Design Flow 2.0, assessing experience during ideation with increased granularity: A proposed method

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This paper presents a new method to measure designers' experience during ideation, by using the technique of self-observation instrumented with a device and an original software. Based on the previous concept of Design Flow and the experience fluctuation model, the proposed procedure asks participants to rate their perceived challenge and skills at each moment of their ideation session while watching the video recording. The method aims at increasing granularity of Design Flow and reducing time of interviews, while retaining the ability to analyse the ideation activity as a whole, not just selected excerpts. After performing a validation test confirming its effectiveness, we conclude that this method is a fast and practical way to obtain continuous quantitative data about designers' experience that can be analysed and triangulated with other sources of data (e.g. verbal analysis).

Keywords: design research, design flow, psychology of design, evaluation, research methods

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Ideation (or conceptual design) is probably the most important phase of the design process. During ideation designers and other relevant stakeholders generate the ideas and make the decisions that will shape the final design concepts (Cross, 2006). At this stage, initial concepts, which are developed by graphic representations allow the designer to continue with the other phases of the design process, which will fully define the design object and eventually lead to its fabrication. Ideation is a complex activity at the core of the *design thinking*, in which dynamics between designers, their representations, and their tools are entangled together. For these reasons and also because *design thinking* is gaining popularity in disciplines other than design, such as business, IT, medicine, education (Dorst, 2008; Farrell & Hooker,

www.elsevier.com/locate/destud
0142-694X *Design Studies* ■■ (2016) ■■–■■
http://dx.doi.org/10.1016/j.destud.2016.08.002

2013), it is a common interest to better understand the ideation process and which factors can affect it.

Cognitive science has made attempts to study ideation, with highly controlled lab experiments concerning task execution, while design theory applied idea generation methods. These two kinds of approaches are needed to develop holistic models of design ideation (Shah & Vargas-Hernandez, 2003). In order to evaluate the effectiveness of ideation we could consider outcome-based approach focussing on the evaluation of the ideas generated or on the results of the ideation process (Shah & Vargas-Hernandez, 2003). However, we eschewed this approach because it is based on the designer's performance, including idea-count, sum-of-quality, average-quality, and good-idea-count, the last being the most recommended (Reinig, Briggs, & Nunamaker, 2007). Evaluating the results of the process of ideation is difficult because it depends on the designer's experience and capabilities, which brings us on a subjective territory. Also, by focussing on indicators such as idea fluency, flexibility, and originality we don't obtain any information about how the person yielded the ideas and we risk to simplify the complexity behind ideation as a creative activity. Glaveanu (2013), for example, propose a framework (the five A's model) accounting for the complexity of creativity rooted in sociocultural and ecological psychology as well as theories of the distributed mind. Hennessey and Amabile (2010, p. 571) state that 'creativity arises through a system of interrelated forces operating at multiple levels, often requiring interdisciplinary investigation'. Taking a systemic perspective, they propose a model that includes different levels such as neurological, cognitive and affective, personality, group dynamics, social environment, and culture.

Design as a process has been approached mainly through protocol analysis (Cross, 2006; Gero, Kan, & Pourmohamadi, 2011). In these works, design was studied by analysing designers' behaviours, their conversations, and their sketches. In a previous study Dorta, Pérez, and Lesage (2008), proposed to complement these approaches adding the designers' subjective experience as an additional dimension to describe ideation, through the concept of Design Flow. This concept of *flow* (Csikszentmihalyi, 1997) is an optimal psychological state occurring when people are deeply engaged in a task, associated with creativity, positive affect and high performance (Engeser & Schiepe-Tiska, 2012). Applying this method to real design sessions, Dorta et al. (2008) found that designers' experience changes throughout the process and they observed patterns of experience characterized by a state of stress before the generation of a relevant idea, an optimal state (called state of flow) during the proposal of the idea, and a 'sense of control' after the idea was accepted. Later, they found (Dorta, Lesage, Pérez, & Bastien, 2010) a statistically significant difference in designers'

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experience between the beginning, the middle, and the end of the ideation process, confirming the pattern previously observed. However, it is important to mention that the Design Flow method was very intrusive during ideation, because the participants have to interrupt their activity in order to identify their psychological state. They looked at the process of idea generation not only perceived by designers themselves, but they also looked at them *during* ideation activity. Since most of the design research tackled with design process leaving apart the designer as well as his context (Dorst, 2008), we are interesting in understanding through which process designers find their solutions for a design problem.

In this article we want to bring that method further by increasing data granularity and reducing its intrusiveness. The aim of the method proposed here is to track changes in designers' psychological states continuously *during* the ideation process. It calls upon the actors' subjectivity to capture their experience. Thus, this paper presents the method's fundamentals, details, its implementation modalities and describes two complementary procedures for its validation. The method proposed seeks to identify the structure of the emotional pattern experienced by designers while engaging in a collective activity of ideation. This study, and the method that ensues from it, targets several specific objectives:

- Develop a method aimed at identifying patterns of designers' experience *during* ideation with more granularity and less intrusiveness
- Allow triangulation with other kind of data, e.g. verbal analysis;
- Link this affective experience to the very particular moment when the ideas emerge.

1 The method's fundamentals

As mentioned above, the Design Flow method is based on the concept of flow. Originally developed by Csikszentmihalyi (1997), *flow* is a concept from positive psychology emerged from his early studies on play, creativity and artists' personality. His studies were initially aimed at understanding what factors motivate people to spend a lot of time doing activities without any external reward. Csikszentmihalyi identified five core dimensions of flow: 1) action-awareness merge (e.g. 'you are what you are doing'), 2) loss of self-awareness (e.g. 'you feel as though you don't exist'), 3) focus of attention (e.g. 'I don't seem to hear anything'), 4) sense of control (e.g. 'I feel immensely strong'), and 5) coherent, non-contradictory demands (e.g. 'you know exactly what you have to do'). When all these components are present, the overall experience becomes 'autotelic', that is rewarding in itself (Csikszentmihalyi, 1975). The 'flow experience' has been associated with positive affect (Landhäußer & Keller, 2012), better learning and sports (Elliot & Dweck, 2013), attracting the attention of several domains such as

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sport, learning, human–machine interaction, well-being, arts (Engeser, 2012).

Recently, in a more comprehensive definition, flow has been described as a positive valenced state occurring when a situation has been appraised as an optimal challenge during which an optimized physiological activation enable full concentration on task demands (Peifer, 2012).

