A STUDY ON THE IMPACT OF HOVER PLATFORMS ON DESIGN TEAMS COLLABORATIVE BEHAVIORS DURING COLLOCATED COLLECTIVE EARLY PRELIMINARY DESIGN ACTIVITIES

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Abstract

HOVER platforms are interactive digital working space composed of HOrizontal and VERtical interconnected tactile surfaces. Since ICED 2011, we defended the hypothesis that interactive surfaces can greatly increase the effectiveness of the early preliminary design phase by increasing collaboration. So it is pivotal to understand the impact of such interactive surfaces on collaborative behaviors of design teams. We present the TATIN-PIC HOVER platform, an example of HOVER platform, that we built as a test tool. We describe our experimental protocol to assess if HOVER platforms change the collaborative behaviors of design teams throughout the idea generation phase, compared to traditional pen-and-paper mediating tools. To achieve this goal, we compare pen-and-paper against HOVER platforms. We measure the equity of contributions in the common objectification process (i.e. writing concepts on post-it) with a sample of 40 young practitioners. Our preliminary results show that HOVER platforms tend to change collaborative behaviors from an exclusive collaboration mode to a mutual one. This opens interesting research paths that are presented in the conclusion.

Keywords: Collaborative design, Computer Aided Design (CAD), Workspaces for design, Conceptual design, Human behaviour in design

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1 INTRODUCTION

The goal of this work is to assess if a class of interactive surfaces - HOVER platforms (that will be presented later in details) - change the collaborative behaviors of design teams, throughout the idea generation phase during collocated collective early preliminary design activities, compared to traditional pen-and-paper mediating tools. To achieve this goal, we compared pen-and-paper against HOVER platforms.

The following considerations motivate this research. A broad range of collaborative environments, each facilitating a different kind of collaboration, can realize computer-supported collaborative design. However, choosing a particular technology impacts the style of collaboration and the potential for each environment (Simoff and Maher, 2000). Moreover, collaboration is listed as one of the key factor in collective collocated design team activities (Buisine et al., 2012b). Furthermore, we share the position of Claudia Eckert and Thomas Howard during last Design Conference debate (Design Conference, 2014), for more efforts in understanding what designers do, before proposing new design methods. Finally, if we add that, according to the Collective Intelligence theory (Woolley et al., 2010), the collaboration style influences design teams' performances, their collaborative behaviors have to be clearly understood.

Since ICED 2011, we defended the hypothesis that interactive surfaces can greatly increase the effectiveness of the early preliminary design phase by increasing collaboration and communication (Kendira et al., 2011). So, it is pivotal to understand the eventual impact of such interactive surfaces on collaboration.

The emerging standard among interactive surfaces is represented by what we call HOVER (HORizontal - VERtical) platforms (Guerra, 2016): multimodal platforms, composed of interconnected vertical and horizontal interactive surfaces.

In Section 2 we describe early, collocated, collective preliminary design activities to define the research context. We focus on the idea generation phase as a common moment among different design methods. We present as well the TATIN-PIC HOVER platform as a support for such activities. Next, Section 3 and 4 present our investigations for understanding the impact of HOVER platforms on collaborative behaviors during the idea generation phase in collocated, collective, early preliminary design activities. Section 3 describe the experimental setting, and section 4 the results. In Section 5 we discuss the results and we conclude by providing perspectives for future work.

2 HOVER PLATFORMS: COLLABORATIVE INTERACTIVE SPACE DEDICATED TO EARLY PRELIMINARY DESIGN ACTIVITIES

2.1 Early Collocated Collective Preliminary Design Activities

The early phases of the design process are characterized by an ill-defined definition of the problem and the solution (Cross, 1982; French, 1999) . Being in the first phases of the design process, both the problems and the possible solutions are still ill-defined (Blessing, 2003); the co-construction and co-evolution of problems and solutions are yet to be done (Dorst and Cross, 2001; Guerra et al., 2013b; Wiltschnig et al., 2013). Design teams during these early phases adopt an effectual (Sarasvathy, 2001) and enactive (Guerra, 2016) cognitive posture to deal with the constrictions and intricacies of these stages.

