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ASSESSMENT OF DESIGN TOOLS FOR IDEATION

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Abstract. Designers interact with a wide range of design tools, in a variety of ways, in order to support their work. Any attempt to produce digital tools aimed at supporting ideation raises the question of the kind of information considered account and what is appropriate to the needs and expectations of designers. We developed and implemented an assessment method for digitally supported conceptual design based on *reflective conversation*, *flow*, *cognitive ergonomics* and *activity theory*. Our approach opens up the evaluation spectrum to include parameters beyond performances factors for conceiving new digital design tools. This assessment approach considers user (the designer), action (ideation) and object (the tool) in the ideation process, namely the designer's experience interrelated to the needs of the task and the characteristics of the tool. In this paper we present the results of several research protocols in which we observed, analyzed and successively acted upon five different stages of the interface of a design tool as it was being developed, the Hybrid Ideation Space (HIS). Taken as a whole, these results suggest the limits and support of designers' optimal relationship with an ideation interface.

Keywords. Ideation; assessment method; design tools; human computer interaction.

1. Introduction

We frequently speak well of the sophistication of computer-based tools and the revolution they have brought to the activity of design in how we act and interact, but we seem to forget that the initial design process, the conceptual design phase, is still done with freehand sketches. At this point, most digital tools do not support ideation in the way they should, partly because most of them were conceived for other purposes and other disciplines. We need to look into the development process of digital tools that support conceptual design in order to understand why these tools play a limited role compared to sophisticated representations of already conceived ideas. This paper presents the results of several research protocols in which we observed, analyzed and successively acted upon five different stages of the interface of a design tool, the Hybrid Ideation Space (HIS) (Dorta, 2007), as it was being developed. The HIS supports sketching and working with physical models in an immersive environment dedicated to ideation. The assessment method in this study for digitally supported conceptual design is based on reflective conversation (Schön, 1983), flow (Csikszentmihalyi, 1990), cognitive ergonomics (Hutchins, 1995) and activity theory (AT) (Kuuti, 1996). Teams of two industrial design students worked in the HIS during the conceptual phase of an ad-hoc design project. The ideation process inside the HIS was examined through video analysis as well as questionnaires. Three levels of activity were considered for the video analysis: operation, action and activity level support. The results from each successive protocol have led to pertinent improvements to support designers' cognitive processes, making the HIS more intuitive with every modification.

2. The challenge of evaluating digital tools

Over the last three decades, design research has largely focused on computer-centered tools imitating hand-driven design. Many studies (Gross et al, 1996; Stappers, 2003) which compare computer-aided design (CAD) systems with sketching to identify how well these support conceptual design, show two results: CAD systems are at a disadvantage to support ideation, considering how sketching suits designers' cognitive process. The CAD/sketch comparisons do not reveal the kind of support designers need during ideation. Digital tools often have an interface conceived with the principles of human computer interaction (HCI), that sees the interface's usability as critical. But HCI research addresses the evaluation of design tools in a different way: 'Conceptual design receives scant attention in HCI literature, with the balance of research firmly on technical developments and system-specific evaluations' (Sener, 2005). Salim and Burry (2010) discussed the key requirements for CAD systems and proposed the notion of *software openness.* Where the 3D parametric software is openly customized, allowing the exchange of information often needed by architects and engineers, as well as a better integration of physical and virtual information, making the transitions between these environments seamless. New ways of interaction with CAD systems are in constant development, such as the Wiimote plug-in for Autodesk Design Review by Autodesk Labs (Sheppard, 2009). The Wiimote is used for navigation through the 3D models. This combination of sensor and physical computing devices has the potential for innovative ways of designing. Consequently, as pointed out by Salim and Burry (2010) software openness in parametric design tools will depend on the compatibility of the physical and omnipresent computing. The demand for supporting creative design thinking and multidisciplinary design with digital tools is influenced by how design tools are developed (propose) and the assessment (how the tools respond to designer's needs). Software openness explored the potential of CAD systems in design but there is a trend to think outside the digital screen that is changing the interfaces of design tools. Any attempt to produce digital tools aimed at supporting ideation raises the question of the kind of information to be taken into account and what is appropriate to the needs and expectations of designers. In order to find how digital tools can support better ideation, it will be necessary to go beyond improvements or changes of existing design tools and develop different assessment instruments.

