The ideation gap: hybrid tools, design flow and practice

Tomás Dorta, School of Industrial Design, Université de Montréal, Bureau 1011 C.P. 6128, Succursale Centre-Ville, Montréal, Quebec H3C 3J7, Canada
Edgar Pérez and *Annemarie Lesage,* School of Industrial Design, Université de Montréal, CP 6128, Succ. Centre-Ville, Montréal, Qc H3C 3J7 Canada

Ideation is still done with traditional analog manual tools because current computer interfaces are inconsistent with the needs of designers. The Hybrid Ideation Space (HIS) was developed to respond to this lack by augmenting analog tools with digital capabilities respecting the designer's needs for uninterrupted reflective conversation with the representation that should, in turn, enrich ideation. To assess ideation, we have developed the notion of Design Flow, which considers the pattern of multiple dimensions involved in ideation. Design practitioners testing the HIS showed that ideation was well supported in synchronous, individual or team settings.

Keywords: conceptual design, design flow, design cognition, reflective practice, design tools

You may have heard the 1950 Montand–Signoret skit called *Le Télégramme*. Yves Montand calls in a passionate love-note while the telegram operator, with mechanical placidity, spells out every word, capturing the message but crushing its spirit. A bittersweet humor is set forth by the absurd and incongruous meeting of the lover's and the operator's intentions. Unfortunately, this is not unlike the relationship designers sometimes have with technology. The discrepancy between the creative impulse and the input needed to activate digital commands often leaves the designer bound to a process that steers him away from design thinking.

In design, the ideation gap is the void of relevant digital support when it comes to generating new ideas. The Hybrid Ideation Space (HIS) was developed in response to this situation with the intention of augmenting analog tools and, in turn, improving the ideation process. To assess ideation, we have devised a method based on the new notion of Design Flow. This paper documents what we observed when we put the HIS to the test of professional practice, studying a few professional industrial and interior designers using the HIS to do the ideation of one of their real projects, in individual and team settings. In a previous comparative study involving industrial design students

Corresponding author:
Tomás Dorta
tomas.dorta@umontreal.ca

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(Dorta, 2007b), it was observed that the HIS did in fact support ideation better than CAD tools do. For this research, we opted to do deeper qualitative observations of each participant's experience, treating them as individual case studies. The participants readily volunteered their impressions on how the HIS compares with their personal practice, allowing us to collect some comparative data, although this was not instrumented as a comparative study. On top of evaluating the ideation process in this new design tool, we wanted to see how the HIS supports ideation in *actual practice* in order to keep our research grounded in the reality of professional needs.

The HIS maintains the intuitiveness and ambiguity needed to generate ideas. It allows users to sketch and make models all around them in real time and in scale using a digital tablet and an immersive projection device. The HIS adds to traditional sketch and models the advantages of a virtual environment, which provides a sense of immersion and presence.

In the process of assessing the HIS, we developed a new evaluation tool to look at the ideation stage: the notion of Design Flow. Current approaches in Human Computer Interaction (HCI) base their evaluation of digital design tools on usability tests concerned with task execution. The notion of flow (Csikszentmihalyi and Csikszentmihalyi, 1988) studied in other fields can become a pertinent notion to evaluate design tools, this time focusing on the engagement of the designer as it unfolds during ideation. The theory of flow centers on the autotelic experience, or intrinsically rewarding activity. To achieve this, a balance is required between the challenge faced and the person's skills. If the complexity of the activity increases, the flow can be kept by developing new skills to meet the new challenges.

In this study, the HIS has shown itself to be well adjusted for idea generation in synchronous, individual or team setting of industrial and interior design practitioners, supporting fluid and ambiguous representations. Furthermore, the notion of Design Flow seems to accurately account for the complex process of ideation and could become a method to evaluate digital and even analog design tools.

1 The detours of technology

Technology is an invaluable partner of the designer, mostly in the tasks of representing already identified concepts. To this day, ideation often happens near an idled computer by sketching or creating physical models with malleable materials as it has been done since the Renaissance. During this period, Brunelleschi and Alberti proposed perspective as a design and representation tool to capture form. Not until the XXth century has it become an exploration device and a mean to present projects (Porter, 1979). On the other hand, building scale models was a way to communicate with clients and construction (Moon, 2005). The tandem of physical models and two-dimensional drawings (plans and perspectives) as tools for representation, has defined architecture as a profession. In the last century, the axonometric view was added to the palette used in design ideation and communication.

Computers have brought faster ways of drawing plans, evolving towards detailed and accurate representations. This suits the later stages of the design process but leaves designers no choice for ideation than to adapt to interfaces and three-dimensional CAD that have been basically built for other disciplines. Computers have managed to support ideation in literature and music, which are more linear processes. The spatial and three-dimensional qualities of design have not widely been served by flexible and intuitive interfaces necessary for ideation. In the design process, computers have become, in fact, instruments of rhetoric left to represent anew already designed ideas.

2 *Ideation: representational conversations and cognitive artifacts*

By ideation we mean the initial idea generation at the onset of the conception of a design solution. More specifically, we are interested in the activity where by designers are exteriorizing their internal mental images, engaging in a conversation of sort with themselves, as opposed to asynchronic collaboration with third party designers or clients.

Designers need qualitative and imprecise external visualizations to interact with their mental images. And they need to be in continuous interaction with them to make design decisions (Visser, 2006). Making sketches and physical models is an interaction, a conversation. Designers see more in these representations then they put in when they make them (Schön, 1983). Designers work with incomplete information, making assumptions and provisional decisions that need to be revisited and reviewed. Imprecision (flexibility), ambiguity (alternative meanings) and abstraction (simplification) characterize the relationship between the actual and the possible solutions (Stacey and Eckert, 2003).

In these reflective representational conversations, designers frame and reframe problems producing new discoveries which call for new *reflection-in-action*. The process goes through appreciation, action, and re-appreciation. In addition, designers' actions also produce unexpected results suggesting new meanings (back-talks). Tools that permit back-talks, graphical and physical, can help by stimulating reflection, engaging conversation and thus achieving a better ideation (Schön, 1983). The construction of internal or external representations with these kinds of materials and tools is considered cognitive artifacts of design (Visser, 2006). When the designer does not have the experience to mentally visualize and resolve design problems, or when the problem is too complex, these cognitive artifacts are essentials to the ideation process.

Ideation in collaborative design team demands cognitive artifacts adapted to different visualization abilities, and pre-acquired representational skills so as to use these artifacts actively and intuitively. The above can enable designers to take decisions *in situ* directly in front of their ideas, as *knowing-in-action* described by Schön (1987) and respond to the problem through improvisation by *reflection-in-action* (Schön, 1983).

2.1 Types of representations

The design process is an evolution of different kinds of representations (Goel, 1995). For each step, a specific type of representation is used for specific tasks. During the ideation stage, a first kind of representation composed of freehand sketches and rough physical models, serves designers, individually or synchronously within a team, to exteriorize and visualize their design intentions, or communicate them with themselves. Goldschmidt (1992) refers to these as idea-sketches. Later on during the process, designers employ a second type of representation, presentation-sketches (Goldschmidt, 1992), made out of digital three-dimensional models, drawings and images, to better communicate asynchronously to colleagues and clients the already designed proposals. At the end of the process, a third kind of representation composed of detailed technical drawings and rapid prototyping models is reached to communicate exact and definitive information to build the artifact. The last two kinds of representation are the results of a will to communicate, which is a passive design task (Marshall, 1992).