The curve in Figure 1 serves as a testimony to the importance of the early preliminary design. As it shows, early preliminary phases have the highest potential to land strategic innovative solutions (fucsia), because the irreversible decisions are yet to be taken (Buet, 2014). With an ill-defined knowledge of the problem space, a high implication of management (orange) is required to structure the future design process planning and resources allocation (Cantamessa et al., 2007). Changing a product or service (usually to correct wrong decisions) in the latter phases of the design process (red dotted) can be painfully expensive (Clark, 2006). Moreover, as a project moves forward in time the level of influence of design choices will decrease (green dotted). A good project plan calls for high initial effort in the early design phases for a more effective and efficient design process.

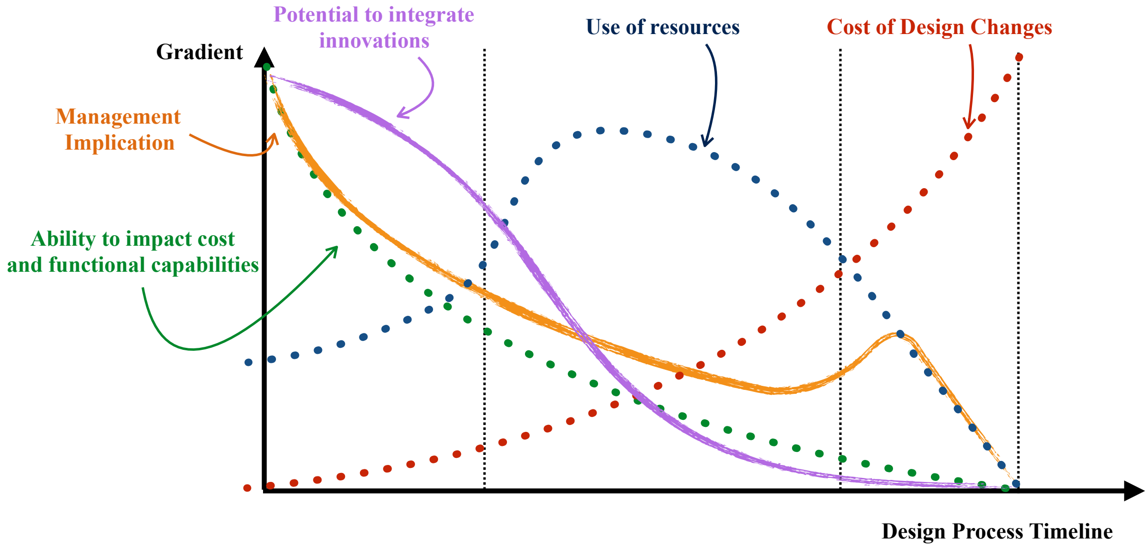

Figure 1. A Multidimensional characterization of the design process according time (Guerra, 2016)

To deal with the constraints and complexities of the early preliminary phases of the design process, Design Thinking (DT) has emerged as a strategic approach. DT has been introduced by Stanford Professors Rolf Faste and David Kelley who later used it commercially as a product design strategy, founding IDEO, a world-renowned design-thinking company for its highly refined design methodology (Brown, 2009). The impact of design thinking is exemplified by hundreds of university programs that teach and research this discipline.

The design thinking methods used in early preliminary design activities, frame the design problems, define user requirements, co-construct process that leads to a satisficing solution (Simon, 1956), and maximize design teams' exploration of the problems-solutions space (Brown, 2009; Lindberg et al., 2011). This exploration follows an interplay of divergent and convergent thinking, shifting from creativity to focus and vice versa (Cross, 2008).

One of design-thinking preeminent features is represented by multidisciplinary teams' collaborative meetings, which are essential for tackling complex challenges. As Tim Brown, CEO and president of IDEO, states: '*Better together is a fundamental business strategy* ' (Brown, 2008). During these meetings, members of multidisciplinary teams tackle the complexity of early design phases by collaborating with each other.