3. Conceptual design and digital tools

During conceptual design, concepts supporting the designer's cognitive process are ambiguous, imprecise and abstract (Bilda, 2003). Naturally design tools have to match this process, preserving these characteristics of conceptual design. Representations such as sketches are abstract and open for interpretation. Designers can generate ideas in different ways such as verbal or visual (Oxman, 2002). It is the designers' speech and gestures that give meaning to their representations thus moving forward the design. In order to bring in digital tools during the conceptual design process, they need to support not only freehand sketching as a data input but also all the elements involved in conceptual design (gestures, annotations, verbalization). As Hernandez (2006) has pointed out even parametric design, once considered highly specialized, is today usual in the traditional CAD systems. This incorporation of parametric models responds to designer's demands for more freedom of manipulation and transformations of 3D models during the design exploration process. However, parametric variations multiply when parametric design becomes increasingly complex in the chaining of changes resulting in an inflexible model (Blurry and Blurry, 2008). Oxman and Sass (2006) presented the Digital Design Fabrication (DDF) method as another option to produce concepts in the early stages of design modeling combining generative computing and rapid prototyping. However digital tools typically channel all input through the mouse, therefore all these software tools feel the same to the designer's hand (Djajadiningrat et al, 2004). Designers still explore their concepts using physical modelling as well as a way to communicate complex design ideas in architecture (Cuff, 1992). Several research approaches have emerged with the promise of developing computerized tools for conceptual design such as the Envisionment and Discovery Collaboratory (EDC) (Arias et al, 2002). This system attempts to maximize the richness of face-to-face communication between different actors involved in the design process mediated by both physical and computational objects. The Share Design Space (Haller et al, 2006) is another system that allows collaboration in a face-to-face setting with sketches using an AR-based tabletop environment. All of these systems support different modes of design drawing. They were developed to replace the keyboard and mouse and allow designers to use the computer like a pencil on paper. This approach seems to be logical, given that sketches are the best way to support conceptual design.

4. New assessment method

The assessment method proposed in this study is based in the principle to examine all that should be considered when conceiving interfaces for digital conceptual design tools. First we borrow from Schön's the notion of 'Reflective conversation', based on his observations of professionals' behavior and performance. Secondly, the concept of 'Flow' defined by Csikszentmihalyi, which is based on a state of concentration when there is no consciousness of effort. We triangulate this information with 'cognitive ergonomics'; in particular through cognitive aspects, (mental representation, memory), perceptual aspects (attention, recognition, perception) and psychological aspects of the human task. The combination of flow and reflective conversation tell us to what extend the designer perceives his performance to have increased or decreased. The relationship of cognitive ergonomics to reflective conversation address the 'cognitive load' involved in the ideation activity. Pairing cognitive ergonomics with flow allows the observation of the 'interaction' between designers and design tools. In a previous study we used the concept of flow to develop what we call Design Flow (Dorta et al, 2008). The Design Flow allowed us to observe the engagement of the designer as it unfolds during ideation. Furthermore, we measured the workload of the task as part of the Design Flow. The actions during the activity (ideation) depend on the goals and the context in which is realized. The video analysis considers three categories based on the activity theory that examines the relation between the subject and object in which the tool is the mediator. The following section summarizes the mains aspects of each category:

- **Operation level support addresses the basic actions of the activity.** Eye and hand coordination: when the participant was able to sketch looking at the representation; manipulation of the interface: clicking on the menu options; outcome: agreeing on one idea; pointing with laser pointer and talking: explaining or share an idea; pointing with laser pointer: moving the laser pointer like sketching.