3 Computers and ideation

Computer interaction requests specific data that often precedes the designer's own clarity about a budding concept, sparing no consideration for his need for uncertainties and expectations (Lebahar, 1983). The mediation of menus and commands is distracting and often carries so many pre-conceptions about how the design process should be that they affect decision-making. CAD systems handle wire-frame geometry with surface and solid modeling. The problem with these representations is that they appear exact, so their *perceptual interpretation space* is very narrow (Stacey and Eckert, 2003).

In order to support better design process, CAD systems are providing assembly modeling, constraint, feature representations and virtual reality. As consequence CAD systems have focused on detail requirements, management of assemblies, complex shape and integration with CAD–CAM applications, which makes them accessible mostly only to computer specialists. The complexity of these systems is partly due to the fact that they come from other disciplines and that they were conceived for other tasks, like engineering. They serve representation, but not ideation. Even with the use of generative parametric solutions (e.g., Marques and Woodbury, 2007) designers still cannot express their actual conceptual intentions.

Hybrid design environments mixing real and virtual objects have been proposed (Casaus et al., 1993; Asanowicz, 2002) based on the hypothesis that they can be a prime source of new ideas, an exchange of information while enhancing understanding. According to Asanowicz, the process of creation and perception in architecture proceeds between real and virtual, (analog and digital). And in other studies (e.g., Do, 2001), CAD is used for sketching during the early design stage combining sketches and digital tools but these end-up imitating or simulating real freehand sketches.

The use of traditional analog tools along with the capabilities of digital tools (Dorta, 2005, 2006) takes advantage of already acquired skills of designers and allows for a continuous exchange between modes, design information being handled by the computer or by hand according to what is relevant at any point. The key for successful hybrid design environments seems to be displacing the digital as the end-process and instead envisioning tools that build on analog practices, supporting them seamlessly with digital technology, while focusing on the user task: designing.

3.1 The Hybrid Ideation Space (HIS)

Several digital tools imitating traditional design tools transform the computer into a 'funnel' for design information treatment. The HIS evolved out of a will to stay away from *imitating* analog processes and instead, augment the advantages of traditional tools. Neither sketch-like rendering made from accurate primitives, nor perfect rapid prototypes share the same advantages of real freehand sketches or rough handmade physical models. On the other hand, computers can immerse us into representations while avoiding scale and proportion problems. What's more, performance capabilities can be used for real-time execution, where digital information is applied to transformations, undo, copy and paste capabilities, difficult to achieve with manual instruments.

Consequently, the HIS was intended as a cognitive artifact for ideation (Dorta, 2007a) stemming from hybrid techniques we developed earlier (Dorta, 2006; Dorta and Pérez, 2006). It puts the user inside the representation, using real sketches and three-dimensional models with manual and digital actions that can be output in rapid prototyping (RP). This system is based on a new spherical mirror model for input and output information: an inexpensive immersive projection procedure as output inspired by the Panoscope (Courchesne, 2000) and planetarium projection systems (Bourke, 2005) and a spherical image capturing method for scale models as input (Figure 1). This system allows the use of the Immersive Sketch (IS) and the Immersive Model Making (IMM) techniques.

3.1.1 Immersive sketching

A spherical graphical template constructed using a reflective sphere in a basic three-dimensional model, serves as reference for sketching. This template is

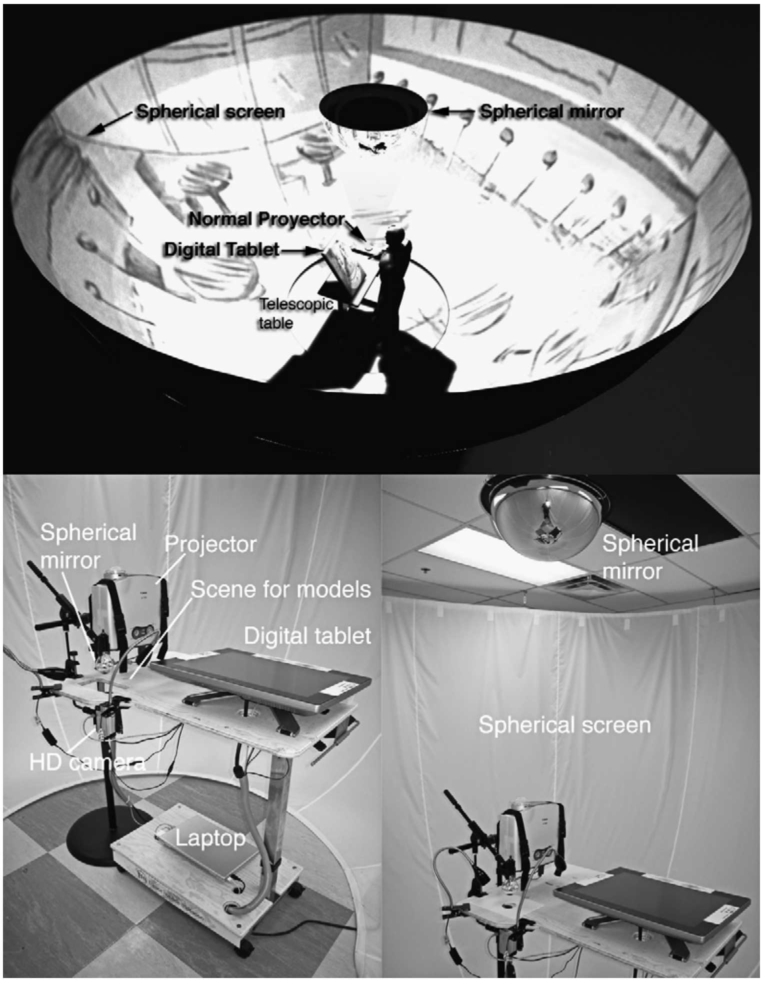


Figure 1 The Hybrid ideation space

used with a painter software (e.g., Corel Painter™) *via* a digital tablet (e.g., Wacom Interactive Pen Display™) as an input device connected to a laptop. The computer simultaneously uses the tablet and a projector displaying the image over a semi-spherical mirror mounted on the ceiling. This projected image is reflected over a semi-spherical screen. The projected spherical template is then corrected, and users can see all around them in a normal perspective, in real-time (Figure 2).

3.1.2 Immersive model making

In order to improve on the Hybrid Modeling technique (Dorta, 2005) and combine it with sketches, we use a HD video camera and a small mirror-ball as input. The camera captures a deformed spherical image reflected by the mirror-ball placed at eye level of the scaled physical or RP model. In this way, as users modify the scaled model, they can see an immersive normal scale projection of the (physical or RP) model around them. The real-time

