Comparing Immersion in Remote and Local Collaborative Ideation through Sketches : A Case Study

DORTA Tomás[1], KALAY Yehuda[2], LESAGE Annemarie[1] and PEREZ Edgar[1]
[1] *Université de Montréal, Montreal, Canada*
[2] *The Technion – Israel Institute of Technology, Haifa, Israel*
tomas.dorta@umontreal.ca, kalay@technion.ac.il, annemarie.lesage@umontreal.ca, uriel.edgar.perez@umontreal.ca

Abstract. Sketches are used in design to support ideation, communication, and collaboration because of their abstraction, ambiguity and inaccuracy. Design collaboration using freehand sketches is possible through whiteboard software over Internet. Although designers can co-design and share design referents through this tool, their sketch retains the same scale problems as on paper : by not being confronted to life-size representations, designers can cheat themselves while sketching without references, by distorting perspective views. In 2007, we developed a system (Hybrid Ideation Space—HIS) that allows designers to be physically immersed in their sketches and physical models, literally inside their life-size, real-time representations while sharing them remotely to another HIS. This paper presents a case study comparing the HIS and a whiteboard software (Vyew™) in local and remote design collaboration. With this initial observation, we wanted to see if immersion benefits to collaborative ideation. Three methodological tools were used : the *Design Flow* pertaining to the designers' experience, the *Collaborative Ideation Loop* (*CI-Loop*) for the design collaboration process and the *NASA TLX* to measure the workload. The local collaboration results show a benefit from immersion while remote results were mitigated because of participant issues.

1. Introduction and theoretical framework

Does an immersive Collaborative Ideation (CI) tool 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? These questions are driving this study.

Design collaboration using freehand sketches is possible through Internet-based whiteboard software. Designers can co-design by sketching and sharing design referents while adding gestures and expressions using webcams. Sketch is used for this kind of collaborations because of its intuitiveness and because it is a strong tool for conceptual design (or ideation) respecting the needed abstraction, ambiguity and inaccuracy. The problem here is that sketch on whiteboards retains the same life proportion and scale problems as sketch on paper, but with digital behaviour (pen tablet display, undo, etc.) and the ability to share sketches in real time 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 (the Hybrid Ideation Space—HIS) [7] that supports life-size immersive freehand sketches and physical models for local and remote collaboration. The HIS allows designers to be physically inside the representations in real time while sharing them to remote collaborators using another HIS, with a VoIP service (Skype™) to support verbal communication. The HIS uses a tablet laptop as a computer to facilitate the hand-eye coordination combined with an immersive spherical panoramic projection. It also has a *blackboard* (black, to lessen brightness) to share any 2D images as referent inside the 3D immersive view.

This paper presents, as an initial case study, a comparison between the HIS and a whiteboard (Vyew™) in context of local and remote design collaboration. A multidisciplinary team (two landscape-architecture students in one location and two architecture students in the other) did the ideation on two ad-hoc landscape-architecture 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 professional cultures. The HIS was the setting for the comparison for both projects : the tablet laptops (without the immersive projection) were used in their capacity as hardware to access the whiteboard on the first day, and as the HIS, with immersive qualities, the next.

We used three methodological tools to make this comparison : the Design Flow we had developed [10] to assess the designers' experience, the Collaborative Ideation Loop (CI-Loop) we also developed previously [8] to evaluate design conversation and the NASA TLX [23] as workload assessment. Design Flow deals with the designer's experience while designing. It evaluates the process rather than the results, going beyond usability and bypassing the subjective

evaluation of design results. The CI Loop assesses design conversation, which is central to collaboration. It regards the design process as a social process.

Although in our results the HIS appears to better support local CI, for methodological reasons, we cannot confirm that immersion delivers better experience in remote CI. In local settings, the HIS delivered the clearest Design Flow, more time spent in design conversations and higher ratings for workload performance, while Vyew appeared to have provided a more demanding experience. Looking to explain these general results, the workload points to a notable difference between the two tools : a higher mental demand in Vyew, where the representation is in 2D top view compared to the immersive 3D representation in the HIS.