These activities take place in collocated meetings: situations where team members are at the same time, in the same physical location. Olson and Olson (Olson and Olson, 2000, p. 142) define collocated as ' *When team members are at the same physical location, either temporarily because they have traveled to a common location or permanently because they are at a common site.'* By the same location, we mean that co-workers can get to each other's' workspace with a short walk (i.e. maximum 30 meters as described by Allen (Allen, 1984) and (Galegher et al., 1990) ".

These collaborative co-located meetings happen in specific environments (Olson et al., 2002), like project rooms, also called 'Obeya' in Lean Management (Morgan and Liker, 2006), where co-workers have mutual access to shared artifacts (display, files, models, whatever they are using in their work) (Olson and Olson, 2000). As Figure 2 shows, tables, walls, and whiteboards are covered with information in the form of Post-it notes, photographs, sketches, and printouts. These are used to visualize, organize and structure heterogeneous content to provide teams with a deeper, shared insight into a problem, using specific design methods.

These design methods start with a phase of idea generation. To give some examples, user generates tasks that are later rearranged in a flowchart in project planning activity, or they generate cause and effects that are used to perform a causal analysis using a bow-tie diagram. In the idea generation stage, also identified with the term common objectification (Weber, 2000), users interact with each other. They interact through bodily interaction, verbal and gestural communication, but also through the use of intermediary objects (Boujut and Blanco, 2003). These intermediary objects exist in two forms, product representations (sketches, prototypes, Post-its) (Darses and Falzon, 1996) and product representations (scenario, tasks, planning, ...) (Gidel et al., 2005). A part of these interactions are mediated by supportive tools (e.g. writing an idea on a Post-it to express it to someone else); this introduces the notion of technical mediation (Preston, 1998). A social system whose interactions are technically mediated is referred as a socio-technical system (Akrich, 1991).

Figure 2. An example of environment used during design-thinking collocated early preliminary design activities.

Kvan identifies three forms of collaborative behaviors in socio-technical systems: exclusive, mutual, and dictator (Kvan, 2000), building upon the work of (Maher et al., 1996). Mutual collaboration happens when participants '*are busy working with each other*', exclusive collaboration happens when participants '*work on separate parts of the problem, negotiating occasionally by asking advice from the other'*, and dictator collaboration happens when participants '*decide who is the leader and that person leads the process*'. These different forms of interaction influence design teams' collaborative behaviors. Hence, the mediation of the support (be it a pen and a Post-it or a HOVER platform) plays an important role in facilitating or hindering them. For this reason, the impact of the media has to be clearly understood.

2.2 HOVER platforms

Researching and developing interactive surfaces to facilitate early preliminary design activities would significantly impact design-thinking process. The features of early preliminary design activities have influenced the form factor of the HOVER platform on several levels such as size, orientation, interaction modalities (Jones, 2012). Academic literature contains some heterogeneous examples of HOVER platforms (Guerra, 2016). However, most of them are prototypes; as a consequence, few commercial solutions are available. In order to perform research on HOVER platforms we had to build our own, that has been used as a case study. Our HOVER platform is called TATIN-PIC (from the French "Table Tactile Interactive – Plateforme Intelligente de Conception"). The TATIN-PIC HOVER platform, in Figure 2 has been developed at the Université de Technologie de Compiègne during a three years project. Like the others, HOVER platforms, it is composed by a horizontal and a vertical interactive surface, whence the denomination of HORziontal VERtical platforms. Such platform and its evolution has been thoughtfully presented in previous Design society conference (Guerra et al., 2013a, 2014, 2015; Kendira et al., 2011).

Providing a group with a tabletop can fulfill diverging activities (e.g. creativity) while a vertical board can satisfy converging activities (e.g. decision-making). The interactive tabletop (i.e. the horizontal surface) serves as the platform on which six to eight participants generate the majority of the contents during the common objectification process, i.e. creating Post-its. Previous research (Kruger et al., 2004) has shown that due to the lack of any visual impairment to visual and verbal communication among users, interactive tabletops contribute to face-to-face collaboration (Rogers and Lindley, 2004). This interaction promotes divergent thinking (Jones et al., 2012).