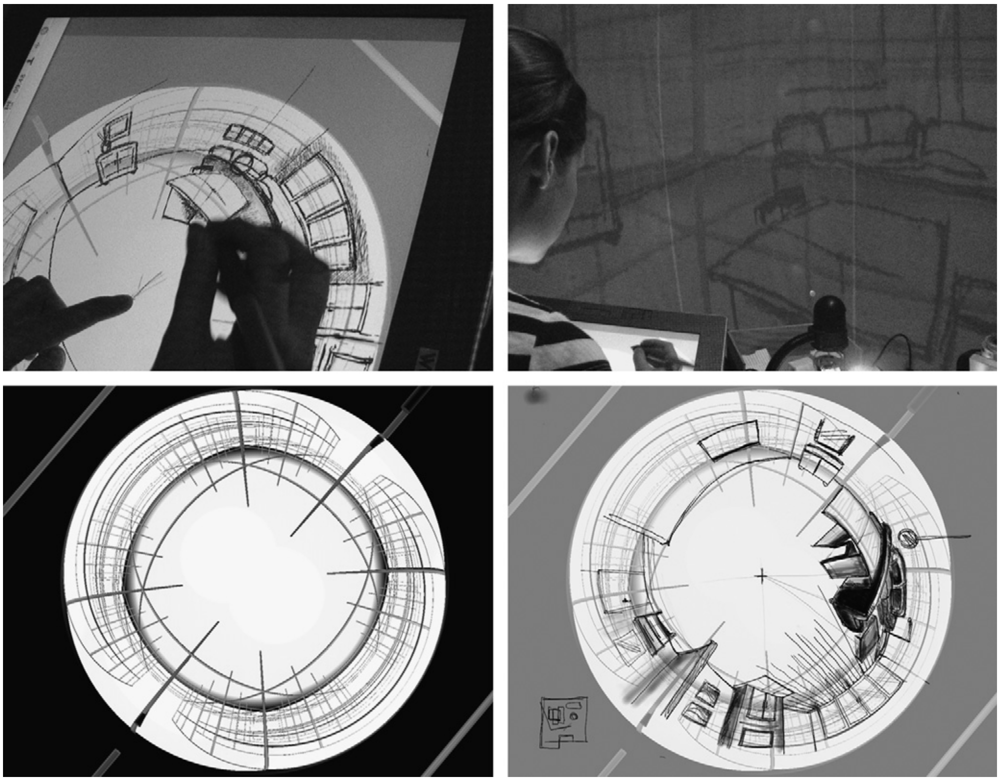


Figure 2 Immersive sketching in action — spherical graphical template — spherical sketch

monitored HD image is also displayed as a background layer in the painter software (Figure 3).

4 Assessing ideation

The main goals of this research are to evaluate if the HIS improves the quality of the ideation process, and to see how it supports professional ideation. We define the quality of ideation in terms of the richness of the process itself as opposed to ideation results, which are both subjective and fully formed at the end of the conceptual design phase, which is outside of the scope of this study. By rich ideation process we mean deeply engaging reflective conversation with the representation on long periods of time without even thinking about the tool they are manipulating.

In order to verify if and how the HIS enriches real professional ideation as well as it has student ideation, we use different evaluation methods, some we have adopted (workload assessment) and some that we have developed (Design Flow).

In previous studies (Dorta and Pérez, 2006) we evaluated the ideation process using the NASA Task Load Index (TLX), a cognitive usability tool. The data

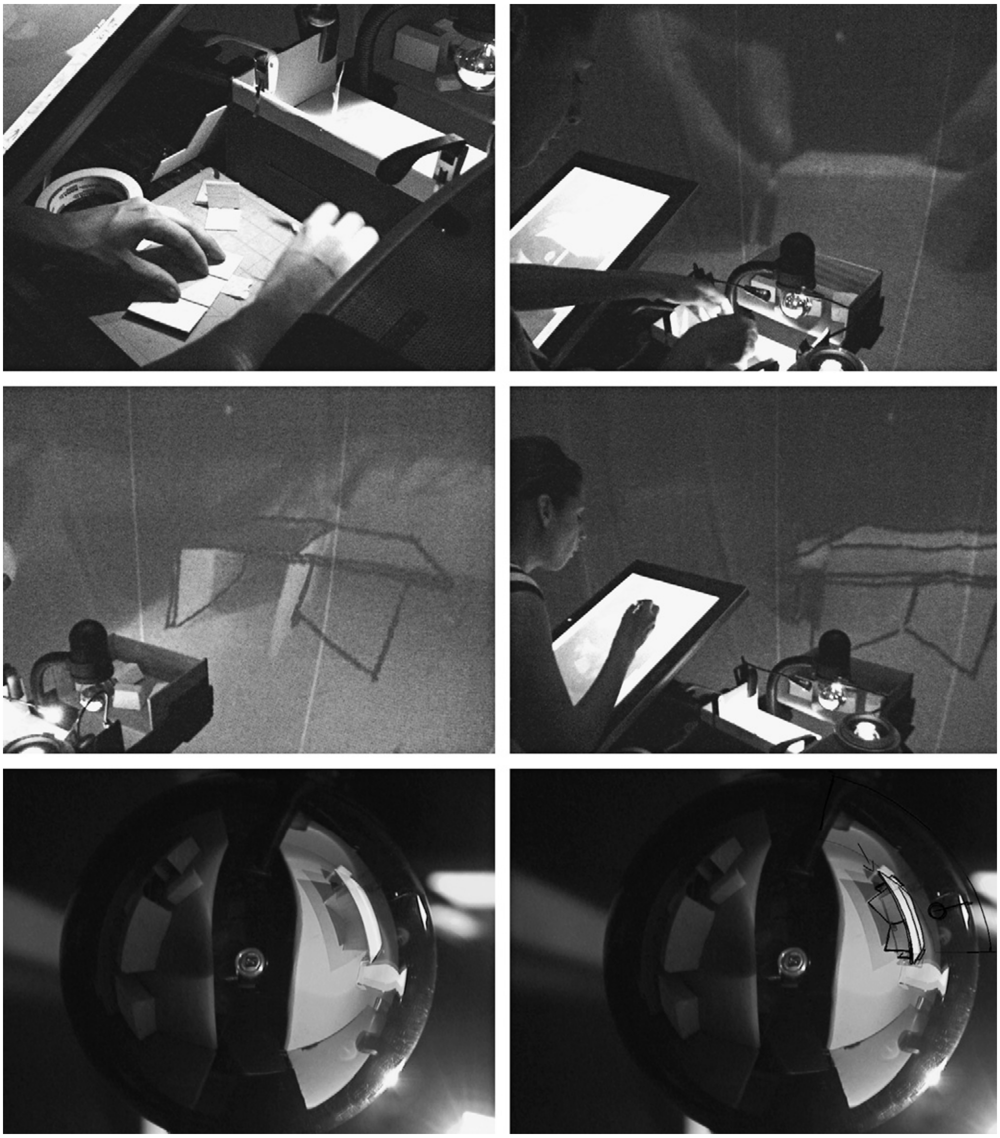


Figure 3 Immersive model making in action – captured image – spherical sketch over the image

obtained suffered from the limitations of current HCI approaches: it was mostly based on usability testing of task execution. HCI is concerned with how technology interfaces with users to maximize task performance (Zhang et al., 2002). Users' attitude, perceptions, acceptance and use of a technology is considered only in relation to the technology's efficiency and performance (Swanson, 1974; Lucas, 1975). Engineers (Shah et al., 2003a,b) have studied ideation in laboratory, seeking to measure effectiveness with four independent parameters: novelty, quality, variety, and quantity of ideas. This method is again more concerned with task performance than with how the designer experiences ideation. The focus on results often leads to making assumptions as to what the designer needs to actually generate new ideas. Treating ideation as a task rather then as a complex process is the first misleading step.

Ideation is, as previously stated, a reflective representational conversation, therefore we regard the relation between the designer and the tool working in synergy. This perspective highlights a gap in the evaluation of design tools. As we looked for an instrument that can provide better insight on how designers ideate and that can address creativity, we came upon Csikzentmihalyi's concept of *flow*, which we have expanded into Design Flow.

