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TRIPLE HELIX IDEATION: COMPARISON OF TOOLS IN EARLY PHASE DESIGN PROCESSING

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1. Introduction

This paper presents a case study on collaborative design interaction (i.e. problem-solving, solution finding) incorporating triple tool modalities. In this study we compare the variety and diversity in tools and methods applied to early phase design processing. The long-term objective is to develop computational design tools and systems that support and assist users in their design activities. Product design and engineering are a complex set of activities beset not only by the limiting enablers but also by the unwitting impact of mediocre designs [Cross 1984] and [Kosmadoudi et al. 2013]. Small errors in the early design phases may not become apparent until much later in the process or until it becomes too late. Ideation is the "ability one has to conceive, or recognize through the act of insight, useful ideas" [Vaghefi et al. 1998]. Nowadays computational tools are the standard in design and engineering and play a crucial role in the design process. There are many views on the massive change that CAD caused [Robertson and Radcliffe 2009], how it influenced user behaviour, user intent, user-experience ,user-interaction, and user-performance and productivity [Wendrich 2013]. Current CAD systems (enabler) are governed by rigid rules and predetermined "canonical" procedures that limit user/designer creativity and intuition [Kosmadoudi 2013]. The transition from masses to user-centred design paradigms sees design and engineering activity and creativity being compromised. The complexity of products has increased dramatically with megatronics and adaptronics. In a globalised world, interdisciplinary and trans-disciplinary product development is part of everyday life. Further complexity is introduced with the demand of Product Service Systems [Birkhofer 2011]. In product development, there is an increasing division of labour. The reduction of production depth is attended by a comparable reduction in "design-depth". As a consequence the deep meaning of personhood is being reduced by illusions of bits; people degrade themselves in order to make machines seem smart all the time [Lanier 2010]. Designers become project managers with product responsibility from the product idea all the way to the release for series production [Birkhofer 2011]. If responsibility for product ideas is part of the designers' task description then this aspect should be a fundamental part of the designer's skill set and education. Key aspects of the design and engineering process, e.g. analogue ideation, intuition, manual skills (i.e. paper modelling, low-resolution modelling), tacit knowledge, and creativity became somewhat trapped and challenged with CAD. Current CAD developments make slow progress towards enactive modes of operation, but still far off from what humans can accomplish in terms of cognitive transformations, sensorimotor representations, through visual manipulations to fully matured formal operations [Sener and Pedgley 2002]. The notion of creating playful CAD environments as a transformation technology to address current drawbacks such as complex menus, limited interactive assistance during the design task, formal conceptual design tool and fixation on design routines that stifle users' creativity, ideation and intuitive process are therefore highly important. The development of methods and tools to support the design process started in the early

1960s with interactive systems mimicking the drafting and calculation tools. This is the area of interactive design where the process of developing solutions to a given set of requirements and constraints cannot be reduced to an algorithmic or procedural process. The sequential steps imply evaluations and decisions that are taken by designers on the basis of global assessments [Bordegoni et al. 2009]. Mixed prototyping, which is the practice based on the use of prototypes consisting of a mix of real and virtual components, has proved more effective for the assessment of interactive products with respect to totally real or totally virtual prototypes [Bordegoni et al. 2009]. The development of hybrid tools (mixed reality) and rawshaping procedure (holistic method) to support design processing started in 2004 [Wendrich 2012] with interactive systems in mixed reality. This paper describes also user interaction with hybrid design tool prototypes to execute a design task.