1.1. Immersive environments and whiteboard applications in design

Remote design collaboration raises new challenges, calling for new approaches. Using only CAAD systems in conjunction with the Internet is not enough [13]. Immersive environments and whiteboard applications are options that offer an alternative for remote design collaboration. The possibility of designing in an immersive environment that provides spatial awareness, stronger sense of presence, stereoscopic depth and sharing information seems ideal. A few examples of these systems are the "Virtual to Virtual Environment V2V" [1] for detail shape modelling and CALVIN [15] with applications for collaborative Architectural Layout Via Immersive Navigation. Even if these systems look to improve remote and local design collaboration, their main focus is still managing large groups, effective data sharing based on detailed 3D models but not on ideation sketches. There are also Collaborative Virtual Design Environments (CVDEs) with a specific application taking in account the needs of design teams and design task [13, 22]. Up to now the whiteboard is used in design meetings as a visual support for sketching, allowing design teams to express their ideas. This is not a problem in face-to-face design collaboration, but when the participants are distributed, the requirements for whiteboard applications are different. Several systems that use a whiteboard have been developed, such as NetDraw [18] and the SYCODE object-based drawing application [14], which are remote collaborative drawing programs. But these had issues with the time delay in remote design collaboration and the lack of detail in the sketch. The advanced EsQUIsE system allows architects to ideate by sketching [5, 19]. It also permits the generation of 3D models based on sketch extrusions. These 3D capabilities where the abstract sketch is transformed into finish shapes (or primitives), were already explored by Do [6], and share a fundamental flaw : the representation is basically in 2D and the shaded 3D model is non-abstract, unambiguous and accurate, in contrast to the sketch itself, and not adapted to the designers' mental images during ideation, as observed by Darses [5]. Another related system named

SketSha (Sketch sharing), without the 3D modelling capabilities, was interconnected to allow the Distributed Collaborative Design Studio for remote exchanges [11], [20]. 3D capabilities set aside, these systems can also be categorized as whiteboards. Although the authors argue that the hardware proposes a Virtual Desktop metaphor [19], mixing analogue techniques (real plans and documents) with digital sketches, these systems are non-immersive : they offer no life-size scale or embodied presence in the project itself. Since the assessment of these systems have been limited to user-centred design methodology [19] with usability and ergonomic assessments in the aim of developing their systems, leaving the ideation activity [5, 20], the collaboration and the designer's experience unevaluated beyond user opinions [11, 20], it is difficult to appreciate their value for CI.

Another approach is the combination of virtual immersion with whiteboard. The immersive whiteboard collaborative system [24] allows users to navigate in a virtual environment with vivid avatars and sketch on the *virtual whiteboard*. The goal of this system is to provide a medium where users feel they are communicating and interacting face-to-face. But in this case, it is a simulation of a real whiteboard used as one more application of the virtual environment without any specific function for design teams thus remaining inadequate for CI.

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

1.2. Interconnected hybrid ideation space

Implemented in 2007 [7] and assessed and compared as ideation and co-located collaboration tool [9], the HIS permits freehand sketching and physical model making layered with in-context images, in immersion (life size and real time) (Figure 1). The model making was not part of this study. It is a low-tech system : a tablet laptop (Axiotron Modbook™), a projector, an HD IP camera 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 and then reflected on the ceiling-mounted semi-spherical 5m-diameter fabric screen. The user sketches in a 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 they look all around at a normal (undistorted) life-size 360º perspective on the screen, thanks to the *trompe-l'oeil* effect (from inside, users feel inside a 3D environment).

To address real practice requirement for remote collaboration, we networked two HIS. The sketch and the immersive real-time video of the model are shared

symmetrically. In this distributed setting, sketch data is relayed to a server that sends the information to the other HIS software; meanwhile the IP camera captures and transmits the participants' image, expressions, gestures and other non-verbal communications to the remote location. Moreover, the drawing area tells who is online (or presence), knowing continuously where the partner is looking and sketching. The two HIS were installed in two universities (UC Berkeley, School of Architecture and the School of Industrial Design at the Université de Montréal). A commercial VoIP supports verbal exchanges. See [7] for the original HIS description.

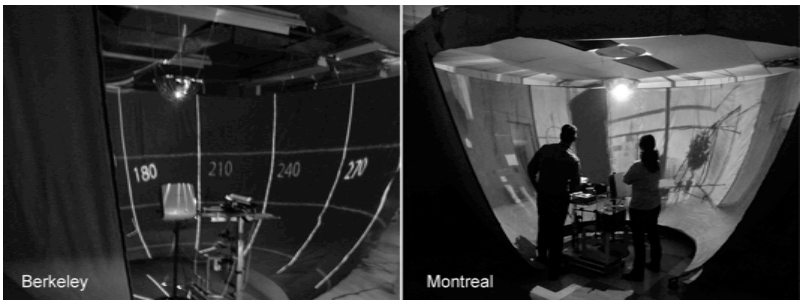

Fig. 1. The interconnected HIS, here with part of the spherical screen open.