- **Action level support allows the observation of the designer's actions to accomplish the activity.** Sketching and talking: thinking aloud or sharing an idea while sketching; sketching looking at the representation: sketching while focusing the attention on the representation; sketching looking at the screen: sketching while focusing the attention on the screen; involved with the representation: sharing or explain an idea with the help of the representation; sketch verification: looking at sketch and reflect on it; sketching and looking at the screen of the iPod; looking at the screen: when the participant's attention is draw to the screen (this apply only to the participant that is not sketching.
- **Activity level support focuses on the main goal, which is the ideation.** Ideation /Co-design: when the participants work and use the interface at the same time; cooperation: when the participants divide the task even if they use the interface at the same time.

There is another section for technical problems, preparing the settings, training and interface issues. The last one addresses the moments when the participants were not able to find a command or when the information in the interface was not clear.

5. Setting of the experiment

The protocols were done in a system that combines immersive sketches with and physical models: the HIS (Dorta, 2007). One particular aspect of this system is the immersive environment where designers sketch and make models all around them in real-time and life-size scale using a digital tablet (sketches) and image capture (physical models). The system allows effortless design conversations between virtual and physical models, which are important in architecture. It has also been used for interior and industrial design. Teams of two industrial design students (second year) worked in the HIS during the conceptual phase of a design project. The ideation process inside the HIS was examined through video analysis as well as questionnaires. A selection of videos from each year was analyzed, particularly the first 10 minutes. The first moments of interaction with the interface are very important since this is when the participants get used to it. From 2007 to 2009 work sessions of 35 teams per year were recorded. The time for each session was 20 minutes per team. From 2007 and 2008 the HIS had a digital tablet (Cintiq® 21") as an input device. The participants were sketching with the help of a spherical template, but this required an adaptation from them since the template caused a deformation on the sketches. One participant was sketching while the other was using the hands to point at the representation. In order to give them more freedom they had a laser pointer. In 2007 three teams used only the Cintiq® then the Cintiq® and the laser pointer. Three more teams used the Cintiq® and laser pointer in 2008. In 2009 the spherical template was changed for a corrected drawing area where the participants sketch without deformation. In addition, another input device was tested: the pen tablet (Wacom™). This time, five teams used both input devices and the laser pointer. Also in 2009 four teams tested different interfaces of the HIS: PC tablet (Modbook® 13"), Wacom™, iPod and two laser pointers. The drawing area was improved in the Modbook® following automatically the orientation of the user's sight by using a rotating device. In all the protocols the participants used the HIS for developing the concept of a car as an ad-hoc project. Figure 1 summarizes the different settings for each year.

Setting of the experiment								
YEAR	2007		2008		2009		2009	
Input device	Cintiq®	Digital Tablet Cintiq® 21" screen	Cintiq® laser pointer	Digital Tablet Cintiq® 21" screen	Wacom™ laser pointer	Pen Tablet Wacom™	Modbook® laser pointer	PC tablet Modbook® 13" screen
	Cintiq® laser pointer	Digital Tablet Cintiq® 21" screen			Cintiq® laser pointer	Digital Tablet Cintiq® 21" screen	Modbook® iPod	iPod touch
							Wacom™ laser pointer	Pen Tablet Wacom™
							Laser pointer laser pointer	
TEAMS	3		3		5		4	

Figure 1. The settings of the experiments from 2007 to 2009.