2. Design methods and alternatives

In general design methodologies and process models have similarities across disciplines [Birkhofer 2011], [Gericke and Blessing 2011] the core of these are common design stages or phases and they propose a stepwise, iterative process. In recent years a wide variety of authors identified and compared these design methodologies and design process models in mechanical engineering, service design, mechatronics and other disciplines, for example [Archer 1964], [Roth 1982], [Cross 1984], [Birkhofer 2004], [Ogot 2004], [Pahl and Beitz 2005], [Howard et al. 2008], [Kim and Meiren 2010], [Gerricke and Blessing 2011] that created some sort of consolidation on commonalities across disciplines. Of course when reviewed extensively the cross-overs become apparent and show common threads, patterns and themes no doubt. However, the different studies on design methodology are also fragmented and flawed by gaps in understanding, insight in context, and properly defined frameworks. Nonetheless, current and future development of design methodologies are in need of reformation [Birkhofer 2011] since they are often insufficient, comprehensive, and long-winded [Birkhofer 2011] that implementation and/or adaptation in industry still is reluctant and partially successful. To keep-up with the fast and rapidly changing world design methodologies should be adapted, developed, and reformed to adhere to the increase and need for multi-disciplinary collaboration in design processing due the rising complexity in design problems [Gericke and Blessing 2011]. The use of computers (CAD) plays a very important, often dominant and crucial role in design processes not only in industry but also in education [Wendrich 2012]. However, most design methodologies only partially meet and/or favour computer use [Birkhofer 2011, p. 8] and could not keep pace with computers. In our research we rely on the interplay between a creative thought and action, based on experience and intuition of the individual designer and a systematic procedure, based on scientific work [Birkhofer 2011, p. 5]. We propose a more holistic view on design processing and methodologies to benefit and gain from unpredictability, uncertainty and intuition. Prior experience, tacit knowledge, practice and learning-by-doing are fundamental in our interpretation in the world of ideas.

2.1 Rawshaping procedure

Since 2009 we deploy the rawshaping procedure to investigate and explore the fuzzy front end and ideation phase of design processing. The methodology and process applied stems from the research and exploration for new design tools, mixed reality, user-interfaces and user experiences based on a holistic framework and learning-by-doing approach to determine next steps in analysis and synthesis for heuristic shape ideation. In fact there is no apparent ‘methodology’ that is required to start a rawshaping process, however to fully benefit from the procedural steps it is necessary to create a re-adjustment of mindset and an open approach towards rawshaping ideation. For more data and full account of rawshaping research we refer to its primary documentation [Wendrich 2010, 2013]. Idea finding, creative exploration, possible solution finding, and ignition of search paths are a dominant part in any design and/or engineering process. In most cases the start or kick-off of such a process, especially when some form of mind-storm, idea-burst or creativity is required or needed, requires a lot of effort and energy regardless of experience, expertise or specialism. Play and CAD Game System (CGS) mechanics are an important aspect of the rawshaping process action; through adaption of these standards the process of design iteration becomes much more playful, engaging and rewarding [Kosmadoudi 2013]. Thereby introducing some randomness in findings and exploring neighbouring solutions preventing to become trapped in a local neighborhood. Furthermore, we recognize a strong metaphorical connection, analogy and cross-over between rawshaping and the Japanese Kansei design and engineering strategy [Levy 2008]. The inclusion of senses (i.e. touch, sight, taste, hearing, and smell), perception (i.e. thermo, noci, equilibrium, proprio) and tacit knowledge (i.e. experience, personality, mood, condition) has a strong foundation in rawshaping as well as in Kansei. Kansei is an advanced function of the brain that can be the source of emotion, inspiration, intuition, pleasure/displeasure, taste, curiosity, aesthetics and creation [Beuttel 2010].

3. Triple Helix Ideation and Experimentation

In the following case-study we show a triple design ideation and representation experiment for an early design activity (fuzzy front end) with three tool environments, i.e. analogue, digital and hybrid for triple helix ideation. We deployed three separate collaborative design-task tests based on the same problem definition in conjunction with three different design tools and set-ups. We studied the correlation between the ease of tool use, tool performance, tool satisfaction, tool expectations and experience. Tool fluency, adoptation and adaptation by users are expected to be immediate and congruent, however we contend that this rapid assimilation of the new or innovative technologies (i.e.tools) only happens when users accept the technology (e.g. device, tool, system) [Kaapu 2013]. In addition the user acceptance and uptake of technology occurs when the user perceives it as a pleasurable extension on their physical reach.

3.1 Test procedures

The testing took place over two test session dates with 4 paired groups of approximately twenty-five students. The students randomly formed pairs on both dates. The participants in this experiment are considered novice students in design engineering and all are second year Bachelor students in design engineering education in our university. During the second testing date one group of students was considered a placebo group and were not informed or made aware of this because of ethical reasons. Their ‘results’ did not matter on our testing and therefore is not included in the results and analysis of this experiment. This study shows preliminary findings and limited in scope.

