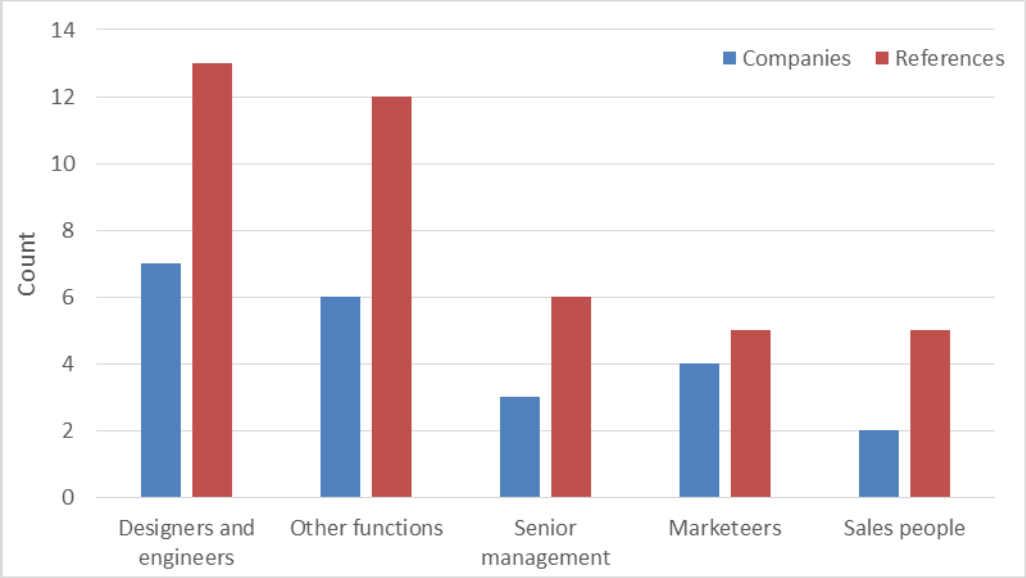

Figure 4.3. Overview of the types of participants in terms of their business function.

The number of participants in a session was considered by the SPARK consortium to be an important consideration as this may have implications for the projection requirements i.e. if there are more participants then it may be a requirement to have the SAR prototype viewable from a wider range of vantage points. The interviews provided very little specific data about the number of participants, but in general there seem to be two sizes of meeting that we can distinguish: 'small' and 'large'. 'Small' meetings are typically quite informal and involve three to five people. 'Large' meetings tend to be more formal, were often focused on review ideas/concepts and involved seven or more participants. These figures are consistent with the types of groups encountered in the observation sessions. The largest meeting mentioned was 20 participants.

Where do they take place?

Table 4.8 shows that whilst all companies hold co-creative sessions at their own site, ten out of eleven companies also hold co-creation sessions at a client site or some other site. 'Other sites' include online meetings and meetings hosted in general meeting venues. The choice of venue was determined by a number of factors such as the number of participants from the client's side, the geographic location of the participants, the normal working practices of the company, and also the objectives of the meeting. For instance, online meetings were used by some companies for internal meetings between different offices within the same company and occasionally for meetings with clients but one participant noted that "We never hold a big creative session through WebEx [a web conference system]". Two companies mentioned hiring meeting venues to get participants away from their normal working environments and hopefully inspire greater creativity.

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The variety of locations used for co-creation sessions led to discussions about the need for a portable system that could be taken to another site and quickly setup for use. This is discussed further in later sections.

Company	Own site	Client site	Other site
A	Yes	Yes	Online
B	Yes	Yes	-
C	Yes	Yes	Inspirational location
D	Yes	Yes	Online
E	Yes	Yes	-
F	Yes	Yes	Online
G	Yes	Yes - Retailer's site	
H	Yes	Yes	Other sites in own company
I	Yes	Yes	Inspirational location
J	Yes	-	-
K	Yes	Yes	

Table 4.8. Locations where the companies hold co-creative sessions.

Types of design representation used

A large variety of design representations are used within co-creative sessions. Some types of design representations mentioned by interviewees did not feature on the design representation chart. These included 'movie or animation', 'simulation', and 'shelf mock-up', which were added during the coding process.

Figure 4.4 shows the number of references made to each type of design representation and the number of companies mentioning that type of design representation. The most frequently mentioned type of design representation was '3D renderings', followed by 'CAD drawings', 'Shape model' and 'Development sketch'. The 'CAD drawings' category included references to three-dimensional CAD models, which are often the foundation for creating '3D renderings' and so it is not surprising that these two types received a similar number of references.

SAR technology requires the production of a three-dimensional, tangible model[2] - references to this category of design representation are shown in the red columns in Figure 4.4 whilst

[2] For the purpose of this analysis 'three-dimensional, tangible model' includes the following types of design representation: shape model, 3D print, functional concept model, appearance model, working prototype, shelf mock-up and pre-production prototype.

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references to other types of design representation are shown in the green columns. From analysis of the coding it was found that every company made references to at least two different types of three-dimensional, tangible model. Furthermore, ten out of the eleven companies interviewed already use 3D printed design representations, with six of the companies confirming that they have their own 3D printing equipment on site. This suggests that the necessity to produce a three-dimensional, tangible model should not be a barrier to adoption of the SPARK platform.

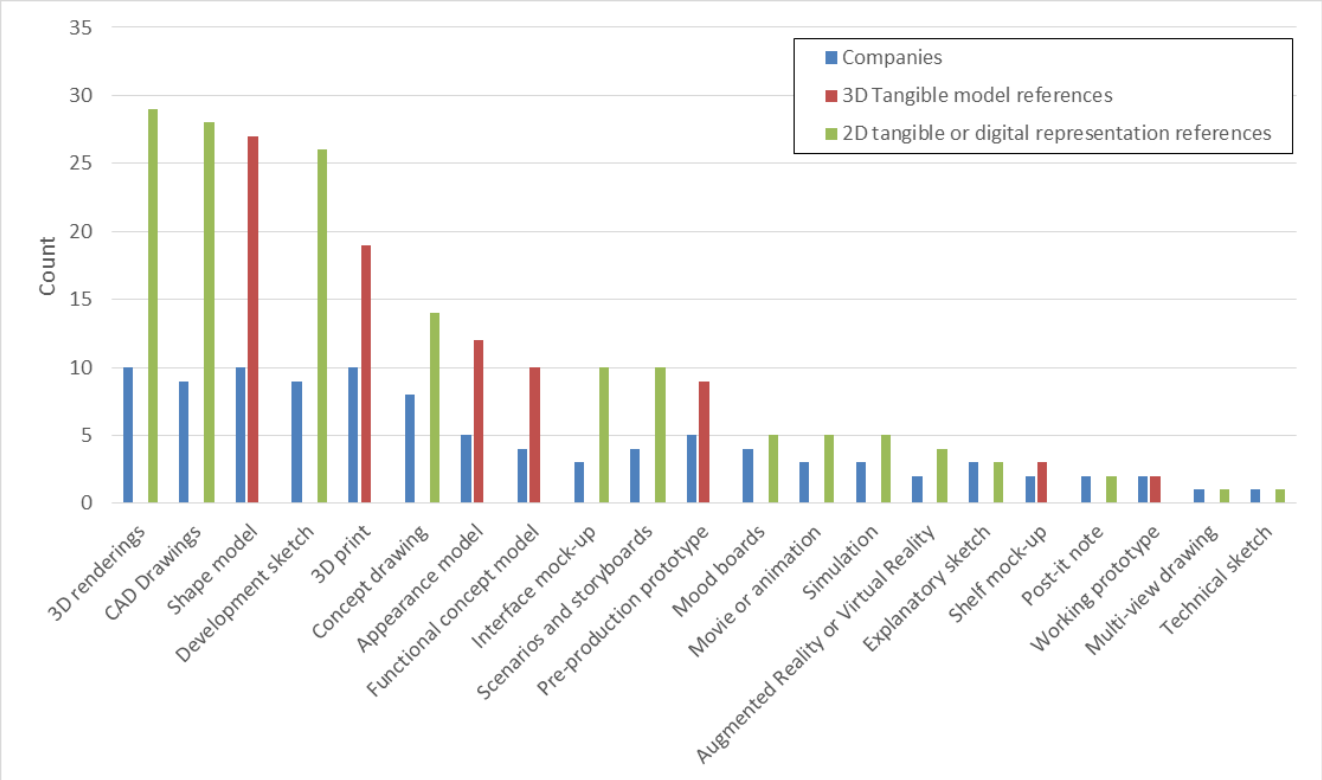

Figure 4.4. Overview of the types of design representations mentioned by interviewees.

4.3.4. What challenges do companies experience within their current use of design representations?

Time and cost to create design representations

Five of the companies stated that they would be interested in finding ways to reduce both the time and cost of producing design representations.

> *"I'm particularly involved in trying to reduce our prototyping expenditure and improve the speed at which we can prototype and both of those things point towards digital visualization of early stage prototypes."*

One of the contributors to cost is the number of similar design representations that have to be created in order to show variations in colour, material and finish options.

> *"Obviously, you can prototype, but again, there's a time and cost implication in making physical prototypes…quite often we will print out boards with a number of*

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> *colour options so you might end up with thirty boards, all cut out in silhouette, just showing the product from one particular view with a certain colour scheme."*

Another major contributor to the overall cost of creating design representations is the cost of producing very high quality, detailed design representations such as photo-realistic renders, appearance models and pre-production prototypes. Two companies stated that they sometimes spend in the region of €5,000-10,000 to produce one appearance model. Another stated that they spend over €500,000 per year on producing appearance models, including around €260,000 per year just on the painting process.

Misinterpretations of design representations

Several interviewees discussed the problem of misinterpretation of design representations by clients or other stakeholders. Judging the size and scale of a product that is represented through sketches or virtual models appears to be a common challenge:

> *"We had a lot of cases in the past that once there was a prototype before their eyes…they said 'Oh, I thought it was bigger', or 'I imagined it smaller' and 'Hmm, now I see it, it's too big.'"*

Another common frustration was that clients will often evaluate design representations as if they are the final product and expect all aspects of the design representation as being a perfect representation of the final product even though it may be a an early-stage design representation:

> *"Often the prototype is working but not so well as the final [product]. And they, you can tell that a hundred times, still they will say 'Oh, it doesn't work so well.'"*

> *"…the client is mostly probably not a designer and cannot look at it in a more relative way - abstract. They cannot make the abstraction of the thing they have seen."*

Achieving the right level of abstraction for the stage of the process

Some interviewees identified a trade-off that needs to be made when deciding on the level of abstraction when creating design representations. As noted above, clients sometimes struggle to provide feedback on design representations that do not look or function like the final product. This implies a need to create very detailed, accurate models (low abstraction) in order to obtain client feedback. On the other hand, presenting this type of low-abstraction model early in the process can limit creativity according to more than one interviewee:

> *"It is quite helpful to keep things quite loose at that stage, because even though the tools are available to visualise the things quite realistically. The way that in particular clients react to that can be unhelpful if it feels like it is too finished at a very early stage. Because you haven't really thought it through and it looks finished… We place a high importance into making things physically, testing them. It is such a powerful communication - models, and they can be misleading too. They are pretty helpful but again it can make things look real and it closes off creative exploration too quickly."*

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Communicating how products function, move and are assembled

One key limitation of virtual representations noted by participants was the ability to communicate to clients how products function and move:

> *"I would say that is probably one of the biggest limitations of 3D CAD is that although is very good for things that are static, as soon as you have got moving parts, it's much, much more difficult to kind of understand how things work and how they fit together, how it feels, how it moves. There is a big value in physical prototyping."*

Similarly, some interviewees noted that they had encountered problems because a virtual representation provides little opportunity to test how a product is assembled:

> *"[Joe[3]] once made a model on CAD and then got it produced and he couldn't assemble them. Because he could assemble them on CAD but couldn't actually do it in real life."*

Gaining feedback on user interfaces and points of user interaction

A final challenge that was noted by several interviewees was the difficulty in creating design representations that would allow for feedback on user interfaces and points of user interaction (such as buttons and dials).

> *"Some of the stuff we have done with making up interactive prototypes, so they have a display on there, but actually the bit you're missing is the physical interaction. Whether it is on a touch screen, keys or whatever else. Difficult to test things like that."*

In conclusion, there are a number of areas in which interviewees were able to identify challenges with their current use of design representations. It seems that given sufficient time and money designers can create highly accurate and effective design representations. However, within the types of market served by the creative industries, such as consumer goods, there is significant pressure to reduce product development lead times and costs. The main challenges therefore are creating design representations that are sufficient to get the feedback they need from clients or end users whilst minimising cost and elapsed time on the project.

4.3.5. What are the potential applications of the SPARK platform?

One of the challenges for the SPARK project is that SAR technology is not currently being used to support co-creation sessions. It is therefore necessary to build an understanding of the specific applications where it could be most useful. There are two ways of doing this: by analysing the current ways of working and identifying areas where SAR technology could be used; and by directly asking design practitioners where they could envisage using the technology.

[3] The name of the person has been replaced to maintain anonymity.

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Considering first the current ways of working, Figure 4.5 shows the number of references made by the interviewees to their current co-creation practices with a breakdown by participant type and activity type. From this we can see that obtaining feedback from end users was the most frequently mentioned activity (22 references), followed by obtaining feedback from a client (15 references). We can conclude that obtaining feedback from end users and clients are two important applications that must be considered for the SPARK platform.

It is interesting to note that there were only 9 references made to generating ideas within co-creation sessions, compared with 43 references for obtaining feedback and 14 for evaluating and filtering. The low number of references to idea generation activities could be due to a number of issues. It could be that the interviewees actually do not hold many co-creative sessions with a strong focus on idea generation. This seems unlikely given that all interviewees mentioned a need for idea generation at several points within their product development activities and the fact that group sessions are a very common method for supporting idea generation with design practice. An alternative explanation is that the interviewees were overlooking the amount of idea generation that occurs during a 'review' session. For instance, several participants mentioned that during a review session where a number of different concepts were presented to the client, they will quite often combine elements of each concept to formulate the final concept for further development. This type of activity might be referred to as 'Morphological Design' (Zwicky, 1969), which is recognised by design researchers as a creative, idea generation activity. However, it may be that the interviewees do not consider this activity to be creative because it is combining existing ideas. Finally, it could be that the interviewees do not experience any problems with idea generation and therefore were more likely to discuss other topics where they do experiences problems - such as reducing the cost and time required to create design representations.
Whatever the explanation for the low number of references to idea generation within the current practices of the interviewees, enhancing both idea generation (the development and improvement of new concepts) and creativity (applying novel approaches to completing product development tasks in general) is one of the primary aims of the SPARK project and will therefore be investigated further as an application of the SPARK platform.

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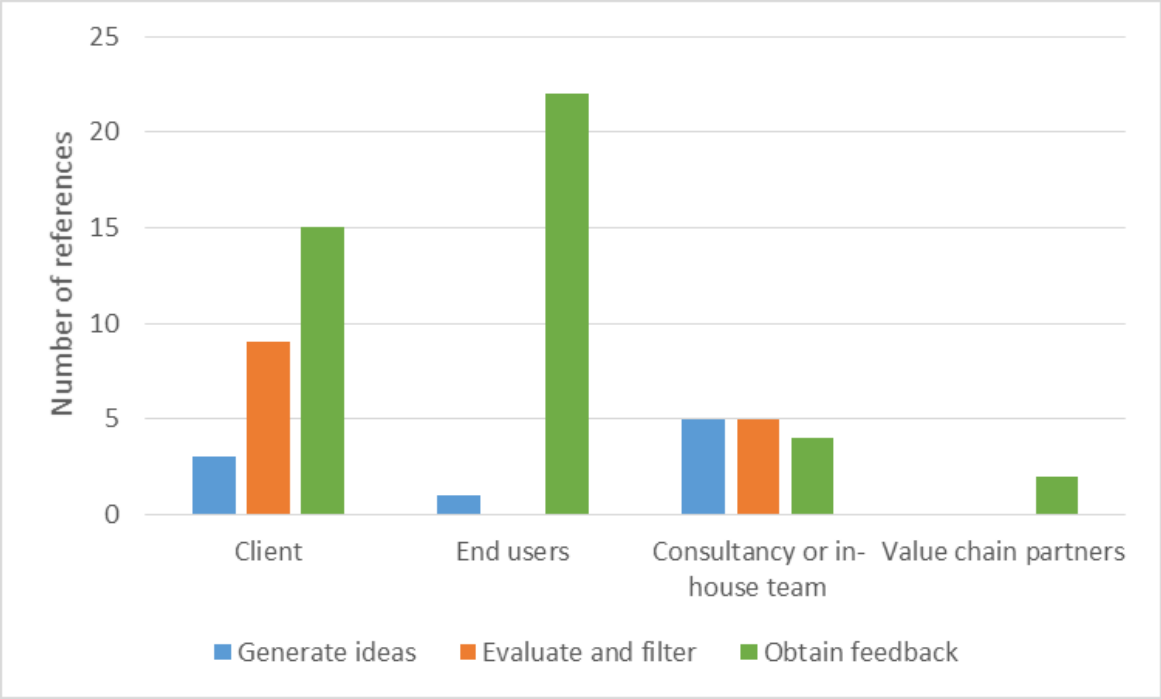

Figure 4.5. Number of references made by interviewees concerning current co-creation sessions with breakdown by participant type and activity type.

