Comparing Immersion in Collaborative Ideation through Design Conversations, Workload and Experience

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ABSTRACT

This paper presents a case study comparing the HIS (Hybrid Ideation Space), a system allowing designers to be physically immersed in their sketches and physical models, and Vyew™, a whiteboard software, in local and remote design collaboration; aiming to see if immersion benefits collaborative ideation. Three methodological tools were used: Design Conversations (Collaborative Ideation Loop “CI-Loop”, Collaborative Conversations “CC” and Collaborative Moving “CM”), Workload using NASA TLX and Design Flow for the designers’ experience. Local collaboration results appear to have benefited from immersion while remote results were mitigated by participant issues. However, looking deeper into users’ experience explains the impact of immersion.

1 Introduction

Does an immersive Collaborative Ideation (CI) instrument make a difference? Does immersion, beyond its initial seduction, deliver better on experience while designing, compared to staying on the laptop screen (non immersive) in local or remote CI?

Design collaboration using freehand sketches is possible through whiteboard software over Internet. Designers can co-design, sketching while adding gestures and expressions using webcams. Sketch is used because of its intuitiveness and because it is a strong tool for conceptual design (or ideation). The problem is that sketch on whiteboards retains the same scale problems as sketch on paper, but with digital behaviour (pen tablet display, undo, etc.,) and the ability to share sketches in realtime with a remote design team. Designers are not in touch with life-size representations, deceived by the proportions of space and shapes, sketching distorted perspective views for lack of graphical references, limited by the 2D representational frame (screen or projection).

We developed a system (Hybrid Ideation Space—HIS) that supports life-size immersive freehand sketches and physical models for local and remote collaboration (Dorta 2007). The HIS allows designers to be physically inside the representations in real time while sharing them with remote collaborators using another HIS. The HIS uses a tablet laptop as a computer combined with an immersive spherical panoramic projection.

This paper presents, as a case study, a comparison between the HIS and a whiteboard (Vyew™) in context of local and remote CI. A multidisciplinary team of landscape-architecture and architecture students did the ideation on two ad-hoc projects with the whiteboard the first day, and in the HIS the second. All participants were new to remote collaboration in design. For each project, they worked locally (in parallel sessions) before co-designing together, each inside a HIS in their location, dealing with the differences in time zones, languages and disciplines. The HIS was the setting for the comparison for both projects: the tablet laptops (without the immersive projection) were used in their capacity to access the whiteboard on the first day, and as the HIS, with immersive qualities, the next.

We used three methodological tools for this comparison: Design conversations patterns (CI-Loop, CC and CM) we had developed, the NASA TLX for workload assessment, and the Design Flow developed previously, to assess designers' experience (Vidulich and Tsang 1985; Dorta et al. 2008, 2011).

2 Immersion

Immersion is defined as a state of consciousness where sensory experience of the actual world is sufficiently muted, and the sensory experience of the virtual world is sufficiently heightened, that people feel they are no longer in the actual world (Boellstorff 2008). In this study, the immersive experience had no loss of awareness of the physical body, as the HIS allows designers to move and physically interact with their representation.

Collaborative Virtual Design Environments (CVDEs) and whiteboards allow designers to share information without problem in local (face-to-face) design collaboration, but when the participants are distributed, the technical requirements for these applications are more challenging (time delay, lack of detail, configuration and connectivity issues, etc.). However, the assessment of these systems have been usually limited to user-centred design methodology with usability and ergonomic assessments aiming to develop the system, leaving the ideation activity, the collaboration and the designer's experience unevaluated beyond user opinions (Safin and Leclercq 2009; Darses et al. 2008). A number of factors impair their use, such as the scale of the representation, working in orthogonal views, leading designers to make proportion mistakes that can be avoided in life-size immersion.

For this study we opted to use Vyew, because it was a free, commonly used, non-immersive Internet-based whiteboard application, allowing freehand sketches and remote collaboration.