The interactive board (i.e. the vertical surface) provides a complementary role; the form factors at play here nurture shoulder-to-shoulder and presenter-audience-style interaction. This interaction promotes

convergent thinking (Potvin et al., 2012). This is quite intuitive if we think that normally people are around a table when they discuss with each other, when they write, sketch, compose music, etc. On the contrary when a common point of view is needed vertical boards are preferred (e.g. a teacher teaching to a class, a presentation during a meeting, etc.). In conclusion, a platform meant to support divergent and convergent thinking should be composed of an interconnected vertical and a horizontal surface,
It is also important to note that HOVER platforms are neither table-centric nor board-centric; the two surfaces constitute a unique workspace where users are free to work.

Figure 3. The TATIN-PIC platform, as an example of HOVER platform composed of a Horizontal and vertical interactive surface

Regarding multi-touch technology, different solutions are available. For the table board the choice was a Laser Light Plane (LLP) illumination technique (Jones, 2012). With proper adjustment and laser positioning, this creates a plane laser beam that is a millimeter above the surface. Therefore, any contact with the surface also breaks this laser light plane, causing infrared light to scatter and to be detected by the cameras with infrared filters. For the vertical board the input technology is a proprietary infrared overlay frame, which uses embedded infrared LEDs and sensors to detect touch points. Though the specifications claim that the infrared overlay frame is built to handle 32 points of simultaneous interaction, in reality, it can handle even more.

3 EVALUATING COLLABORATION ON TATIN-PIC PLATFORMS

In academic literature, the idea generation phase has emerged as the exemplary scenario and benchmark for the collocated collective early preliminary design phase activities that HOVER platforms can support (Geyer et al., 2011; Hilliges et al., 2007; Tse et al., 2008).
During two semester observations were conducted to compare the TATIN-PIC HOVER platform to traditional tools regarding collaborative behaviors of collocated collective group activities during early preliminary design phases. These observations were modeled after a similar set of experiments conducted in literature like the DigiTable project (Buisine et al., 2012a). This has been done to allow us to compare our findings with established work in literature. The protocol was designed to compare the results of idea generation activities conducted in the control condition, in a conventional project room with Post-its and pens, to idea generation sessions on the TATIN-PIC HOVER platform.
The protocol of the observation was to give to each group a list of 45 concepts (in the form of a text to be written on a post, hence 45 post-its to write), and then to assess the collaborative behaviors during the common objectification process. In other words, to measure:

- the throughput rate of production for each participant in each condition (number of post-it/time),
- the number of post-its written by each member of the team

These experiments included a total of 40 participants divided into 8 groups of 5 people. Groups A1, A2, C1, C2 in the control condition (i.e. pen-and-paper), groups B1, B2, D1, D2 in the experimental condition (i.e. on the TATIN-PIC HOVER platform).

The participants can be divided into two categories: 33 engineering students aged 20 to 26 years and 7 cooperative-education students aged from 20 to 39 years. They have been working together for the previous 3 weeks and have a medium knowledge of preliminary design methods. These two categories were spread as evenly as possible throughout all groups. All participants spoke French as a common language, and therefore the experiments were conducted in French. Contrary to the previous observations, the group did not experience both conditions. The choice to be either in control or experimental condition was randomized. The experiments lasted 1 hour and were conducted, for one afternoon. The afternoon was divided in two rounds. Two groups, one for each condition, working in parallel in the first round, a short break in between, and the second round with the remaining two other groups working in parallel as well. The experiments were filmed.

The setup, shown in Figure 4, consisted of project rooms according to a design thinking approach as described in Figure 2 of section 2.1. One was equipped with traditional paper tools, the other with the HOVER platform. These rooms were equipped with three cameras recording from three different perspectives in the control condition (left) and four cameras recording from four different perspectives in the experimental condition (right). In both conditions a microphone to record audio has been used.