6. Results

Figure 2 shows the results of the participants using the different combinations of input devices from 2007 to 2009. In 2007 (1) the participants spend between 4 and 6 minutes sketching and looking at the s Cintiq's screen. Sketching on the spherical template required the students' attention on the screen as well as some time for adaptation. However, the students that didn't have the laser pointer were more involved with the representation (1). With the incorporation of the laser pointer the students improved their design conversation by pointing and talking about their sketches (2). In 2008 (3) the participants were still sketching and looking at the Cintiq's screen (5 min). Nevertheless they were more involved with the representation and the use of the laser pointer increased significantly (4 min). The participants spend more time sharing concepts and agreeing on their ideas (co-design). By 2009 (4 and 5) the drawing area was implemented in order to avoid the deformation. Even with the use of the drawing area the time for sketching and looking at the Cintiq's screen was

6 minutes (5). This is almost the same time as with the spherical template in 2007. The participant's attention was focused on the Cintiq® due to size of the screen. The Wacom™ doesn't have any screen and the students needed to look at the representation all the time (4). Because of this they were more aware of the immersive environment as well as their partner's actions. However the students spend more time trying to draw straight lines and less time defining their concepts. In all cases the students were able to develop a concept as well as maintain a design conversation.

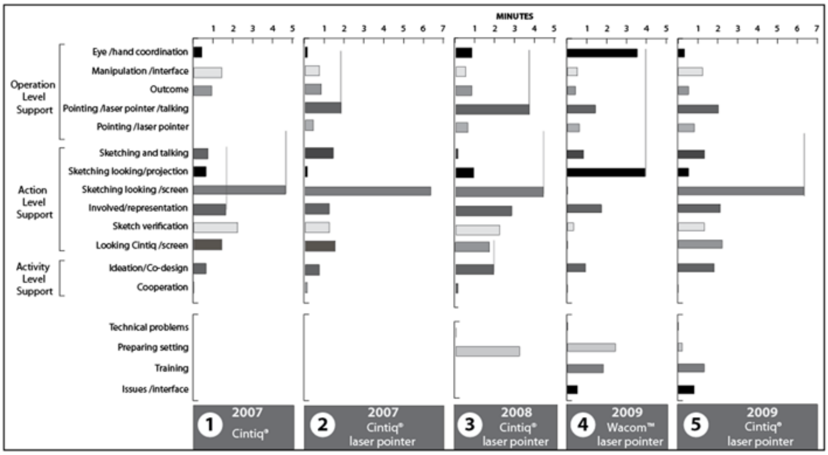

Figure 2. Video analysis of different input devices in the HIS (2007 to 2009).

6.1. FOUR INTERFACES

The data from the previous protocols showed that the interface could have an impact in the way the participants work. In order to improve the ideation process four different interfaces were tested in 2009 (Figure 3). The Cintiq® was replaced for a PC tablet (Modbook®) keeping a smaller screen as a direct feedback of where to sketch. This time the participants were able to sketch with the laser pointer. Sketching directly on the representation with two lasers pointers allowed the participants to moved freely and sketch at the same time on different parts of the representation. But they only shared their ideas after their sketches were finish working in cooperation (4). The hand eye coordination was not a problem but moving the whole arm for sketching was not natural for them (Figure 3). The combination of the Wacom™ and the laser pointer (only for pointing) (3) allowed the students to sketch looking at the representation as much as with the two lasers (4 minutes). However they spent more time trying to sketch what they wanted and less time discussing their ideas. With the Modbook® and iPod (2) the participants sketched simultaneously and each student started to sketch on their own just like with the two laser pointers.

