Influence of Immersive Contextual Environments on Collaborative Ideation Cognition

Through design conversations, gestures and sketches

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In the design studio, Virtual Reality (VR) has mainly been included as a visualization tool to explore pre-designed ideas developed in traditional 3D software or using pen on paper. Meanwhile, a reshaping of the design process has been taking place, bringing forward interaction/experiential concerns and co-design approaches throughout disciplines in a push for a more thorough consideration of projects' contexts. This paper reports an exploratory study of how immersive contextual representations influence the co-ideation process. Audio-video recordings of co-ideation sessions (9) from a pedagogical studio were analyzed through verbal and representational (sketches and design gestures) exchanges as occurring in three different conditions: (a) pen on paper, immersive headset-free VR (b) without, and (c) with the use of contextual immersive environment (photogrammetric scans and 3D models). Results show that, although design conversations were similar across all conditions, design gestures were more often directly related to- than independent from the graphical representation only when using an immersive contextual environment. Furthermore, the rate of sketching episodes in general and sketching explanations were considerably lower in this condition. This could imply that use of pre-made context greatly reduces the need of sketching elements to support a clearer co-ideation.

Keywords: Immersive context, Design gestures, Design conversations, Sketches, Co-design studio, Design cognition

INTRODUCTION
When people want to creatively express themselves by singing for example, they need the appropriate contextual environment to support effortlessly the activity through the mediums’ prime characteristics, such as acoustics for music. If the space has the appropriate acoustics, becoming the contextual support for the creative expression, the singer will have
more ease to express harmonies for others as well as to adjust his or her voice. In design, the use of an appropriate contextual environment should positively influence the ideation process, providing references and cues that will help better harmonise ideas to the project’s expected reality. What is more, studying the influence of the context during design becomes even more relevant in the era and near-future development of augmented reality as an integral display for designing.

In the social environment of the design studio, VR has been principally used as a visualisation instrument to support spatial and formal problem finding and design reviews (geometric conflict detection, wayfinding issues, proportion errors, construction challenges) (Messner, 2006). However, VR has rarely been used to conduct live ideation collaboratively inside immersive environments, often being instead limited to purposes of visualising ideas that were designed and developed in traditional 3D modeling software with interfaces and command languages unfit for creative ideation. Even for parametric approaches, the creative process can remain difficult to achieve from within VR because of the challenges of complex interactions based on relics from traditional desktop menus (Hawton, 2018). Even large databases of contextual environments such as Google StreetView(TM) in VR are now widespread for visualization, but for now do not benefit from the interactions necessary to drive the ideation process.

Additionally, there is a trend noted regarding the process in the disciplines of design, architecture and urban planning where user centered, interaction and experiential approaches are brought forward during the development of projects (Coelho, 2015). A corollary of this shift is a more thorough consideration for the underlying perceptual characteristics of how architectural environments are experienced (Jelić, 2015) and for co-design approaches including all the stakeholders of the project (Steen, 2013). Even if the use of contextual representations is common practice for final design presentations, few projects analyzed it in traditional design process, but it is hard to find studies that have explored how immersive contextual representations could influence the ideation phase, at the early stage of the design process. Common traditional modes of design representations could aggravate sensorial distance from the project. There is a risk of occulting the actual experience of contextual environments and lead to project integration conflicts (Lehtuvuori, 2016) where the design intentions do not match the project’s real needs. These new grounds of concern require the embodied perspectives of future users’ needs and an increased attention with the existing projects’ context, whether built or natural.

This paper reports an exploratory study of how immersive contextual representations influence the co-ideation process. Audio-video recordings of the co-ideation sessions (9) from a pedagogical studio review were analysed through verbal and representational (design gestures and sketches) exchanges as occurring in three different representational conditions: (a) pen and paper, immersive headset-free VR (b) without, and (c) with the use of contextual immersive environment (photogrammetric scans and 3D models). Results show that design gestures were more often directly related to- than independent from the graphical representation only when using an immersive contextual environment. Furthermore, the rates of sketching episodes in general and sketching explanations were the considerably lower in this condition compared to the two others. This could imply that use of pre-made context greatly reduces the need of graphically representing additional elements to clearly exteriorize designers’ ideas, putting forth the idea that the context supports clearer conceptual propositions.