1.3. Design flow

We have developed the Design Flow [10] to assess conceptual design through the experience of the designer, based on Csikszentmihalyi's concept of flow [3]. 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 [4] giving rise to eight possible dimensions [17] : apathy, worry, anxiety, alert, flow, control, boredom, and relaxation.

We have observed that during the ideation process, 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 [10]. 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.

1.4. Design conversations

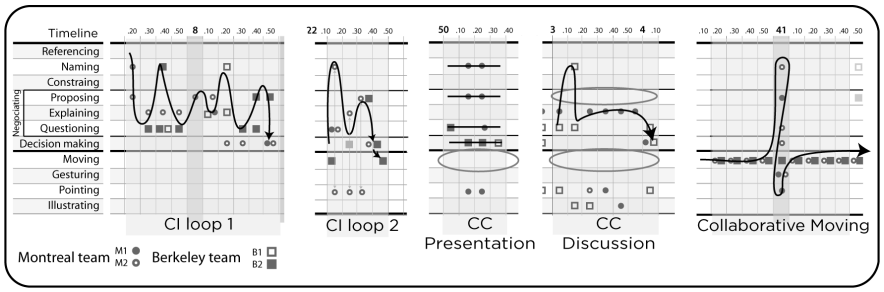

Fig. 2. Sample of CI Loops 1 and 2, CCs and CMs patterns.

The CI Loop is a methodological instrument to observe collaborative ideation, paying attention to the design conversation [8]. This methodological instrument is a composite grounded in Bucciarelli's design as social process [2], Schön's reflective conversation [21] and Goldschmidt's graphical representation of concepts and actions [12]. We developed this 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 (time, budget and other constraints). They will be *negotiating* or articulating verbal meanings associated to visual images. This category is expanded to three subcategories : *proposing*, verbally making a design proposal, *explaining*, substantiating, and *questioning*, raising issues about or giving a rebuttal to a given proposal. 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 in the form of verbal exchange, while the *moving* is an act, which transforms the design situation [12]. We called this CI pattern a loop because it repeats itself, and it seems to spring from one to the next. To be considered a CI Loop a conversation 1) has to involve more than one participant; 2) starts with a *naming*; 3) ends with a *decision-making* (agreement or disagreement); 4) has to have an exchange, so it will have at least one *constraining*, *proposing, explaining* or *questioning* (and an agreement); and 5) has to have at least one occurrence of *moving* or *proposing,* or both. There are two different types of CI Loops [8] : CI Loop 1 focuses on securing larger design concepts (e.g. "*the plan should echo the design of the façade*"), which invites wider verbal exchange (more *negotiations* than *moving*). CI Loop 2 focuses on giving form to the previously agreed general concepts and is involved with specific issues that can be resolved in and by the representation

(e.g. "*Maybe we can use a bamboo wall here*"). These conversations are usually shorter, having less *negotiation* and more *moving*, since they are confined to a specific issue present in the representation.

We also consider two other types of conversations linked to the ideation process : the Collaborative Conversation (CC) [8] and Collaborative Moving (CM) (Figure 2). CCs 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. CMs, happen once the concept is secured. It is a bout of rapid ideation where a number of small decisions are being made on the sketch as it progresses. It is often an exciting moment where both designers are involved (actively by drawing, or passively by following the progression, analysing the coming result and making punctual proposals as needed). See [8] for a more detailed description.

1.5. Workload

In past studies [8, 9, 10], we had associated the workload to the Design Flow, but here the NASA TLX [23] complements both Design Flow and CI Loop instruments (both process-based measurements) by giving a cognitive appreciation of the overall experience.

2. The experiment

The research protocol was conducted between UC Berkeley, Architecture School and Université de Montréal, School of Industrial Design. Over two days, four undergraduate students (two architects in Berkeley, two landscape-architects in Montreal) 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 a public space between three buildings*. The next day, using the HIS, they had to create an *outdoor classroom* taking into account noise, privacy and other issues. For each project, the four participants had 3 hours to go from inception to a unified concept. The four participants agreed that one of them would act as project lead (a Montreal participant), reproducing real-life structure of a design project. The two Montreal students were a working design team in real-life. The Berkeley students knew each other, but had never worked together. The structure for both days was : 1) short remote project-launch where the 4 participants establish the general approach for the day's project; 2) a period of local work, where each team worked on their own followed by a lunch-break; then 3) a final remote session, where they came back together to wrap up the project. The lunch-break split the daily 3-hour in two; each half is referred here as a *session*.