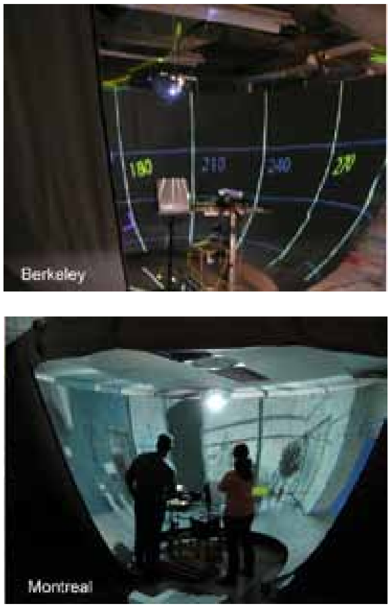

Fig. 1

3 Interconnected Hybrid Ideation Space

Implemented in 2007, assessed and compared as an ideation and co-located collaboration tool, the HIS permits freehand sketching and physical model making layered with in-context images, in immersion (life size and real time) **(Figure 1)** (Dorta 2007; Dorta et al. 2009). It is a low-tech system: a tablet laptop, a projector, HD IP cameras and a 360º immersive projection system based on spherical panoramas. The user sketches on the tablet or makes a rough scale model (in the model station) while spherical images are projected upwards to a semi-spherical mirror on the ceiling, then reflected on the ceiling-mounted semi-spherical 5m-diameter fabric screen. Users sketch in normal perspective while the HIS software distorts the sketch in a spherical panorama. The tablet laptop is mounted on a rotating device that allows users to always sketch in front of them inside a drawing area while looking all around at a normal (undistorted) life-size 360º perspective on the screen, thanks to the trompe l'oeil effect (from inside, users feel as if they're inside a 3D environment). Based on the same optical distortion, an IP camera combined with a tiny semi-spherical mirror captures the rough scale model in realtime (low fps) (avoiding the Gulliver effect).

We networked two HIS, sharing sketches and immersive realtime video of models symmetrically. In distributed setting, sketch data is relayed to a server sending the information to the other HIS software; meanwhile an IP camera captures and transmits the participants' image, expressions and gestures to the remote location. Moreover, the drawing area tells who is online (presence), knowing continuously where the partners are looking and sketching. It also has a blackboard (black, to lessen brightness) to share any 2D images as referent inside the 3D immersive view. The two HIS were installed in UC Berkeley and Université de Montréal. Skype™ supported verbal exchanges.

4 Design Flow

We have developed Design Flow to assess ideation through the experience of the designer, based on Csikszentmihalyi's concept of flow (Dorta et al. 2008; Csikszentmihalyi and Csikszentmihalyi 1988). 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. The balance between challenges and skills determines the Flow state, giving rise to eight possible dimensions: apathy, worry, anxiety, alert, flow, control, boredom, and relaxation (Csikszentmihalyi and Larson 1987; Massimini and Carli 1988).

We have observed that during ideation, designers proceed through a predictable pattern of psychological states, from stressful states (worry, anxiety and alert) at the beginning while giving form to ambiguous ideas, to alternating alert and flow once the concepts are starting to form, falling into flow with every satisfying result. Once a concept is identified and designers are working at stabilizing it, the states experienced will alternate from flow to control to relaxation; less stressful states (Dorta et al. 2008). This predictable design flow pattern spans the time it takes to develop one concept (25 to 50 minutes for a 3-hour ideation), which imposed its timeframe to this study.

5 Design Conversations Patterns

CI Loop is a methodological instrument to observe CI, paying attention to the design conversation (Dorta et al. 2011). It is a composite grounded in Bucciarelli's design as social process, Schön's reflective conversation and Goldschmidt's graphical representation of concepts and actions (Buccarelli 1988; Schön 1983; Goldschmidt 1990). We developed an analysis grid based on five elements common in the analysis of the design conversation and design process among those three authors: naming, constraining, negotiating (proposing, explaining, questioning), decision making and moving **(Figure 2)**. Designers will be naming the object of design or the specific element being discussed, constraining the project through its requirements and boundaries. They will be negotiating or articulating verbal meanings associated to