As mentioned before, the concept of flow emerged by studying the experience of people fully concentrated on creative activities (e.g. artists) indicating an association between cognitive activity underlying creativity and flow state. In fact, even though people involved in these studies belonged to very different disciplines (architects, musicians, engineers, writers, athletes, etc.) a recurrent description of the flow experience was 'it is like designing or discovering something new' (Csikszentmihalyi, 1997). The facilitating effect of flow on creativity could be in part mediated by his positive valence. In a meta-analysis of 102 effect sizes Baas, De Dreu, and Nijstad (2008) conclude that creativity is enhanced most by positive mood states that are also activating and Cseh, Phillips, and Pearson (2015) found a relationship between positive affect and self-rated creativity. Also, designers are often confronted with high demanding tasks because of the wicked nature of design problems (Farrell & Hooker, 2013; Rittel & Webber, 1973). Assuming that designers usually appraise the opportunity to solve a design problem as an optimal challenge, flow state would enable them to maintaining deep concentration on the task over long periods of time without feeling fatigue. Thus, the flow state seems to enable cognitive, affective processes associated to creativity.

Most of the process-based studies about creativity focused on reasoning (heuristics) aiming at explaining the occurrence of new ideas. However, a pure rational and logical model of cognition does not consider other important factors that could enable or prevent creativity (Csikszentmihalyi, 1988). For example, *energistic factors* such as motives, emotions, desires, values, or preferences could influence the process and the outcome of our mental activity as much as logic does (Csikszentmihalyi, 1988). Moreover, these energistic factors can modulate attention (Kahneman, 1973) determining which and how information is processed (Pessoa, 2009; Vuilleumier, 2005). Thus, considering that attentional resources are not allocated only by logical rules, including energistics factors in the study of creative cognition become relevant.

In this perspective, the Design Flow method, based on the flow theory, enable researchers to identify flow as well as other psychological states during any designers' activity. Among the different ways of operationalize and measure flow, we adopted the Experience Fluctuation Model, also known as 'channel model' (Massimini & Carli, 1988). This model was developed in order to

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improve the four-quadrant model of Csikszentmihalyi and LeFevre (1989) by providing a more realistic and accurate classification system of subjective experience (Moneta, 2012). It partitions the world of experience in eight main states (arousal, flow, control, relaxation, boredom, apathy, worry, anxiety) according to the levels of perceived challenge and perceived skills during a specific activity. It also allows to estimate the intensity of such psychological states.

Massimini and Carli (1988) validated the Experience Fluctuation Model for the first time by studying the subjective experience in daily life. Using the Experience Sampling Method − ESM, they asked subjects, at random times, to answer a questionnaire on queries about their objective situation (e.g. location, social context, activities) and their subjective state (e.g. affect, activation, cognitive efficiency, motivation) at that moment. They also measured the level of perceived challenge and perceived skills in order to explore the relationship between the eight channels of subjective experience (independent variable) and other subjective and objective (dependent) variables. They results showed that in a *Flow* state (channel 2, defined by high challenge and high skills) people reported higher level of happiness, concentration, desire to do the activity, and involvement, confirming that the condition high challenge/high skills is a psychological state of high and effortless concentration, involvement, control of the situation, clear goals, intrinsic reward and positive affect; *Relaxation* (channel 4, defined by low challenge and high skills) is characterized by positive mood and intrinsic motivation, as well as low cognitive investment; The experience of *apathy* (channel 6, defined by low challenge and low skills) is characterized by the lowest levels of involvement, concentration and happiness; *Anxiety* (channel 8, defined by high challenge and low skills), individuals do not feel able to cope with the situation, and they report high cognitive investment, low happiness, low sense of control, and difficult concentration (Delle Fave, Massimini, & Bassi, 2011).

2 *Principles*

In the original version of the Experience Fluctuation Model, subjects were equipped with a beeper and were asked to evaluate their subjective experience several times during the day at the moment of a beep. The Experience Sampling Method (Massimini & Carli, 1988), enabled researchers to obtain data about their inner experience avoiding the memory flaws associated to retrospective evaluations. However, this procedure presents some problems when we want to measure designers' experience during design activities. First, the ESM, as well as one of the first versions of the Design Flow, forcedly interrupt the activity to ask people how they feel. In addition, since the goal was to measure experience during different activities along the day and for many weeks, data were scattered over time with long periods of

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'data void'. This issue prevents the possibility to relate specific events occurring during ideation (e.g. proposal of a new idea) to what happened before and after the event. Therefore, we developed a procedure to obtain continuous data about the psychological state of each designer along the whole ideation session. The method is based on the principles of a structured self-observation interview (Boubée, 2011). Regularly used in ergonomics applied also in design settings (Luczak & Springer, 2000), self-observation is a method in which a subject observes his own activity, often through a video recording, while rating specific factors of interest, conveying a subjective perspective as a complement to the other type of analyses done by researchers.

To assess the designers' experience, we decided to instrument the auto-confrontation with a material device and a user interface (see Section 2.1) in order to, firstly, quantify our analyses and, secondly, to facilitate the holding of these interviews, reducing them in time (self-observation can be a lengthy technique).

2.1 The device and the user interface

The material device is composed by a laptop along with a slider device (Figure 1) and a specific interface (Figure 2) showing the video of the session. The slider consists in a MIDI controller with USB connection, including many sliders and buttons. Here, only the playback control elements and two vertical sliders are used (Figure 1). The first allows the interviewee to manipulate the video, and the latter to rate his perception of challenge and skills during the ideation activity. As the video of the session is displayed, the participant must move the two cursors in real time, to describe the degree of perceived experience on these two dimensions (high or low). At any time, s/he can pause the video, rewind or fast forward.

The interface is as follows (Figure 2): it includes a large space for the video (a), a visualization of the position of the two sliders (b), and a timeline showing the evolution of the curves of challenge and skills ratings (c) (Figure 3).

2.2 Development of the self-observation interview

At the end of the ideation activity, the participant takes place in front of the screen, the console in his hands. A researcher stands next to him to explain the operation of the system, to give the instructions, and to ask questions. This interview is entirely recorded through a screenshot of the procedure, which allows researchers, afterwards to see the ratings of the participant in connection with the video of his activity and his verbalizations about his judgements, whether spontaneous or induced by the interviewer.