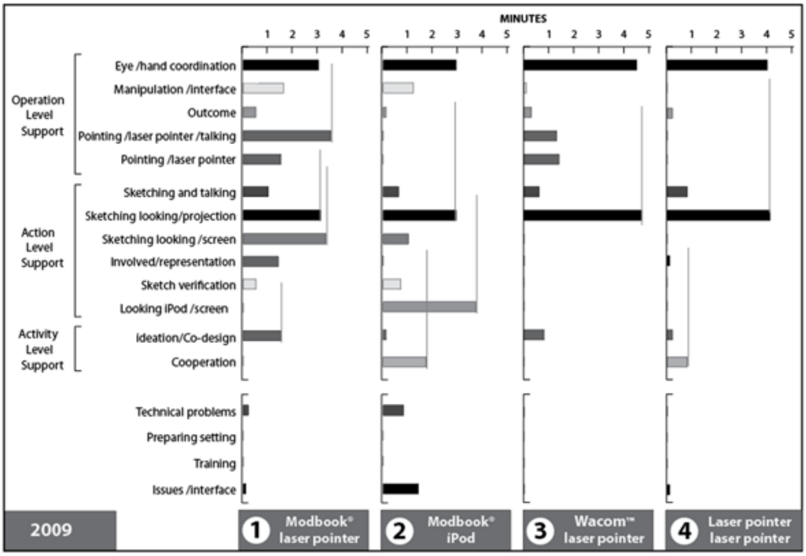

Figure 3. Video analysis of four interfaces in the HIS (2009).

The students worked in cooperation for 2 minutes (2). The participants with the iPod were looking almost all the time at the iPod's screen (4 minutes). The student with the Modbook® was able to sketch looking at the representation (3minutes). The combination of the Modbook® and laser pointer (only for pointing) (1) was the most efficient. The students spent the same amount of time (3 minutes) sketching and looking at the representation as well as using the laser pointer and talking. They discussed more their ideas and agree on them (co-design, 2 minutes).

The flow and workload questionnaires (Figure 4) were applied only to the Modbook® and laser pointer and Modbook® and iPod. The reason for this is because the laser pointer as an input device was still in a prototype phase and the Wacom™ was tested before. With the results from the video analysis, flow questionnaire and workload is possible to see their relationship in order to do a general assessment of the ideation. The interface that obtained the best results was the Modbook® and laser pointer because the students were more involved, focused and willing to redo the experience, thus performing better (Figure 4, flow Q). The results from the workload confirm this with lower effort, frustration and higher performance (Figure 4). The video analysis showed that the students expressed, shared and reflected more on their ideas. They were engaged in design conversations that required higher mental demand (Figure 4, workload). But, their performance was also higher and required less effort showing that they worked better with the interface. The interaction with the Modbook® was always intuitive for the participants since they were sketching in a manner similar to paper and pencil.

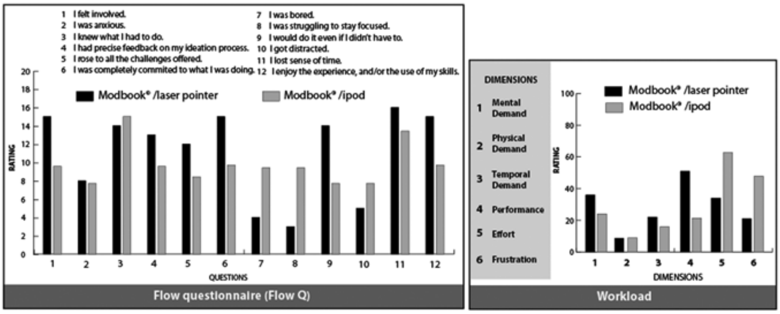

Figure 4. Flow questionnaire and workload (2009).

7. Conclusions

The video analysis confirmed some of our observations in previous studies and provided new guidelines for what could be the next interface in the HIS. Having a smaller screen in the rotating device encouraged the participants to take advantage of the representation while they sketch. But with two sketching devices the participants tend to work in cooperation. The concepts discussed here (reflective conversation, flow, cognitive ergonomics and activity theory) provide a framework for understanding ideation and for fostering design tools. The presented assessment method do not necessary convey the completed evaluation of the ideation process. However, by combining all four concepts, it is possible to expand the field of study and link results (crossover) to produce an approach that will build a unified body of knowledge. In order to provide a convenient new assessment method, further testing will be needed. At this stage the overall goal of the assessment is to verify if this framework still reflects the experience adequately and if the knowledge extracted can inform the next design iteration for the conceptual tool.

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