3.2 Group participants

In the first test session we divided a group of over fifty students (variance per dates) in two and paired them to form collaborative groups. The A-groups (16 gr. Analogue – 32 part.) only used analogue design tools (e.g. markers, paper, pencils) to execute the design task. The D-groups (11 gr. Digital – 23 part.), used their laptops (e.g. CAD software incl. mouse, tablet, etc.). No access to the Web was allowed during the execution of the design task. In the second test we once again randomly divided the students in two paired groups. The H-groups (19 gr. Hybrid – 38 part.) were to use two hybrid design tools [Wendrich 2010, 2012] for execution of the design task.

3.3 Design-task, facilitators and constraints

The design task was to collaboratively design and ideate a hydrogen car (Figure 1 left) thereby include the predetermined constraints of functional elements within the possible design solution space. The objective of the design task was to make as much iteration as possible. The time frame allowed was 10 minutes. Groups A and D were handed A4-prints with constraints or download a pdf (Figure 1 middle). The H-groups used the hybrid tools and 3D printed scale models of the functional element constraints (Figure 1 right). During sessions we used facilitators for simple instructions to participants.

Figure 1. Hydrogen car framework, 2D constraints and 3D constraints

3.4 Tools and Set-up

The A and D were separated in the lecture room (Figure 2 left). The A's were required to use analogue tools and papers, D's were to use their laptop with tools of their choice. For the H's the setup included two hybrid machines with one facilitator each for initial instructions and brief assistance (Figure 2 right).

Figure 2. Triple helix ideation setup

3.4.1 Analogue and Digital environments

Figure 3 shows the analogue collaborative interaction and representation, face-to-face communication embedded with sketch, draw and idea creation. Use collective processing to find suitable and possible solutions in a fast, iterative, and interactive way of working. Sharing knowledge and ideas this way feels natural, intuitive and real. However, the need for adequate drawing and sketching skills to convey your thoughts and ideas are also part of a successful performance and communication. Most sketches and/or drawings were a mixture of two- and three-dimensional representations of possible embodiments of car-like designs. Most of the concepts contained the constraints such as motor, fuel-tank, and wheels in different assembly configurations. Many drawings showed annotations depicting the key features, requirements and relevant information about the proposed ideas behind the concepts. This kind of fine-tuning shows a certain skill-based level, depending upon the continuous updating of the sensorimotor schemata to the temporal and spatial features of the task environment, the speed-accuracy trade-off [Rasmussen 1998].

Figure 3. Analogue tabletop ideation

During digital ideation we observed the use of a variety in user interfaces (i.e. mouse, keyboard, tablet, fingers) as input devices and diversity in CAD software (tool) usage (Figure 4). We noticed the use of Adobe Photoshop (4 part.), MS Paint (16 part.), SketchBook (tablet) (2 part.), Sculptris 3D (1 part.) and Adobe Illustrator (1 part.). Surprisingly relative simple programs were used to design and 'sketch' ideas, most of these programs are primarily used for two-dimensional graphic representation and visualization. Strikingly, when we asked the participants after the test which program they had used the most; it showed that 70% worked in MS Paint. The other 30% used Adobe or SketchBook. The reason why is probably on the rule-based level, the performance depends on the empirical correlation of cues with successful acts. Humans typically seek the path of least effort. Therefore, it can be expected that no more cues will be used for discrimination among the perceived alternatives for action in the particular situation [Rasmussen 1998]. The drawings made with the digital devices and tools (laptops) showed a large variety in quality, depth, scale, skills and outcome. All concepts were two-dimensional elevations of possible solutions, most of them were very frugale and simple line drawings. In a few cases we found a combination between embodiment and assembly configurations.

Figure 4. Digital laptop ideation

3.4.2 Hybrid environment

The second test with the hybrid design tools showed a back and forth between material representation and playful activity between the participants (Figure 5). The three-dimensional constraints were used to create virtual models in conjunction with sketches, drawings and other material artefacts. The negotiations between abstract and material representations are instrument to thinking, learning-by-doing, exploration, reflection, and discovery [Schön 1984], [Brereton 2004], [Wendrich 2009].

Figure 5. Hybrid workbench ideation

3.5 Performance and results

The following results from the triple helix ideation experiment show variety, diversity and serendipity in representation of ideas on paper, screen or hybrid mixed reality.