Csikszentmihalyi's (1965) concept of flow is a complex psychological state that describes a perceived optimal experience characterized by engagement in an activity with high involvement, concentration, enjoyment and intrinsic motivation. There are basic conditions required for the flow state to happen, clear goals, direct and immediate feedback, high degree of concentration and focus, above-average challenges matched by skills. Once these conditions are met and flow state is engaged, the subject experiences a sense of control, an altered sense of time, a loss of self-consciousness, and a merging of action and awareness. The flow state is determined by the balance between challenges and skills (Csikszentmihalyi and Csikszentmihalyi, 1988). The relation between perceived skills and challenges gives rise to eight possible dimensions (Massimini and Carli, 1986): apathy, anxiety, arousal, flow, control, boredom, relaxation and worry.

5 Methodology

To observe ideation in the HIS, data was collected on workload and Design Flow using four basic methods of protocol analysis cross-checking each other: by observing and recording the work sessions, encouraging participants to think-aloud; by asking participants to periodically identify their *state* on the flow graphs; by having them fill questionnaires, and by doing a semi-structured interview at the end of each session.

Protocol analysis, having them describe their reasoning in progress and later in interview, was motivated by our need to get inside the designer's experience. The transcripts of their discourse revealed patterns in their behaviors as well as suggest explanations for those patterns.

5.1 Workload

The NASA TLX questionnaire has been used in this study to monitor cognitive aspects of the relation between the designer and the design tool (HIS). It is a multi-dimensional rating procedure that assesses the demands imposed on the subject by the tool as well as the interaction of the subject with the task (Vidulich and Tsang, 1985).

5.2 Design Flow

Two basic methods have been devised to gather data on Design Flow: the Flow questionnaire, filled after each session, and quick monitoring of participant state every 10 min during the sessions. To complement these data, issues related to Design Flow were touched upon in interviews allowing the participants to substantiate some of their responses. Design Flow, being characterized by a pattern of multiple dimensions, is identified when analyzing the data.

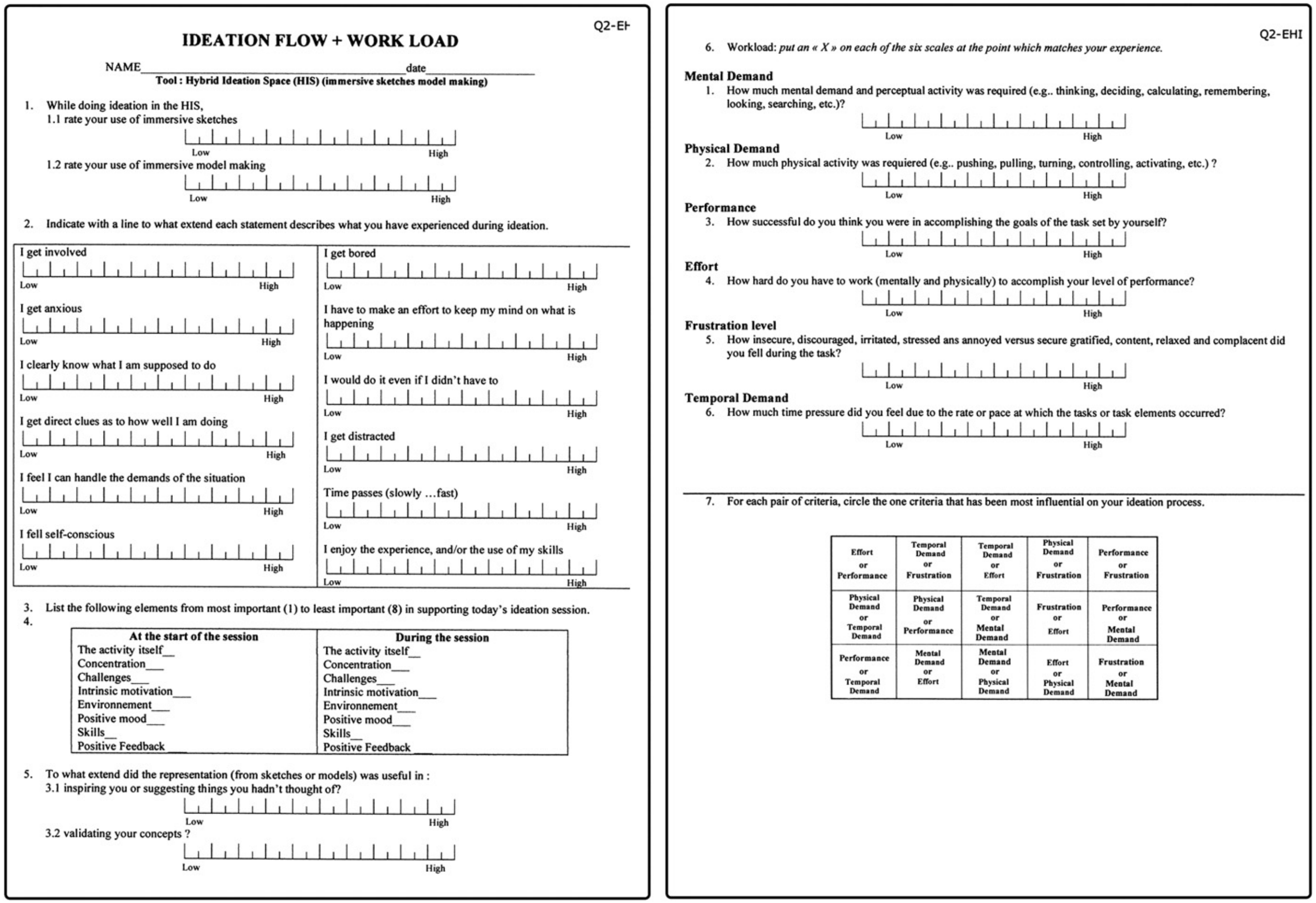
The Flow questionnaire was inspired by Csikszentmihalyi's questionnaire (1975) and by the Experience Sample Form (ESF) from Csikszentmihalyi and Larson (1987) which was combined with Mayers' twelve questions related to the flow experience (1978). The resulting questionnaire asks the participants first to evaluate the twelve dimensions (Mayers, 1978) of the flow using a 20-point scale, and secondly, to rank the eight dimensions of the flow according to how important each is in inducing flow and keeping it going (Figure 4). The questionnaires also covered questions on the use of Immersive Sketching (IS) and Immersive Model Making (IMM) in the HIS, and back-talking.

Flow is such a fleeting state; to complement the questionnaire, phenomenological data were also collected. Every 10 min, while in session, participants were asked to pinpoint their state from the eight dimensions of the *Flow wheel*, adapted from Massimini and Carli (1986) (Figure 5). That particular graphical version proved problematic in that it required participants to stop what they were doing to decode the graph, thus interrupting their flow.

After the first two sessions, improvements were made to the graph. The flow wheel became the *Flow panorama* (Figure 6) and was placed inside the HIS (tablet and spherical screen) in a way that required no effort to be consulted. The wheel required the participant to relate the amount of skills to challenge whereas the panorama allows quick choosing of a word state.

6 Sampling

In previous studies we used design students as research subjects. Student projects have limitations such as being hypothetic, having few real-life constraints and being driven by novices. For this study we decided to work with practitioners in order to put the HIS to a real-life test. Professionals have expertise and incentive to make the most of their ideation time. Their approach to a project is based on constraints like budget, clients and timeframe. Their way of working takes in consideration their job function as well as the technical complexity of their firm's design process from inception to finish product. And lastly, professionals are aware of the serious consequences of failure. Interior and industrial designers were invited to participate in this study because between them they work on both form and space.