Figure 1. *The interconnected HIS, with part of the spherical screen open*

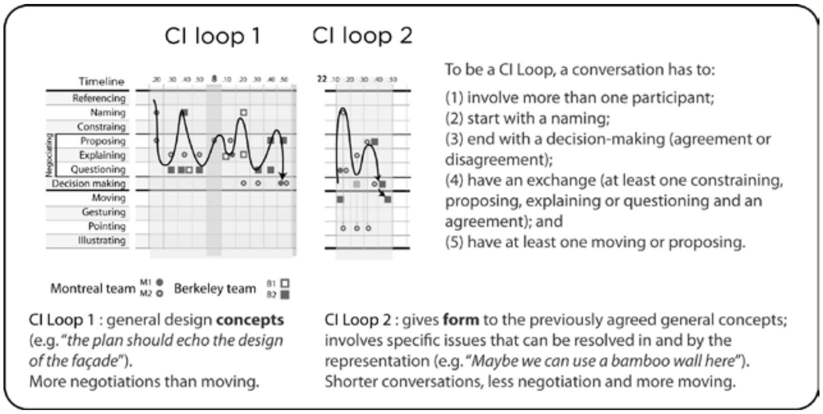

Fig. 2

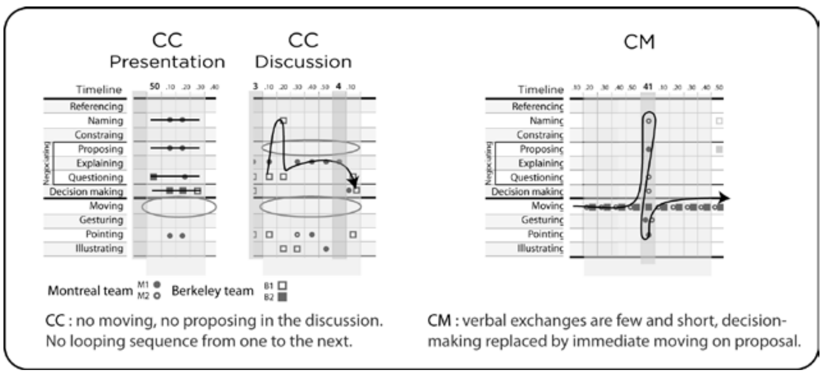

Fig. 3

visual images. Negotiating is expanded to three subcategories: proposing, explaining, and questioning. They will be making decisions, specifically agreeing or disagreeing, on a proposal, thus marking the end of the negotiation. They will be moving, by adding to the representation and making pointing and sketching gestures. The first four actions are usually verbal exchanges, while moving is an act, which transforms the design situation (Goldschmidt 1990). We called this CI pattern a loop because it repeats itself, and it seems to spring from one to the next.

Collaborative Conversations (CC) are indirectly involved in the ideation as either a discussion about concepts indirectly related to the design, or the presentation of a resolved design solution **(Figure 3)** (Dorta et al. 2011).

Collaborative Moving (CM) happens once the concept is secured. It is a bout of rapid ideation where a number of small decisions are made on the representation as it progresses. It is often an exciting moment where both designers are involved (by drawing, or by following the progression, analysing the coming result and making punctual proposals as needed) **(Figure 3)** (Dorta et al. 2011).

6 Workload

In past studies, we had associated the workload to the design flow, but here the NASA TLX complements both design flow and Design Conversation instruments (both process-based measurements) by giving a cognitive appreciation of the overall experience (Dorta et al. 2008; Vidulich and Tsang 1985).

7 The Experiment

This study was conducted between Berkeley and Montréal. Over two days, four undergraduate students (architects in Berkeley, landscape-architects in Montréal) collaborated on the ideation of two ad-hoc landscape-architecture projects involving the same site. On the first day, with Vyew, the project involved circulation flow through

Figure 2. *Samples of CI Loop 1 and 2*

Figure 3. *Samples of CCs and CM*

Project launch		Local CI		Remote CI
		Montreal	Berkeley	
Day 1 Vyew	Initial brainstorm 24 min	First 30 min: review of all variables tied to the site. Then co-designed 3 concepts. 76 min	Launched into a concept right away. Worked cooperatively, therefore having less design conversations. Last 10 min: 2nd concept unfinished. 88 min	Presented each other's concepts (first 44 min) Co-designed a final concept 88 min
Day 2 HIS	Initial brainstorm 30 min	Launched into a concept quickly. 25min later: dead-end Communication break-down (no CI) Stressful phase then a good 2nd concept. 56 min	10 min talk Then worked individually until the last 10 min. Presented 2 individual concepts. A participant disengaged, resisting others' effort to co-design. 60 min	Long and limp presentation of all concepts (Project-lead was stressed) Connectivity issue (15 min) Last 10 min: produced a final concept (less conversation, no flow) 68 min

Table 1

a public space. The next day, using the HIS, they had to create an outdoor classroom taking into account noise and privacy. For each project, the four participants had 3 hours to go from inception to unified concept. The four participants agreed that one of them would act as project-lead (a Montréal participant), reproducing real-life structure of a design project. The Montréal students were a working design team in real-life. The structure for both days was: (1) short remote project-launch; (2) two local parallel sessions; a lunch-break; then (3) a final remote session **(Table 1)**.