VISUAL-SPATIAL PERCEPTION OF THE CONTEXT
While traditional CAAD tools and graphic documentation (2D photos, perspectives, mood-boards, etc.) remain widely used as the main representational support to design projects’ components, a tension arises regarding their ability to provide designers with a
suitable experience of the projects’ contexts. In apprehending an existing context through traditional representations there is a risk of drastically diverging from its reality, when voluntary inspection of the lived experience is prompted by a discordant mediation, showed within flat, small foveal-angle displays. Accordingly, based on findings in neuropsychology and phenomenological inquiries, architectural ambiances have more recently been proposed to stem from pre-reflective cognition (Pallasmaa, 2014; Rooney, Condia & Loschky, 2017). They would act as a holistic, embodied sensory background in a space’s experience. Herein is introduced the idea that, in the ordinary direct encounter of an environment, the ambiance stands closer to the pre-conscious grounds of one’s cognition during any activity, including designing. There is a growing body of research laying out the idea that the peripheral visual field plays a fundamental role in the pre-reflective visual perception of a place (Rooney, Condia & Loschky, 2017). This traces a situational grasp, similar to certain properties of earlier accounts on architectural ambiances (Zumthor, 2006) and perception of essential structure of a scene (Larson & Loschky, 2009).

**REPRESENTATIONAL GESTURES, VERBAL EXCHANGES AND MENTAL IMAGES**

Considering that design is a social process, one can expect that designers need to communicate in whichever way readily available to them, verbal exchanges being the first design toolkit (Jonson, 2005). Studies showed that gestures accompanying speech reflect and stem from speakers’ mental images and facilitate the expression and the communication of such contents. Hostetter & Alibali (2008) proposed that “gestures emerge from the perceptual and motor simulations that underlie embodied language and mental imagery”.

**Gestures and speech**

Regarding communication, design studies have focused mainly on verbal behaviour and gestures, the few of the latter have been motivated mainly by the desire to interface gestures in CAAD systems (Visser & Maher, 2011). Gestures in design help to develop ideas by providing essential information lacking in the speech. They convey not only 3D information about physical objects but also their actions and movements in space or time, and provide information not verbally expressed (Härkki, Seitämaa-Hakkarainen & Hakkarainen, 2018). Moreover, part of them resulted to directly contribute to designing, such as introducing structures and movements before sketching them.

Gestures and speech seem to be closely related. Gestures, and in particular representational gestures (i.e. gestures used for pointing, depicting shape or motion, representing objects) co-occur frequently with sentences expressing visuo-spatial information (Alibali, 2005). When people talk, they produce more representational gestures in association with sentences evoking mental images or motor tasks than in association with sentences concerning more abstract topics. If gestures are prohibited, it is more difficult to verbally express spatial information (Alibali, 2005). In addition, there is evidence that gestures not only coincide with spatial information but reveal also the speaker’s viewpoint on the mental image described (Alibali, 2005). Gestures are believed to allow spatial thinking, independently of the need to communicate to another person. Gestures could facilitate the retrieval of spatial terms by activating in the brain the spatial and action-based properties of the concepts represented by the term; also, they could activate mental images and help to maintain them in the working memory in order to analyse or describe them (Alibali, 2005).

**Gestures and mental images**

According to Hostetter & Boncoddoo (2017), representational gestures are to be considered as tied with perceptual-motor representations in one’s mind much the same way embodied cognition has brought us to consider action - or its anticipation - as key to perception (Glenberg, Witt, & Metcalfe, 2013). In this light, gestures become more than mere ex-
ternalized traces of individuals’ thoughts. When enacted through movements structurally or semantically related to the content of the activity at hand, such gestures can strengthen the designer’s mental representations or even institute new knowledge (Hostetter & Boncoddo, 2017). This tight relationship between apparently so different mental processes can be understood if we consider cognitive activity as being embodied, that is directly based on the sensory-motor processes without the need of intermediate mental representations of the external objects independent from perception and action (Hostetter & Alibali, 2008).