We consider next the comments from interviewees about the potential applications they could envisage for the SPARK platform. From the comments, a number of potential applications were identified including the type of user, the type of activity and the type of product.

For the type of user and type of activity, the comments were consistent with the earlier analysis, with most of the comments talking about gaining feedback from clients or end users. In particular, there seemed to be interest in being able to use the SPARK platform within end-user testing in order to reduce the cost of making a variety of high quality models and allow for last-minute changes:

> *"…they spent hundreds of thousands on creating high resolution mock-ups that they put on the shelf and they just use them that one time… But if you could do that with white printed mock-ups that you could project on and then it allows people to go 'what if we did it in pink?' Because I can tell you now, that when we do the mock-up work, you can guarantee a week before someone from graphics goes 'I don't like these graphics' and then you go 'Well, it's too late' and they will go 'Well I am not happy with this, I am not happy with that.' In that controlled environment, for researching, I would invest in that."*

One interviewee did note a potential drawback of using SAR technology with end users:

> *"I think that consumers would be distracted by the technology and not focused on what they are trying to research. They would be like 'Wow, how does this thing work?' So I can see them being distracted then because they are not marketing savvy."*

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Several interviewees also identified a potential barrier to the use of SAR technology with clients which is the difficulty of transporting the equipment to the client's office:

> *"We have a lot more meetings at the client's site than ours so I think it would be a clear limitation if we have got this great thing but you have to come here to see it…But it ultimately wants to be portable."*

This challenge led some to conclude that a safe starting point for the technology would be for internal use:

> *"So maybe the first point of entry is for internal presentations and discussions. Get people comfortable with what is possible with the technology, and as it evolves, then maybe you would start showing it to retailers and things like that"*

In terms of the type of activity and type of product, most comments were about obtaining feedback on colours, materials, finishes and graphics, particularly in the context of packaging design:

> *"I think that for us, the immediate application that I would see it is something like the kind of FMCG graphics on packaging…We can easily use it - have a dummy bottle and demonstrate to the clients or to users the whole bunch of different branding options or graphic treatments, that sort of thing."*

Although there were several comments about the potential to gain feedback on user interaction and user interfaces:

> *"Even something like a blood glucose meter type model - when you are putting a strip [in] and doing something, and things are happening on the display. I think that those kinds of interactions, I see a value from that dynamic kind of technology"*

In conclusion, the quantitative analysis of the coding and the qualitative analysis of the interview transcripts have led to the definition of three of the most common potential scenarios for the SPARK platform, which are summarised in Table 4.9.

Application scenarios	**Expected business benefits**
Client feedback sessions in which multiple concepts are to be presented and discussed. Ideally, it would be possible to conduct such sessions at the client site.	+ Reduced time and cost to produce multiple design representations as they can be projected onto one physical model. + Avoid misinterpretations of size and scale that can occur with virtual representations. + Reduce the time required for design iterations by enabling on the fly modifications to the concepts presented.
Evaluation and filtering sessions with clients in which the aim is to reduce the number of concepts to be developed further. Ideally, it would be possible to conduct such sessions at the client site.	+ Reduced time and cost to produce multiple design representations as they can be projected onto one physical model.

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	+ Enable the creative combination of ideas from different concepts when defining the final concept for development.
End user feedback sessions, particularly for products such as FMCG packaging and for user interaction/interface design aspects.	+ Reduce the cost of producing high-quality design representations for use in end user tests. + Better quality feedback from end users on interaction/interface design aspects due to more realistic, three-dimensional design representations.

Table 4.9. Most common potential application areas for the SPARK platform.

In the following sections, we look in more detail at the requirements discussed by the interviewees that would need to be fulfilled in order to offer satisfactory performance in the application areas defined here.

4.3.6. What requirements do practitioners have for the SPARK platform?

The requirements for the SPARK platform discussed by the practitioners are identified in this section. The first part identifies requirements related to the modules and main functions that make up the overall architecture of the platform, shown in Figure 4.6. The second part considers requirements related to overall system properties such as ease of use and price. Finally, the results of the requirement ranking activity are discussed.

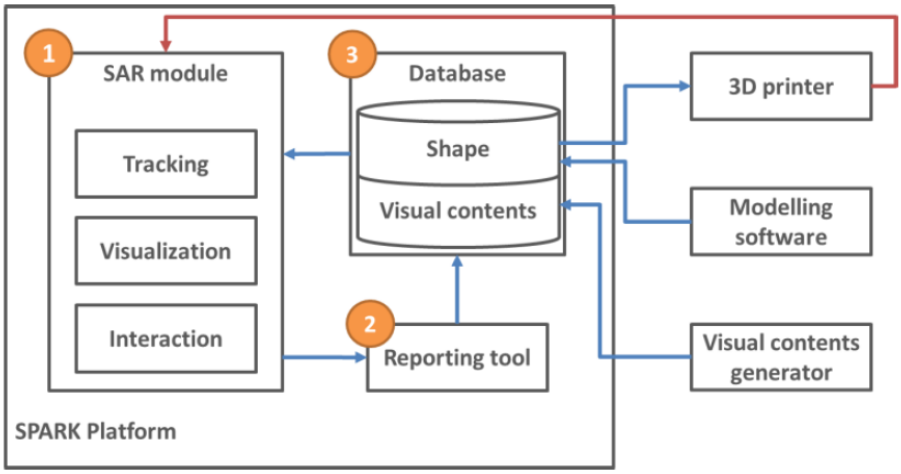

Figure 4.6. SPARK platform architecture.

SAR module: Visualisation

The most commonly mentioned category of requirement was to do with the accurate rendering of colours, materials and finish. Many participants felt that this was the most important requirement, going as far as to say that they would not buy the platform if it could not perform this function satisfactorily

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> *"You would never ever consider using it unless you had fairly accurate renderings of material, colours and finishes."*

Several participants specified their requirements in this area in comparison to existing technologies with some hoping that SAR would exceed the performance of those existing technologies:

> *"For me if I was selling to a client, the quality has got to be… it just has to blow them away, that is how good it has to be. It can't be anything that a 3D CAD render can do now."*

Projection resolution was often closely linked to accurate rendering of colours materials and finishes:

> *"I would definitely go with accuracy being up there. And I would say that goes hand in hand with projection resolution because to get an accurate rendering of material and colour and finish it needs to project at high resolution."*

Whilst several of the companies are involved in packaging design, only one mention was made of the need to be able to read text on the prototype:

> *"Because of the line of work we are doing [packaging design], for obvious reasons, resolution would have to be pretty high. Because if you can't read what you have got on there, you don't want to go 'Oh, look at the render that we have done', it's kind of like, what's the point?"*

Beyond accuracy of rendering and resolution, the other requirement related to projection concerned the viewing angle of the SAR prototype. The responses on this topic were mixed with some participants suggesting it was important whereas others felt that any limitations in field of view could be overcome:

> *"View the model from various vantage points. Yeah, that's sort of important as well 'cause…but you can get people to walk around your room. If you say 'Can you gather round here' or something. It's important but it's not the end of the world."*

SAR module: Tracking

On the topic of tracking interviewees were asked about the speed with which the visualisation responds to movements of the target object and how important this was. Some companies, such as Company H, felt this was not important, perhaps because they expect to use the system without significant manipulation of the target object. For at least five of the companies it was important to minimise the response time, or 'latency', in relation to movement in order to maintain a realistic experience for the user and avoid introducing any bias into the evaluation:

> *"Response speed in relation to movement...It's -- I have the feeling that it would be biasing the experience, or the feeling that the person gets when he's manipulating the part. If you -- cause what I saw in the short movie, if you just want to experience the different materials, textures and colours then it's not making sense that you*

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handle the product and evaluate. And at that time when you would do that and add the, a slow response speed, it would certainly bias the experience."

Several interviewees asked how the tracking technology would work and if it would require the types of markers shown in the SAR technology video. No specific feedback was sought from the interviewees on this topic, but no specific objections were raised to the use of such markers.

SAR module: Interaction

Comments related to interaction were focused on three main issues: testing of user interfaces and user interactions; being able to directly manipulate the features of the SAR model; and obtaining feedback on surface texture and feel.

In Section 4.3.3, it was noted that one of the challenges practitioners face is obtaining feedback on user interfaces and points of user interaction - such as buttons and dials. Whilst user interaction is a feature of almost every product, user interface and user interaction design was a major part of the design activity for six of the companies interviewed. For these companies, the possibility to display elements of a user interface on a physical, three-dimensional model seemed exciting:

"So if that could be top, if you could really do that, if it is not just visibility of the model, it's the use of it. So it behaves like a virtual physical prototype, I think if that was possible that would add value."

As well as obtaining feedback, some interviewees liked the idea of being able to make changes to design concepts through direction manipulation of the SAR model:

"It would be really cool if you could edit your artwork on the product rather than on the computer. So if you have got your artwork on it already and then you can start to drag and move things around and it automatically save."

For the companies that focus less on user interaction and more on the aesthetic qualities of the product, their interest was in being able to obtain feedback on the texture and feel of the model surface:

"What about from the model itself, can you control the texture? Because some things, for example in an iPhone, some parts are very shiny, other things are metal and cold. Or it might be that something is more fabric…this industry is very tactile, what does it feel like?"

This requirement would be important to consider if it was decided to focus the development of the SPARK platform on application scenarios in the later stages of the product development process, where aesthetic models and pre-production prototypes featuring realistic materials and finishes are often used. Conversely, it would be less relevant for application scenarios in the early stages of the product development process where 3D

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printed, cardboard or foam models are often used - presumably because tactile properties are not a high priority in the early stages of process.

Reporting tool

Reporting capabilities is not a feature associated directly with design representations currently. Interviewees were asked about their current design information management approach. All the companies confirmed that they try to capture and record all design representations and ideas, as well as photographs of flipcharts and post-it notes that contain ideas or feedback.

Company J was the only one that reported using a dedicated Product Lifecycle Management (PLM) software to formally manage design information. Three other companies reported using online collaboration tools such as Slack and Asana to help with this challenge. The most common approach to capturing design information was to keep it on a central server using an agreed approach to the naming and structuring of folders. Interviewees did not express any concerns or challenges related to this simple approach.

One company mentioned an interest in being able to record the interactions between a user and the SAR prototype:

> *"That is an interesting aspect, recording interactions… is that something that can be built into the system or is it something that you need to do externally?"*

The same company also expressed a need to be able to share design representations with the client to enable their client to hold meetings internally:

> *"P1:Often our clients might be gate keepers and they need material that they can share.*
>
> *P2: Yes, that is often a big requirement. 'I have got a meeting with a steering committee next week, I need X, Y and Z', so there is a big requirement for stuff like that."*

This would suggest the need for some kind of 'client portal' to enable the sharing of files between a consultant and their client.

Interviewees were also asked about their practices in terms of managing tasks during a project. These were generally captured in meetings notes and kept with the project files.

There was very little discussion of how companies currently capture feedback on design representations. One interesting example was identified of a company using online tools to capture feedback about design representations:

> *"At the moment, we don't have any way of interactively engaging with our retailers or customers…or to enable them to help us design the products. It's basically a discussion board…and there's no way of sort of having a two-way interaction on whatever we're presenting. It's always 'Here's what we've done, what do you think?'"*

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From this statement, it appears as though there is some frustration with the asynchronous nature of the communication that prevents, live two-way dialogue. Therefore, it might be interesting to offer some mechanism to capture live feedback, both from face-to-face and online sessions.

Database

The requirements for the Database module of the SPARK platform were not discussed in any detail within the interviews but some requirements can be identified or inferred from the responses.

The most significant requirement was that the Database should allow the user to project the exact colour, texture and material that is desired.

> *"I think that working with a lot of brand guys, they are very on it with their brands and their colours and things like that…the colours are going to have to be the right colour if you are going to pass any judgement on them"*

This may require the ability to specify colours using a system such as the Pantone Colour Matching System for example.

On a different aspect related to the Database, one company noted that they sometimes had difficulty in manufacturing a product to match what had been shown on a design representation:

> *"If someone wants a metallic feel on something, the suppliers and the engineers will get really nervous…'Oh, you want that finish?' and people would be like 'Yes, that is what I want' and suddenly they deliver the product that has been injection moulded and senior management, the stakeholder, will go 'That doesn't look like that, that I saw on my projector, it looks just a bit rubbish!'"*

This comment might suggest the need for the platform to limit users to materials, colours and finishes that are manufacturable by the company. This would help to ensure consistency between what is discussed in through the design representations and the final product, but at the same time this would of course limit creativity and the exploration of new colours, materials and finishes.

Price

Of the general system requirements, the sales price of the system was the most frequently discussed. However, interviewees found it difficult to rate the importance of price without having any suggestion as to the likely sales price of the SPARK platform nor sight of the final system specification. Most companies did not place any limit on the system cost but would look to evaluate the ratio of the cost compared to the value it could bring to the company:

> *"The cost is only once facet, the return on investment is -- if it costs three million but we can use it for everybody, or we can only use it for two or three customers. So the system cost in relation with our business and how many of the projects we could use it in"*

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For some interviewees there was also an expectation (or hope) that using the SPARK platform would reduce the costs of creating physical models:

> *"I think, fundamentally, it's gonna be a lower cost approach than physical prototyping."*

Within the interviews with design consultants, there was also some discussion as to who would buy the SPARK platform: them or their clients?

> *"I would be assuming I am not buying it - it would be somebody else's stuff. Because I don't think it is a system we would be investing in, but if it was a research or a customer, you would probably expect them to buy it"*

This suggests that careful consideration should be given to selecting the customer segments to target when developing the business strategy and business model for the SPARK platform exploitation.

Set-up, preparation and usability

Within discussions about the system set-up, preparation and usability, the topic of portability often emerged. Six companies expressed an interest in having a portable system and therefore placed high importance on being able to set-up the system quickly and reliably:

> *"We have a lot more meetings at the client's site than ours so I think it would be a clear limitation if we have got this great thing but you have to come here to see it. But it might that you get really experienced here because we have got the room set up to do it. But it ultimately wants to be portable."*

A portable system is not the top priority requirement of the SPARK project, but it is an important feature to note for consideration within long-term exploitation plans.

Another common requirement was to ensure good usability of the system. An important aspect of usability was the speed and ease of being able to change modify colours, materials and finishes or switch between pre-defined complete concepts:

> *"So we're gonna be drawing up the graphics in two different styles. That would be very cool if you have a model and you just [clicks fingers] 'that's one style,' [clicks fingers] 'that's another style.'"*

Other companies expressed a desire that the system be very simple to use so that a wide variety of people, including clients and end users, could make use of the system without training:

> *"I think ease of use is gonna be a key factor, 'cause [Joe[4]] has mentioned the variety of people that might be using this, and it's everyone from design engineers up to the CEO. And you can hand someone a stack of papers with loads of different renders and they can leaf through it. I guess there needs to be a replacement for that. Like,*

[4] The name of the person has been replaced to maintain anonymity.

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you can hand the object and they can change and interact with it instinctively, without learning how to use the system."

Finally, interviewees were keen that the process for preparing a SAR model be as simple as possible, with one interviewee suggesting that being able to scan an existing physical model might help to simplify the process:

> *"Yes, it needs to be as easy as sketching. Which mean you don't want to do a quick prototype and then do a CAD model of it and then you can map the graphics on it that you have had to create as well. It needs to just scan the physical model and chuck on something and figure it all out"*

Room requirements

In relation to the room that will be used for the co-creative session, the main concern from interviewees was the possible need to darken the room to facilitate easier viewing of the SAR prototype. In particular, three companies were concerned that this could bias the feedback from customers or end users:

> *"You have to make sure that the environment in which they are thinking doesn't actually affect their perception of it. If they are dealing with a yogurt pot for example. Probably most of us have yogurt for breakfast time when it is lightened, and all of a sudden you are there in the dark… it would be wrong, it wouldn't feel quite right."*

None of the interviewees expressed any concern about the size of the room required to set-up the SAR technology, as they all felt that a suitable room could be found.

System noise and safety

Regarding system noise the majority of interviewees confirmed that this would not be an important requirement below a threshold level:

> *"System noise is that just like physically making a humming noise? I would not be concerned by that unless it was ear-deafeningly loud I don't think it would be a real issue"*

No indication was provided by the interviewees as to what the acceptable threshold level of noise would be.

No concerns were raised by interviewees about the safety of the system.

Results of requirement ranking activity

The final part of the interview required the interviewees to place a predefined list of requirements into rank order of importance. A summary of the ranking by each of the companies is provided in Figure 4.7. A ranking of one indicates the highest importance. In some cases, interviewees placed two or more requirements at the same level of importance. In those cases, the points were distributed evenly amongst those requirements i.e. two requirements placed in the 4th rank position receive (4+5)/2=4.5 points each. The 'Product' column shows the mathematical product of the rankings from each company for that

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particular requirement. The 'Overall rank' column is based on the product score where a low product score means it is more important. Company F did not participate in the ranking activity as the interviewees felt that they had not been provided with sufficient information about the SPARK platform to complete the activity.