Q2-EH

IDEATION FLOW + WORK LOAD

NAME____________________date__________

Tool : Hybrid Ideation Space (HIS) (immersive sketches model making)

1. While doing ideation in the HIS,
   1.1 rate your use of immersive sketches
   Low High
   1.2 rate your use of immersive model making
   Low High
2. Indicate with a line to what extend each statement describes what you have experienced during ideation.

I get involved Low High	I get bored Low High
I get anxious Low High	I have to make an effort to keep my mind on what is happening Low High
I clearly know what I am supposed to do Low High	I would do it even if I didn't have to Low High
I get direct clues as to how well I am doing Low High	I get distracted Low High
I feel I can handle the demands of the situation Low High	Time passes (slowly …fast) Low High
I fell self-conscious Low High	I enjoy the experience, and/or the use of my skills Low High

3. List the following elements from most important (1) to least important (8) in supporting today's ideation session.
4.

At the start of the session	During the session
The activity itself__	The activity itself__
Concentration___	Concentration___
Challenges___	Challenges___
Intrinsic motivation___	Intrinsic motivation___
Environnement___	Environnement___
Positive mood___	Positive mood___
Skills__	Skills__
Positive Feedback ___	Positive Feedback ___

5. To what extend did the representation (from sketches or models) was useful in :
   3.1 inspiring you or suggesting things you hadn't thought of?
   Low High
   3.2 validating your concepts ?
   Low High

Q2-EHI

6. Workload: *put an « X » on each of the six scales at the point which matches your experience.*

Mental Demand

1. How much mental demand and perceptual activity was required (e.g.. thinking, deciding, calculating, remembering, looking, searching, etc.)?
   Low High

Physical Demand

2. How much physical activity was requiered (e.g.. pushing, pulling, turning, controlling, activating, etc.) ?
   Low High

Performance

3. How successful do you think you were in accomplishing the goals of the task set by yourself?
   Low High

Effort

4. How hard do you have to work (mentally and physically) to accomplish your level of performance?
   Low High

Frustration level

5. How insecure, discouraged, irritated, stressed ans annoyed versus secure gratified, content, relaxed and complacent did you fell during the task?
   Low High

Temporal Demand

6. How much time pressure did you feel due to the rate or pace at which the tasks or task elements occurred?
   Low High

7. For each pair of criteria, circle the one criteria that has been most influential on your ideation process.

Effort or Performance	Temporal Demand or Frustration	Temporal Demand or Effort	Physical Demand or Frustration	Performance or Frustration
Physical Demand or Temporal Demand	Physical Demand or Performance	Temporal Demand or Mental Demand	Frustration or Effort	Performance or Mental Demand
Performance or Temporal Demand	Mental Demand or Effort	Mental Demand or Physical Demand	Effort or Physical Demand	Frustration or Mental Demand

Figure 4 Questionnaire

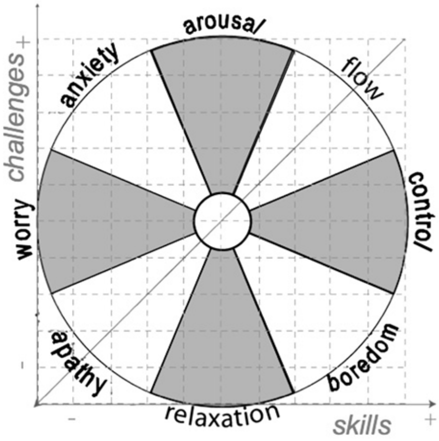


Figure 5 Flow wheel

Since we are considering ideation as a process and not only from the point of view of the results it produces, we felt it was important to understand the system in which each participant operated: their constraints (client requirements, time, and expectations tied to their roles), their personal design habits, and the design process in their team settings. The small sampling does not allow any kind of generalization but it does offer an initial portrait of what is at work. Still, this sampling covered the variables we felt were needed to be representative of active professional designers (Figure 7).

Participants had enough time to master the HIS, to complete their work, allowing us to do interviews and administer questionnaires. This study is based on three series of meetings done over a month with four participants: two were individually met, and two met as a team. The participants spent three 3-h periods working on their project (ideation phase) inside the HIS, the first period being for training.

6.1 Participants profiles

Designer A was a young freelance interior designer. In the HIS, she worked on an industrial design problem, namely a multi-purpose table. Designer B was a junior industrial designer, an expert technology user and a prolific draftsman. At his job, he spends most of his time getting concept in a visual form to communicate to others on the design team. Typically, he will do a series of quick sketches on paper and once he is clear enough on a concept, he will

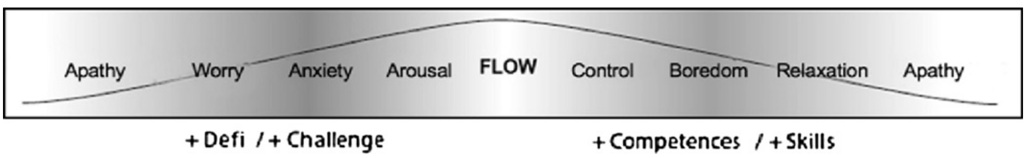


Figure 6 Flow panorama

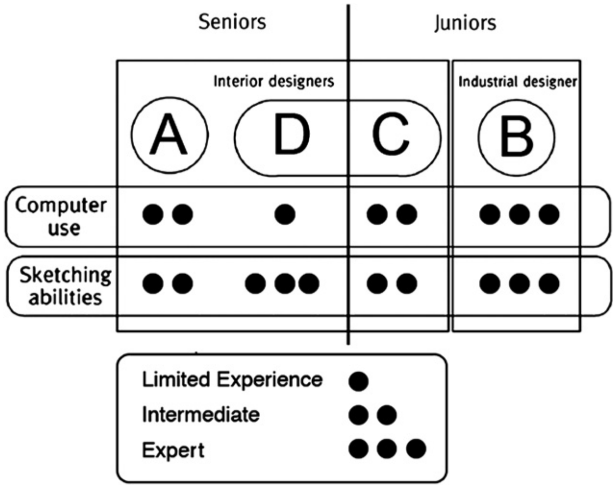


Figure 7 Outline of the variables for the participants

work out the details on CAD. In the HIS he worked on a train cockpit (exterior and interior). Subject B was expected to bring back work to the rest of his team. Designers, C and D, a team of interior, had to design a bar in a hotel lobby. Subject C, a junior designer, was accountable to one of the partners for the work done in the HIS. Subject D, a senior designer, was not actually assigned to this project but had time to volunteer for the study.

7 Results

For three out of four participants, the ideation sessions went well. In the first session, they were expectant and slightly disoriented. It took them more or less 10 min to get use to drawing in spherical perspective, and the full first session to develop a functional ease with the various techniques. In the second and third sessions, we gradually saw richer flow episodes. Designer A would surprise us with quick switch between techniques; all of them doodled and drew plans or elevations in the margins when needed. In the third session, they would often draw while staring at the immersive representation, instead of looking at the tablet. By the end, we had to kindly insist it was over.

Designer B, however, had a very different experience. As a computer power user, he was frustrated not to be able to drive the tool to perform highly precise representations. He was under pressure to come up with presentation-sketches he could share with his team in asynchronous collaboration, and to save time, he showed up with his ideation half-done on paper, ready to *translate* it on the tool, as he usually does with CAD. In a way, he was a perfect counter-example.