2.1. Methodology

Table 1. List of methodological tools and their data collection and analysis.

TOOLS	DATA COLLECTION TECHNIQUES		DATA ANALYSIS
Design flow	Flow call	When:	Create a timeline
		In 7-10 min intervals, *throughout the protocol*	
CI Loop	Video recording	*Throughout the protocol*	Video analysis to identify the CCs, CI Loops 1 & 2 and CMs
NASA TLX	Questionnaire	2x day, *after* each session	Tally the survey

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 [4]. It allowed 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*.

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 sometime slowed the ideation a little after the call. The protocol software matched its data to the video, in wait to be compared to CI Loop 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 the Experience Sampling Method. This flexible approach to flow data collection delivers reliable design flow patterns, since this pattern spans 25 to 50 minutes.

CI Loop—Two research assistants reviewed all video recordings, coding them into 10-second increments, identifying every action and their matching gestures. They reviewed each other's coding to insure the reliability of the results. 10-second increment allows 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 in time. The CI Loops 1 and 2, CCs and CMs are identified once the video is coded (Figure 2). The four types of conversations have varying lengths in time : as short as 20 seconds for some CI Loop 2, and up to 5 or 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.

Workload—The NASA TLX questionnaire was administered four times, twice on the first day (at the mid-session break and at the end of the protocol) and twice the second.

2.2. Results

To interpret the results, it is useful to be aware of the sequence of events in all sessions. On day 1 (with Vyew), session 1, after the initial brainstorm, the two teams launched their respective local CI. The Berkeley team was fired up by a concept they wanted to explore. As the concept progressed, the number of design conversations diminished because of their preference for cooperative work (working separately then regrouping) over co-designing. Fifteen minutes before the end, a second concept was initiated but not completed. The Montreal team spent the first 30 minutes of their local session reviewing the site to identify all its variables, then co-designed three concepts. When Berkeley and Montreal came back together (day 1, session 2) they took half the session to present and analyse each other's concepts before co-designing one unified final concept.

On day 2 (in the HIS), the initial brainstorm was longer (30 min), and the Montreal team came out of it with a specific concept. After 25 minutes developing it, they realized their idea was a dead-end. There was a breakdown in communication (no CI) and after a stressful phase, they came up with a better concept that pleased them both. In Berkeley, the team talked for 10 minutes then decided to work separately, producing two individual concepts. One of the participants progressively disengaged from the protocol, responding less and less to others' attempt to co-design. The presentation time (day 2, session 2) was arduous and limp, which worried the volunteer project-lead. This second session was also marred with connectivity issues that took 15 minutes away from the work time. At the end the participants put aside their expectations in favour of producing a final concept (last 10 minutes: less design conversations and no flow).

2.2.1. Design flow and design conversation

In both Figures 3 and 4, the combination of the two graphs tells the story of what the two teams did together remotely and on their own locally (Design conversation, 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, CI Loop results are represented not in CI Loop count, 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 3 and 4, the progression from CC to CI Loop 1, to CI loop 2 is represented by an increased darkness, CI Loop 2 being the peak of ideation; CM (a sign of successful CI Loop

2) follows it 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.