3.5.1 Analogue and digital results

In Figure 6 and 7 we present a concise selection from analogue and digital ideation and iteration processing. The application and adaptation of the constraints are clearly visible as an intrinsic part of the representations. Some indicate the parts as symbols (letters), others as drawing or pasted graphic from the pdf. Notice that the digital sketch visualizations predominantly show side view elevations.

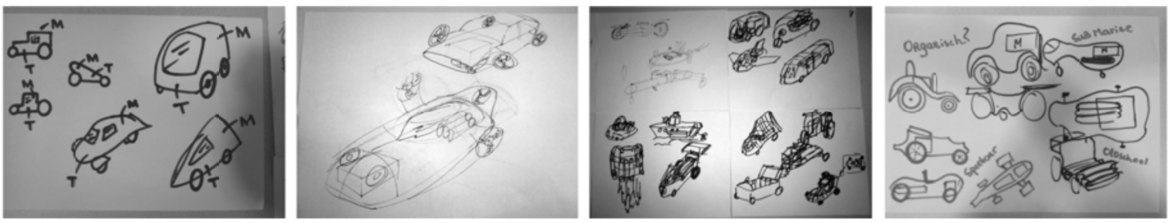


Figure 6. Analogue sketches with 2D constraints

Figure 7. Digital sketches with 2D constraints

3.5.2 Hybrid results

Figure 8 presents a random selection of merged representations from user interaction. The visualizations clearly show the functional element constraints and iterative solutions. The visualization shows various viewing angles and elevations. Representation in two-dimensional space seems like a common denominator in visualization and an easy-way-out. Although the hybrid design tool affords both two- and three dimensional iteration, the novice users probably feel more comfortable and at ease to work on a horizontal (tabletop/workbench) plane instead of using the spatial capabilities of the tool. The facilitator specifically did not mention this to the novice users to observe how they would interpret and use the tool from the onset. Remarkably, none of the H-groups started working in three-dimensions right away; they focused more on fulfilling the design task than on exploring the possibilities and features of the tool. Even the three-dimensional constraints were not seen as essential or prospective triggers (as more or less expected), the artefacts were used as 2D objects within their respective solutions.

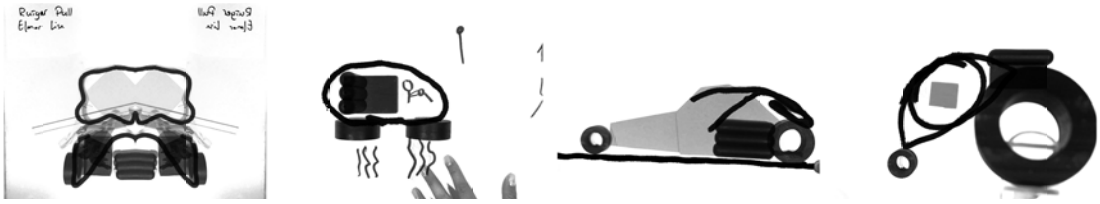


Figure 8. Hybrid sketches with 3D constraints

3.5.3 Hybrid results with facilitator nudge

After 5 minutes the facilitator stepped in to give some simple instructions and pointers to disrupt the process and make the participants aware of the multi-dimensional iteration space. Some results of these next iterative steps are shown in Figure 9.