Design conversations—Two research assistants reviewed all video recordings, coding them into 10-second increments, identifying every action and matching gestures. They reviewed each other's coding to insure reliability of results. A ten-second increment allows for identifying two or three actions, which gives enough granularity to be meaningful. If an action was longer than 10 seconds (e.g. a long explanation) it was coded again, as long as it lasted, thus showing its importance. The CI Loop 1 and 2, CCs and CMs were identified once the video was coded **(Figures 2, 3)**. These patterns have varying lengths in time: as short as 20 seconds for some CI Loops 2, and up to 6 minutes for CCs and CMs. Since in this study, we are pacing our observations to the natural timeframe of a design flow pattern (varying from 25 to 50 minutes), we are considering here a macro view of the design conversation, looking at the progression of types of conversation as the ideation develops.

Design flow—Measuring design flow accurately without disrupting ideation has been a challenge. For this study, we developed a Protocol software inspired by the Experience Sampling Method (ESM) (Csikszentmihalyi and Larson 1987). It enabled observing the psychological states in real time during the session for each participant. The software sent a pop-up message on the tablet laptop, where each participant privately chose one of eight emotional states by clicking on the screen. We refer to this as the Flow call **(Figure 4; Table 2)**.

Once familiar, this procedure has proven to be swift (3-5 seconds), particularly when the participants were strongly engaged. Its disruptiveness appears to have little impact on the data collected although it has sometimes slowed the ideation after the call. The protocol software matched its data to the video while waiting to be compared to Design Conversations video analysis. A Flow call tells of a punctual psychological state (how a participant felt at that moment). Flow calls were not taken at fixed intervals but every 7-10 minutes in accordance to ESM. This flexible approach to flow data collection delivers reliable design flow patterns, since this pattern spans 25 to 50 minutes.

Workload—The NASA TLX questionnaire was administered at the mid-session break and at the end of each day.

Table 1. *Sequence of events in all sessions*

Fig. 4

Tools	Data collection techniques		Data analysis
	Name	When	
Design conversations	Video Recording	*Throughout the protocol*	Video analysis to identify the CI Loops 1 & 2, CCs, and CMs
Design flow	Flow call	In 7-10 min intervals, *throughout the protocol*	Create a timeline
NASA TLX	Survey	2x day, *after* each session	Tally the survey

Table 2

8 Results

8.1 DESIGN CONVERSATIONS AND DESIGN FLOW

In **Figures 5 and 6**, the combination of the two graphs tells the story of what the teams did together remotely and on their own locally (Design conversations, top of graph), and how they experienced it (design flow, bottom of graph). To better highlight the progression of types of conversation as the ideation developed, Design Conversations results are represented not in number of counts, but in how much time was spent engaged in each type of conversation in a given 4-minute time frame (4 minutes: to preserve granularity of our data and be able to represent the whole protocol in a single figure). In **Figures 5 and 6**, the progression from CC to CI Loop 1, to CI loop 2 is represented by an increased darkness, CI Loop 2 reaching mature concepts; CM (a sign of successful CI Loop 2) follows by materialising what has been decided. Individual ideation, unrelated conversations and technical manipulations are left out and show as blank in the 4-minute segments.

In the Montréal local session with Vyew **(Figure 5)**, the design conversations are denser and rapidly darker (leading to more CMs). With Vyew, two recognizable patterns of design flow (anxiety, alert, flow and control in this order) can be seen **(Figure 5**, see dash lines**)**. Noticeably, other states, generally less stressful ones from Berkeley and more stressful ones from Montréal, accompany the design flow, which suggests that the teams did not share the same level of engagement. design flow happened where the Berkeley and Montréal participants shared the same states. The extra psychological states appear to be noise in the group experience. Perhaps they reflect cultural differences tied to the respective geographies or professional cultures. The remote session shows a progression of design conversations, from initial CCs while presenting the local concepts, to CI Loops 1 and 2, with a single interrupted CM (they started drawing on the same spot, laughed and quit the CM).