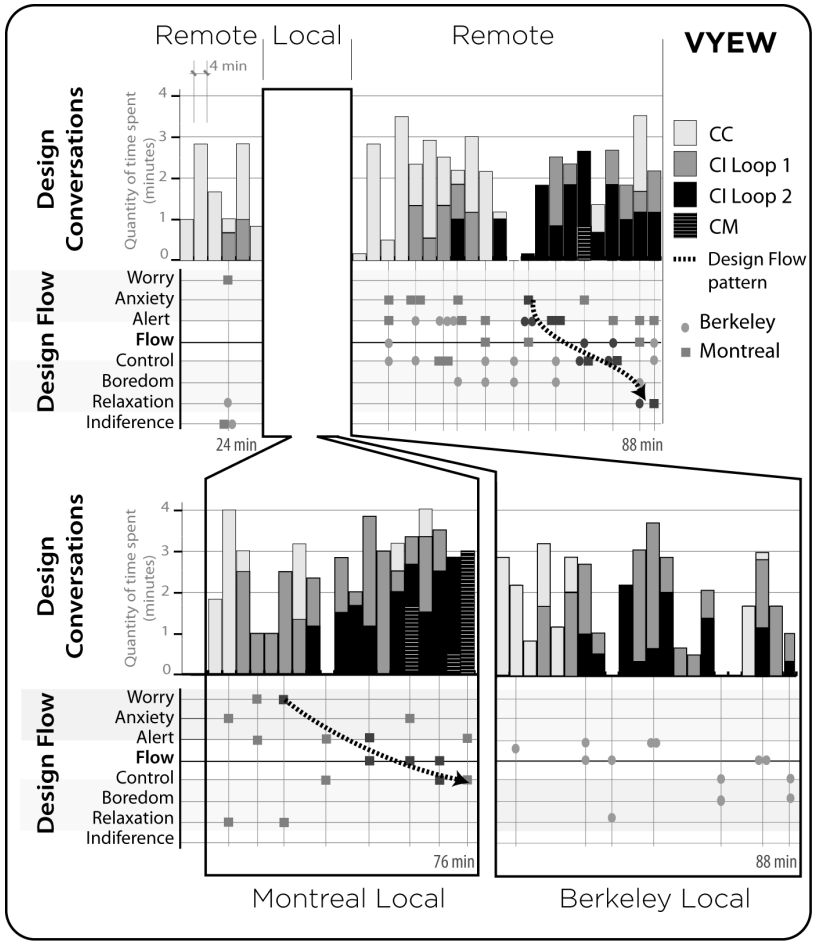

Fig. 3. Timeline of activities with Vyew, matching design conversation to Design Flow (day 1).

In the two local sessions with Vyew (Figure 3), the design conversations are more prevalent than in the remote session; and in the local Montreal session, they are denser and rapidly darker (leading to the more CMs). With Vyew, two recognizable patterns of Design Flow (anxiety, alert, flow and control in this order) can be seen (Figure 3, highlighted by a dash line). Noticeably, other states,

generally less stressful ones from Berkeley and more stressful ones from Montreal, accompany the Design Flow, which suggests that the teams did not share the same level of engagement. Design Flow happened where the Berkeley and Montreal 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 show 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 Montreal team working locally in the HIS (Figure 4) experienced the clearest Design Flow of this protocol, delivering an unambiguous progression of stressful to less stressful states. In comparison, the remote session in the HIS shows again a Design Flow 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 Loops 1 and a good CI Loop 2 sequence, with fewer conversations as the project progresses. There were slightly less design conversations with Vyew than in the HIS (see Figures 3 and 4) as seen by the height of columns. There were the most occurrences of CMs in the HIS.