The link between perception and motor activity has been firstly demonstrated with the discovery of mirror neurons. The ability to understand one’s action while watching him/her (cognitive activity) involves the activity of the same neurons we must activate to perform that same action (motor) (Rizzolatti et al., 1996). Going further, the embodied cognition hypothesis claims that this tight coupling of motor and perceptual processes may also be important for mental representations, or, in other words, when we just think (Yanchar & Spackman, 2013). From this perspective, the act of thinking about a table (in absence of the material table) should directly and therefore pre-reflectively activate the same neural substrate active when we see, touch, and interact with the real table as well as the associated memories. In this perspective, language is also considered embodied, explaining the link between language and visuo-spatial information: when we talk about visuo-spatial features of an object in absence of that object, our brain automatically activates the perceptive and motor properties of what we are talking about (Spackman & Yanchar, 2013).

**Speech and mental images**

There is evidence that, when we talk about the physical world, we listen, or we read a description, our understanding passes through the automatic and concurrent generation of the visual image representing what we are talking about or listening to (Hostetter & Alibali, 2008). Similarly, when we think about the physical world it is likely that we also perform mental actions aimed at mental objects. Also, just hearing verbs such as tick, pick, or lick was associated with patterns of brain activation very similar to those observed during the actual movements corresponding to those words (Hauk, Johnsrude, Pulvermuller, 2004).

In light of this related work, the exchange components of gestures and speech combined to the exteriorization by sketching could potentially provide clues regarding designers’ cognition and the influence of immersive contextual representation during ideation.

**STUDY**

This paper aims to compare the influence of different graphical representational co-ideation supports, namely: (a) analog studio setting using pen and paper (P&P), VR environment (b) with empty background (black or with a sky) using imported textured or white Wavefront .OBJ 3D models (VR-noC), and (c) with immersive contextual representations (photogrammetric scan or 3D modeled .OBJ mesh or .PLY point cloud of a built urban area) (VR-C). More specifically, we here aim to investigate the implications of integrating immersive contextual representations of the project on participants’ design cognition during the early stages of ideation through design gestures, sketches and conversations.

**METHODOLOGY**

We observed a third-year industrial design studio based on a co-design pedagogical approach, spanning a fourteen weeks semester. The project was related to the implementation of electrical vehicles charging solutions in the city. After the student’s preliminary research phase, the co-ideation sessions occurred twice a day for each team, bi-weekly for a period of four weeks. Teams were composed of two students collaborating directly with the studio teacher, co-ideating exclusively on the concepts of one of the student, alternating every session (this way each stu-
dent was allocated two sessions per week for their concepts. In total, seven teams pairing fourteen local students underwent these 20-minute meetings. Morning sessions took place in an immersive collaborative VR environment without headsets allowing 3D sketching (Hyve-3D) (Dorta et al. 2016) (Figure 1). This system allows real-time multi-user design collaboration by sketching and interacting locally and remotely. Local teams were interconnected with a teacher and pre-assigned teammates from an ergonomics program at a remote university in France. Afternoon co-ideation sessions alternated bi-weekly between the immersive environment and the analog studio condition. Among the seven teams, for exploratory purposes, the results presented in this paper were obtained from analyzing only nine sessions (3 hours) of three teams co-ideating for the first time their concepts in each of the three above-mentioned conditions (a, b, c). A short introductory lecture about photogrammetry was given during the initial research phase of the studio for students to produce their own contextual models using this technique. The students were free to choose to have a context or not while in the VR environment, leading to few teams exposed to all three conditions early in the ideation process.

Speech episodes segmentation was conducted based on the elements proposed by the Design Conversations model (Dorta et al. 2011). In this model, the dominant content-based verbal exchanges pertain to proposing design ideas and negotiating them through questioning and explaining. Within the Design Conversations methodology, gesturing and sketching are embedded in the notion of moving forward the idea (Schön, 1983). Gestures’ coding distinguished between organizational, non-design discourse and interaction management (Visser, 2010), and representational gestures. We call the latter design gestures considering the role they play in the ideation task and to avoid confusion with other situational aspects studied. They were circumscribed in accordance with McNeill’s (2005) definition of beginning and end points as observable stable resting positions of the gesturer’s hands. Thus coded gesture episodes would stretch from preparation to retraction, encompassing pre-stroke, stroke, and post-stroke hold phases (McNeill, 2005) as a single uniform segment. We excluded referring pointing gestures from design gestures to better trace subtle relationship of gestures with the representation. For example: one participant could point a part of the graphical representation and then move away to execute the design gesture in a reference space independent from that representation. Conversely, another participant could enact the design gesture directly embedded within the representation’s referents. In this way, without going much further into detailing and characterizing the form and nature of gestures, we...
interpreted each instance as either directly related to- or independent from- the graphical representation the team faced in hope of underlining potential patterns in some way attributable to the different conditions. This step was informed by the gestures’ position in space relatively to the representation medium, the gesturers’ gaze and posture as well as by partial insights (appearing in the discussion section) provided during retrospective interviews carried on several weeks after the studio’s end, using session recordings. Sketching episodes were also coded to take into account the traditional sketches of pen on paper and the 3D sketches as well as their affine transformations (duplicate, rotate, scale and translate) in Hype-3D.