The Montréal team working locally in the HIS **(Figure 6)** experienced the clearest design flow of this protocol, delivering an unambiguous progression of stressful to less stressful states. In the remote HIS session, the design flow is again accompanied by other states. The extra states could be attributed to cultural differences and, or to team issues. Nevertheless, the design flow was matched by a typical progression of design conversations: CCs, to CI Loop 1 and a good CI Loop 2 sequence, with

Figure 4. *Flow call auto-evaluation window for participant A*

Table 2. *List of methodological tools, data collection and analysis*

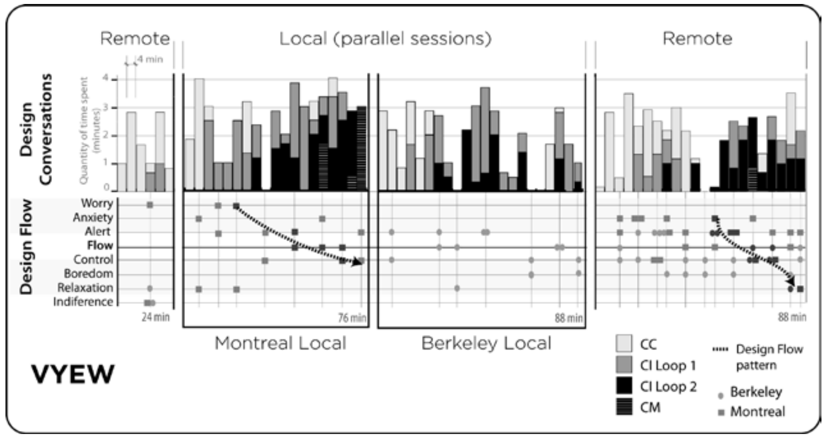

Fig. 5

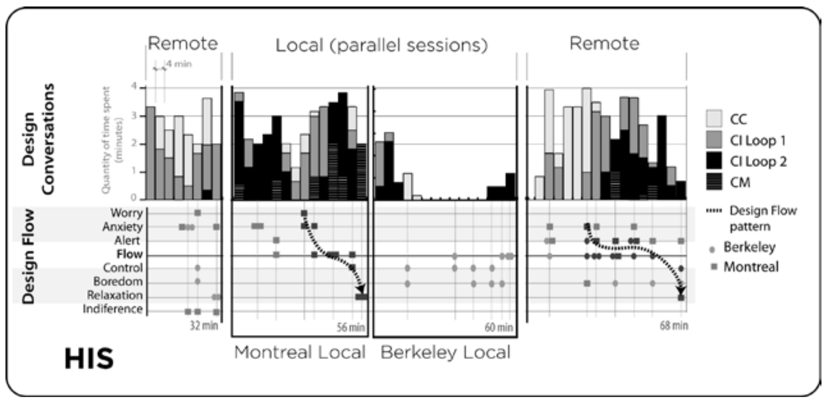

Fig. 6

fewer conversations as the project progressed. There were slightly less design conversations with Vyew than in the HIS (**Figures 5, 6** note height of columns). There were the most occurrences of CMs in the HIS.

8.2 WORKLOAD

In **Figure 7**, the local CI results are an indicator of the ability of each team to work together, which should translate in high performance and matching mental demand with low effort and frustration. The Montréal team appears well matched, because they were apparently able to perform well with low effort and frustration. In Vyew their mental demand and performance matched. In the HIS, they said to have experienced much lower mental demand for a noticeably higher performance; the HIS apparently having a positive impact on their CI. This is possibly attributable to the difference between working in top views on a laptop screen versus immersive perspectives.

The Berkeley team, on the other hand, shows unusually high effort and mental demand in both tools—a red flag for their ability to work together. In spite of this, in the HIS (local setting), their mental demand lowered and their performance rose compared with their ratings with Vyew; the HIS apparently having a positive impact on their CI too.