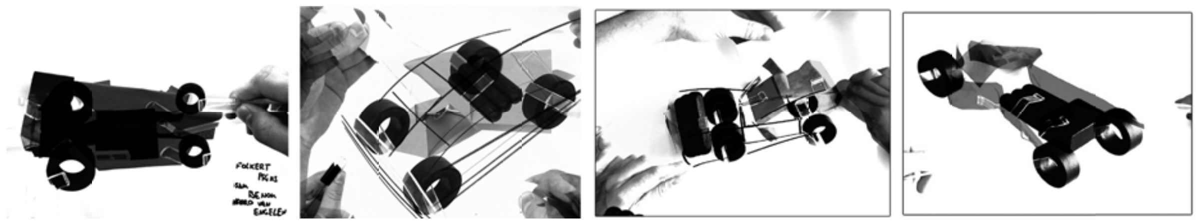


Figure 9. 3D Hybrid sketches with constraints

3.6 Reflection and feedback

All the participating groups were asked to fill in questionnaires made available online directly after the test sessions. We used SurveyMonkey [SurveyMonkey 2009] to acquire responses and compile all the data from the questionnaires for analysis and evaluation. We issued three different questionnaires for each of the three test set-ups (Tables 1 - 3). The A-groups had 9 questions, the D-groups and H-groups both had 10 questions. In addition to survey, we captured all the interaction and testing on video for further analysis and evaluation. In this paper we only present the data from the three surveys as preliminary findings and results. The questions about the tools ranged from user experience; user interaction (input); ease of use; user productivity; user satisfaction; user exploration; user performance; user progression; user expectation; and user success (output).

4. Findings survey

The data from the survey showed clear evidence of how tools influence the behaviour, ideation, and interaction, performance and productivity of users during design processing.

4.1 Analogue and Digital Q&A

The following survey results show the percentages and ratings of the questions with regards to the analogue test (Table 1) and the digital test (Table 2). The first question in Analogue was: "Did you have previous experience with traditional design tools?" Response was: 100% Yes and 0% No.