Company:	A	B	C	D	E	G	H	I	J	K	Product	Overall Rank
Accurate rendering of materials, colours and finishes	1	1	2	1	5.5	1	3	3.5	1.5	4.5	780	1
Ease of set-up and use	4	2	5	5	1.5	7	1.5	2	6.5	2	81900	2
Visibility of model from various vantage points	2	5	1	3	3.5	3	5	5.5	4	7	242550	3
Projection response speed in relation to movement	3	4	3	2	3.5	4	7	5.5	3	3	349272	4
System cost	5	6	7	6	8	6	1.5	1	5	1	453600	5
Project resolution	7	3	4	7	5.5	2	4	3.5	1.5	4.5	611226	6
Room requirements	6	7	8	4	1.5	8	7	8	8	6	43352064	7
System noise	8	8	6	8	7	5	7	7	6.5	8	273960960	8

Figure 4.7. Ranking of requirements with breakdown by company and sorted by overall ranking.

The result that accurate rendering of materials, colours and finishes received the highest overall ranking is consistent with the qualitative analysis in the SAR Visualisation module, which emphasised the criticality of this aspect of the SAR technology. Whilst projection resolution was often discussed in the same context as accurate rendering of materials, colours and finishes the former has been ranked significantly lower (6th position). This may be because the interviewees were not sure about the distinction between these two requirements or because the availability of 'high-definition' projectors means that they do not expect resolution to be a problem.

The high ranking of ease of set-up and use seems to be based on the assumption that a portable version of the SPARK platform will be produced. Several of the participants mentioned the importance of being able to set-up the SAR equipment quickly and reliably at a client's office when discussing the ranking of this requirement.

The visibility of a model from various vantage points came third in the overall rank, although there are significant variations in the individual rankings by the companies ranging from one to seven. This appears to be due to different interpretations of how the system would be used. Some felt that it was important that all participants in a meeting would be able to see an accurate visualisation on the SAR module from wherever they were sat. Others felt that it would be possible to ask people to move to one particular location to view the model, or that only one person would ever be interacting with the model at a time and so gave this requirement a lower ranking.

The low ranking of system noise requirement was not surprising as the interviewees expect modern projectors to be reasonably quiet. The ranking of room requirements in seventh position suggests that the majority of interviewees are not concerned by the room size requirements, or the need to dim the lighting in the room to aid the visualisation aspects.

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As a general point, it will be interesting to see how the requirements ranking provided in this exercise prove to be valid given that they are based on the practitioners' *expectations* of what their requirements will be for SAR technology. It is likely that practitioners will be able to provide much more effective feedback about their requirements once they have had an opportunity to use the SAR technology and apply it within a realistic context. For instance, if a darkened room does become a necessity for good visualisation performance, will practitioners still consider 'room requirements' a low priority issue? Gaining this type of feedback based on practical experience will be a key objective of the WP4 activities.

5. COLLECTION AND ELABORATION OF EMERGED EVIDENCES FROM THE EXPERIMENTAL ACTIVITIES (T1.6)

This section presents the results of Task 1.6, the aim of which is to bring together the findings from the observations of co-creative design sessions (Tasks 1.3 and 1.4 described in Section 3) and the interviews with co-creative people (Task 1.4 described in Section 4) in order to identify the key, overarching insights that can inform the development of the SPARK platform.

Section 5.1 presents the key insights concerning the behaviour of participants within co-creative sessions. Section 5.2 presents some of the challenges concerning SAR technology and proposes how these can be turned into opportunities within the SPARK platform development. Finally, Section 5.3 proposes a first attempt at a basic roadmap for the SPARK platform based on the priorities identified.

5.1. WHAT HAVE WE LEARNT ABOUT CO-CREATIVE SESSIONS?

Overall, the SPARK consortium is now in a strong position to start development of the SPARK platform having completed the activities of WP1. In particular, we now know significantly more about topics such as:

- The types of co-creation session that take place
- The goals of these sessions
- Where the sessions typically take place
- What type of people and the number of people involved in co-creative sessions.

Going beyond these basic characteristics of co-creative sessions, we also have a much better understanding of how co-creative sessions work including: how designers prepare design representations for use in those sessions; how design representations are used during a session; and the types of activity that take place. Some of the key insights within these topics are discussed further here.

Concerning the preparation of design representations, it was found that when designers are preparing design representations they have to take into consideration a wide range of

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factors. First, factors about the project, such as the type of product (packaging, consumer goods, electronic equipment etc.), and where they are in the product development process when the co-creation session takes place. Secondly, they must consider the specific details of the session such as:

- the objectives of the session;
- who will participate in the session and what their level of design knowledge is;
- the time and budget available for preparing design representations;
- which aspects of a concept they wish to discuss with a client.

Overall, the main challenge for designers in preparing design representations appears to be deciding how to represent the key features or elements of a concept that they want to discuss in a way that the client will be able to understand whilst minimising time and effort and not limiting scope for creativity. The conflict here is that clients often struggle to understand and provide useful feedback on these key features or elements unless they are presented in a way that offers a low level of abstraction. However, creating such design representations requires significant time, effort and cost and - according to the opinion of several designers - does limit the scope for creativity because the client then sees the idea as 'fixed' and 'complete'.

Through our observations of real co-creative sessions, we have also learned a lot about what happens during sessions and the role of design representations. For instance, we can say with confidence that design representations and other artefacts play a very important role in the communication between designers and clients, as around 90% of these interactions involve some kind of artefact. Both tangible and digital artefacts are used in these interactions by both designers and clients, although it seems that clients have a preference for using tangible artefacts when they are available.

How design representations are used during sessions depends on the goals of the session, but we know some of the affordances that design representations offer include: communication of the visual, tactile and emotional aspects of a concept, as well as supporting context setting. The main positive impact that design representations have on co-creative sessions, according to designers, is that they support the communication of concepts that allows clients (and end users in some instances) to understand the concept and provide feedback on it. However, even in this role there can be challenges. Specifically, it seems that clients often need a design representation with a low level of abstraction from the final product in order to provide useful feedback, but then they are confused or disappointed when not all features or aspects of a design representation are exactly as they would be on a final product (i.e. colour or texture is different, buttons do not depress, status lights do not work etc.).

In terms of the design changes that were proposed during the co-creative sessions that were observed, there were different trends according to the type of product being developed. Key

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types of modification made to design representations in PACKAGING design sessions are colour, look, position and the number/presence of a feature. Key types of modification made to design representations in PRODUCT design sessions are size, number, position and look (shape). There were also differences identified between phases of sessions that were more concerned with review compared to those focus on idea generation. Review phases tended to focus on the 'functions' the design has to fulfil, whereas idea generation phases tended to focus more on 'structures'. These insights can all be used to inform the development of the SPARK platform such as deciding the types of interaction and manipulation of features that must be supported by the platform.

Despite the range of idea generation and creative activities observed during the sessions, it is noticeable that the designers interviewed in T1.5 did not express a strong view on the role of design representations in supporting idea generation or creativity. As previously noted in Section 4.3, it may be that the designers underestimate the creativity that takes place during a 'review' session or that they do not experience significant problems in generating ideas. Whatever the reason, it seems that the SPARK platform could play an important role in enhancing support for creativity (applying novel approaches to completing product development tasks in general) but that effort should also be made to raise awareness amongst designers of the creativity that takes place during review sessions. This relates to the idea of the 'creative review' session, introduced in Deliverable 1.1 of the SPARK project.

One final interesting and important observation was the use the occasional use of 'imaginary artefacts' during interactions. The fact that the participants had to resort to using hand gestures and these imaginary artefacts implies that there are some aspects of design that could not be easily communicated using the tangible and digital artefacts that were available. Further analysis of the verbal data related to these gestures should enable a better understanding of the purpose of these gestures and the, as yet, unmet need that these gestures fulfil.

5.2. Summary of challenges and opportunities for the SPARK platform

Within the interviews completed as part of Task 1.5 and described in Section 4 a number of challenges were identified concerning certain aspects of SAR technology and its performance. Many of these challenges have been mentioned in previous sections and so a summary list is provided below along with the corresponding opportunity for the SPARK platform developed. The challenges and opportunities are grouped by theme where possible and with references to relevant sections of the report shown in brackets.

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Challenges and concerns	Opportunity for SPARK platform development
Not sure of the added value compared to existing technologies:	
Can't represent colours, materials and finishes better than a high quality 3D render on a computer monitor or printed on a board (4.2.6 - SAR module: visualisation, 4.2.6 - Database)	Provide high quality visualisation comparable in quality with a 3D render or printed board.
Can't simulate a user interface better than an iPad/tablet (4.2.4)	Provide API integration with user interface mock-up tools such as Balsamiq (https://balsamiq.com/) or moqups (https://moqups.com/)
Can't simulate user interactions (buttons, dials etc.) better than a pre-production prototype (4.2.4)	Will still need pre-production prototypes to test physical interactions but can focus on ability to show multiple colour schemes and graphics on one physical prototype.
Not sure if it will be cheaper or faster than producing other types of design representation	Ensure very short preparation time through good design of the user interface. Conduct a comparison with the time and cost required to prepare conventional design representations.
Can't get feedback on textures (4.2.6 SAR module: Interaction)	Investigate the potential to create a variety of surface textures with current 3D printing and rapid prototyping technology.
It might reduce the quality of the feedback from clients and end users:	
A darkened room could influence the mood/perception of an end user (4.2.6 Room requirements)	Identify projectors that can provide the necessary visualisation quality without the need to significantly darken the room.
The SAR technology itself might be a distraction for end users (4.2.5)	Provide user educational material that can be used to introduce and explain SAR technology to new users before they start co-creation sessions.
Slow response in relation to movement (latency) could give an unrealistic and frustrating experience (4.2.6 SAR module: Tracking)	Target very low system latency.

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SAR technology might not be sufficiently simple and intuitive to use for stakeholders that have no prior experience of it (4.2.6 Set-up, preparation and use)	Seek regular feedback from potential end users during the SPARK platform development to ensure that it is as simple and intuitive as possible to use.
It may not enhance innovation and creativity:	
By the time the geometry is sufficiently detailed to create a SAR model the real innovation is complete.	Provide system features to support early-stage innovation, such as the ability to 3D scan basic foam models and use them as a SAR model.
The time required to make changes to a concept after a review meeting is often used by designers to reflect on the feedback and can lead to better designs. The SAR technology might eliminate some of these iterative improvement cycles and result in a less innovative product.	This is a usage issue rather than a technology challenge. Therefore could write White Papers to describe different approaches to using SPARK platform and good practices to support innovation.
Other challenges and concerns	
Lack of portability so can't be used for client meetings (4.2.5, 4.2.6 Set-up, preparation and use) or for user testing at users' homes.	Investigate potential for creating a portable version of the SPARK platform in the future.
Shadows from other users would ruin the visualisation (and tracking)	Use multiple projectors and tracking devices to reduce the impact of shadows on visualisation and tracking.
Won't be able to change the shape of the target object, only the graphics, colour, material and finish	Consider workflow integration with 3D printing to enable changes in the geometry of the target object.

Table 5.1. Summary of the challenges and opportunities for the development of the SPARK platform.

During the development of the SPARK platform, it will be important to try and address these challenges and opportunities where possible. During the post-project exploitation of the SPARK outcomes, this list may be useful in preparing marketing materials and strategies for handling objections by potential users.

5.3. Suggested roadmap for the development of the SPARK platform

Based on the activities, results and insights from the project to date, the following roadmap for the development of the SPARK platform is suggested. The aim of this suggested roadmap is to provide some inspiration and guidance for the partners working on the development of the hardware modules (WP2) and software platform (WP3). It is not intended as a binding plan for the SPARK platform development. More detailed development plans and roadmaps will be generated by the relevant partners later in the project that will take into account other

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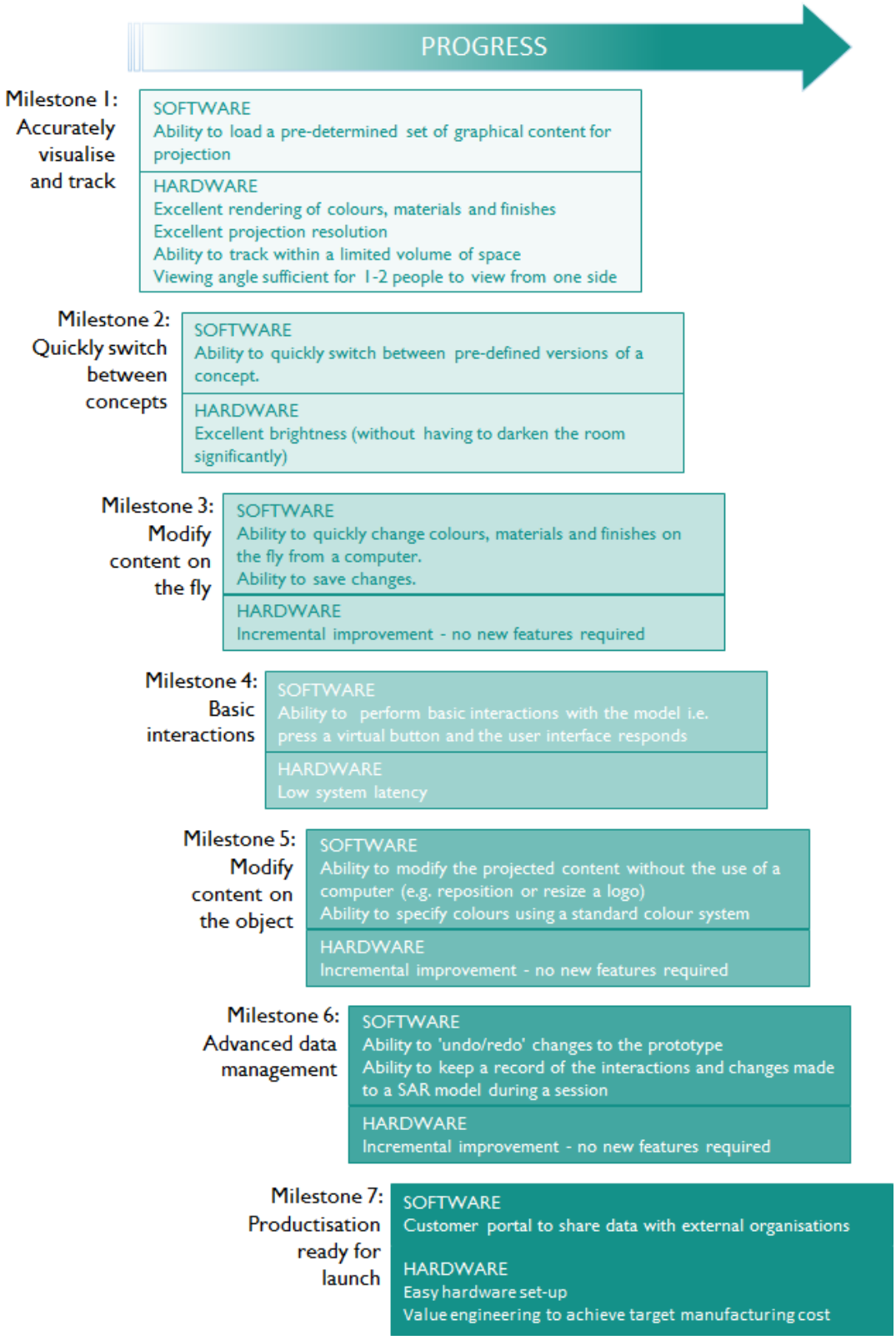
factors such as technical feasibility, sequencing issues, performance conflicts, availability of staff, etc. The development partners will also need to consider which features might appear in each of the SPARK platform releases, scheduled for M21, M26 and M31.

Figure 5.1. Suggested development roadmap for the SPARK platform.



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APPENDIX I: DESCRIPTION OF THE CASE STUDIES

CASE STUDIES AT ARTEFICE

Case Study n°1: Company 1

Company presentation:

Alce Nero is the brand name of a co-operative of more than one thousand farmers, beekeepers and organic processors in Italy and worldwide that provides raw materials from biological agriculture in quality food products.

Session plan and goals:

During this session, Designers from Artefice received their clients and 5 customers.
The goal was to allow their clients to ear some feedback from "real" customers about the packaging propositions they previously validated during previous internal meeting. The designers did not discuss any basic graphic design elements; only suggestions on the final presentation of the packaging were welcomed.