Using Atlas.ti software, we then proceeded by contrasting the verbal elements lying in the participants’ speech (proposing, questioning and explaining) with the moving elements based on gesturing and sketching episodes, looking more specifically at their co-occurrences.

RESULTS
Results are presented following the three main dimensions of participants’ exchanges while comparing across the studied conditions:

GESTURING
Overall, design gestures were observed as occurring with similar rates in all three conditions, VR-C (average of 1.36 design gesture per minute) trailing close behind P&P (1.48/min) and VR-noC (1.49/min). Average gesture length was fairly shorter when occurring in condition P&P (4.2s) than in VR conditions without context (5.5s) and with context (5.8s). Though, one striking pattern emerging from our analysis lies in the direct relation the gestures held or not with the graphical representation. While design gestures for P&P (79%) and VR-noC (70%) are for the most independent from the representation, the trend shifts symmetrically for VR-C where 69% of instances are related directly to the immersive contextual representation at hand during the gesture’s execution (Figure 2).

Furthermore, the rate of design gestures for proposing are fairly similar across all conditions, standing at 0.46/min in VR-C, 0.47/min in P&P, and 0.52/min in VR-noC. Finally, the design gestures used for questioning during the co-ideation process are more frequently observed in VR-noC (0.38/min) than with P&P (0.15/min) and VR-C (0.20/min), although the two formers are showing a similar pattern concerning the relationship to the representation (Figure 2).
SKETCHING
Proportionally, there were quite fewer episodes of sketching observed when using VR-C (0.37/min) than when in the VR-noC (0.81/min) and P&P (1.06/min) conditions. This difference was observed for all kinds of Design Conversations (proposing, questioning and explaining), although for questioning sketching the trends displayed a higher rate in VR-noC (0.21/min) than in P&P (0.15/min) and VR-C (0.09/min). Sketching linked to explaining episodes was almost two times more frequent in the P&P condition (0.64/min) than in VR-noC (0.39/min) and four times more than when using an immersive context, in VR-C (0.15/min). In addition, there are sketching episodes recurring during conversation spans combining the questioning and explaining of design ideas only in the condition of VR-noC (Figure 3).

DESIGN CONVERSATIONS
Findings indicate that, for all three conditions, the design conversations occurred according to similar patterns. One notable trend is that the type of conversation most frequently present pertained to explaining design ideas (Figure 4), accounting for 58% of verbal interventions in P&P, 54% in VR-C and 49% in VR-noC. Moreover, data indicates there is a similar proportion of verbal design conversations pertaining to proposing in all three conditions: 28% in P&P, 32% in VR-C, and 33% in VR-noC. Finally, within conversation spans, we observe co-occurrences of proposing-questioning and questioning-explaining only in the condition of VR-noC (Figure 4) making it, when also considering data concerning sketching activity, the condition with the most intertwined verbal and graphical exchanges. One additional observation is that rates for questioning (0.51/min) and explaining (2.13/min) stood at the lowest levels in the case of VR-C compared to P&P (0.64/min and 2.69/min) and VR-noC (0.88/min and 2.26/min) respectively. Questioning rate was highest in the VR-noC condition and explaining lead in P&P.

DISCUSSION
In this study, all the participants made design gestures during their ideation interventions in collaborative sessions. Regarding the use of the graphical representation during those interventions, design gestures were more frequently related to the representation only when an immersive contextual environment was used. It seems that the immersive contextual environment supports further negotiating ideas through its use as a reference. Considering differences in sketching instances observed across conditions, this implies that use of pre-made context greatly reduces the need to sketch elements to exteriorize ideas, in particular for this kind of design project where solutions have to take into consideration multiple scales of integration, existing infrastructure and uses (sidewalk, parking, traffic, light poles, weather, etc.). Using pen and paper, one could assume that gestures’ trend to be independent is due to the scale and proportional issues resulting from a representa-
tion constrained within the size of the paper (Figure 5). However, the same pattern was observed in the life-sized VR in the absence of a representation of the project’s context.