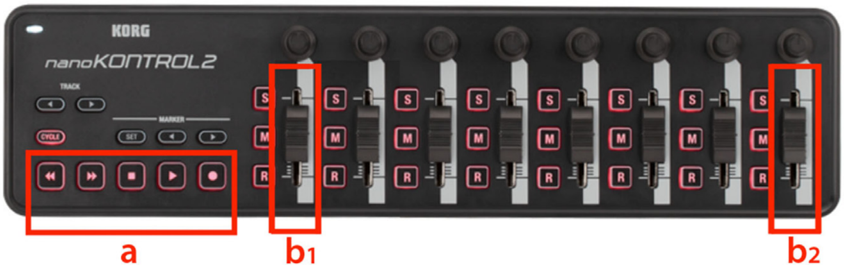

Figure 1 NanoKONTROL2 operating console: (a) the video control buttons: play, pause, rewind, etc.; (b1-2) the two cursors used, left Challenges (b1), right Skills (b2)

The instructions are as follows:

"*The purpose of this interview is to describe your emotional experience during the activity you have done this morning. We will ask you, if you agree, to re-immerse yourself into this activity and to evaluate what was the degree of challenge that was asked and the level of skills you have used. To help you, we will replay the video of this activity. We ask that you use the console in front of you. As you observe yourself working, you can rate with the two sliders the following two parameters*:

1. *The degree of challenge that the task requested at every moment, that is to say, if you felt that the demands from the task were strong or weak (external pressure) or if you felt any pressure (high or low) from the task (external to you).*
2. *The degree of skills you perceive having access to, at every moment, that is to say, the internal resources you can summoned, to what extend you felt you could, with confidence, move forward with the work (confidence in your skills – internal resources)*

We want to emphasize the fact that this is not about mechanically assessing the situation but to understand your emotional experience during ideation, e.g. your perceived skills and the perceived challenge you had to meet, from your point of view.

To illustrate the difference between the two parameters, let's place ourselves in the shoes of a tennis player equipped of his racket, of his past experience, of the right balance of sleep, coffee and preparation. Throughout the game, his level of confidence in his abilities will vary with each serve, with every ball return, sometimes surprised or destabilised (casting doubts about his ability to successfully meet this last stroke), and sometimes in full mastery (This is about your perceived skills – an internal parameter).

In addition, different strokes sent his way have different characteristics (this is the challenge – an external parameter). The evaluation of this parameter varies from weak to strong at every moment, depending on whether it is estimated that

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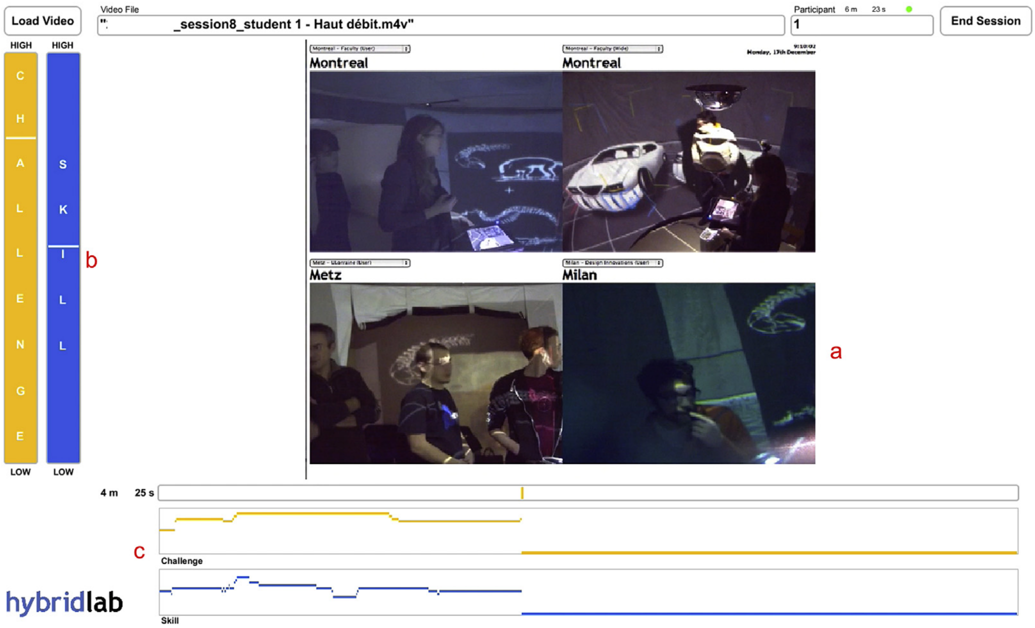

Figure 2 The interface: (a) video of the activity being analysed, (b) current state of both sliders, (c) timeline showing the evolution of data

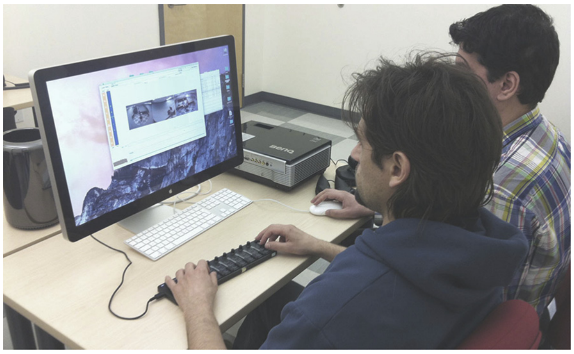

Figure 3 Self-observation interview, with a user handling the device

the ball will be easy or difficult to hit or if it falls outside the court (disengagement-application very easy), etc.

All skills and challenge combinations are possible. Therefore, to illustrate, in some cases the player will feel very confident to catch balls s/he considers difficult (high challenge – high skills), sometimes s/he will feel overwhelmed by a situation perceived difficult (high challenge – low skills), sometimes s/he will feel very confident in situations perceived to be simple (low challenge – high skills) and

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sometimes s/he will feel unskillful in situations s/he considers easy (low challenge, low capacity).

We now ask you, if you agree, to evaluate, like the tennis player, your challenges and skills in the co-design session you had this morning. We remind you that there is no right or wrong answer, but simply your emotional experience, as you re-interpret it in light of the video.

The interview is recorded. You can comment your assessments orally to qualify, supplement and explain them.

We thank you for your participation in this research."

2.3 The collected data

At the end of each interview, the device gives us two kinds of data that can be processed:

- A video of the interview process, on which we can see the interface (screenshot), the evolving graphs of challenge and skills, and the audio recording of the interview. This file is used for qualitative analyses.
- A data file in XML format including data in three columns: (a) the time-code for the video, in seconds; (b) the level of skills rated for each second, on a scale of 1–120; and (c) the level of challenge rated for each second on a scale of 1–120. This file is used for quantitative analysis and automated data processing.