7.1 Design Flow

Concerning the twelve-point question related to the flow (Figure 8), participants gave high ratings to options *involved* (a), *clear goals* (c), *direct feedback* (d), *in charge* (e), *self-rewarding* (i), *altered sense of time* (k), *pleasure* (l) which

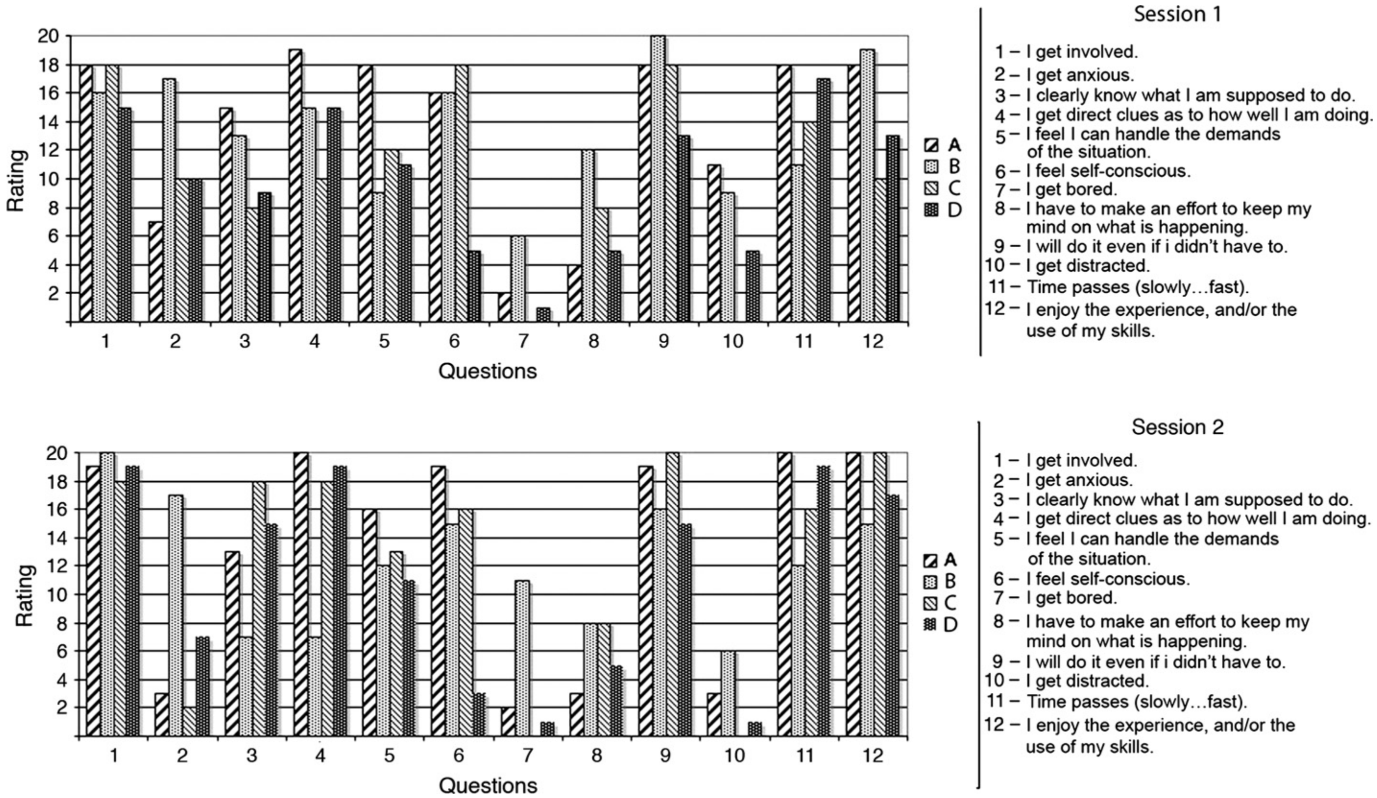


Figure 8 Twelve-point question related to the flow

are the conditions of Csikszentmihalyi's flow, and an indicator of Design Flow. It is interesting to note that designers A and D who did not depend on second opinions for making design decisions, experienced flow more easily during both sessions.

Figure 9 shows wheel flow chart results for designers A and B, while Figure 10 shows panorama results for designers C and D. The results for A, C, and D follow a pattern that seem to confirm that ideation happens beyond the boundaries of the single flow state. All participants have experienced flow showing a pattern of dimensions neighboring flow. We have observed that many of the spot-checks yielding *arousal* and *anxiety* were called in the thick of idea generating, while *control* and even *relaxation* came more often once an idea had been identified. Designer B's low rating of flow, according to our observations, is related to a stressful experience with fewer positive results. These data suggest that the attainment of the actual flow state is an indicator of a productive ideation.

The graphs of the eight dimensions of flow (Figure 11) are shown in chronological progression. Designers C and D's ratings have shifted over time from leaning towards uncomfortable states (worry, anxiety, and arousal) to comfortable ones (control and relaxation). This shift corresponds to a greater knowledge of the tool and to an increase in the quality of their ideation process.

In these graphs, the variation between designer C and D is of interest considering what has been observed. In the beginning, C was unsure and worried about not delivering quality results to her team. Overtime, anxiety, then arousal, remained high while she developed a sense of control. By the end, her flow state seemed to be associated to control and relaxation. Designer

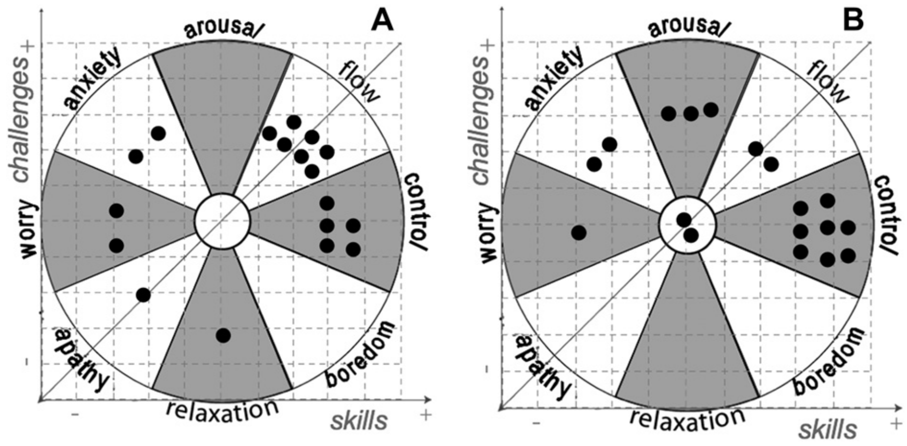


Figure 9 Flow wheel of designers A and B

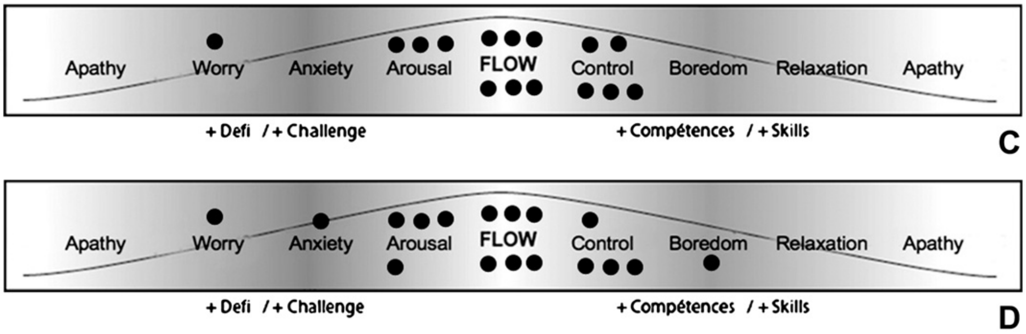


Figure 10 Flow panorama of designers C and D

D's development was different: his highest ratings throughout were arousal and flow. He was actively designing all along, peaking in an impressively productive ideation episode in the last half-session. These data suggest that ideation peaks somewhere between arousal and flow.