The remote CI workload speaks of the ability of the distant teams to collaborate together. With Vyew, the mental demand, performance and effort are high (receiving similar ratings), which points to a challenge in remote collaboration. Yet, both teams rated their performance as higher than in "local setting", which indicates that CI between them was working. In the HIS, the results are mixed with both teams giving very different ratings in temporal demand, performance and frustration.

Figure 5. *Timeline of activities with Vyew, matching Design Conversations to Design Flow (day 1)*

Figure 6. *Timeline of activities in the HIS, matching Design Conversations to Design Flow (day 2) (Berkeley local: no CI, they opted for individual ideation instead)*

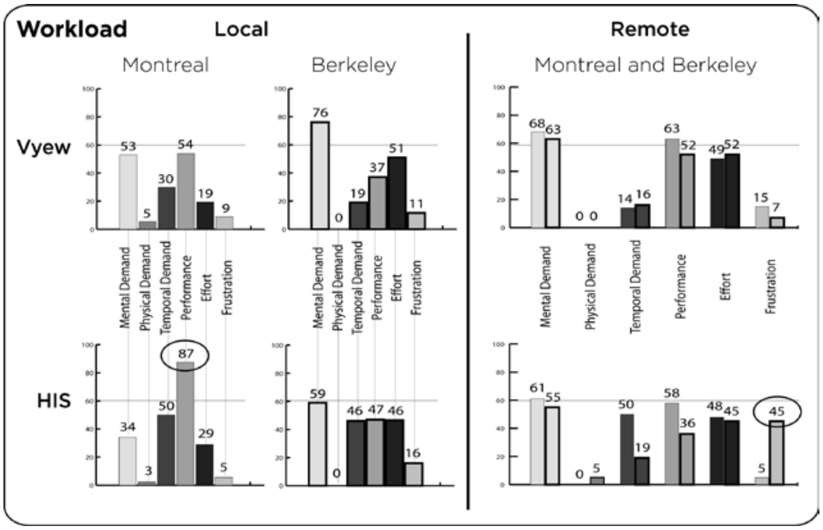

Fig. 7

Verbal process (black line in Figures 8-9)	**Spatial process** (shaded areas in Figures 8-9)
Looking at the tablet laptop	Looking at the immersive representation (in the HIS only)
	Looking at distant collaborators
	Finger/laser pointing
	Arm and body gestures

Table 3

9 Experience Versus Verbal/Spatial Processes

Notwithstanding the weakness in the sampling, these results begged the question of why did immersion deliver better workload and design flow. Furthermore, the quality of the designers' experience with each tool appeared to have been very different. In this section we seek an explanation for this quality difference, inspired by a separate study, by looking at the participants' cognitive use of verbal/spatial processing codes and visual channels (Lesage and Dorta 2011; Wickens 2002).

Processing codes define the distinction between verbal, linguistic, analytic, abstract on one hand, and spatial, analogical, concrete processes on the other. This verbal / spatial dichotomy apparently is responsible for the high degree of compatibility of the manual and visual responses (manual usually responding to visual stimuli, both spatial in nature), and vocal to auditory (both verbal). There are two visual channels: focal and ambient vision. Focal vision will operate as a verbal/abstract process if it narrowly focuses on fine detail and pattern recognition, and as a spatial process when the focus is wide. Ambient vision relates to peripheral vision (Wickens 2002). CI is understood as a predominantly verbal process since it is the act of collaboratively exteriorizing abstract mental images first through words then through visual representations.

The general results show that Vyew fosters fewer spatial processes than the HIS, which may explain the noticeably lower mental workload in the HIS. This suggests that by splitting the designer's resources between verbal processes (Design Conversations) and spatial processes (as available in the HIS), the mental demand is lowered.

The specific results show how the different processes have been called for as the projects developed. In design flow point a (Figure 8), the participants used more arm gestures although the Vyew interface does not support this. In the HIS (Figure 9), at the heart of their stressful phase (point b), the Montréal team focused on the laptop screen while trying to regain control of the project. The most interaction with the immersive representation (point c) happened at the breaking of the new concept, which coincided with peak flow and a peak in body movement (point d). Back together, the sharing of their immersive concepts lead to the stressful beginnings