While the video can be used to put in perspective the data collected (qualitative analysis), the file generated by the interface is processed in order to build additional visualizations of the changes in designers' experience and to perform descriptive statistics. Each data point about challenge and skills is placed on an Euclidean plane following Massimini and Carli's method (1988) and a psychological state for each second is derived from the channel model.

2.4 Data processing: determining the emotional states

Like Massimini and Carli (1988), we believe that individuals rate their skills and challenges on their own personal scales. One can imagine that some people consistently underestimate the difficulty of the tasks in which they are engaged, which does not mean that these tasks are actually simple. To compare the judgements of different individuals and different situations, standardizing the scores is in order, removing the effects of individual scales. The standardized scores are calculated as follows:

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$$Z_{\text{skills}} = \left(\frac{X_{\text{skills}} - M_{\text{skills}}}{\sigma_{\text{skills}}}\right) \quad \text{and} \quad Z_{\text{challenge}} = \left(\frac{X_{\text{challenge}} - M_{\text{challenge}}}{\sigma_{\text{challenge}}}\right)$$

- Z_{skills} and $Z_{challenge}$ are normalised scores of the skills and challenge dimensions
- X_{skills} and $X_{challenge}$ are observed scores of each dimension (one score per second)
- M_{skills} and $M_{challenge}$ are the average of each dimension unique to each subject (they are calculated from the data from each interview and they apply only one session)
- σ_{skills} and $\sigma_{challenge}$ are the standard deviations

So if at the time t_1 a positive skills Z score is observed, it means that at that moment the subject perceives a higher level of skills compared to his average level throughout his own activity. Once each subject's scores are normalised, we can therefore observe the changes within an activity, identify potential patterns and compare activities to each other and to different people.

At any time, using these normalized data (Z-skill and Z-challenge), we obtain a pair of numerical coordinates that allow us identify a unique point on the skills/challenge plane (Figure 4). The centre of this plane corresponds to a Z-scores value of 0, representing the average score of each subject on both skills and challenge dimensions for the session.

We based this method on two models operationalizing flow and other psychological states in a slightly different way: the quadrant model partitioning the world of the experience in four quadrants (Csikszentmihalyi & LeFevre, 1989) (Figure 5a) and the above mentioned Experience Fluctuation Model, also known as 'channel model', partitioning the world of the experience in eight channels (Figure 5b).

In his original formulation, the Experience Fluctuation Model aimed at measuring specific affective states, during different activities, occurring at different times. Since during a design session we are interested in *fluctuations* of the experience *within* the same activity as a process, based on previous findings (Dorta et al., 2010; Dorta et al., 2008), we also defined three *zones of ideation experience* based on the eight channel of Massimini & Carli's model (Figure 5c). We think that the concept of 'zones of ideation experience' is more suitable for identifying subtle changes and recurring patterns occurring *within* the same activity, than the more complex operationalization of the eight 'affective states'. In fact, our main goal is to know how the psychological experience evolves during ideation and not to exactly determine what is the affective state of the designer. Therefore, although we use the eight channels defined

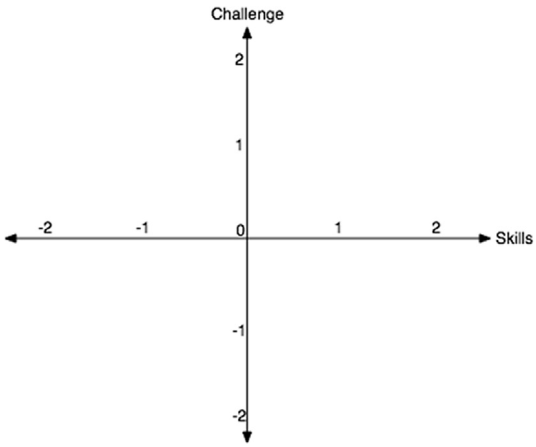

Figure 4 The skills and challenge plane

by Massimini and Carli (1988), we also define zones of ideation experience, to understand more efficiently ideation. The three zones are:

- A zone of 'sense of stress' where perceived challenge level is high and perceived skills level is medium or low (anxiety and arousal states)
- A zone of optimal experience (flow state) where the perception on both variables is high. This zone is narrower than the other.
- A zone of 'sense of control' where the level of perceived challenge is medium or low and the level of perceived skills is high (control and relaxation states)

Thus, by using the coordinates obtained from the z-scores of challenge and skills, we can classify at each moment (second) the designers' zone of ideation experience. This allows to analyse the designer's experience either statically or dynamically.

2.5 Static visualisation of data and its interpretation

On the base of the collected data, we first generated *static* visualisations of zones of ideation experience. These visualisations make possible to see the evolution of the psychological experience and compare the different activities. We generate two static types of visualisation: timelines and descriptive statistics.

We built three types of timelines (see Figure 6):

1. A timeline showing the evolution the perception of challenge and skills;
2. A timeline showing the evolution of the psychological state according to the quadrant model;
3. A timeline showing the evolution of the psychological state according to the channel model, from which we identified the zones of ideation experience.

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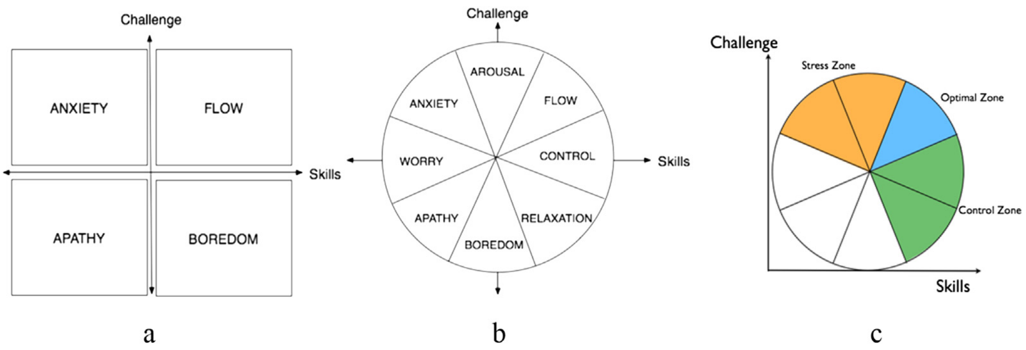

Figure 5 Experience models: (a) the 4-quadrant model, (b) the 8-channels model, and (c) the three zones of ideation experience *of the Design Flow model*