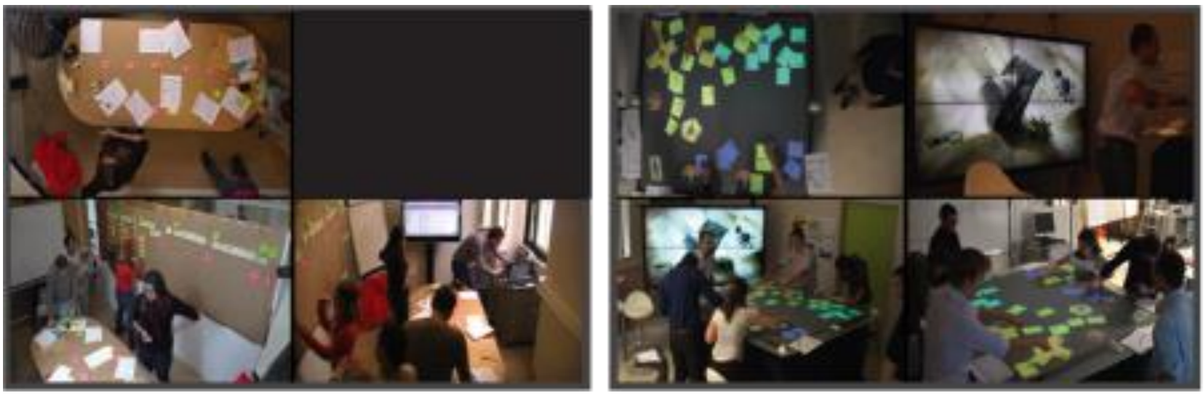

Figure 4. An example of environment used during design-thinking collocated early preliminary design activities.

4 RESULTS

We assessed technically mediated participants' collaborative behaviors during the common objectification phase from video recordings of the experiments. Similarly, to assess video extracts, the software ANVIL has been used. The results are reported in Table 1 and 2 in Appendix, which shows both the repartition of the Post-its and the throughput rate.

Table 1 and 2 shows that average throughput rate of control condition is faster than experimental condition. By calculating the average value of Control conditions (A1, A2, C1, C2) vs. Experimental conditions (B1, B2, D1, D2) we obtain a value of 1 post-it each 34,04 s for the control condition and a value of 1 post-it each 40,4825 for the experimental condition. Moreover, they show that in control condition the contribution to the common objectification process (i.e. writing down concepts on Post-its) is more unbalanced that experimental condition. In fact, while in both groups of experimental conditions, each team member participates in the process, in the control condition at least one member for the group does not participate at all. Moreover, the delta between the weakest and strongest contributor has a mean value of 6 in the experimental condition, while it has a delta with a mean value of 20 in the control condition (these values have been rounded to the nearest integer).

Table 1. Analysis of the Post-it throughput and distribution for users, in control and experimental condition of the four groups during the common objectification process in the idea generation phase in Session 1

GROUP / SUBJECT		Throughput (rounded to upper decimal) in Post-its per second		Repartition of Post-it for users (on a total of 45 concepts to write on a Post-it)
GROUP A1 CONTROL	T1	1 Post-it each	-	0
	T2	1 Post-it each	23.87 s	16
	T3	1 Post-it each	22.1 s	11
	T4	1 Post-it each	35.5 s	8
	T5	1 Post-it each	30 s	10
Average Group A1		1 Post-it each	33,83 s	9
GROUP B1 EXPERIMENTAL	T1	1 Post-it each	21.77 s	9
	T2	1 Post-it each	17.45 s	8
	T3	1 Post-it each	52.67 s	8
	T4	1 Post-it each	58.31 s	12
	T5	1 Post-it each	22.33 s	8
Average Group B1		1 Post-it each	34.51 s	9
GROUP C1 CONTROL	T1	1 Post-it each	-	0
	T2	1 Post-it each	-	0
	T3	1 Post-it each	-	0
	T4	1 Post-it each	30.71 s	24
	T5	1 Post-it each	42.04 s	21
Average Group C1		1 Post-it each	36.37 s	9
GROUP D1 EXPERIMENTAL	T1	1 Post-it each	30.12 s	8
	T2	1 Post-it each	59.14 s	7
	T3	1 Post-it each	52.43 s	14
	T4	1 Post-it each	36 s	7
	T5	1 Post-it each	42 s	9
Average Group D1		1 Post-it each	43.94 s	9