Table 3. *List of observed processing codes*

Figure 7. *Workload for each session*

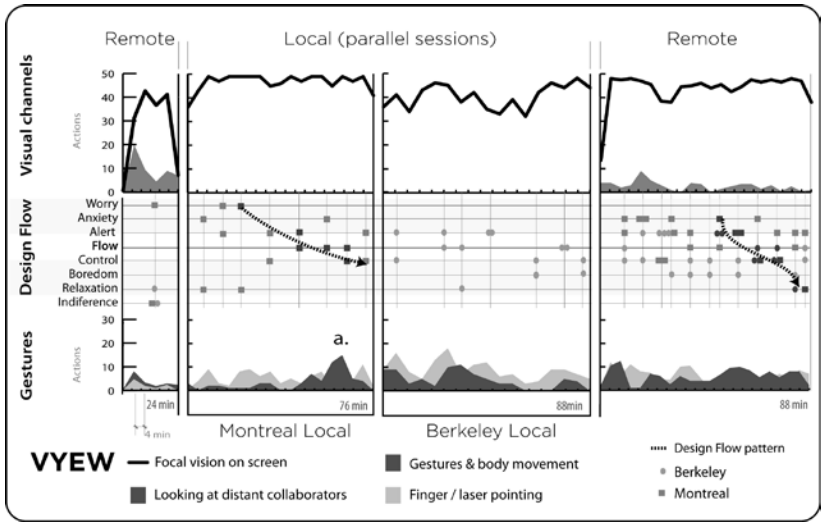

Fig. 8

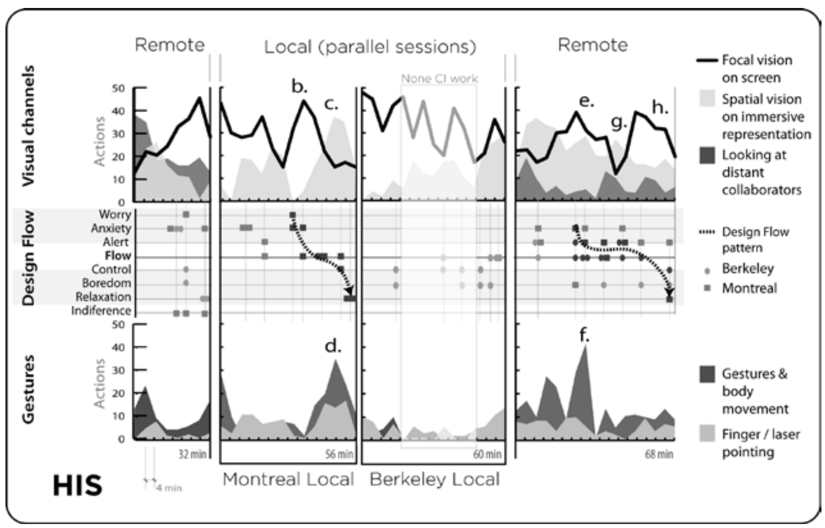

Fig. 9

of a design flow pattern (point e) with peaks in gestures (point f) accompanied by high laptop use and high interaction with the immersive representation. In flow, they stayed away from the laptop (point g). Once the concept was identified, the focus came back to the laptop (point h), while in CM mode (see Figure 6).

10 Conclusion

In this case study, in local settings, immersion appears to have better supported CI. The HIS delivered more time spent in Design Conversations, lower mental demand for all participants and the most CMs, all of which possibly linked to its immersive quality, resulting in higher workload performance. In local setting, each distant team worked on their own, therefore alleviating the cultural / communication challenges. This may explain why the clearest design flow was observed in a local HIS session.

Unfortunately, one of the distant teams had uneven CI abilities (see workload), thus the remote results are inconclusive, and therefore we cannot infer or confirm that immersion delivers a better experience in remote CI. Interestingly, this methodological issue allowed us to observe how different engagement levels between teams map out. Design flow emerged where the two teams' experience overlapped. Yet, new concepts appear to have benefited from spatial processes provided in the tools' interface. As the work of giving form progressed (in CI Loop 2 and CM), the more organised verbal processes appeared to be called for. Likewise, verbal processes appear to be called upon when struggling to regain control over a stressful situation. But the spark of ideation seems to be kindled by spatial processes.

Figure 8. *Timeline with Vyew, matching verbal/ spatial processes to Design Flow*

Figure 9. *Timeline in the HIS, matching verbal/ spatial processes to Design Flow*

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