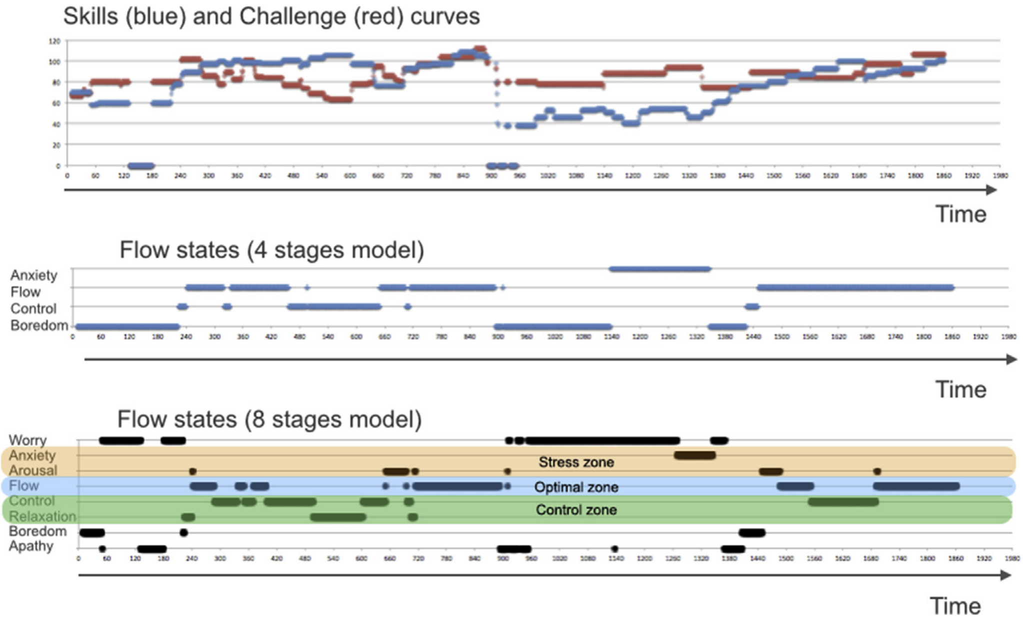

Figure 6 Three timelines produced from the same activities (32 min)

These timelines enable a visual understanding and intuitively identify the Design Flow patterns (Dorta et al., 2008) of the activity. According to the above mentioned theoretical framework of the Design Flow, we expect that, during ideation, designers will experience the following pattern: stressful states when tension rises and idea generation starts, followed by a state of flow associated to the finding of a relevant idea, followed by a state of sense of control, e.g. a release of the psychological tension. For example, for the activity presented above (Figure 6), we can identify a break in the activity (particularly visible in the timeline of challenges and skills). This break is a real rupture

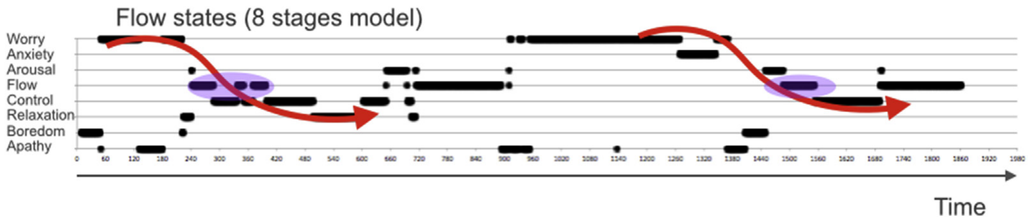

Figure 7 Design Flow patterns identified on the timeline

in the observed activity, where designers decided to move to a second design issue.

In a second example, we could also identify two patterns predicted by the Design Flow theoretical model, shown in Figure 7, where the flow states are circled and the observed patterns are highlighted by an arrow. The identification of these patterns on the timeline makes it possible to go back to the video for a qualitative interpretation of the events that occurred during each Design Flow pattern.

In addition to these timelines, a table is generated (Table 1) with a summary of descriptive statistics: the name of the associated video, session total time, time spent in each of psychological states and the session averages for skills and challenge ratings.

These data give a general picture of the activity and allows to compare them with different people doing the same activity (in team or individually), different people doing different activities, and the same subject doing different activities.

2.6 Dynamic data visualisation

On the basis of the various statistical visualizations, we create a video animation (see Figure 8) including:

Table 1 Descriptive statistics of the activity

Activity	*Session3_student7 − Broadband.m4v student7test*				*Mean skills*	*Mean challenge*	
Total time	*1853 seconds*				*74.68*	*81, 64*	
8-scale model	1. Apathy 135	2. Relaxation 87	3. Boredom 129	4. Control 364	5. Flow 503	6. Arousal 87	7. Anxiety 77	8. Worry 471
4-Scale Model			1. Boredom 535	2. Control 255	3. Flow 854	4. Anxiety 209		

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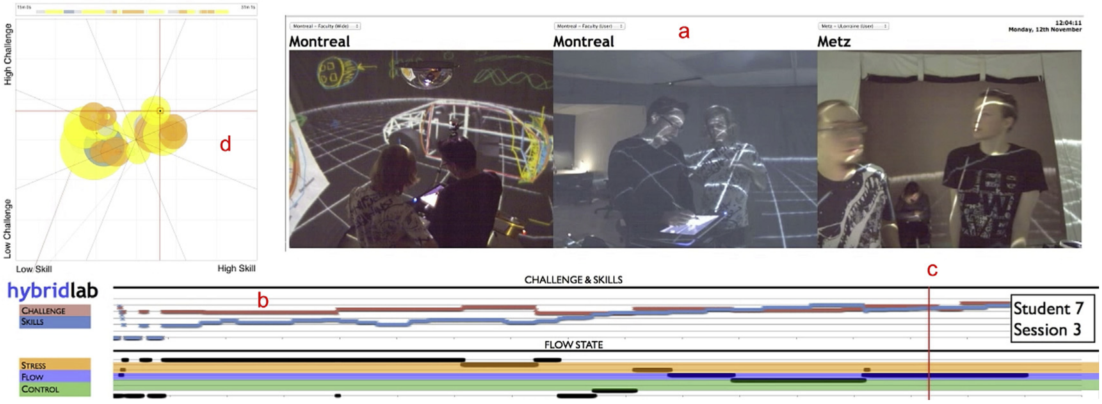

Figure 8 Screen capture of a video (dynamic visualisation)

- The video of the activity used for the self-observation (a);
- The timelines (b);
- A marker moving on the timelines, running along with the video, identifying at every moment the emotional experience (c);
- A two-dimensional plane of challenge and skills' levels as reported by the subject. Circles are formed as the video plays. The centre of the circle corresponds to the coordinates of skills and challenge on the plane, and the radius of the circle is proportional to the time during which these coordinates were reported in that position (d).