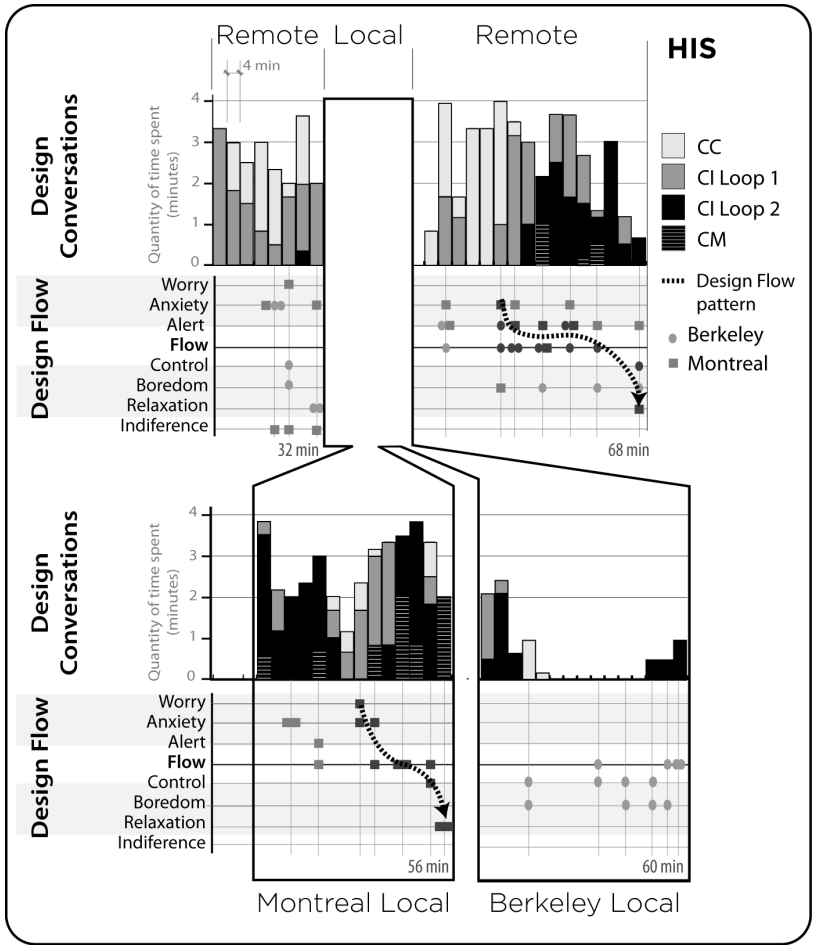

Fig. 4. Timeline of activities in the HIS, matching design conversation to Design Flow (day 2) (Berkeley local: no CI, they opted for individual ideation instead).

2.2.2. Workload

In Figure 5, 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 Montreal 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 perfectly. 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 on their ability to work together. This seems to have had an impact on the Montreal team during the remote CI. In spite of this, in the HIS in 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 two 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 suppose 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.

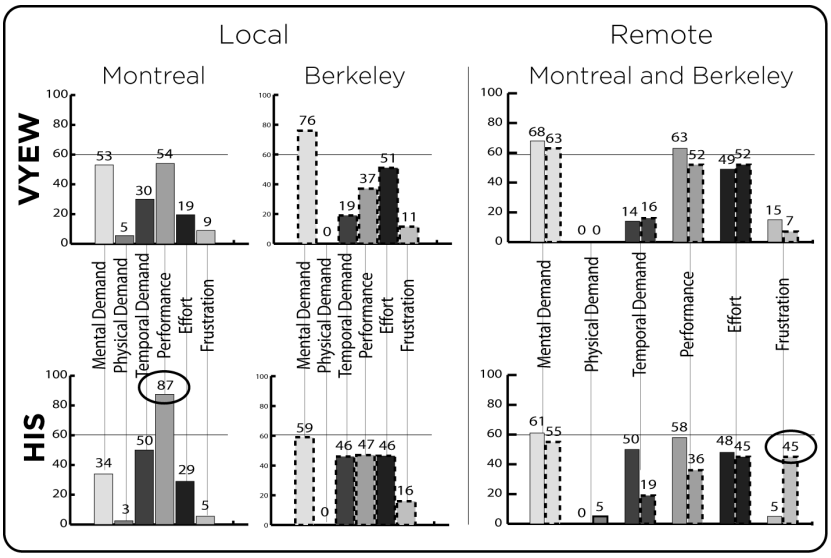

Fig. 5. Workload for each session.

3. Conclusion

In this case study, in local settings, immersion appears to have better supported CI. The HIS delivered more time spent in design conversation, lower mental demand for all participants and the most CMs, all of which possibly linked to its

immersive quality (surround perspective views), 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 infirm or confirm that immersion delivers better experience in remote CI. Interestingly, this methodological issue has allowed us to observe through the Design Flow, how different engagement levels between two teams map out. Design Flow emerged where the two teams' perceived experience reached the same states, meeting in the middle in this case. Considering these results, we sought in an ulterior work, possible explanations why immersion delivered a better experience, by looking at the mental workload in relationship to the experience [16]. However, more research has to be done ensuring that all participants have equal CI abilities.

4. Acknowledgments

We thank SeungWan Hong, Kartikeya Date, Michael Hoffman, Ignacio Calvo and Morgane Erenati for their valuable contribution, all the participants, and Quebec Research Fund on Society and Culture (FQRSC).