7.2 Workload

The results from workload assessment (NASA TLX) are useful to sort out the difference between frustration and anxiety inherent to the ideation process. In the detailed workload (Figure 12) we can observe that designer B's results are different than the others: his frustration, mental demand and temporal demand

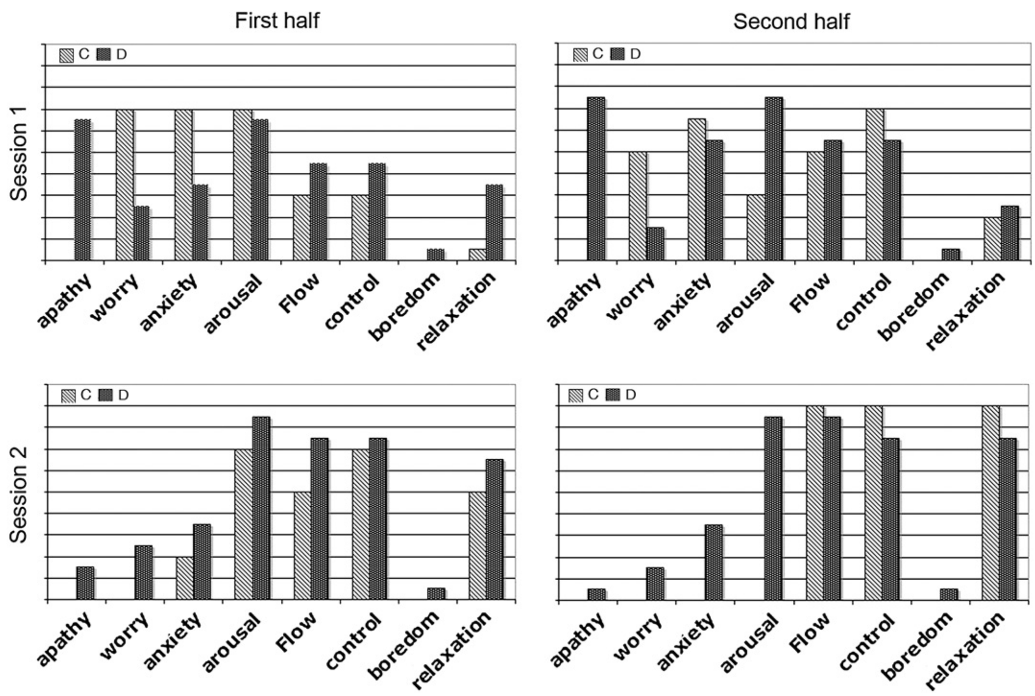


Figure 11 Eight dimensions during sessions

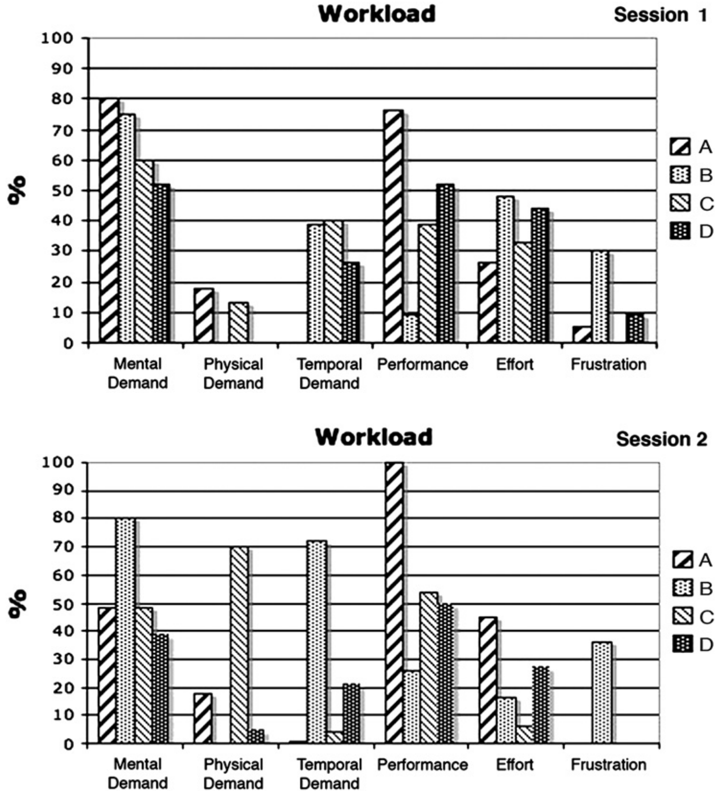


Figure 12 Detailed workload

are the highest while his performance, the lowest. And yet, when it comes to comparing the overall workload (Figure 13), his ratings are just slightly higher than the other three who experienced little frustration and more productive ideations. As shown above, ideation in the HIS is marked by anxiety and arousal, which can be interpreted as positively challenging without being frustrating.

7.3 Immersion and whole brain processing

We have witnessed participants being at first slightly disoriented than stimulated by the immersive quality of the HIS. The overwhelming nature of all around representation creates a perceptual shift where by information

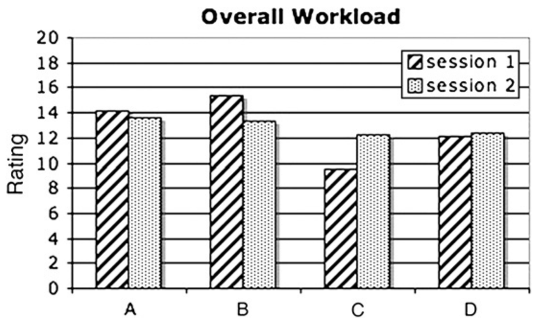


Figure 13 Overall workload

is processes not only by the orderly and conceptual left-brain but by both left and right hemispheres, in what is called whole brain activity. Whole brain activity is associated with creative thinking because it combines perceptual and analytical processes in fluid and dynamic exchanges (Meneely and Portillo, 2005).

It often takes special efforts to activate the right brain processes: the dominant left-brain needs to be bypassed by right-mode type information (Edwards, 1979). Right and left mode processes are respectively: non-verbal vs. verbal, synthetic vs. analytic, concrete vs. symbolic, analogical vs. abstract, non-temporal vs. temporal, non-rational vs. rational, spatial (seeing relationships) vs. digital (using numbers and individuals), intuitive vs. logical, conceptual vs. perceptual, and holistic vs. linear. If, on a cognitive level, immersion stimulates creative thinking, then the HIS can claim another quality in support of a rich ideation process.

8 Conclusion

In this research, we had set out to assess with a research protocol based on Design Flow, if the HIS improved, in the sense of enrich, the ideation process. Design Flow data suggest that the attainment of the actual flow state is an indicator of a productive ideation. Ideation peaks somewhere between arousal and flow and can be interpreted as positively challenging without being frustrating. The shift from anxious states to more controlled states corresponds to a greater knowledge of the tool and to the point where an acceptable concept has been identified.

With our evaluation method, if the results tell us that the Design Flow is high then the ideation process is richer, or running on full steam. We have observed that the Design Flow was high for three out of four participants. In think-aloud situations and semi-structured interviews, those three participants have told us that the ideation done in the HIS surpassed their expectations in comparison with their current practice. With the state of our research thus far, it seems that the HIS does enrich the ideation process, particularly stimulating for synchronous idea generation in individual and team setting. Keeping in mind that ideation is but the first step of the whole conception phase, it is beyond the reach of this research to comment of the impact of an improved ideation process on the quality of concepts brought to fruition.