This video helps interpret the data collected in static visualisations. After identifying patterns or sequences of particular interest, watching this video puts static analyses in the context of the actual development of the activity. Conversely, watching the activity also allows to directly identify the designers' experience in relevant moments of the ideation process.

2.7 Data interpretation in conjunction to other coded data

The advantage of this method is that it can be used in conjunction with other coded data. As time-codes are synchronized with those of the video, we can apply on this video coding grids. Figure 9 shows a screen capture generated from the design flow data, along with other grids qualifying (a) verbal exchanges between designers in a collaborative activity, (b) the dynamics of collective ideation, and (c) the occurrence of key ideas that will shape the design concept and define the main axis of the final product.

3 Validation through double measurement

To validate the method, we have implemented a test. We conducted the self-observation interview twice with one expert designer about the same activity.

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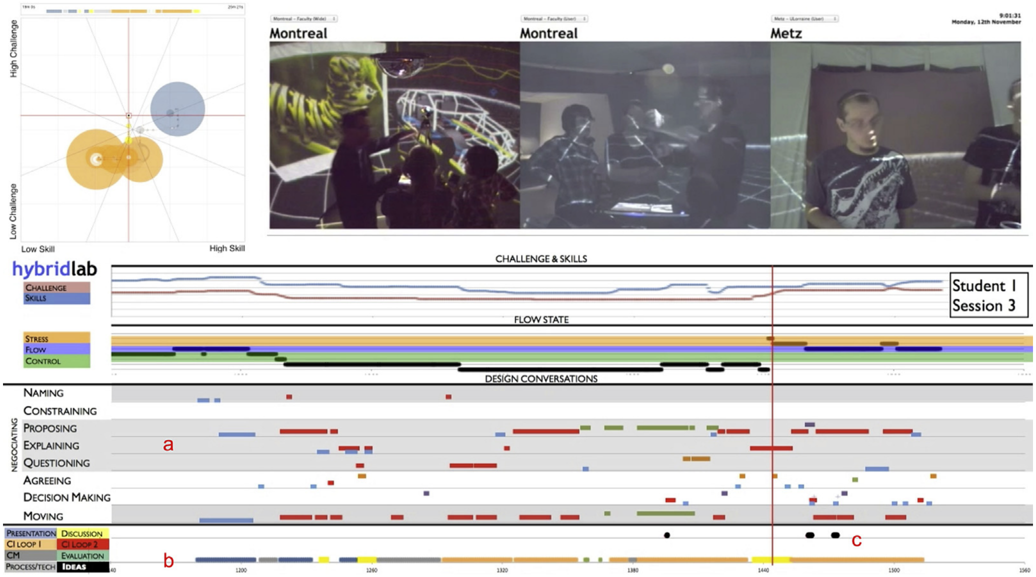

Figure 9 Screen capture of a video with joint multiple encoding grids

This test intended to evaluate consistency of challenge and skills scores when rated at the same time vs. in sequence (before challenge, then skills).

The purpose of this validation was 1) to evaluate the consistency of the skills and challenge ratings; and 2) to see if there was a jointly handling two different sliders with the two hands at once (joint rating) and the double evaluation process (sequential rating) introduced a bias in the ratings.

For this validation, a subject underwent the self-observation interview about an ideation activity of an hour three times:

1. The first time rating the two dimensions (challenge and skills) at once, by manipulating a cursor in each hand;
2. The second time by rating only the level of perceived challenge;
3. A third time by rating only the level of perceived skills.

For each interview, 3600 data are collected, one per second. These data were *cleaned*, removing the first and last minutes (where the video is started but the activity has not really started) and a middle section corresponding to a short break. A total of 2700 s (45 min) were considered for our sample. We then calculated different Bravais-Pearson's correlations: between the two successive evaluations of each variable, to see whether the results obtained in the two interviews were stable over time; and between the two dimensions assessed jointly or separately, allowing us to identify any bias related to the use of both hands simultaneously.

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For *challenge*, the correlation between the two tests was 0.55, a strong positive correlation ($p < 0.00001$). For *skills* the correlation was 0.33, a significant positive correlation ($p < 0.00001$). These results allow us to draw the following conclusions:

First, the measure appears to be relatively accurate: between the two coding sessions, the two scores on the same dimension are positively correlated, meaning that they tend to change in the same way. This first result is very important because it is a measure of validation of the method: the scores do not associate arbitrarily, but two consecutive measurements substantially follow the same pattern: at every moment, the score for a dimension in the first interview is close to the score in the second.

Secondly, the intensity of the correlation is not the same depending on the measured variable while *challenge* showed a stronger correlation between the two coding sessions then skills. This means it would be easier for a subject to assess the challenge of a task, than the skills it mobilizes.

The third observation also relates to the intensity of the correlations. Although these correlations are moderate to strong, they deviate from the desired value of 1. This observation needs to be explained; the validation method indeed suffers from many small inaccuracies in the measurement: the slider coding is done every second and from one coding session to the other, it is entirely possible that changes in perceived challenge and skills are not identified exactly at the same second (because the reaction time of a subject may slightly differ from one coding session to another). This inevitably leads to small measurement errors which affect the correlation coefficient.

To give a clearer idea of the comparison, Figures 10 and 11 show the timelines during the two coding tests, the blue curve represents the scores of challenge and skills, when both dimensions were evaluated together; and red curve represents the scores of challenge and skills when each dimension was rated on its own.

In Figure 10, we see that the challenge follows a similar curve in the two sessions, with the exception of two moments: the first minutes of activity; and just before the break. These moments of activity seem to suffer from a certain ambiguity on the part of the subject.

In Figure 11, we see that the two ratings related to perceived skills follow a similar development, but the *overall level* is significantly higher when skills were coded alone. This means that the evaluation of the average skills may be affected by the rating modality (joint or sequential rating). This difference is confirmed by examining Table 2 showing that the average stays stable for the 'challenge', but is different for the 'skills' dimension.