Table 2. Analysis of the Post-it throughput and distribution for users, in control and experimental condition of the four groups during the common objectification process in the idea generation phase in Session 2

GROUP / SUBJECT		Throughput (rounded to upper decimal) in Post-its per second		Repartition of Post-it for users (on a total of 45 concepts to write on a Post-it)
GROUP A2 CONTROL	T1	1 Post-it each	34.3 s	7
	T2	1 Post-it each	-	0
	T3	1 Post-it each	-	0
	T4	1 Post-it each	29 s	18
	T5	1 Post-it each	31.2 s	15
Average Group A2		1 Post-it each	31.5	9
GROUP B2 EXPERIMENTAL	T1	1 Post-it each	44.12 s	11
	T2	1 Post-it each	26,47 s	7
	T3	1 Post-it each	38.36 s	10
	T4	1 Post-it each	47.2 s	12
	T5	1 Post-it each	56.21 s	6
Average Group B1		1 Post-it each	42.47 s	9
GROUP C2 CONTROL	T1	1 Post-it each	-	0
	T2	1 Post-it each	39.3	22
	T3	1 Post-it each	29.65-	23
	T4	1 Post-it each	- s	0
	T5	1 Post-it each	- s	0
Average Group C2		1 Post-it each	34.48s	9
GROUP D2 EXPERIMENTAL	T1	1 Post-it each	31.23 s	7
	T2	1 Post-it each	46.54 s	9
	T3	1 Post-it each	34.1 s	13
	T4	1 Post-it each	36 s	8
	T5	1 Post-it each	57.2 s	8
Average Group D2		1 Post-it each	41,01 s	9

5 CONCLUSIONS

These experiments let us investigate the impact of HOVER platforms on design teams' collaborative behaviors during the idea generation phase in collocated collective early preliminary design activities. Some limits of such experimental approach have been described carefully in (Guerra et al., 2016) This paper contributes to knowledge by providing evidences that HOVER platforms impact the collaborative behaviors of groups involved in collocated collective early preliminary design activities during idea generation phase. Collaborative behaviors were structured around two forms of collaborative behaviors, among the three described by (Kvan, 2000; Maher et al., 1996): exclusive and mutual collaboration. Results show that HOVER platforms (in this specific case the TATIN-PIC platform) change group members' collaborative behaviors, by promoting a mutual collaboration. The difference is particularly evident when considering, for example Group C control in Table 1 and 2 against Group A or Group D. While in groups C only two people did the work of common objectification, in the fourth experimental groups every single team member was engaged in the task. The measurement of the delta between the weakest and strongest contributor (6 vs. 20) confirms that the mutual collaboration produced a more equitable production of the work. However, this advantage is hindered by a worse throughput rate in the experimental condition, probably caused by a lower efficiency of the virtual keyboard on the experimental setting as discussed in (Jones, 2012; Guerra et al., 2015). We can conclude that users collaborate more equitably when HOVER platforms mediate their activity. This happens for the common objectification process (i.e. writing Post-its). If we link these findings with the Collective Intelligence theory (Woolley et al., 2010), stating that equitable interactions improve a group collective intelligence, we may hypothesize that group mediated by HOVER platforms would present a Collective Intelligence higher than other groups. This opens an interesting research's path, i.e. the assessment of Collective Intelligence on group mediated by HOVER platforms. We plan to incrementally toughen our experimental protocol to corroborate our findings repeat similar experiments understand, under a prescriptive perspective, the impact of HOVER platforms on more key factors of collocated collective early preliminary design activities.

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