Table 1. Questions 2 – 9 read from left to right, top to bottom

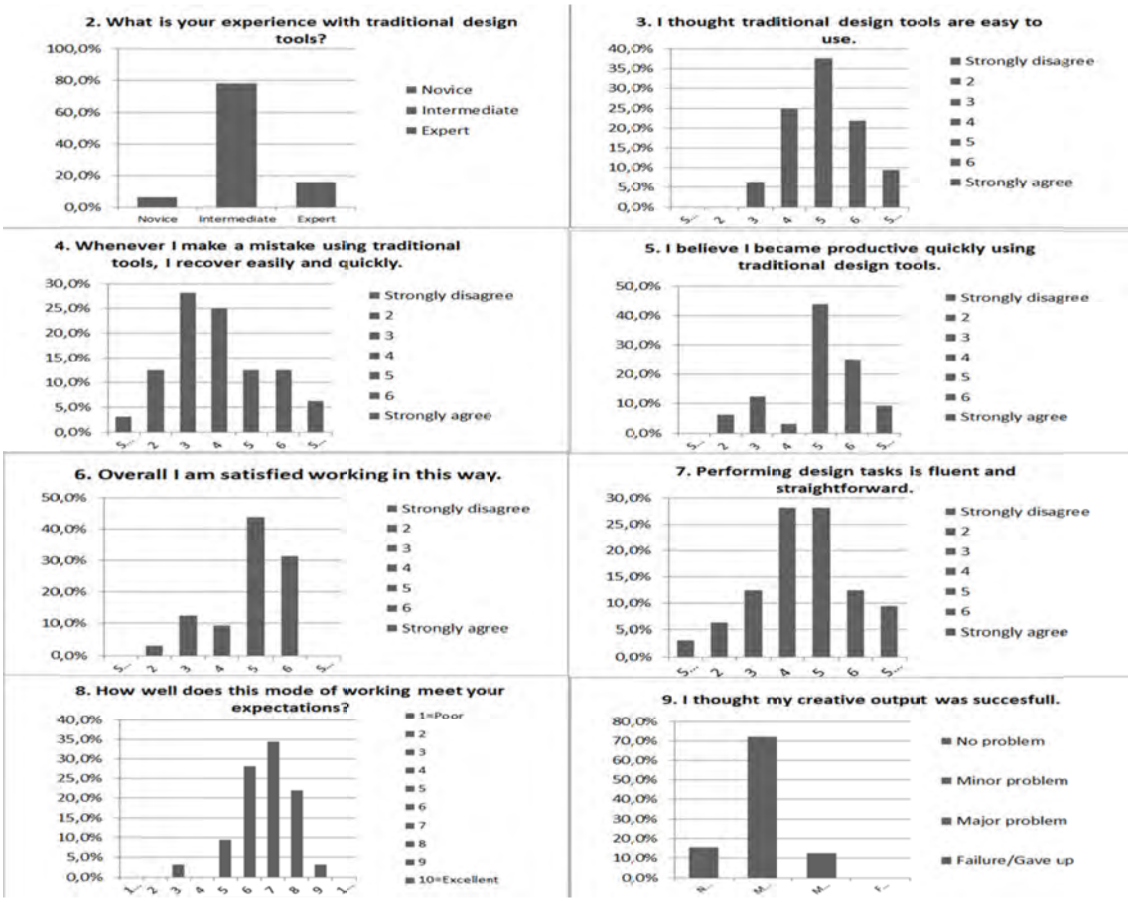
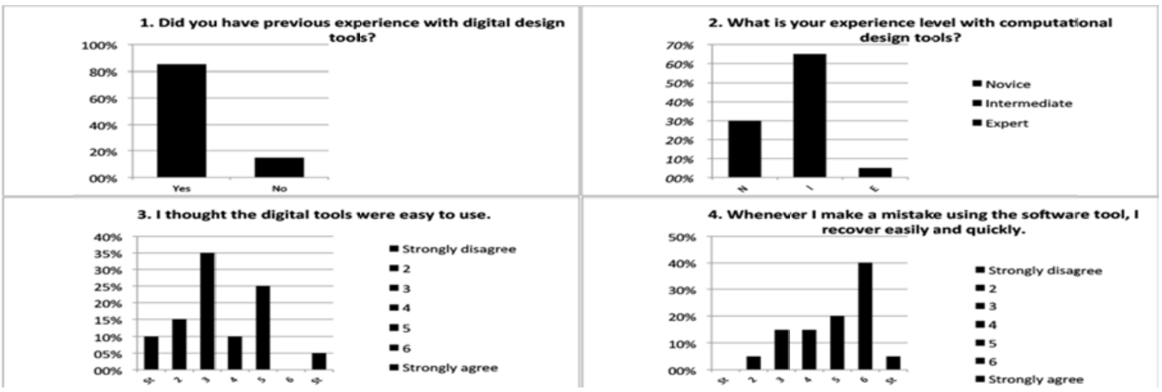
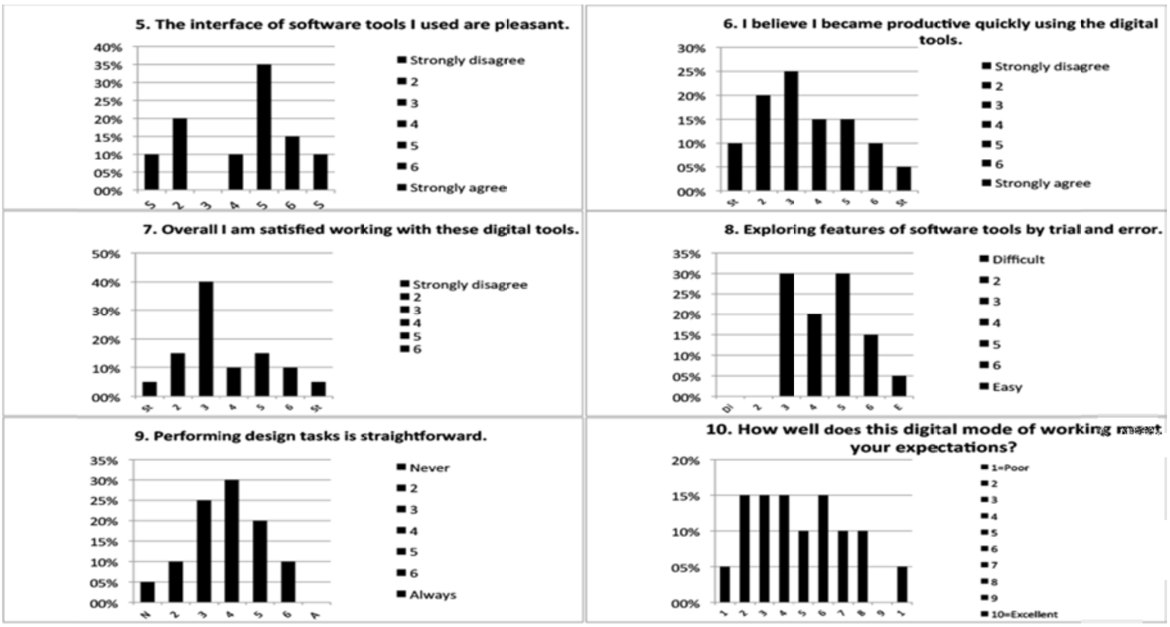