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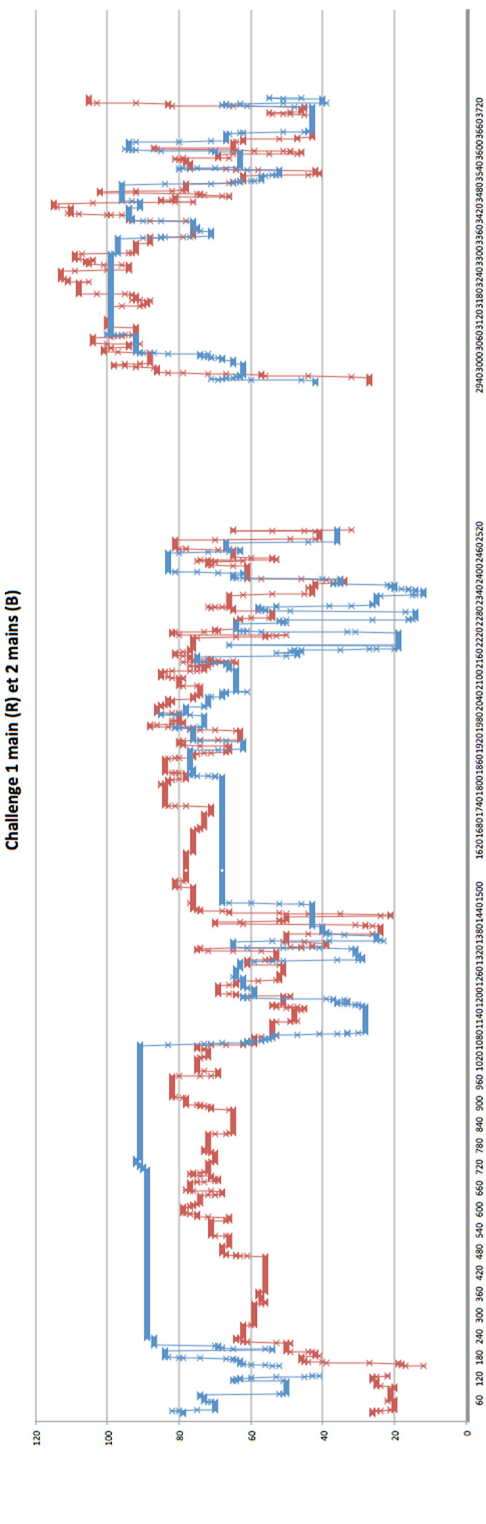

Figure 10 Challenge: coded at the same time with skills (blue) and coded alone (red). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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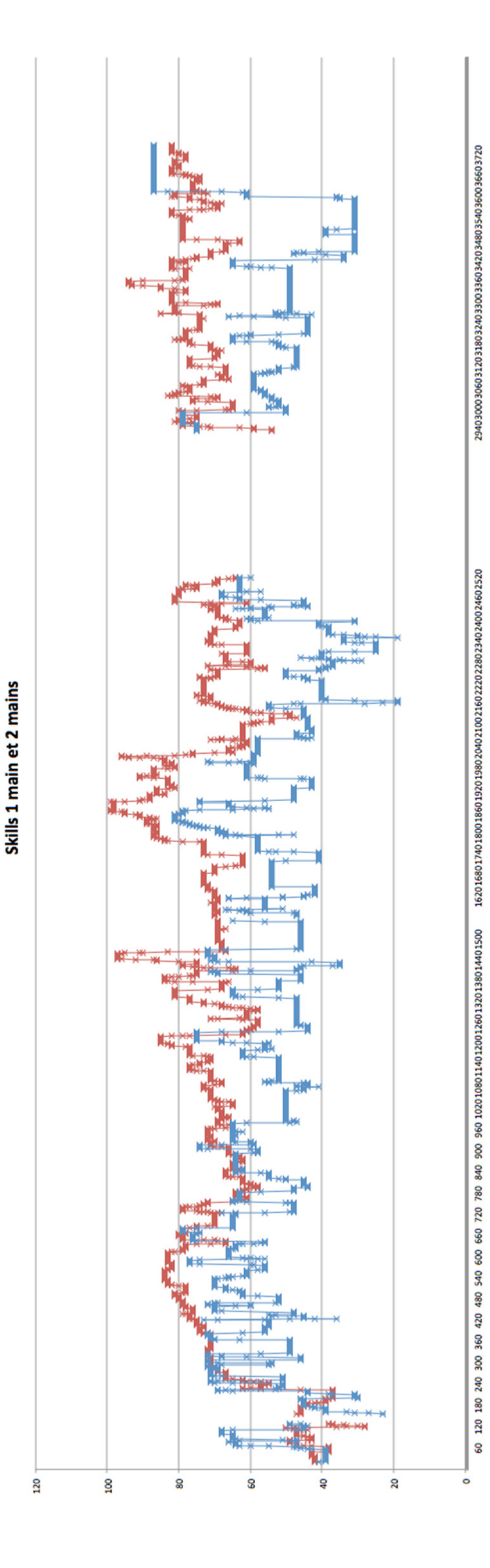

Figure 11 Skills: coded at the same time with challenge (blue) and coded alone (red). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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Table 2 Averages of both dimensions for the two coding sessions

	Joint rating	*Sequential rating*
Average challenge	71.65	69.33
Average skills	54.58	71.76

This further confirms the benefits of using standardized scores to compare activities. In fact, by plotting the timelines of the Z-skills scores, we get the following Figure 12, where the two curves are much closer than in Figure 11.

Thus, these differences do not raise a major problem because for the identification of experience ideation zones we use the standardized scores. Finally, we found that both dimensions tend to move together in both conditions, but more in the joint rating (sequential rating 0.26; joint rating 0.15). Even though during the joint rating condition the correlation between the movement of the two hand increases the correlation remain weak. These potential biases appear to be a minor issue in the light of the time gained by simultaneously coding the two dimensions: coding separately means coding twice, which means doubling the interview time.

4 *Comparison to previews Design Flow methods*

In past studies, Dorta et al. (2008) and Dorta, Kalay, Lesage, and Pérez (2011) proposed different techniques to study designers' experience within the framework of the Design Flow. First, as we mentioned in the introduction section, the procedure was very intrusive, because required the participants to interrupt the ideation activity in order to identify and communicate their psychological state using a *Flow wheel* or a *Flow panorama* graphs (Dorta et al., 2008). In both cases users had to decode the graph, to pinpoint (in the Flow wheel) or to verbalize (in the Flow panorama) their affective state at the moment the activity was stopped by the researchers. After the ideation session, they applied additional questionnaires on Flow (Csikszentmihalyi, 1975): even if through these instruments they were able to obtain quantitative data from a standardized questionnaire the problem of detecting changes in the experience throughout the process was not solved. The technique of the Flow wheel was also used by Perteneder, Hahnwald, Haller, and Gaubinger (2013) to evaluate the designer experience with the same limitations.