The session was organised as follows:

- Presentation of biscuit packages (organic vs non organic packages
- Presentation of four alternative concepts (A, B, C &D), each concept being implemented for a specific type of biscuit and the associated package. The customers' opinion was recorded using red and green post-its, where the positive and negative arguments of each proposition were displayed.
- New design
- Re-design session using multi-touch screen

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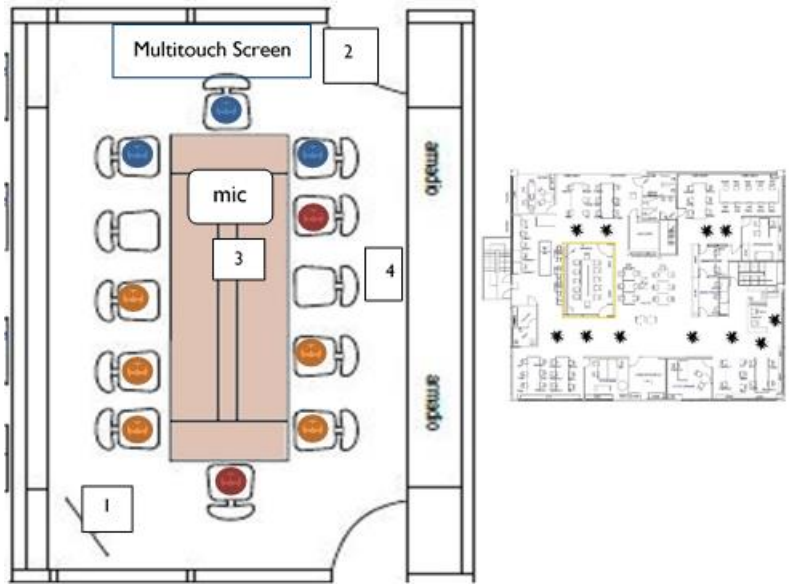
Date & Time	02-05-2016. Start at 2:15pm end at 5:50pm
Language	Italian
Process design stage	
Product	**Organic Biscuits**
Participants	T, P, A: Designers, Creative and Art Director from Artefice F&G: Marketing Directors from Company 1 E,C,E,T,E : Customers
Room and Observation setting	-Luminosity: 2 lights on -Windows: two big windows on each side of the room but with curtains almost closed -Movement between rooms: No movement outside of the room, only around the table. -On the following map of the meeting room we present: furniture, layout of people, camera number, microphone 
Observers	JFB, GP, CV, FBG: from Grenoble INP MB: from Bath university GC, NB: from Polimi GB, PB: from Artefice
Tools, equipment and Design representation:	Multi-touch screen + keyboard Each participant has: Paper, Pencil, Green & Red post-it 4 white cardboards - Printed Concepts 4 prototypes (concept A, B, C,D)

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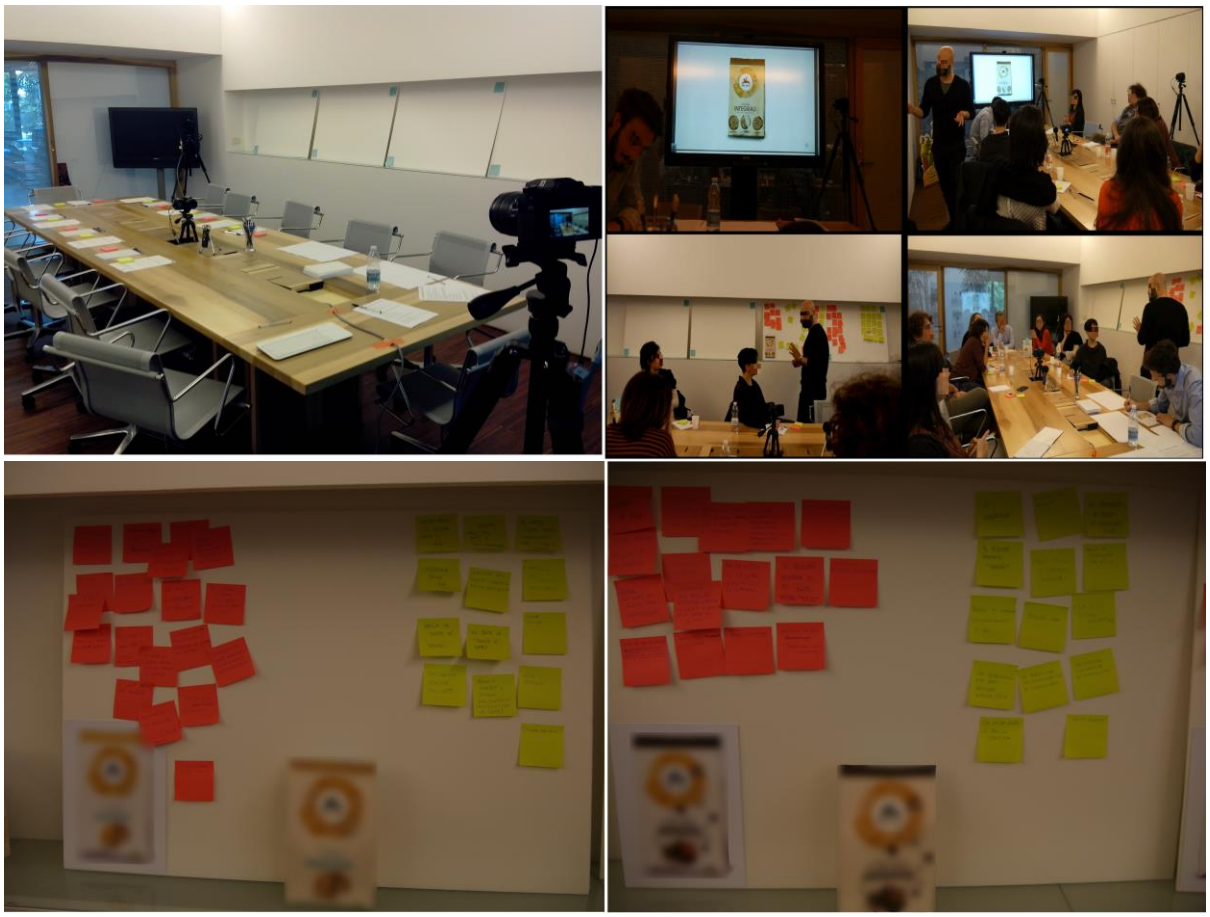
Illustrations of case study one at Artefice:



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Case Study n°2: Company 2

Company presentation:

G7 is a company that produces hand-made ice-cream that promotes ancient recipes and fabrication methods of the traditional Italian ice-cream makers. This company is very proud to preserve and make this tradition still alive.

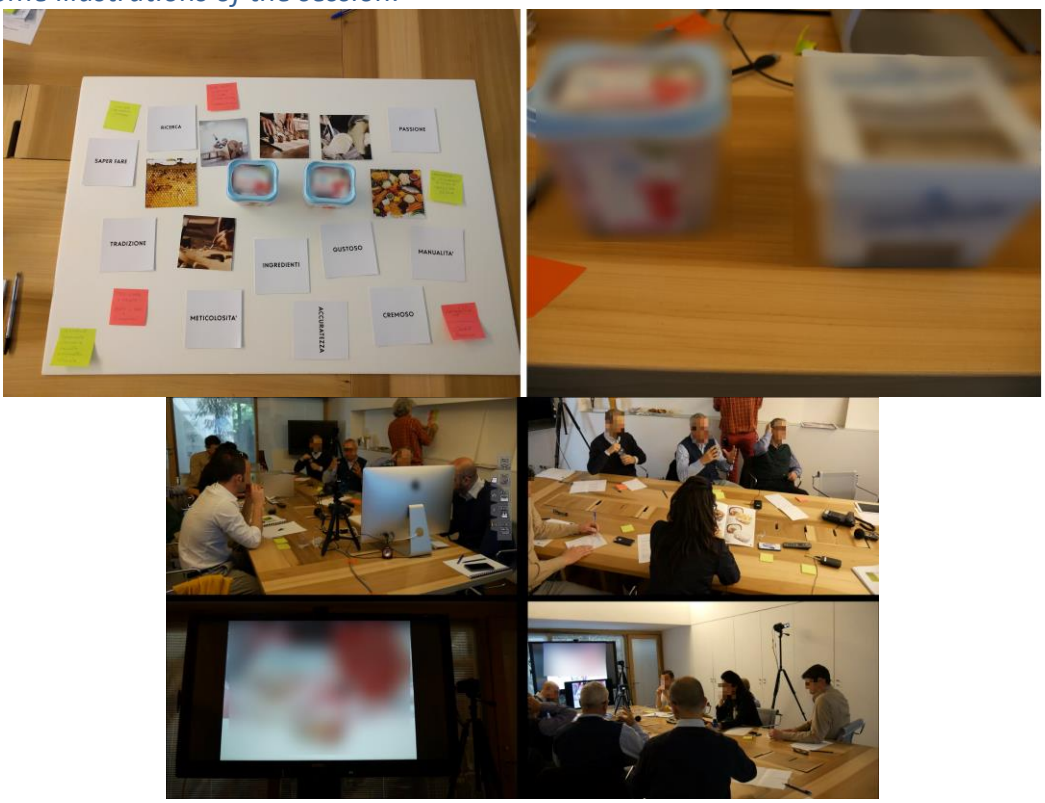
Session plan and goals:

During this meeting, Artefice's Designers collaborate with their clients and two consultants (who work for G7).

The aim was that Artefice team work with their clients together in order to validate the designers' vision presented in the form of 9 prototypes suggestions. They try to reach an agreement about visual identity elements like logo, slogan, material and their placement on packaging.

1. This part was arranged in 3 moments, each one being dedicated to present a particular ice cream package. Client's preferences were recorded with red and green post it, displaying pros and cons arguments for each proposition (1, 2&3) also with the help of some pictures and keywords.
2. This part was dedicated to some comparison with other competitive brands.
3. Finally there was a live package modification using the Multi-touch screen.

Here are some illustrations of the session:



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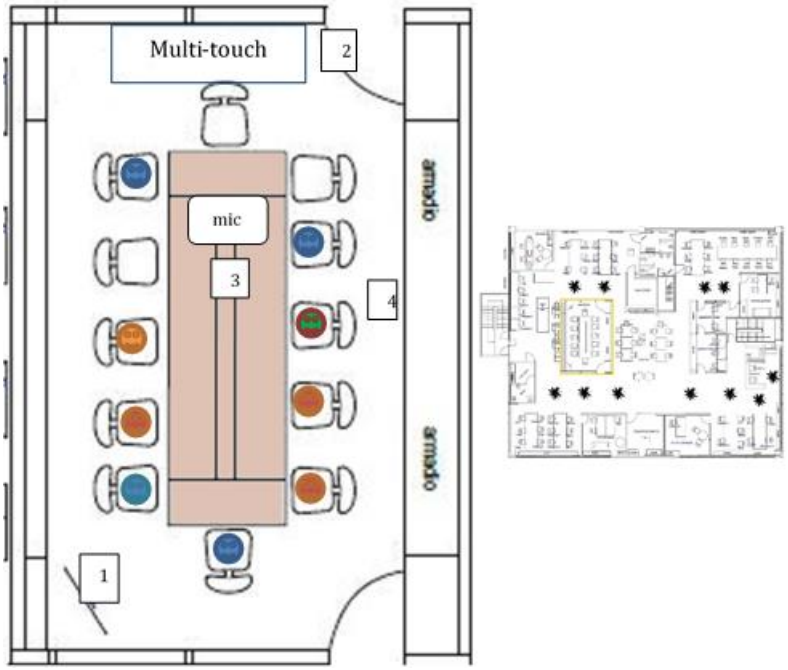
Date & Time	04-05-2016. Start at 10:30am to 1:20pm
Language	Italian
Process design stage	BRIEF > ANALYSIS > STRATEGY > CREATIVITY > OUTPUT IDEAS DEVELOPMENT IDEAS EXECUTION
Product	**Ice Cream**
Participants	M, A, P, A: Designers, Creative and Art Director from Artefice G, G&G: owners of Company 2 F,L : Consultants.
Room and Observation setting	-Luminosity: 2 lights on -Windows: two big windows on each side of the room but with curtains almost closed -Movement between rooms: No movement outside of the room, only around the table. -On the following map of the meeting room we present: furniture, layout of people, camera number, microphone 
Observers	GP, CV, FBG: from Grenoble INP GC, NB: from Polimi GB, A, L: from Artefice
Tools, equipment and Design representation:	Multi-touch screen + keyboard Each participant has: Paper, Pencil, Green & Red post-it 4 white cardboards - Printed Concepts 9 prototypes (ice cream box) Keywords and pictures

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CASE STUDIES AT STIMULO

Case Study n°3: Company 3

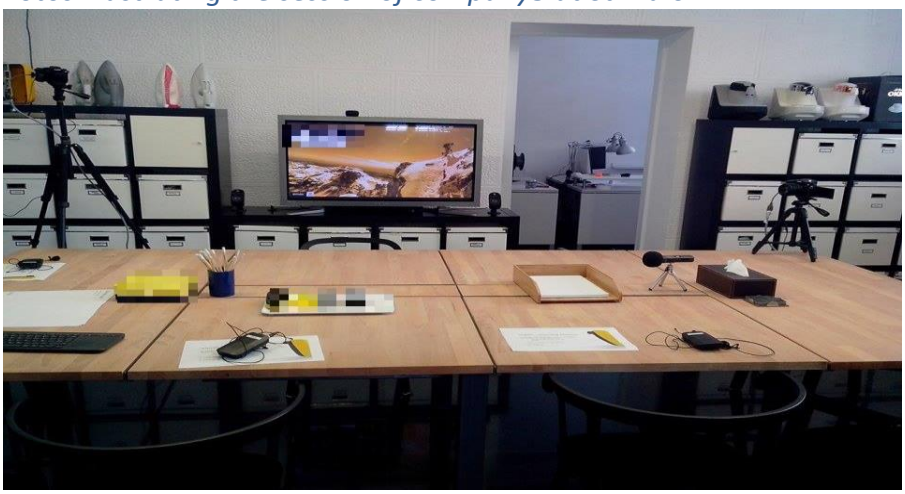
Company presentation:

Company 3 offers a communication and security solution to be used outdoor. It is a specialised service focused on personal rescue for people practicing outdoor activities and sports. It enables the user to activate an emergency alert if they encounter sever problems, the device can be located accurately even without mobile coverage.

Session plan and goals:

During this session, Stimulo team receives their client: CEO of company 3.
The goal is to review ideas from previous meeting like ID definition.
The meeting plan is about approaching final product structure such as colour, materials and aspect.
Designers were also looking forward to have feedback on the user interaction aspects and the client's opinion about packaging before fabrication.

Here are some photos illustrating the session of company3 at Stimulo:



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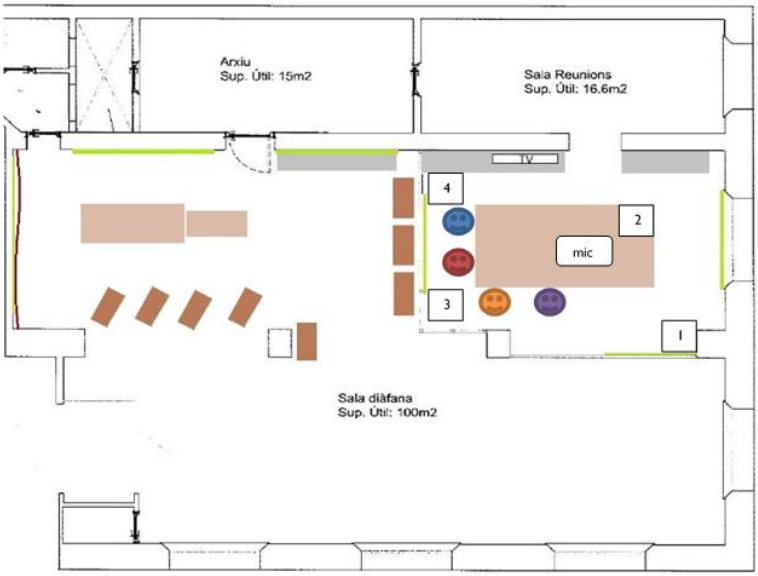
Date & Time	25-04-2016. Start at 2:20pm to 3:40pm
Language	Catalan
Process design stage	
Product	**GEO Devices**
Participants	XM, RM, MP: Business developer, Designer and Engineer from Stimulo MB: CEO from Company 3
Environment Observation	-day luminosity -Movement between rooms: Designers often move outside of room to bring some prototypes -On the following map of the meeting room we present: furniture, layout of people, camera number, microphone 
Product	GEO Devices
Participants	XM, RM, MP: Business developer, Designer and Engineer from Stimulo MB: CEO from Company 3
Observers	CM, CV, FBG: from Grenoble INP MB: from Bath university
Tools, equipment and Design representation:	TV screen + keyboard Electronic test Paper pencil Mock up