This being said, it is important to highlight that the three conditions did not notably affect the verbal exchanges in different manners: looking at the results related to the occurrences of elements of Design Conversations, the three conditions show similar proportions patterns. Nonetheless, noting multiple co-occurrences of proposing-questioning and questioning-explaining only in VR without the use of context, patterns of conversation come off as more intertwined in this condition. Overall, the prevailing amount of explaining episodes for all conditions could be due to the pedagogical nature of the sessions consisting to some extent in project reviews with the professor and collaborators co-ideating. Although, in respect with this pattern, a surprising observation is how the design gestures, sketches and conversations used for questioning during the co-ideation process are more frequently observed in VR without contextual environment than when including a context or using pen and paper. This could mean that the use of uncontextualized, isolated 3D models within an immersive environment is more prone to support extensive spatial and formal related discussions. Future research should investigate possible divergence or resemblance of such representations with perceptual characteristics of mental simulations used by designers or decision makers for
deliberative evaluation or challenging of solutions (Klein, 2008; Ball et al. 2001).

According to Hostetter & Alibali (2008), representational gestures seem to be intentionally used for communicating visuo-spatial information to other people, especially in complex and ambiguous verbal messages. Representational gestures are more frequent when the speakers can see the addressees (co-located) and they seem to influence addressees’ comprehension first by matching the contents of the words (e.g. saying “the table is that high” showing how much), and second by conveying additional information not verbally expressed (e.g. saying “we have a cup” showing how big). In fact, there is evidence that speeches accompanied by redundant gestures are comprehended better than those accompanied by mismatching gestures (Alibali, 2005).

Concerning the above, the design process is a complex activity and during ideation, although mental images of ideas can appear to be clear to students as reported in interviews, details or relationships within these ideas can remain hazy. During the process of externalizing embryonic ideas, verbal exchanges on their own could be imbued of this ambiguity, making them insufficient to communicate design intentions. In this case, immersive contexts in a collaborative environment could act as a launchpad for idea externalisation to lean on.

Other considerations are related to the fact that sketching in space using Hyve-3D is different and takes more time than sketching with pen on paper. Since participants are not drawing in perspective in Hyve-3D, they represent orthogonal parts of the sketch through subsequent spatial manipulations of their 3D Cursor to construct in a manner somewhat akin to modeling. Thus, a limitation of this study is that students were still learning to interact properly with the Hyve-3D during the ideation sessions, which lead in part to slower sketching. However, the participants sketched according almost to the same rate of episodes on paper than in VR without context, and we can therefore assume that most of the sketching was required to represent the envisioned context of the concept, as expressed by some participants during interviews. This issue could point towards a higher risk of leading to additional introduction of error factors where ideas generated carry on mistakes from the context’s representation. For future work and related to Alibali (2005), it would be relevant to investigate speaker’s viewpoint in mental images underlying gestures enacted in a VR context and how it compares to the representation’s point of view, bringing us to a more detailed characterisation of design gestures in VR and AR.

CONCLUSION

Observations gathered in this study propose that design gestures were more often directly related to than independent from the graphical representation only when using an immersive contextual environment. Furthermore, the rates of sketching episodes in general and sketching explanations were considerably lower in this condition compared to VR without the context and pen and paper. Paired with results showing similar patterns of design conversations of proposing, questioning and explaining throughout all conditions, although rates of occurrences differed, this could imply that use of pre-made context greatly reduces the need of graphically representing additional elements to clearly exteriorize designers’ ideas, putting forth the idea that the context supports clearer co-ideation. A goal of conducting this study was to lay a basis for a broader reasoned diagnostic regarding the possible contribution, drawbacks or shortfalls of using VR with 3D scan techniques to adequately foster some of the contemporary disciplinary revisions in architecture and design. This way, a better grasp of how they impact the design process is needed, both at the level of the designer and the designed projects, in education and practice, to avoid undesired social impacts as a result of blind technology adoption.

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