Overall, the results affirm our understanding of Design Flow. Although Csikszentmihalyi's flow is often an indicator that the ideation delivered positive results, Design Flow accounts for the full measure of the ideation process, which involves episodes of anxiety, arousal and control as well as flow, at the very least. There is anxiety and arousal because the act of formulating new concepts is similar to a walk towards the unknown, and there is control because designers give form to new ideas with tools they master. The ideation is often an uncomfortable, yet most productive time. Once a solution was in sight, designers experience flow, then control and relaxation. When considered as a process, it makes sense that designers sustain uncomfortable periods when the skills and challenges are not match, chancing it in hope of positive outcomes. Design Flow designates this spectrum of states experienced during the ideation process.

9 *Future works*

Some of the information extracted from this first in-depth study with professionals will be laying the ground for future research on collaborative work in the HIS. Furthermore, we are continuing to develop the scope of design flow as an evaluation tool for ideation during the design process.

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References

Asanowicz, A (2002) Hybrid design environment, connecting the real and the virtual-design e-ducation, in *20th eCAADe Conference Proceedings*, Warsaw (Poland), pp 572–576

Bourke, P (2005) Spherical mirror: a new approach to hemispherical dome projection, in *Proceedings of the 3rd International Conference on Computer Graphics and Interactive Techniques in Australasia and South East Asia*, Dunedin, New Zealand, pp 281–284

Casaus, A, Fargas, J and Papuzian, P (1993) Hybrid design environments – a research program on creative collaboration and communication, in *eCAADe Conference Proceedings*, Eindhoven (The Netherlands), pp 2–11

Courchesne, L (2000). Panoscope 360, in *Proceedings of the Siggraph Conference*, New Orleans

Csikszentmihalyi, M (1965) Artistic problems and their solution: an exploration of creativity in the arts. Unpublished doctoral dissertation, University of Chicago

Csikszentmihalyi, M (1975) *Beyond boredom and anxiety* Jossey-Bass, San Francisco

Csikszentmihalyi, M and Larson, R (1987) Validity and reliability of the experience sampling method *Journal of Nervous and Mental Disease* Vol 175 pp 526–536

Csikszentmihalyi, M and Csikszentmihalyi, I (1988) *Optimal experience. Psychological studies of flow in consciousness* Cambridge University Press, New York

Do, E Y (2001) VR sketchpad in *Proceedings of the CAAD Futures Conference*, Computer Aided Architectural Design Futures, Eindhoven pp 161–172

Dorta, T (2005) Hybrid modeling: manual and digital media in the first steps of the design process in **J Duarte**, **G Ducla-Soares and Z Sampaïo** (eds) *Proceedings of Digital Design: The Quest for New Paradigms* eCAADe 2005, Lisbon, September 2005 pp 819–827

Dorta, T (2006) Vers la maîtrise du virtuel à travers le réel: un nouvel usage de l'informatique en design in *Proceedings of ACM Interaction humain machine: Nouveaux espaces d'interaction* IHM 2006, Montreal, April 2006, pp 131–138

Dorta, T (2007a) Augmented sketches and models: the hybrid ideation space as a cognitive artifact for conceptual design in **G De Paoli**, **K Zreik and R Beheshti** (eds) *Proceedings of Digital Thinking in Architecture, Civil Engineering, Archaeology, Urban Planning and Design: Finding the Ways* EuropIA 11, Montreal, September 2007 pp 251–264

Dorta, T (2007b) Ideation and design flow through the hybrid ideation space, in *Proceedings of Communication in the Visual Society* in **O Vásquez** (ed) *Proceedings of Communication in the Visual Society* SIGRADI 2007, Mexico D.F., October 2007 pp 418–422

Dorta, T and Pérez, E (2006) Immersive drafted virtual reality: a new approach for ideation within virtual reality in **G Luhan**, **P Anzalone**, **M Cabrinha and C Clarke** (eds) *Proceedings of Synthetic Landscapes* ACADIA 2006, Louisville, Kentucky, October 2006 pp 304–316

Edwards, B (1979) *Drawing on the right side of the brain* J.P. Tarcher, Inc., Los Angeles

Goel, V (1995) *Sketches of thought* MIT Press, Cambridge, MA

Goldschmidt, G (1992) Serial sketching: visual problem solving in designing *Cybernetics and Systems* Vol 23 pp 191–219

Lebahar, J C (1983) *Le dessin d'architecte. Simulation graphique et réduction d'incertitude* Editions Parenthèses, Roquevaire (France)

Lucas, H C (1975) Performance and the use of an information system *Management Science* Vol 8 No 21 pp 908–919

Marshall, T B (1992) The computer as graphic medium in conceptual design in *Proceedings of the ACADIA Conference, Computer Supported Design in Architecture, Mission, Method, Madness* ACADIA'92, pp 39–47

Massimini, F and Carli, M (1986) La selezione psicologica umana tra biologia e cultura in **F Massimini and P Inghilleri** (eds) *L'esperienza quotidiana* Franco Angeli, Milan

Mayers, P (1978) Flow in adolescence and its relation to the school experience. Unpublished doctoral dissertation, University of Chicago.

Marques, D and Woodbury, R (2007) Federation modeling: interactions in parametric design in **G De Paoli**, **K Zreik and R Beheshti** (eds) *Proceedings of Digital Thinking in Architecture, Civil Engineering, Archaeology, Urban Planning and Design: Finding the Ways* EuropIA 11, Montreal pp 305–322

Meneely, J and Portillo, M (July 2005) The adaptable mind in design: relating personality, cognitive style, and creative performance *Creativity Research Journal* Vol 17 No 2&3 pp 155–166

Moon, K (2005) *Modeling messages: the architect and the model* The Monacelli Press, New York

Porter, Tom (1979) *How architects visualize* Van Nostrand Reinhold, New York

Schön, D A (1983) *The reflective practitioner: how professionals think in action* Basic Books, New York

Schön, D A (1987) *Educating the reflective practitioner* Jossey-Bass, San Francisco

Stacey, M and Eckert, C (2003) Against ambiguity *Computer Supported Cooperative Work* Vol 12 No 2 pp 153–183

Shah, J J, Smith, S M and Vargas-Hernandez, N (2003a) Metrics for measuring ideation effectiveness *Design Studies* Vol 24 No 2 pp 111–134

Shah, J, Smith, M, Vargas-Hernandez, N, Gerkens, R and Wulan, M (2003b) Empirical studies of design ideation: alignment of design experiments with lab experiments, in *Proceedings of DETC 2003: ASME 2003 International Conference on Design Theory and Methodology*, Chicago, IL pp 1–10

Swanson, E B (1974) Management information systems: appreciation and involvement *Management Science* Vol 2 No 21 pp 178–188

Vidulich, M A and Tsang, P S (1985) Assessing subjective workload assessment: a comparison of SWAT and the NASA-bipolar methods in *Proceedings of the Human Factors Society 29th Annual Meeting* HFS, Santa Monica pp 71–75

Visser, W (2006) *The cognitive artifacts of designing* Lawrence Erlbaum Associates, Mahwah

Zhang, P, Benbasat, I, Carey, J, Davis, F, Galletta, D and Strong, D (2002) Human–computer interaction research in the MIS (management information systems) discipline *Communications of the AIS (Association for Information Systems)* Vol 20 No 9 pp 334–355