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Case Study n°4: Company 4

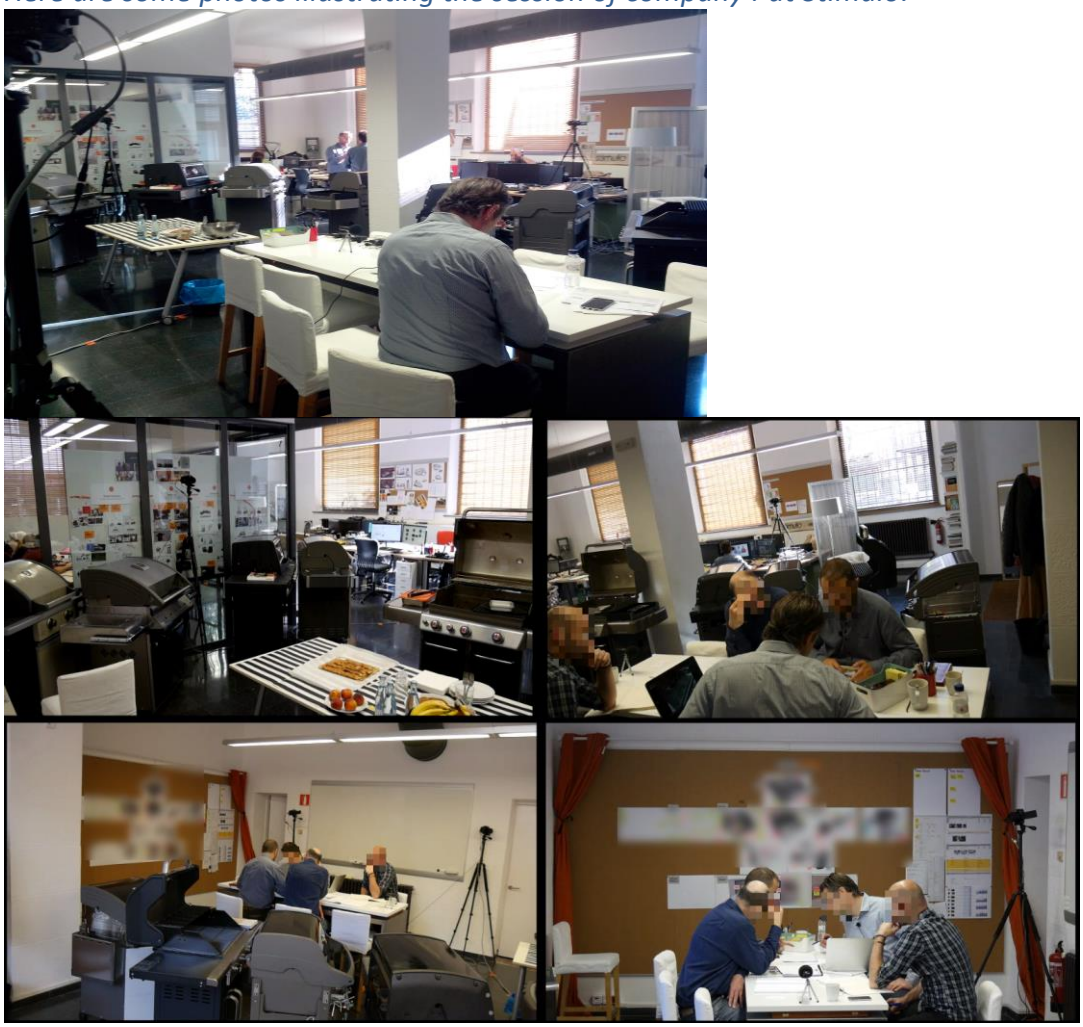
Company presentation:

Company 4 provides a set of high quality gas barbecues. In fact, they designed and produced some of the first ever gas barbecues and sold it in more than 30 countries worldwide. They are offering to their customers the most innovative products and designs at the most affordable prices.

Session plan and goals:

During this session, Stimulo team received their client: the sale manager of company 4.
They aimed at reviewing general ideas generated during previous meetings such as matching target users, cost and assembly time. Then they discussed about different parts of the barbecue: hood, grills, fascia, placement of the logo on knobs or not and if possible setting a digital interaction.
A set of 9 barbeques were displayed in the meeting room, so the client could take compare the propositions, manipulate and test.
As a last point, designers and their customer will try to fix future work to do.

Here are some photos illustrating the session of company4 at Stimulo:



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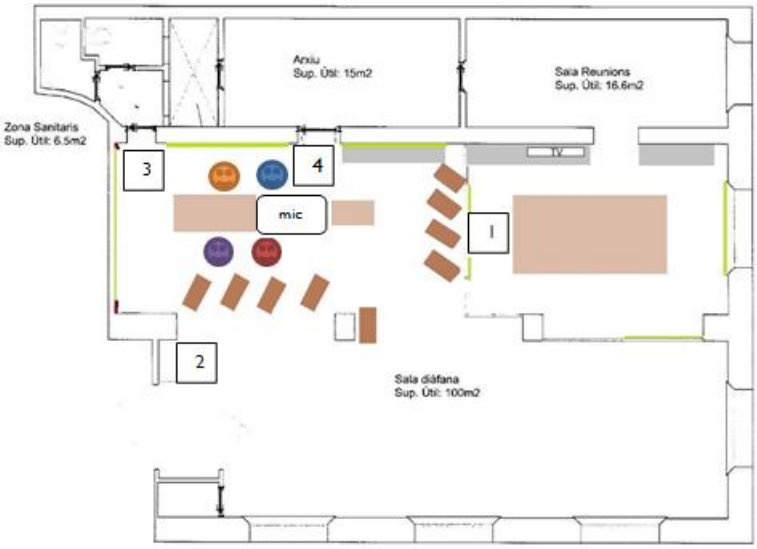
Date & Time	26-04-2016. Start at 9:15am to 10:50am
Language	English
Process design stage	Product Design → Design Approach → Design Lab → ID Definition → Technical Approach
Product	**Gas barbecue grill**
Participants	XM, RM, MP: Business developer, Designer and Engineer from Stimulo P: Sales manager from Company4
Environment Observation	-day luminosity -Movement between rooms: Designers often move outside of room to bring some prototypes -On the following map of the meeting room we present: furniture, layout of people, camera number, microphone 
Observers	CM, CV, FBG: from Grenoble INP MB: from Bath university
Tools, equipment and Design representation:	Laptop Paper/pencil/post-it Printed concept Board 9 BBQ

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APPENDIX II: OBSERVATION PROTOCOL

	NAME AND SURNAME	PARTNER
AUTHOR(S)	C. Varvatis	
TYPE OF DOCUMENT	Observation Protocol	
	25-03-2016	V 1.0
	04-04-2016	V 2.0
	NAME AND SURNAME	PARTNER
VERIFIED	JF Boujut	GINP
DATE & VERSION	31-03-2016	V 2.0

OBSERVATION PROTOCOL

❖ ABSTRACT OF THE PROJECT

➢ TITLE OF THE PROJECT

SPARK : Spatial Augmented Reality as a Key for co-creativity

➢ SCIENTIFIC FIELD

Computer supported collaborative work, Design creativity, Product and packaging design

➢ PROJECT LEADER

Gaetano Cascini, Full professor at Politecnico Di Milano, department of Mechanical Engineering.

➢ PARTICIPANTS

Politecnico di Milano (IT)
Viseo (FR)
Institut polytechnique de Grenoble (FR)
University of Bath (UK)
Artefice Group (IT)
Stimulo Design (SP)
Flanders Inshape (B)

➢ OBJECTIVES

The SPARK project aims at realizing a responsive ICT platform that exploits the potential of Spatial Augmented Reality for supporting and fostering collaborative creative thinking in the design process by reducing language barriers due to diversity of background and sketching skills of the design team members. Spatial Augmented Reality enhances the innovation

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capabilities of creative industries through the facilitation of brainstorming and the early assessment of design solutions in a **Co-Design environment**.
This empowers the conception of new ideas, especially in the fields of product and packaging design, where the need to reduce the realization of physical prototypes is strongly felt. The project aims also at validating the effectiveness and efficiency of the SPARK platform on a real operational environment and at fostering its deployment by the SME creative industries.
Here you can see an example of a similar platform:

https://www.youtube.com/watch?v=Ra4C49uwQlI

SPARK project will last 3 years.

For the purpose of the project, in the WP1 we will have to collect data from real co-creative sessions with customers. To achieve this we will record pre-defined sessions at the companies' premises and post process these data for purpose of subsequent analysis.

❖ METHODS AND EQUIPMENT

➢ PARTICIPANTS TO THE RECORDING SESSIONS

From Grenoble the participants (GINP) will be at least:
- Fatma BenGuefrech : research engineer (computer scientist)
- Clémentine Varvatis : research engineer (ergonomics and design engineer)

Permanent staff will join on the basis of at least one person:
- Cedric Masclet : Associate professor
- Guy Prudhomme : Associate professor
- Jean-Francois Boujut : Full professor

➢ METHODOLOGY

- **Protocol description**

For the SPARK project we need to collect information from the design teams. Indeed, we need to **record a creative design session** where designers and customers are working together through (or not) **virtual prototypes** (as a 3D representation) or **physical prototypes** (as a mock up for example).
Here is the description of the observation's progress:

1- Setting up material: Before the beginning of the session, GINP Team will install the observation equipment.
We will probably ask clients and designer to wear lapel microphone.

2- Inform participants: The participants will be informed of the protocol and invited to sign the consent to participate.

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3- Record the meeting: the meeting will take place and be recorded. During the sessions the observing team will sit apart in another room.

We want to minimize the impact of the presence of the researchers on the designers' activity. The client and designers have to work as they usually do.

4- Interview: Post session interview will be carried out with each participant.

5- Pack the material

6- Post process and store the data (anonymization, synchronization, formatting, etc.)

- **Equipment used**

- Maximum 4 cameras + Tripods
- Microphone
- Lapel microphone
- A computer which synchronizes the records (video)
- A recorder which synchronizes the records (audio)

- **Location of the observations**

The sessions will take place at our design partners' premises. (i.e. Stimulo's or Artefice's). They will run the meetings where they usually do with their clients. (meeting room, showroom…)

- **Schedule of the observations**

The perfect schedule would be:

Day 1, afternoon: installation, first case study (first recording with client 1)

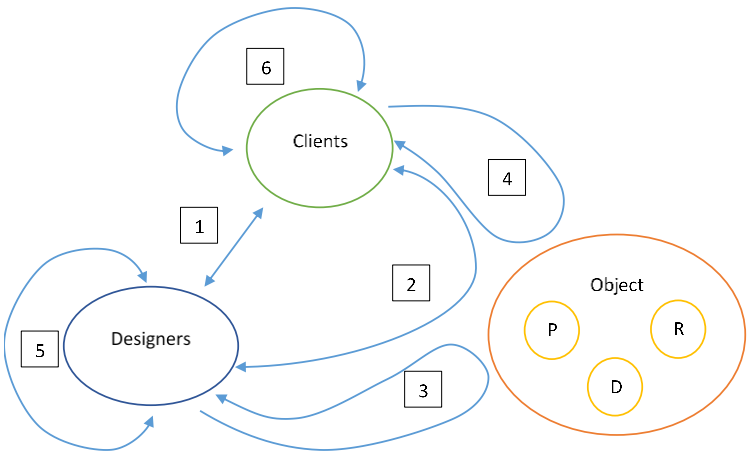
Day 2, morning: second case study (second recording with client 2), uninstall

A recording session happen as follows:

- Researchers install the equipment (at least 1 hour)
- Client comes and meeting starts with the designers (duration as needed)
- A short interview after the meeting.

- **Data analysis framework**

We will concentrate the analysis on the gestures and gazes involving the artefacts (physical and digital) and the designers.



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The framework (figure above) considers all the potential configuration of interactions:
P = prototypes
D = Drawings
R = Resources

Correspondences with Figure 3.2	interaction	definition
1	Interaction from the **clients** to the **designers**, WITHOUT object	The client will explain/show something to the designer without using an object
	Interaction from the **designers** to the **clients**, WITHOUT object	The designer will explain/show something to the client without using an object
2	Interaction from the **clients** to the **designers**, THROUGH an **object**	The client will explain/show something to the designer by using the object
	Interaction from the **designers** to the **clients**, THROUGH an **object**	The designer will explain/show something to the client by using the object
3	Interaction of the **designers** with an **object**	The designer will use/manipulate the object for himself
4	Interaction of the **clients** with an **object**	The client will use/manipulate the object for himself
5	Interaction between the **designers**, WITHOUT **object**	The designer will explain/show something/talk together without using an object
6	Interaction between the **clients**, WITHOUT **object**	The client will explain/show something/talk together without using an object

➢ Benefits and risks

The analysis of the recorded sessions will give us qualitative results on co-creative activities and other current practices that occur during the sessions with the clients. It will enable us to gain understanding on the co-creative mechanisms involving clients and designers and consequently to **define more precisely the requirements for the SPARK platform**.
For example:

- How many people are participating to the meeting? Are they moving in the room? (Define the size and configuration of the platform)
- What kind of prototypes are used? What size, shape…? (What types of prototypes can be applied on the SPARK platform?)
- Requirements in terms of interaction capability with the prototypes: Who interacts more with the prototypes: client or designer (frequency, intensity…)? Which type of interaction (pointing out, manipulating, testing, understanding…).

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Confidentiality issues will be dealt using the clients' NDA forms.
The major risk here concerns the availability of the teams at the given date and the quality of the data (understand the quality of the interactions in the recorded session).
The results of the study will be used in another workpackage to compare the results of the sessions in the original environment with the sessions simulated in the SPARK environment.
Is there more interactions between client/designer/prototypes with the platform? Does it help to be more creative? More prototypes? Does it helps the client to understand the concepts? etc.

❖ DATE PROCESSING / CONFIDENTIALITY

➢ ANONYMISATION

All data that we will share in the consortium will be anonymised.

➢ DATA ACCESS

SPARK consortium only will have access to the data (videos). The data will be used exclusively for purpose of interaction and speech analysis, particularly argumentation and decision-making by the SPARK researchers.
Verbal exchange may be translated in English for purpose of inter rater analysis.
The data will be stored on an external hard disk drive and backed-up on another one for security. The data will be stored at G-SCOP – Grenoble INP – 46 ave Félix Viallet – 38031 Grenoble for a duration of 5 years.

❖ AGREEMENT TO PARTICIPATION

Participant will sign consent to participate at each session and will have the opportunity to ask any question they want.

INFORMED CONSENT TO PARTICIPATE
IN A RESEARCH PROJECT STUDY

Research project Title: SPARK - Spatial Augmented Reality as a Key for co-creativity
Project Coordinator: Gaetano Cascini
Person in charge of conducting the studies: [It will change according to the tests and the people involved] Clémentine Varvatis

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PURPOSE OF THE STUDY

You have been asked to participate as a subject in a research project study about the creativity and the use of Spatial Augmented Reality for increasing the creativity in design collaborative sessions. In particular this study will focus on the analysis of interactions during co-creative session with clients. More precisely our aim is to characterize and evaluate the types of interactions the participants have with physical or digital artefacts in co-creative sessions.

You have been asked because you are at least 18 years of age and a designer/ a customer of a design studio/a design/engineering student at Politecnico di Milano / a possible user of the SPARK platform.

Please note also that the final aim of the project is to commercially exploit the SPARK platform.

PROCEDURES

If you choose to participate in this project, you will be asked to perform a task possibly involving the use of Spatial Augmented Reality technologies related to co-creation and decision making.

The procedure will include the recording of co-creative design sessions where you are involved as a participant in your natural working environment.
During the post-test session, which will last 20 minutes, you will be debriefed and qualitative data about your preference for the human-machine interface and impression will be collected.

RISKS AND DISCOMFORTS

The risks to you as a participant in this study are not greater than what would be encountered in everyday life. There is however a risk of discomfort due to the presence of cameras and microphones.

BENEFITS

There are no direct benefits to you as an individual. However, your participation will help with the contribution of knowledge to the society and the scientific community; knowledge deriving from the testing results will be useful for designing better the SPARK platform so as to improve its impact on creativity.

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COMPENSATION OR COSTS TO STUDY PARTICIPANTS

Refreshments in the form of snacks will be provided at the end of the test session to show our appreciation to you for volunteering for the study. You are free to decide whether or not to take it. The study is free and voluntary; therefore, there will be no cost involved in participating. Also, the study involves no risks for injury; therefore, there will be no compensation for injury.

CONFIDENTIALITY

All information collected in this test will be kept completely confidential to the extent permitted by law. Efforts, such as coding of research records, keeping research records securely on a password protected computer information system, and allowing only authorized people to have access to research records, will be made to keep your information safe. A report of general and combined results from several participants in this project will be prepared, and may be submitted to a professional publication or conference at a later time. The data used for publication will be strictly anonymized. All information obtained during this study by which you could be identified will be held in strict confidence, and kept for five years after the study.

INCIDENTAL FINDINGS

In general, ***Incidental findings*** are previously undiagnosed medical or psychiatric conditions that are discovered unintentionally and are unrelated to the aims for which the tests are being performed. The Consortium has as primary purpose to respect participant's integrity, autonomy and rights and to act in the respect of the best interest of the participants involved in the tests. Therefore, The Consortium will ask you to decide and declare in the following if you want to be informed or not about possible incidental findings related to yourself.

QUESTIONS ABOUT THE STUDY

If you have any questions about your involvement in this project, you may directly ask the person in charge of conducting the test or the project coordinator, Prof. Gaetano Cascini, at the following e-mail address: gaetano.cascini@polimi.it

VOLUNTARY PARTICIPATION/WITHDRAWAL

Your participation is voluntary, and you may end your participation at any time. Refusing to participate or leaving the study at a later time will not result in any penalty or loss of benefits to which you are entitled. Your grade, record, academic standing, or relationship with the University will not be affected if you choose not to participate or withdraw.