References

1. Arangarasan, R. Gadh. (2000). Geometric modeling and collaborative design in multi-modal, multi-sensory virtual environment. Proceedings of DETC'00, ASME 2000, 1-9.
2. Buccarelli, L. (1988). An Ethnographic perspective on engineering design. Design Studies, 14(3), 159–168.
3. Csikszentmihalyi, M. & Csikszentmihalyi, I.S. (1988). Optimal experience : psychological studies of flow in consciousness. New York : Cambridge University Press.
4. Csikszentmihalyi, M. & Larson, R. (1987). Validity and reliability of the experience sampling method. Journal of Nervous and Mental Disease 175(9), 526–36.
5. Darses, F., Mayeur, A., Elsen, C. & Leclercq, P. (2008). Is There Anything to Expect from 3D Views in Sketching Support Tools ? In JS Gero, AK Goel (eds.) Design Computing and Cognition '08, Springer, 283–302.
6. Do, E.Y. (2001). VR Sketchpad. Proceedings of the CAAD Futures conference, Eindhoven, 161–172.
7. Dorta, T. (2007). Implementing and Assessing the Hybrid Ideation Space : a Cognitive Artefact for Conceptual Design. International Journal of Design Sciences and Technology, 14(2) : 119–133.

8. Dorta, T., Kalay, Y., Lesage, A. & Perez, E. (2011). The first steps of the augmented design studio. In C.M. Herr, N. Gu, S. Roudavsky & M.A. Schnabel, (eds.). Circuit Bending, Breaking and Mending : Proceedings of the CAADRIA 2011.
9. Dorta, T., Lesage, A. & Pérez, E. (2009). Design tools and collaborative ideation. In T. Tidafi & T. Dorta (eds.), Joining Languages, Cultures and Visions : CAADFutures 2009, PUM, Montreal, 65–79.
10. Dorta, T., Pérez, E. & Lesage, A. (2008). The ideation gap : hybrid tools, design flow and practice, Design Studies 29(2), 121–41.
11. Elsen, C. & Leclercq, P. (2008). "SketSha" – The Sketch Power to Support Collaborative Design. In Y. Luo (ed.) : CDVE 2008, Springer-Verlag, Berlin, 20–27.
12. Goldschmidt, G. (1990). Linkography : Assessing design productivity. World Scientific, Trappl, R. (ed.), Singapore, 291–298.
13. Horváth, I., Vergeest, S.M. & Rusák, Z. (2002). Six ingredients of collaborative virtual environments. International Design Conference, 67–74.
14. Jabi, W.M. & Hall, T.W. (1995). Beyond the Shared Whiteboard : Issues in Computer Supported Collaborative Design. CAAD Futures 95, Singapore, 719–725.
15. Leigh, J. & Johnson, A.E. (1996). Supporting transcontinental collaborative work in persistent virtual environments. IEEE Computer Graphics and Applications, 47–51.
16. Lesage, A. & Dorta, T. (2011). Beyond the functional / pleasurable split : User Experience with Conceptual Design Tools. In C.M. Herr, N. Gu, S. Roudavsky & M.A. Schnabel (eds). Circuit Bending, Breaking and Mending : Proceedings of the CAADRIA 2011. (In press).
17. Massimini, F. & Carli, M. (1988). The systematic assessment of flow in daily experience. In Csikszentmihalyi, M. & Csikszentmihalyi, I.S. (eds). Optimal Experience : Psychological Studies of Flow in Consciousness, Cambridge University Press, Cambridge, MA, 266–287.
18. Qian, D. & Gross, M.D. (1999). Collaborative Design with NetDraw. Proceedings of the Eighth International Conference on Computer Aided Architectural Design Futures, Atlanta, 213–226.
19. Safin, S., Delfosse, V. & Leclercq, P. (2010). Mixed-Reality Prototypes to Support Early Creative Design. In E. Dubois, P. Gray & L. Nigay (eds). The Engineering of Mixed Reality Systems, Springer-Verlag, London, 419–445.
20. Safin, S. & Leclercq, P. (2009). User Studies of a Sketch-Based Collaborative Distant Design Solution in Industrial Context. In Y. Luo (ed) : CDVE 2009, Springer-Verlag, Berlin, 117–124.
21. Schön, D. (ed.). (1983). The reflective practitioner : how professionals think in action, Basic Books, New York.
22. Siddique, Z. & Rosen, D. (1997). A virtual prototyping approach to product disassembly reasoning. Computer-Aided Design, 29(12), 847–860.
23. Vidulich, M.A. & Tsang, P.S. (1985). Assessing subjective workload assessment : a comparison of SWAT and the NASA-bipolar methods. Proceedings of the Human Factors Society 29th Annual Meeting HFS, Santa Monica, 71–75.
24. Zon-Yin, S., Belle, T. & Wing, H.L. (2001). Immersive Whiteboard Collaborative System. Annals of Software Engineering 12 : 193–212.