Aiming at reducing the intrusiveness of the measurement, Dorta et al. (2010) used the Flow wheel at only three moments of the ideation activity, the beginning, in the middle and at the end. The measurement was far less intrusive but without enough detail to observe changes of the psychological state.

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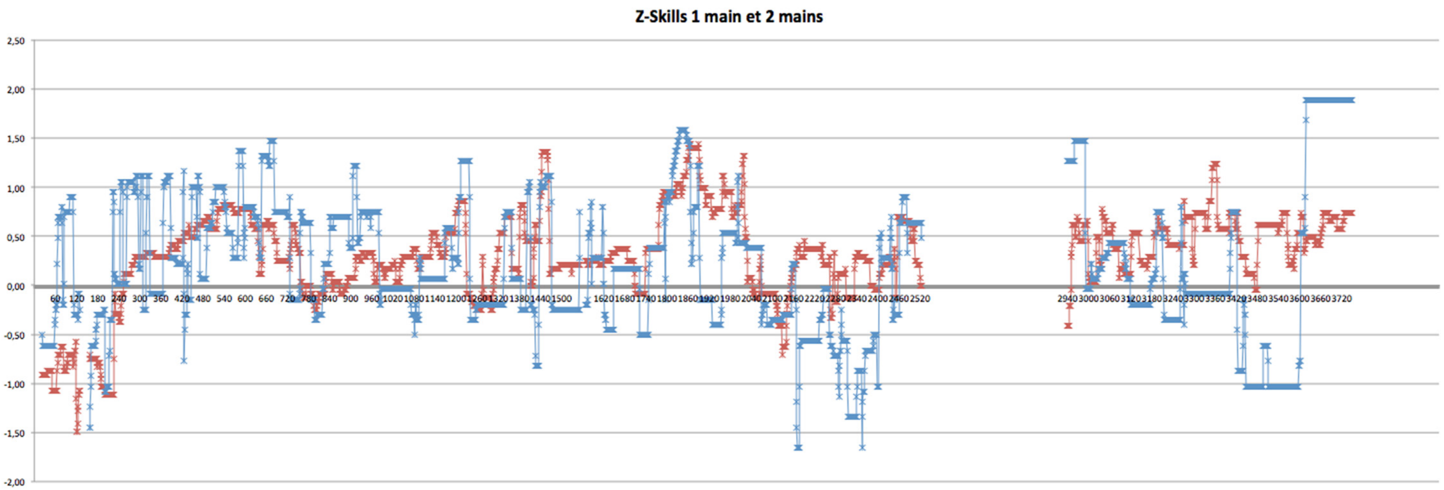

Figure 12 curves of 'Z-skills' dimension (standardized scores) during the first coding session (with two hands, blue curve) and the second session (one-handed, red curve). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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More recently, it has been developed a software able to pop-up a *Flow call window* showing eight buttons (Dorta et al., 2011), one for each state of the Experience Fluctuation Model. The software, enabled researchers to decide when the flow call window would appear: they asked designers about their psychological state around every 10 min, but they were able to anticipate or to postpone the pop-up in order to not interrupting a conversation. Intrusiveness appeared somehow reduced but increasing granularity was still too low to allow a triangulation between experience and design conversations and other activities.

Finally, the last method, used by Lesage (2015), the designers had to self-observe their video recordings while the researcher asked the participant for their psychological state around every 10 min. However to interview *each* participant about their inner state added more time to the interview due to more verbal exchanges between researchers and participants.

All the procedures tackled the problem of data granularity and intrusiveness without really solve them. The proposed method it does allow a continuous assessment of subjective experience detecting changes in experience moment by moment allowing to triangulate design activities with the affective state of designers. In addition, data of perceived challenge and skills can be quantified. Finally, the post-task interview resulted to be 25% longer than the actual activity (40 min of interview for 30 min of activity).

5 Discussion and future works

This paper presents a new version of the Design Flow method in order to analyse psychological states of designers during the ideation. The method is based on a novel form of self-observation interview instrumented by a material device and an original software. It serves several complementary objectives: (1) to reduce interview time, which is necessary given the practical constraints presented by educational settings (2) while retaining the ability to analyse the activity as a whole, not just selected excerpts, and (3) to allow comparing the activities' and situations' data with each other, because of the increased granularity of data.

From this point of view, the method meets these objectives. All the interviews have been conducted in almost real-time (about 40 min of interviews for 30 min of activity), while providing reliable results.

The method also enjoys the advantage of being largely automated. We designed the software to automatically launch all necessary records and generate a data file that can be easily imported into a spreadsheet. For the statistical data processing and the creation of timelines, we have designed a relatively complex Microsoft Excel™ spreadsheet, which automatically calculates once

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the data is imported, averages, standard scores, positions in the challenge & skills plane, determining the experience states according to several models (quadrant or channel models) and which generates different timelines: the challenge dimension, the skills dimension, and the development of designers' experience. Based on these elements, the generation of videos for dynamic analysis is easily achieved.

Of course, the use of this method must be accompanied, for interpretation, by a qualitative analysis of the activities observed. These are made possible thanks to the generation of videos (dynamic data visualisation), in addition to static representations. In this study, we have limited the analyses to retrospectively identify structuring design concept, but we are carrying other types of analyses relative to collective design conversations, to the design process, or the use of external representations in design.

The purpose of this study was essentially to validate the new method, although it gives clues about the psychological states *during* conceptual design, and what happens before and after an idea appears. In future works, we will of course do extensive use of the method to:

- Characterize the experiential processes related to the use of different representational tools.
- Identify more extensively experience patterns. In addition to the top-down approach developed here (where the identified patterns were derived from the theoretical framework in which the method fits), we wish to develop a bottom-up approach, where recurrent patterns can be identified from the aggregation of a large mass of data.
- To link the designer's experience with various other facets of the ideation process: the verbal analysis of collaborative ideation and the use of external representations.
- To cross the data from different designers engaged in the same ideation process to identify potential patterns characteristic of collective ideation.
- To compare these subjective data with real time psychophysiological data from designers in action.

Acknowledgements

We would like to thank J.M. Christian Bastien, Julie Giraudon, Carmelo Di Bartolo, Duccio Mauri, Damien Hanser, Anne-Marie Hébert, all the participants, and the reviewers for their valuable contribution to this paper. This research was supported by the *Insight Grants* program from the Social Sciences and Humanities Research Council of Canada (SSHRC) (Grant number 90803).

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