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Each person participating in the study will be asked to complete the following:

	Y	N
1. Have you read the information sheet?	☐	☐
2. Have you had the opportunity to ask for more information about the study?	☐	☐
3. Are you happy with the answers to any questions you had, if any?	☐	☐
4. Do you understand that you are free to withdraw from the study at any time?	☐	☐
5. Do you agree to take part in this study?	☐	☐
6. In the remote possibility that incidental findings will be discovered, would you like to be informed?	☐	☐

Signed (Participant).....

Print Name (Participant)..... Date.....

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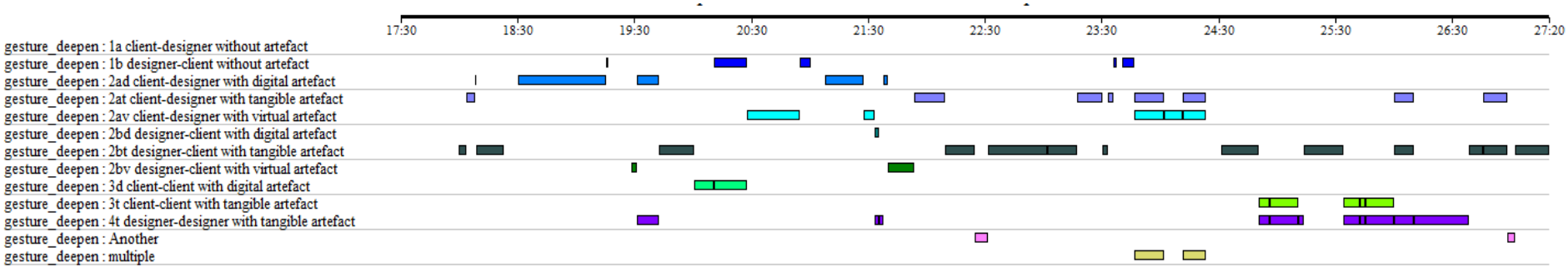
APPENDIX III: RESULTS OF GESTURE INTERACTIONS LEVEL 1.2

First episode

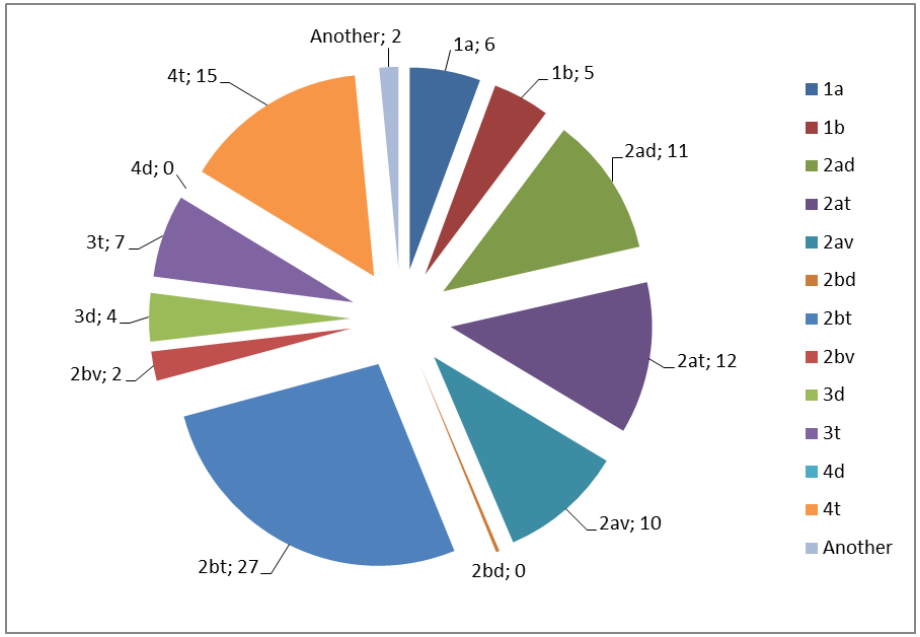
Duration: ~10 minutes, from 17:38 to 27:20

Using digital representations and existing Barbecues

Time line of interactions



Breakdown of interactions (percentage of time)



Percentage of multiple: 4

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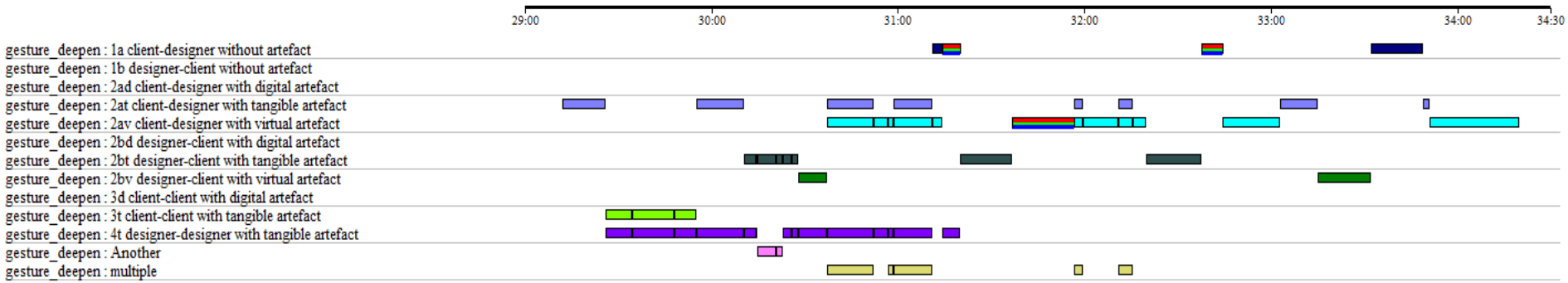
Second episode

Duration: ~5 minutes, from 29:34 to 34:18

A lot of gesture from client



Breakdown of interactions (percentage of time)

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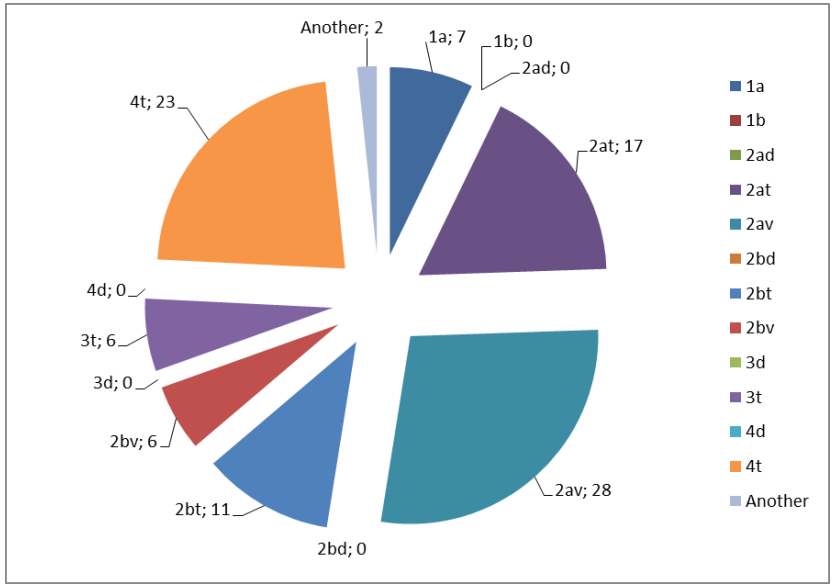

Percentage of multiple: 8

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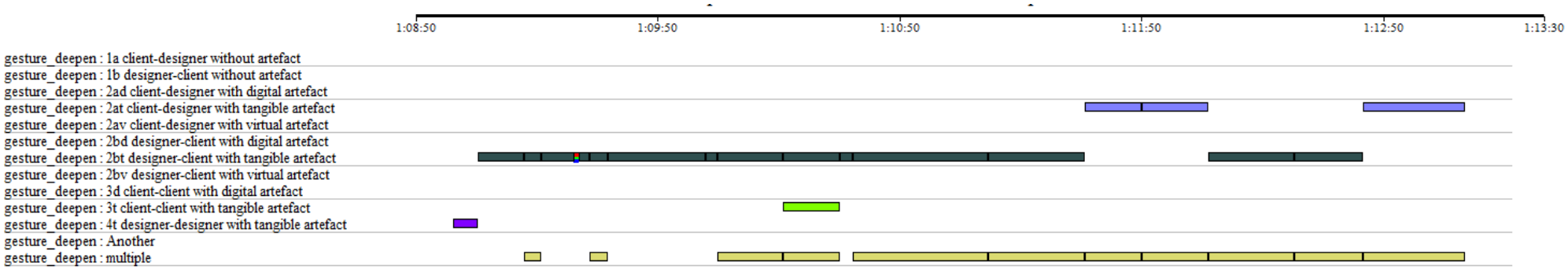
Third episode

Duration: 4 minutes and a half

From 1:08:55 to 1:13:17

Client and designers use stickers, stick, unstick, move them on the upper part of a barbecue

Annotation are made on stickers by a designer.



Breakdown of interactions (percentage of time)

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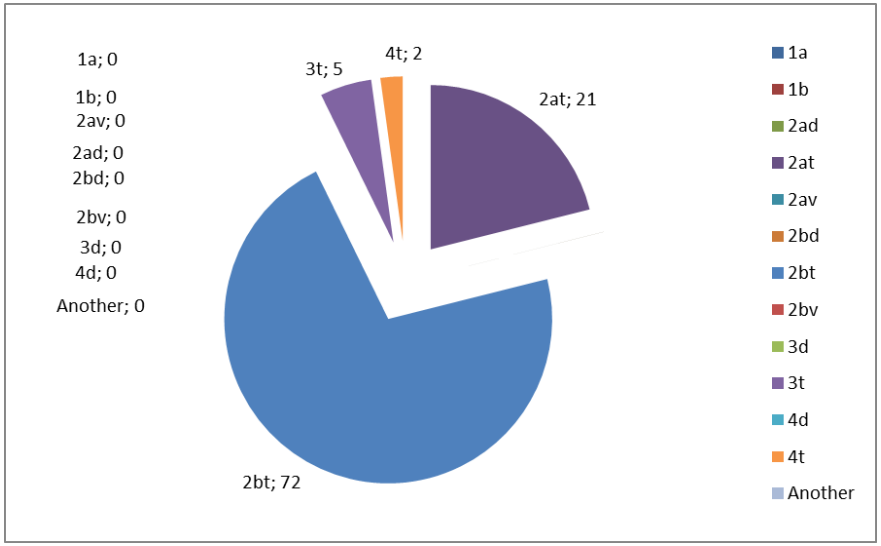

Percentage of multiple: 73

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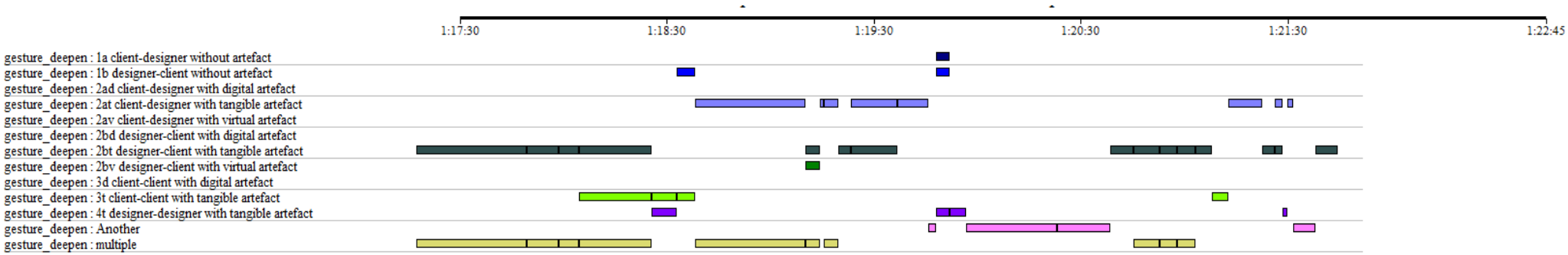
Fourth episode

Duration: ~ 5 minutes, from 1:17:38 to 1:22:36

Designers and client handled knobs, confronted them to the global aspect of the real barbecue and the design representation of the barbecue in design displayed on the pin board.

They also use material for simulation of haptic manipulation



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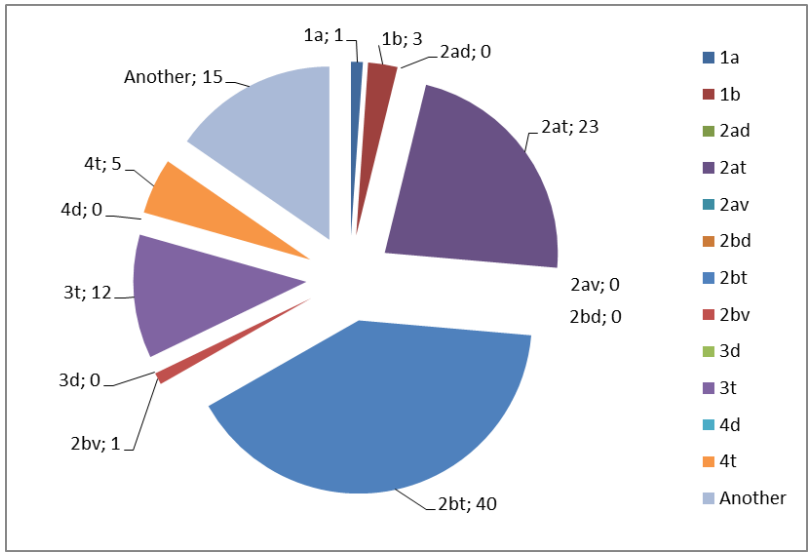

Breakdown of interactions (percentage of time)
Percentage of multiple: 39

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APPENDIX IV: START LIST FOR CATEGORISATION

This appendix contains the start list of categorise that was used during the quantitative content analysis in the study of the impacts of design representations on the observation sessions.

- Session Goal
- Session Participants
- Session Activity
    - Idea generation
    - Idea evaluation and selection
    - Communication of design information
    - Identifying or completing project tasks
- Used Design Representations
    - Use of Representation
    - Representation Affordance
    - Representation Challenge
    - Impact of Representation
        - Idea generation
        - Idea evaluation and selection
        - Communication of design information
        - Identifying or completing project tasks
- Best contributor to session
- Other
- Quotes

APPENDIX V: MANIFEST LEVEL CASE-BASE META MATRIX

This appendix contains the case based meta-matrix that was created as the result of the quantitative content analysis in the study of the impacts of design representations on the observation sessions.

	Design Rep	Use	Affordance	Challenge
Case 1	Physical Model (Mock-Up)	Show graphical treatment	Accurate communication of design Scale representation Realistic physical representation	Hampers idea generation Mock up mistaken for final product Materials, textures and finishes not representative of final product
	PC + Monitor	Add digital interactivity to session	Exploring a new approach to co-creative sessions Participants feel their inputs are valued Real time preview of participants' ideas	Participants cannot personally implement changes
	Post-It Notes	Participant's concept evaluations	Capture participants' views	
	2D Images	Create 'mind map'		
Case 2	Text	Communicate vision Capture participants' feelings and sensations	Provide keywords from participants to concepts Give participants inspiration Allow participants to imagine concepts Context setting	
	Mood Board	Communicate vision Capture participants' feelings and sensations	Context setting	Do not represent concepts
	Physical Model (Mock-Up)	Show graphical treatment	Accurate communication of design Realistic physical representation	Mock ups mistaken for final product
	PC + Monitor	Add digital interactivity to session	Quicker feedback on ideas over whole process Exploring a new approach to co-creative sessions Real time preview of participants' ideas	Interactivity side tracked session Some changes hard to execute (time and effort) in real time Hiccups with technology Requires an extensive database as input Scope of interactivity limited to pre-prepared materials

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CASE 3	3D Rendered Images	Context setting		Digital look differs from physical reality
	Physical Model (Mock-Up)	Show feel, look and configuration Session discussion focal point	Quick decisions can be made Shows physical conflicts that are not apparent digitally Accurately explore materials, textures and finishes Physical interactions with product can be tested Accurate physical representation Accurate communication of design Realistic physical representation	
	Sketching	Rough representation of idea	Explore and communicate spontaneous ideas quickly	
	Digital Simulation	Representation of digital feedback	Realistic digital representation Accurate digital representation Real time preview of participants' ideas Quick decisions can be made	
CASE 4	Technical Drawings	Detailed representation of concepts Session discussion focal point	Accurate and detailed drawing	
	3D Rendered Images	Create 'mind map'	Represent functions and features individually Visual representation of space being explored	
	Physical Products	Physical exploration of competitors' products	Access to real life competitor solutions	
	Sketching	Rough representation of idea	Explore and communicate spontaneous ideas quickly	

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APPENDIX VI: LIST OF HOLISTIC MANIFEST LEVEL CODES

This appendix contains the list of manifest level codes that were created as the result of the quantitative content analysis in the study of the impacts of design representations on the observation sessions.