Table 2. Questions 1 – 10 read from left to right, top to bottom

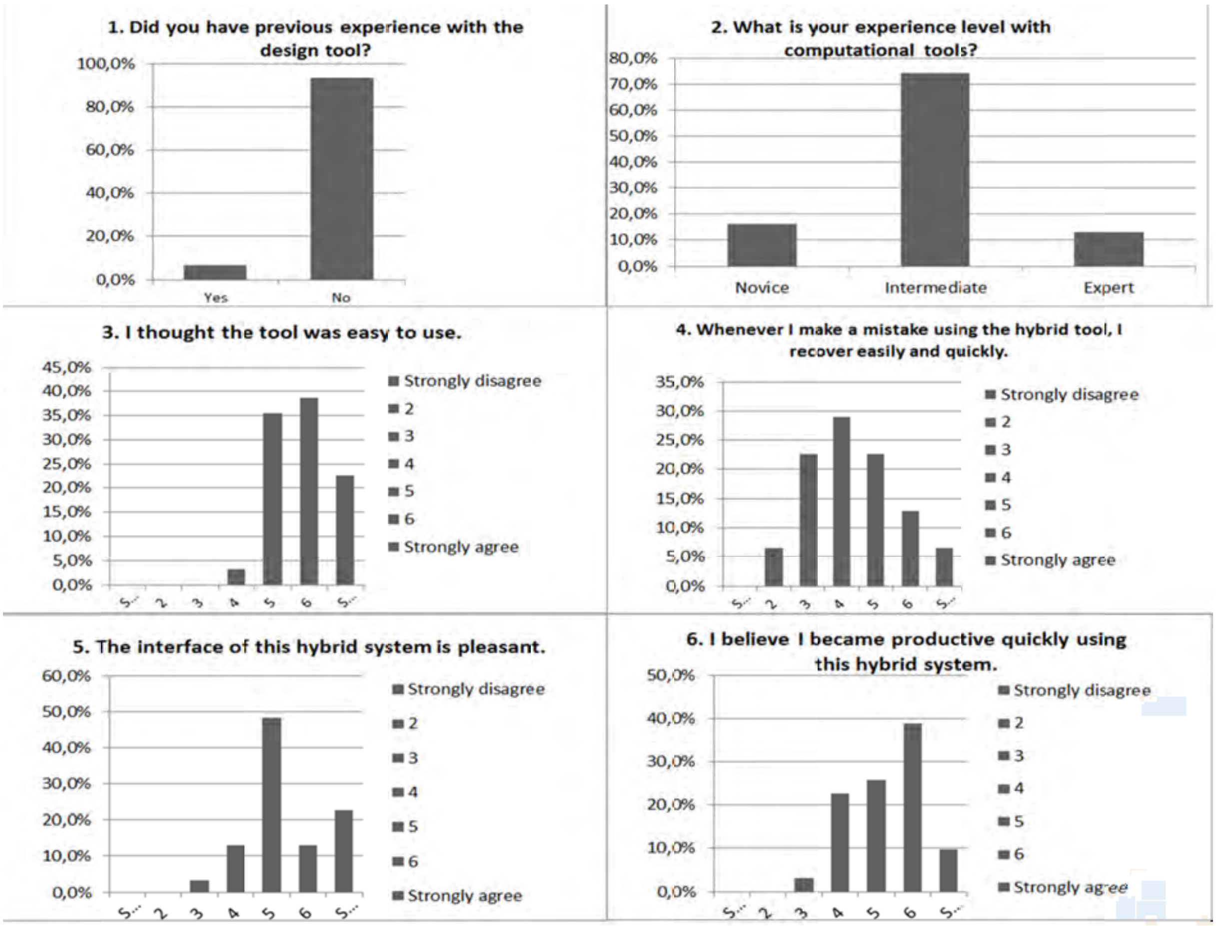


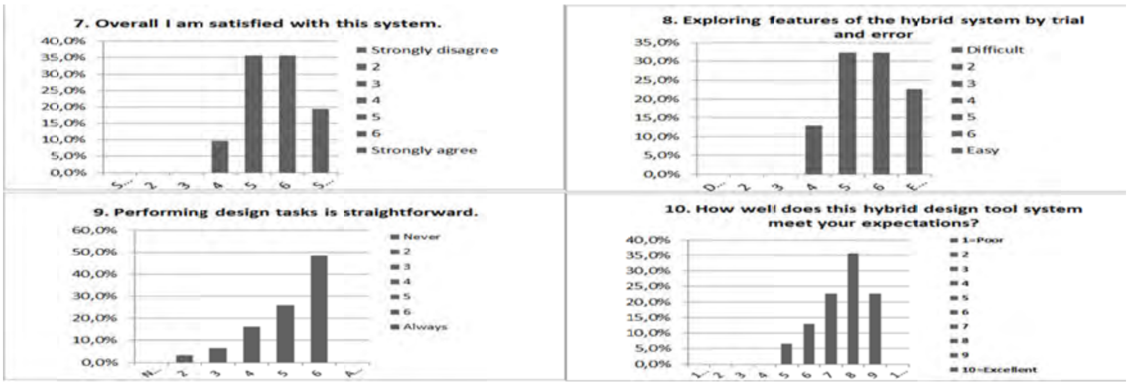


4.2 Hybrid Q&A

The following survey results show the percentages and ratings of the questions with regards to the hybrid test (Table 3).

Table 3. Questions 1 - 10 read from left to right, top to bottom





5. Conclusions

We presented a case-study on collaborative design ideation. The participants had to iteratively design and ideate a hydrogen car including predetermined constraints. Design task time was ten minutes per test. This test required focus, attention and creative inspiration from both participants collectively. Playful suggestions in sketch, low-resolution models and show-and-tell enforced the common ideas and creation of possible solutions within the design space. The representations of ideas on paper, screen or hybrid mixed reality show a wide variety and differences in solutions and possibilities. The majority of solutions were based two-dimensional elevations and representations. Only the analogue (A) sessions showed a rich mix of two- and three dimensional visualization and iteration. Perhaps the analogue domain intuitively feels more comfortable to represent in multiple dimensions. Probably affords being less restricted in externalization, scalability and presentation. The participants working on laptops and using software tools mostly used illustration based programs to create and make representations. After analysis, feedback and evaluation of the uploaded digital (D) content we found that 90% of the participants used MS Paint. Only a few participants used other graphical programs to convey their ideas. We noticed a strong focus and emphasis on side elevation views in their overall solutions. The initial hybrid tool (H) outcome showed various angles and elevation views, however congruent to the digital these were also mostly two-dimensionally structured and designed. There seems to be a strong tendency to ideate and create on a two-dimensional plane when asked to digitally design and solve a design problem. Even with a hybrid tool, however intuitive and multi-dimensional, the participants rather