- Use of Representations
  - Show graphical treatment (1-MU 2-MU)
  - Show feel, look and configuration (1-MU)
  - Add digital interactivity (1-PC, 2-PC)
  - Participant's concept evaluations (1-PI)
  - Create 'mind map' (1-2D, 4-3D)
  - Capture participants' feelings and sensations (2-T, 2-MB)
  - Communicate vision (2-T, 2-MB, 3-3D)
  - Rough representation of idea (3-S, 4-S)
  - Representation of digital feedback (3-SM)
  - Physical exploration of competitors' products (4-PP)
- Design Representations Affordances
  - Realistic physical representation (1-MU 2-MU 3-MU)
  - Scale representation (1-MU)
  - Accurate communication of design (1-MU 2-MU 3-MU)
  - Accurate physical representation (3-MU)
  - Physical interactions with product can be tested (3-MU)
  - Accurately explore materials, textures and finishes (3-MU)
  - Shows physical conflicts that are not apparent digitally (3-MU)
  - Quick decisions can be made (3-MU, 3-SM)
  - Real time preview of participants' ideas (1-PC, 2-PC, 3-SM)
  - Participants feel their inputs are valued (1-PC)
  - Exploring a new approach to co-creative sessions (1-PC, 2-PC)
  - Quicker feedback on ideas over whole process (2-PC)
  - Context setting (2-T, 2-MB)
  - Capture participants' views (1-P1)
  - Allow participants to imagine concepts (2-T)
  - Give participants inspiration (2-T)
  - Provide keywords from participants to concepts (2-T)
  - Accurate digital representation (3-SM)
  - Realistic digital representation (3-SM)
  - Explore and communicate spontaneous ideas quickly (3-S, 4-S)
  - Visual representation of space being explored (4-3D)

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  - Represent functions and features individually (4-3D)
  - Access to real life competitor solutions (4-PP)
- Design Representation Challenges
  - Materials, textures and finishes not representative of final product (1-MU)
  - Mock up mistaken for final product (1-MU, 2-MU)
  - Hampers idea generation (1-MU)
  - Participants cannot personally implement changes (1-PC)
  - Scope of interactivity limited to pre-prepared materials (2-PC)
  - Requires an extensive database as input (2-PC)
  - Hiccups with technology (2-PC)
  - Some changes hard to execute (time and effort) in real time (2-PC)
  - Interactivity side tracked session (2-PC)
  - Do not represent concepts (2-MB)
  - Digital look differs from physical reality (3-3D)
- Best contributor to session
  - Detailed and representative (4-TD)
  - Visual and tactile (3-MU)
  - Work together (2)
  - Stand-alone (1-PC)

The brackets next to the individual codes refer to the case and design representation type in the following manner:
Show graphical treatment (1-MU, 2-MU) represents that assigned code, the relevant study case and design representation. It is read as code 'show graphical treatment' was assigned to data relating to case no. 1 referring to the mock up and case no. 2 referring to the mock up.

KEY FOR LABELS		
1: Case 1	3D: 3D Rendered Images	PP: Physical Products
2: Case 2	MB: Mood Boards	SM: Simulation
3: Case 3	MU: Physical Model (Mock Up)	S: Sketching
4: Case 4	PC: PC + Monitor	T: Text
2D: 2D Images	PI: Post-It Notes	TD: Technical Drawings

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APPENDIX VII: LIST OF HOLISTIC LATENT LEVEL CODES

This appendix contains the list of latent level codes that were created as the result of the quantitative content analysis in the study of the impacts of design representations on the observation sessions. The numbers in brackets represent the total number of unique manifest codes categorised within each of the latent codes.

- Use of Representations (25)
  - Visual Aid (6)
  - Tactile Aid (2)
  - Emotional Expression Aid (3)
  - Idea Expression Aid (2)
  - Context Setting Aid (3)
  - Session Enhancement (4)
  - Evaluation Aid (2)
  - Mapping (3)
- Design Representation Affordances (97)
  - Similarities between representation and real product (11)
  - Facilitates design communication with non-designers (12)
  - Accurate and/or realistic representation of concept (11)
  - Exists as it would in the real world (7)
  - Physical manifestation (7)
  - Digital manifestation (2)
  - Impact on co-creative design process (20)
    - Time and efficiency based (8)
    - Collaboration (7)
    - Method (2)
    - Creativity (3)
  - Allows focus on a specific area or element (11)
  - Overcome limitations of digital representations (3)
  - Allows mapping of functions and features (2)
  - Real time (5)
  - Working with imaginary elements (4)
  - Capturing session outputs and participant views (2)
- Design Representation Challenges (22)
  - Differences between representation and real product (4)
  - Differences between digital vs. analogue representation (1)
  - Keeping session focused (2)
  - Individual interaction to implement changes not possible (1)
  - Restricted by pre-session prep and requirements (2)

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    - Expertise required (3)
    - Barriers to real time interactive changes (3)
    - Technology issues (1)
    - Limited usability (6)
- Best contributor to session (4)
    - Realistic representation of what you need to show in the simplest form possible (4)

Visual Aid: allows you to visually show an element of interest e.g. image, colour, shape etc.
Tactile Aid: allows you to convey what an element of interest feels like e.g. textures and finishes
Emotional Expression Aid: allows you to convey what your emotions are e.g. expressing how a concept makes you feel
Idea Expression Aid: allows you to express an idea e.g. present an idea graphically or with words
Context Setting Aid: allows you to set the context surrounding a concept e.g. convey a sense of elegance
Mapping Aid: Allows you to map an element of interest e.g. create a mind map.

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APPENDIX VIII: OBSERVATION SESSION DESCRIPTIVE STATISTICS

This appendix contains descriptive statistics related to the study of the impacts of design representations on the observation sessions.

ACTIVITIES WITHIN SESSIONS:

Sessions with idea generation: 2
Sessions with evaluation and selection: 4
Sessions with communicating design information: 3
Session with task progression: 1

FREQUENCY OF DESIGN REPRESENTATION USE:

		CASE 1	CASE 2	CASE 3	CASE 4	TOTAL
DESIGN REPRESENTATION	Physical Model (Mock-Up)	(X)		X	X	3
	3D Rendered Images	X	X			2
	Sketching	X	X			2
	PC + Monitor			(X)	X	2
	Words (Text)				X	1
	Mood Boards				X	1
	Simulation	X				1
	Technical Drawings		(X)			1
	Physical Products		X			1
	2D Images			X		1
	Post-It Notes			X		1
		4	4	4	4	16

* () denotes best contributor to session

DESIGN REPRESENTATION USE:

Total Number of Unique Design Representations Used Across Sessions: 11
Total Number of Design Representations Used per Session: 4
Total Number of Unique Uses of Design Representations Across Sessions: 10
Cumulative Number of Uses of Design Representations Across Sessions: 25
Most Frequent Use of Design Representations Across Session: Visual Aid x 6
Total Number of Design Representations Used as Visual Aids Across Sessions: 4
Highest Number of Unique Uses Across Sessions: Physical Model (Mock-Up) x 2, Mood Board x 2
Highest Number of Cumulative Uses Across Sessions: Physical Model (Mock-Up) x 3
Most Used Design Representation Across Sessions: Physical Model (Mock-Up) x 3

FREQUENCY OF HOW DESIGN REPRESENTATIONS WERE USED:

Visual Aid: 6
Process Enhancement: 4

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Context Setting Aid: 3
Emotional Expression Aid: 3
Mapping: 3
Tactile Aid: 2
Evaluation Aid: 2
Idea Expression Aid: 2

DESIGN REPRESENTATION AFFORDANCES:

Total Number of Unique Design Representation Affordances Across Sessions: 23
Cumulative Number of Design Representation Affordances Across Sessions: 97
Most Prevalent Design Representation Affordance Groups Across Sessions:

- Facilitates design communication with non-creative practitioners' x 12
- Similarities between representation and real product x 11
- Accurate and/or realistic representation of concept x 11
- Allows for focus on a specific area or element x 11

Most Prevalent Individual Design Representation Affordances Across Sessions:

- Accurate communication of design x 3 – Physical Model (Mock-Up)
- Realistic physical representation x 3 – Physical Model (Mock-Up)

Highest Number of Unique Affordances Across Sessions: Physical Model (Mock-Up) x 8
Highest Number of Cumulative Affordances Across Sessions: Physical Model (Mock-Up) x 12

DESIGN REPRESENTATION CHALLENGES:

Total Number of Unique Design Representation Challenges Across Sessions: 11
Cumulative Number of Design Representation Challenges Across Sessions: 22
Most Prevalent Design Representation Challenge Groups Across Sessions:

- Limited usability x 6
- Differences between representation and real product x4

Most Prevalent Individual Design Representation Challenges Across Sessions:

- Mock up mistaken for final product x 2 – Physical Model (Mock-Up)

Highest Number of Unique Challenges Across Sessions: PC + Monitor x 6
Highest Number of Cumulative Challenges Across Sessions: PC + Monitor x 6

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APPENDIX IX: DESIGN REPRESENTATIONS CHART USED FOR INTERVIEWS WITH EXTERNAL ORGANISATIONS

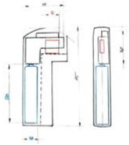
DEVELOPMENT SKETCH

These show what the design ideas look like as physical objects. They are used to investigate appearance and visual impact of ideas. They are also known as thumbnail, thinking or napkin sketches.

EXPLANATORY SKETCH

These explain information clearly and enable discussions where all parties share a common graphical setting for the idea being debated. They are also known as information or talking sketches.

TECHNICAI SKETCH



These are informal representations used to communicate design decisions outside of the design process. They involve the use of technical information (i.e. dimensions, material, part lines and surface finish). They are also known as specification sketches.

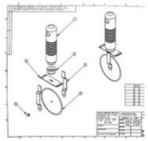
CONCEPT DRAWING

These are drawings that show what the design proposal will look like as a finished product. They are created in a formal way with precise line drawings and detailed information by convention means or with digital 2D CAD.

SCENARIOS & STORYBOARDS

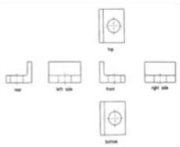
They are used to suggest user and product interaction and to portray usage in the context of artefacts, people and work practices.

CAD DRAWINGS



These include General Arrangement and Technical Drawings. General Arrangement drawings embody the refined design but omit the most internal detail. While Technical Drawings represent the built object and cover every detail of the product to be manufactured.

MULTI-VIEW DRAWING



They are diagrammatic views through first- angle or third-angle projections in which the form is flattened out with plan views, front elevations and the end elevations.

3D RENDERINGS

These create an image from a model by means of software. It gives the final appearance to models with visual effects, such as shading, texture mapping, shadows, reflections and motion blurs.

MOOD BOARDS

These are collection of pictures, images or text, related to a design theme. They are widely used to convey a design idea by visually illustrating the design style to be pursued.

APPEARANCE MODEL

They are an exact representation of the proposal and are seen as the conclusion of an industrial design input as they accurately define the product form and use. They are also known as block, iconic or qualitative models.

SHAPE MODEL

This is a relatively accurate three dimensional representation and are different from the design development model with thought out details such as parting lines.

FUNCTIONAL CONCEPT MODEL

They show functionality, highlighting important functional parameters like yield and performance factors.

WORKING PROTOTYPE

They combine the finalised product functionality with the final aesthetic outlook (form). They are highly detailed, working full-sized models very closely resembling the completed product.

PRE-PRODUCTION PROTOTYPE

They are the final class of physical models that are used to perform a final part production and assembly assessment using the actual production tooling. Small batches are usually produced.

Adapted from Pei (2009)

APPENDIX X: CODING SCHEME AND CODING SUMMARY FOR INTERVIEWS WITH EXTERNAL ORGANISATIONS

The following table provides a summary of the coding scheme used for the interviews with external organisations (Section 4.3). The 'Companies' column indicates the number of companies in which a particular code was identified. The 'References' column indicates the number of individual references made to that code across all companies.

Name	Companies	References
Characteristics of potential users		
Designers and engineers	7	13
Knowledge of design and design process	4	6
Marketeers	4	5
Other functions	6	12
Sales people	2	5
Senior management	3	6
Characteristics of the environment		
Lighting	9	14
Own site or other site	11	31
Size	6	9
Creating design representations		
Cost to create a design representation	11	28
Process to create a design representation	10	37
Time to create a design representation	10	21
Potential users and stakeholders		
Consultancy or in-house team	10	28
Customers or Client	9	55
End users	7	36
Number of users in a session	7	11
Value chain partners	3	7
Properties and affordances of design representations		
Colour, Material and Finish	9	28
Graphics and text	3	3
How the product works or is assembled	4	9
Shape and form	3	3
Size, volume or mass	5	8
User interaction or user interface	8	12

Quotes	10	47
Requirements		
Doubts and concerns about SAR technology	11	28
Information management	11	26
Interaction	7	20
Portability	7	9
Preparation time or effort	7	17
Price	10	12
Projection	10	35
Recreate the context and environment of the product	1	1
Safety	0	0
System noise	7	8
Target object	10	19
Tracking	8	12
Usability of system	8	12
Scenarios of use		
Evaluate and filter	8	22
Generate ideas	9	16
Obtain feedback	11	47
Other specific applications of SAR technology	8	33
Types of design representation		
3D print	9	19
3D renderings	10	29
Appearance model	5	12
Augmented Reality or Virtual Reality	2	4
CAD Drawings	9	28
Concept drawing	8	14
Development sketch	9	26
Explanatory sketch	3	3
Functional concept model	4	10
Interface mock-up	3	10
Mood boards	4	5
Movie or animation	3	5
Multi-view drawing	1	1
Post-it note	2	2
Pre-production prototype	5	9
Scenarios and storyboards	4	10

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Shape model	10	27
Shelf mock-up	2	3
Simulation	3	5
Technical sketch	1	1
Working prototype	2	2
Value of design representations		
Challenges and costs	11	78
Opportunities and benefits	9	33

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APPENDIX XI: EVIDENCE FROM INTERVIEWS WITH EXTERNAL ORGANISATIONS

POSSIBLE APPLICATIONS MENTIONED BY INTERVIEWEES

Packaging

"I think that for us, the immediate application that I would see it is something like the kind of FMCG graphics on packaging. I wouldn't say it is necessarily an issue right now but I can see that being easily applied to. We can easily use it. Have a dummy bottle and demonstrate to the clients or to users the whole bunch of different branding options or graphic treatments, that sort of thing."

"I think yeah, maybe. We do work for some fast moving consumer brands and more and more actually. So in that corner of our business potentially it could be a benefit."

Interaction design:

Even something like a Blood Glucose meter type model when you are putting a strip and doing something and things are happening on the display. I think that those kinds of interactions, I see a value from that dynamic kind of technology

Internal

So maybe the first point of entry is for internal presentations and discussions. Get people comfortable with what is possible with the technology, and as it evolves, then maybe you would start showing it to retailers and things like that

With clients

"I think it's absolutely fantastic. We would find endless uses for that technology in how we present to our customers, and how we ask for our customers feedback, how we ask for retailers feedback, how we present to our retailers, how we present to our board of directors, how we pitch products into the business… We would find endless uses for that and it would significantly reduce our early stage painted models."

"I think it looks very cool. I think it would be quite useful in some situations to be able to for example, if you had an idea for a company like [company] that have several brands and you wanted to communicate a thermochromic ink, so changing colour or something, it would be very cool if you could have a standard can and then say this is what it looks like when you have it on a [Brand 1] can. That's how it looks like on your [Brand 2], that would be quite powerful. Anything that engages with the your customers more is useful"

"That would be quite a cool feature. If you're showing a customer, "I'm not quite sure about that", "Ok, what about this colour?""

With end users

"I could see an application for it there. Because if you can really quickly have your consumers validate a design and then the next day you can change that design really quickly, project something different

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on it for the test the next day and then ask them "how is this looking now?" I can see it working there."

"Under what this technology can do, I definitely think that the benefit is sharing with consumers at those stage gates. And rather than the collaborative tool, it is collaborative but not necessarily with the team, you are doing it with consumers to learn. That is the only place I can see it in our world at the moment."

"Because what they normally do in certain tests is they spent hundreds of thousands on creating high resolution mock-ups that they put on the shelf and they just use them that one time. Our model making friends, they make hundreds of thousands of pounds just by making 40 of these… But if you could do that with white printed mock-ups that you could project on and then it allows people to go "what if we did it in pink?" Because I can tell you now, that when we do the mock-up work, you can guarantee a week before someone from graphics goes "I don't like these graphics" and then you go "well, it's too late" and they will go "well I am not happy with this, I am not happy with that". In that control environment, for researching, I would invest in that."

"And again, you could do that in research but you have to be careful that the consumer… I think it would be good for clients but not for consumers. I think that consumers would be distracted by the technology and not focused on what they are trying to research". They would be like "wow, how does this thing work?" So I can see them being distracted them because they are not marketing savvy, whereas the marketer could look at it and say "wow, that is really good, I can see that on there, I would never have thought about that unless I was able to pick it up and turn it around". So I think it is a very commercially focused tool, probably not great for research only for people that understand what research is about and why you do the research. For me it is an insight kind of thing"

Requirements

Colour, materials, finish and resolution

"Well, so I think that for me the most important is accurate rendering, because if it doesn't do that properly then that is a real problem."
"For me if I was selling to a client, the quality has got to be… it just has to blow them away, that is how good it has to be. It can't be anything that a 3D CAD render can do now."

"SV: And I think accurate rendering is also important. FD: The colours and the, that's the basic function."