work on an X-Y plane to make their iterations. This may-be caused and influenced by earlier analogue-digital experiences, common approaches, routines or initial blindness to potential possibilities when confronted with a new design tool. We showed that with some nudges from the facilitators, users/participants had the ability, vision and flexibility to enhance their performance and started to create three-dimensional models with the hybrid tools. In our preliminary findings we conclude that analogue tools are still very fast, easy-to-use, flexible and comfortable. There seems to be fluid and confluent transformation sequencing between two- and three dimensional processing. The digital domain remarkably showed evidence of restrictiveness, cumbersome and latent interfaces in working fast, fluid and creative interaction. The overall results showed merely stacked structures of functional elements in conjunction with a car-like shape ideation. We were amazed by the fact that so many participants used MSPaint to create and iterate ideas. This possibly shows some evidence on how the current (solid) state-of-the-art in design tools, interaction and usability are perceived and used by novice designers. Although the participants were free to use any software program, we realize that there might be some bias in these findings. The interaction and representation with the hybrid tools showed initially more of the same sort of solutions as with digital tools. However, after brief instructions (nudging) of the facilitators the participants showed lively and vivid interaction with the tools. The generated content indicated progressions and transformations in three-dimensions whereby the 3D-constraints formed the core of the hydrogen vehicle and shape aspects indicated the embodiment. Noteworthy are the variety in assemblies and constructive inventiveness of the solutions. We observed playful aspects, motivation, focus and creative tinkering in the participants during the last part of the design sessions with the hybrid tools. This case-study is part of our on-going research in hybrid design tools, ecosystems and design environments.

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