"CW: I think that given the quality of visualisation that everyone is used to seeing these days, for me things like the resolution, **the accurate rendering of materials, colours and finishes**… Because that is what it has got… A particular value is that flexibility to project onto the model and I guess in terms of the interaction bit the response in relation to movement is important. Because **if this is not like the real thing, it is quickly going to fall over in terms of having real value.**"

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"JM: I think that working with a lot of brand guys, they are very on it with their brands and their colours and things like that. So the example of the footwear, I know it's an early prototype but we have worked on footwear and the **colours are going to have to be the right colour** kind of thing… **If you are going to pass any judgement on them**, which I guess it will mean a lot about the room you are in, the projector, the material of what you are projecting on and whether you can replicate something which is representative of when someone needs to make a decision. So yes it is about colour and quality…. "

"LD: I would definitely go with accuracy being up there. And I would say that goes hand in hand with projection resolution because to get an accurate rendering of material and colour and finish it needs to project at high resolution."

"H: I would say visibility of the model from various vantage points can be point be put low from my point of view. But on the other side, the projection resolution and the accurate rendering should, I would put high. **It's not making any sense if you do less than what other technologies can do now."**

"And if I rank it, the accurate rendering of materials, colours. Because if you want to -- **this system only make sense when you can convince that it is like a real stuff**.

PM: And I think especially for [Company] about...

ES: Because that's would not be the case then it makes for me no sense to spend on this type of system, that's really the most important one."

"So, at a basic level, we could use this kind of interactive approach to replace our 2D renderboards, so I think the most important thing from that perspective would probably be resolution. Being able to project with a high resolution. Not necessarily large, but just at high quality. Because the 2D renderboards that we do, that we present at the moment are you know, **nicely glossy printed with nice quality renders and photorealistic materials** and things like that. So, having that resolution would be important."

"We have started experimenting, we bought an **interactive projector**, where the projector sits above the whiteboard, and it projects the render onto the whiteboard and allows you to draw on the top of it, interact with it. But I found that the resolution wasn't high enough. So it was a grainy -- it just **wasn't good enough quality to make it useful replacement of the high resolution 2D printouts**, which are pretty cheap. So I think that's a little bit of a challenge."

"I think you've got more value with the 3D stuff, but again, I would temper that with the fact that all of our 3D models currently are very high resolution and we -- they're nicely painted. When we put that in front of a retailer or a consumer, or a user, **we're putting our best foot forward as company, we're showing them a high quality product**."

"DD: **You would never ever consider using it unless you had fairly accurate renderings of material, colours and finishes**."

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"Because of the line of work we are doing, for obvious reasons, resolution would have to be pretty high. Because **if you can't read what you have got there**, you don't want to go "oh, look at the render that we have done". It is kind of like, **what is the point?**."

Field of view

"CW: I kind of assume that being able to see it from different vantage points is a given really, otherwise…

PP: Yes most of the time I guess we are dealing with single user scenario so in some ways it might even not be that important but maybe from a UX point of view. If we have got a **single user and a single system**, as long as they can see it from where they are standing"

"H: I would say visibility of the model from **various vantage points can be point be put low from my point of view**. But on the other side, the projection resolution and the accurate rendering should, I would put high. It's not making any sense if you do less than what other technologies can do now."

"ES: I would require when I think on the room it's a two-hundred degrees would be fine I think"

"SS: If multiple people could look at it at once but what is the real reason -- the real benefit if you can hold it and turn it and then you have one vantage point. So for me it would be less. Lets say four."

"PM: Visibility of model three-hundred and sixty degrees

X: (( )) we're quite flexible"

"Obviously you have to see different angles because it is 3D"

"Let's go with it's easy to use, then you can see it from all angles of the thing you are looking at, and then its bloody good quality."

"View the model from various vantage points. Yeah, that's sort of important as well 'cause -- but you can get people to walk around your room. If you say "can you gather round here" or something it's important but it's not the end of the world."

SAR module: Tracking

"Tracking speed in relation to movement. That's fairly important. 'Cause if it's a for example, shaped can or an asymmetrical thing you wanna be able to have it, then turn it over, rather than have it still and make people walk around or something."

"SV: The first thing is not so important, that you can move it and it has to react quickly."

"A particular value is that flexibility to project onto the model and I guess in terms of the interaction bit **the response in relation to movement is important**. Because if this is not like the real thing, it is quickly going to fall over in terms of having real value."

"JL: So in the top 2, obviously speed is quite important **if you start moving something around and you are seeing the wrong thing**….

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CS: Because you would expect the user to interact with the design?
JL: Because if you have to turn that really slowly, we sort of get back to the problems we had"

"BH: Response speed in relation to movement...It's -- I have the feeling that it would be biasing the experience, or the feeling that the person gets when he's manipulating the part. If you -- cause what I saw in the short movie, if you just want to experience the different materials, textures and colours then it's not making sense that you handle the product and evaluate. And at that time when you would do that and add the, a **slow response speed, it would certainly bias the experience**."

"And then the other thing, with using projectors and interaction, it is just the shadow situation. So the interesting thing for us would be that you can pick it up and it will track it and you can kind of move **but if its going to be shadowed… it kind of messes up the whole thing**."

"SS: For me [visualisation latency] could be the same as the vantage point."

<u>SAR module: Interaction</u>
"BH: On the other hand if you are using it as some **validating tool for interaction on user interface it's more important that it's as realistic as possible**."

"So if that could be top, if you could really do that, if it is not just visibility of the model, it's the use of it. So it behaves like a virtual physical prototype, I think if that was possible that would add value. So that would go to the top if that was doable, but you don't probably know yet what is possible and what is not."

"What about from the model itself, can you control the texture? Because some things, for example in an iPhone, some parts are very shiny, other things are metal and cold. Or it might be that something is more fabric… Otherwise this is very 2D, this industry is very tactile, what does it feel like? If you pick a beautiful cosmetic bottle and you close your eyes, what does it feels like? It might be like "it feels amazing". And if from a consumer's point of view, you can't see it, is an awful lot of theatre and drama for then somebody to say "what does it feel like?". Maybe that is a watch out because if you can't do that with the modelling…"

<u>Database</u>
"LD: Sometimes when you go into a rendering program there is kind of a library of colours, textures that you can use… and they are often quite limited. And if you are not a great designer, you use what the program gives you, whereas what you should really be doing is finding the right way to project your idea and maybe the red in the CAD station is not the right thing. And my kind of nervousness with something like that, if it were almost like a CAD station and you could select this panel is going to be red and is going to have a dotted texture… that unless that library is so vast, that you might lose stuff. And we might just go away and find the piece of material and it is just that you wouldn't want it to limit your creativity, because its possibilities are not broad enough. Does this make sense?"

"JM: I think that working with a lot of brand guys, they are very on it with their brands and their colours and things like that. So the example of the footwear, I know it's an early prototype but we have worked on footwear and the colours are going to have to be the right colour kind of thing… If you are going to pass any judgement on them, which I guess it will mean a lot about the room you

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are in, the projector, the material of what you are projecting on and whether you can replicate something which is representative of when someone needs to make a decision. So yes it is about colour and quality…."

"WD: I almost wonder whether the actual projection thing is almost the smart bit as opposed as whether it has to be 3D. I get it that it might vary on different things, because I quite liked what you were showing there with the texturing and the looks and the tones. Because at the moment, for us to do that, we would just render them up and maybe put little animations together and send them over. The problem that we might have with some of the texturing that we might do is that if you get to "design development", if someone wants a metallic feel on something, the suppliers and the engineers will get really nervous on what they would recommend. Because they are always risk adverse on going "oh, you want that finish?" and people would be like "yes, that is what I want" and suddenly they delivery the product that has been injection moulded and senior management, the stakeholder, will go "that doesn't look like that, that I saw on my projector… it looks just a bit rubbish". So that is why sometimes they almost don't like us doing mock-ups, even as well-made as they are, they say it's a false read against what someone is actually going to be signing off."

<u>Price</u>

"And there the cost is only once facet, the return on investment is -- if it costs three million but we can use it for everybody, or we can only use it for two or three customers. So the system cost in relation with our business and how many of the projects we could use it in"

"So I am not really worried about the system cost, it needs to be cost effective."

"system cost, I guess it depends on like if this is… I don't know, if you have a ballpark figure? It's impossible to tell. So it is obviously important, but it really depends on, I'm not entirely comfortable saying it."

"And then cost is obviously important but its got to work first. These things usually get cheaper with time anyway."

"They are all really important, if there is any which aren't important, I would say is system cost. I would just leave it off, because if it is that good, it will just pay by itself.
CS: Yes yes, in the end it's the added value that it brings"

"BH: From my point of view, system cost at first place. If it will be a technology which has to be bought."

"I can't think somewhere exactly where it would fit it but there will be, it should be something fast and cheap."

"SN2: I think system cost… I think, fundamentally, it's gonna be a lower cost approach than physical prototyping."

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Reporting tool

"DH: Depending on the size of the meeting. If it is a key meeting, then somebody will do what we call ´contact report´. And that contact report will highlight everything that was said in the meeting, what the key actions points were and it is circulated. It goes upon a system called Slack and we just run a Slack channel and everything is up there. The good thing about Slack channel is that everything is up there, so nobody can say "oh I can't find the brief", it's up on the Slack channel… "what did that visual look like?", it's up on the Slack channel… Slack has been great."

"CP: Yeah. So we normally sort of – a project manager for each, but we do lots of share the work out between us and sometimes we have a project manager, a (()) team manager for your project. And effectively, when you're getting the ideas into the concepts phase, they've been relatively well thought out already, so hopefully there isn't too much stuff to do. Sometimes when you (()), you can stop to see flaws in the design and we'll just generally have a chat amongst ourselves. Or if you think it's gonna be -- if you're coming up with a new end, a new scope (()) or something, we talk to one of the engineers on sight and ask them about previous projects, their past experiences and hopefully with that, and your own knowledge, you'll be able to come up with a solution that works."

"MM: Ok. And then in terms of capturing all the information that comes up, do you have a system that you adopt, so you come up with lots of ideas here and lots of…

CP: So what we do is, at the end of our brainstorm, when we've come up with these ideas, we scan them into a scanner and then we take it saved into "Ideas" file – it's just all of them. And then when we do that next peer review stage do the exact same thing, we scan them and save them and then we update those files and they get archived and you always have the ((nearest one, like, the last one))."

"SV: No but what we do is, all the concepts that have been, not the ideas, we of course we write them down and for that project normally the buyer writes everything down and then everything gets assigned to someone. But what all concepts that have been made are stored. So once an idea gets, we don't necessarily have to have made them, but once an idea is ok, you say its ok to work out. I mean those concepts are kept always.

FD: We see them under the clients name or under the project name or the license number."

"There is more of an attitude of sharing early and often with the client. So we are very often compiling into power point for example, in order to gather stuff together. It might be early sketches, scans of post-it notes, it might be more finished… It is usually some communication media that stuff is dumped into in order to provide some communication vehicle for sharing with the client. Often our clients might be gate keepers and they need material that they can share.

PP: Yes, that is often a big requirement. "I have got a meeting with a steering committee next week, I need X, Y and Z", so there is a big requirement for stuff like that."

"PP: Certainly, even in the case of people doing sketches, for reasons like being able to share with clients for internal purposes, we want to capture everything digitally. Even hand drawn stuff, our models get quickly scanned or photographed or whatever to be brought together. So in terms of our process, we have a fairly defined folder structure for our data, so people know where to look for stuff.

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If you think about "I was out on holidays last week, but I know we made those models", even if no one else was there to talk to you, you would know where to go and you would find the photographs of the models, you would see the latest project status/update. It has been collected typically to share with the clients but also act as an internal point of focus as well. We look for presentations as they are gathering together all the stuff. And then you know… alright we did that, and I might work from now to then on that CAD model… and I know where to find it jumping off that central collision vehicle.

MM: But do you have a specific type of software that you use? Something like a PLM system?

PP: We have look at a number of PLM systems over the years but we always found issues with them, in terms of the level of flexibility that they allow and so what we have is a quality management systems that covers a defined sort of folder structure. So we use techniques like revision control and within final names (??) and things like these to kind of control revisions and latest versions of data. It is really to do with where things are stored and dictated by a file structure, so we have things like an "input" and "output" folder, which are kind of controlled so that any information forms design inputs is listed in one place and any design outputs listed in another place. So anyone who wants to see the story of that project can see all the stuff that came in and all the stuff that came out just by looking in two places. And then working data is stored in another folders, but once people understand and get used to that folder structure, they are very easily able to find what the need. So we find that this works very well for us. I wouldn't say we have had huge pressure to migrate to some PLM system, it is that kind of thing that once you have done it is kind of impossible to undo it and we have not yet identify a system that really supports our needs fully in the way that we needed to work."

"PP: Yes most of the time I guess we are dealing with single user scenario so in some ways it might even not be that important but maybe from a UX point of view. If we have got a single user and a single system, as long as they can see it from where they are standing and you can then maybe record it in some way. That is an interesting aspect, recording interactions… is that something that can be build into the system or is it something that you need to do externally?"

"At the moment, we don't have any way of interactively engaging with our retailers or customers to help them to -- or to enable them to help us design the products. It's basically a discussion board. It could be like this, here's a view of that and there's no way of sort of having a two-way interaction on whatever we're presenting. It's always "here's what we've done, what do you think?"

<u>Ease of set-up, preparation and use</u>

"CW: We have a lot more meetings at the client's site than ours so I think it would be a clear limitation if we have got this great thing but you have to come here to see it. But it might that you get really experienced here because we have got the room set up to do it. But it ultimately wants to be portable. And again, relating it to VR, which by the looks of things it's going to happen quite a lot more because of the cost of the technology coming down… I saw a presentation by some architects who had been fairly recent converted to VR and were showing some video of the client presentation at the client's office and you sat there with the googles on and he was looking at the architectural layout. It is kind of comedy because you watch him do and his colleagues are like… he is getting all excited

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looking at the ceiling… so it is the equivalent thing, in that case in a pretty immersive environment. So you want to be able to think ultimately to take it to the client's just to have real value."

"I think it would be quite useful in some situations to be able to for example, if you had an idea for a company like [Company] that have several brands and you wanted to communicate a thermochromic ink, so changing colour or something, it would be very cool if you could have a standard can and then say this is what it looks like when you have it on a [Brand 1] can. That's how it looks like on your [Brand 2], that would be quite powerful."

"So we're gonna be drawing up the graphics in two different styles. That would be very cool if you have a model and you just [clicks fingers] 'that's one style,' [clicks fingers] 'that's another style.'"

"CP: Yeah, definitely. So I'm guessing when you're changing projections you have all your files setup already and it's just like the flick of a button somewhere that makes it change. So you have to have your files setup ready and designed…

MM: Yeah. You have to have something but then at the same time you can also manipulate those files in real time…

CP: Ok. So if you want to use it like, a colour change or something that would be achievable?

MM: Yeah. It captures everything that you do. It's got also like another software package that goes with it that catches everything, so if you did have that few and you change different colours, it would then capture that and update whatever original file you used so then you do have sort of all those design changes.

CP: That would be quite a cool feature. If you're showing a customer, "I'm not quite sure about that", "Ok, what about this colour?""

"It would be really cool if you could edit your artwork on the product rather than on the computer. So if you have got your artwork on it already and then you can start to drag and move things around and it automatically save."

JM: Yes, it needs to be as easy as sketching. Which mean you don't want to do a quick prototype and then do a CAD model of it and then you can map the graphics on it that you have had to create as well. It needs to just scan the physical model and chuck on something and figure it all out…

<u>Room requirements</u>

Size of room and projector

"I suppose that what I am unsure about is the limitations of it and how much machinery do you need. Is it just a small camera that projects or is it a very big kind of …"

"MM: So for you, would like it to be something smaller, less intrusive…?

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DH: Yes, I think it could be small and less intrusive."

"DH: No problem, I think it is a really interesting tech. I think **its about seeing physically how big it is** and its portability and all that kind of stuff."

"Room requirement is the first not a problem."

"CW: Then for the room requirements, these things are solvable limitations"

Lighting conditions

"**You have to make sure that the environment in which they are thinking doesn't actually affect their perception of it**. If they are dealing with a yogurt pot for example. Probably most of us have yogurt for breakfast time when it is lightened, and all of a sudden you are there in the dark… it would be wrong, it wouldn't feel quite right."
"**But having it in a darkened room is one of the main limitations**, I struggled enough historically when you go to a clients' meeting and they say "can you pull down the blinds? I can't see what you are projecting" or "I can't see you screen, put your laptop a bit this way". Having a dark room, like a photographic dark room… the realities of having that in commercial use are zero, it is never going to happen"

"Could it be possible for you to work in a darkened room? Because the projection quality will be better in a darker room.

SV: **The light goes on automatically in the sample room**."

"The room is quite important because you don't necessarily want to go into a dark room cupboard because that is not very natural."

"Most of the things looked like you almost need to turn the lights off to be able to see it and that seems a bit of a shame to me, to **not be able to feel what is going on around you beyond the product on your hands.** So that would be something else that would be interesting to explore…"

"PM: Could you work in a little bit darkened room with the products?

ES: Yep it's no problem"

"I would say room requirements is fairly low. It's likely that we would have a dedicated space for this sort of thing anyway"

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