7 Sample UVE

Creating a practical UVE

An open competition, organized by Visionair, provided for the support required for creating this real/practical UVE. Visionair is an acronym for "VISION Advanced Infrastructure for Research". Visionair applies European infrastructure for high level visualisation facilities that are open to research communities across Europe and around the world. By integrating existing facilities, Visionair aims for conducting state-of-the-art research in visualization, thus significantly enhancing the attractiveness and visibility of the European Research Areas (ERA). With over 20 members across Europe participating, VISIONAIR offers facilities for Virtual Reality, Scientific Visualization, Ultra High Definition, Augmented Reality and Virtual Services. The fund for Visionair activities is provided by Fp7 (Framework Program for Research and Technological Development).

ITIA-CNR (http://www.itia.cnr.it/en/), Italy, was assigned via the Visionair funding body, as the chosen authority to provide the virtual reality (VR) facilities. The experiment was subsequently conducted in December 2013. The results of the experiment were presented in the Visionair conference in Rennes, France in 2014.

After creating the UVE, a group of 20 participants were asked to navigate in the environment. They were asked to provide a written feedback pertaining to their feelings, expectations, strategy of navigation and in general, their experience.

§ 7.1.1 **Introduction**

By applying virtual environments in design processes, architects can expect a variety of solutions, as compared to conventional methods despite the problems with visual perception or mental workload or frequency of iteration between creation and modification (Schnabel & Kvan, 2003).

Designers use different tools to communicate and express their thoughts. Although some architects visualize their design decisions through large-scale models, modelling

is always limited by the overall dimensions, scale, resource constraints and material restrictions. To overcome these constraints, architects implement virtual environments (Bertol & Foell, 1997). Although virtual environments can be easily found everywhere, immersive virtual environments (IVE) are typically found in research-laboratories or universities. Recent progression in technology provided the ground for IVEs to be implemented in the consumer electronics sector such as the gaming industry (Leach, 2002). The story is the same in the discipline of architecture and opportunities for applying VEs in architectural design are still developing (Stuart, 2001). VEs are employed successfully to study, communicate, collaborate, and present architectural designs but are rarely used for the actual act of creation and form-finding in the field of architecture (Maze, 2002).

In this chapter another application of the IVEs is proposed: to create an immersive UVE. This application is not developed for the purpose of visualization or form finding, but specifically for enhancing creativity.

§ 7.1.2 Building the UVE

The UVE has been built using the 3D Max software platform. Attempts have been made to implement all the [unconventional] qualities for separating the virtual environment from the physical world as much as possible. With the help of a 3D physical interface, termed Giove, developed in ITIA-CNR, the 3D max environment, is converted into an interactive, 3D stereoscopic environment. This allowed the participants to navigate the UVE by wearing a 3D goggle (figure7.1).

FIGURE 7.1 Participant wearing a 3D goggle

§ 7.1.3 Instruction for the participants:

The participants were asked to navigate the UVE using the 3Dconnexion (Figure 7.2). They were asked to consider that they are in a real environment when they are walking/ navigating through the simulation (Figure 7.3). After the experiment, the participants were asked to write down their opinions about the experiment such as their most prominent feelings, strategies to navigate the environment etc.

FIGURE 7.2 Instruction for using 3D Conexxion
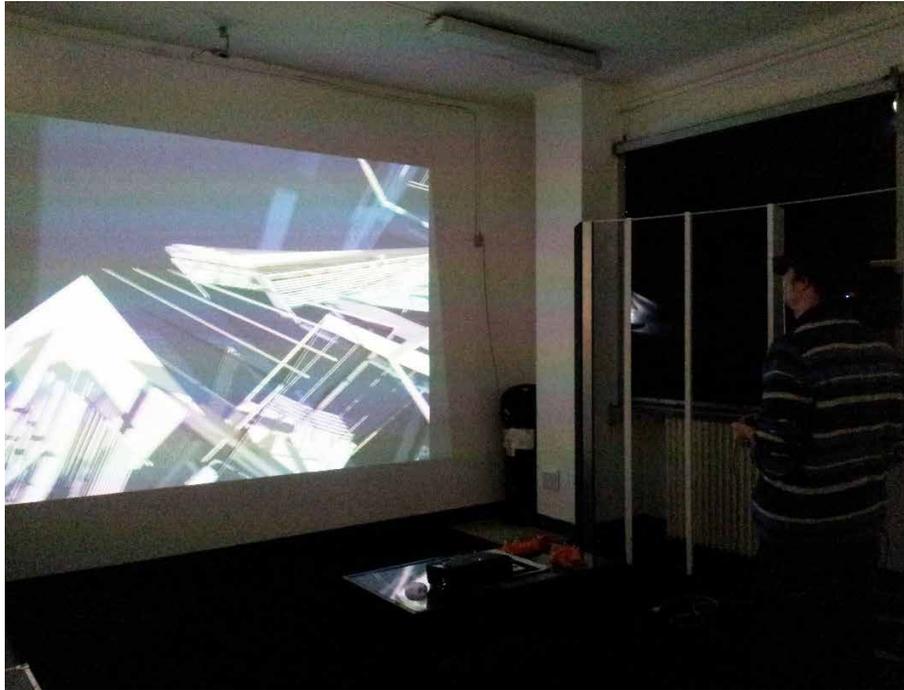
FIGURE 7.3 Participant while navigating in a UVE

Feedback of the participants

The post-experiment analysis of the participant's comments, suggest that almost all of them have the similar feelings of confusion, dis-orientation and dizziness while they begin the navigation process, however, after a while they get used to the navigation process and develop a feeling of excitement and enjoyment. Smaller groups of participants also commented on the time required for navigation. Some, found it "boring" after the second minute while some preferred to voluntarily spend time inside the UVE to perform a task, rather than pure exploration. All comments of the participants (unedited) have been listed in Table 7.1. These comments will be considered for future experiments to optimize the experiment duration and interaction.

POST EXPERIMENT FEEDBACK	
PP1(M)	The dominant feeling during the first minute (or so) was confusion as the brain was trying to establish a clear relation between the subspaces (i.e. lines and planes) to define relative position and perspective in general. Then the confusion gradually developed itself into curiosity as these relations were explored more, but this process was not as fast as expected maybe due to erratic spaces and non-familiar alignments (as opposed to those familiar features in the daily life). Afterwards came the amusement as the curiosity was fulfilled (or may have worn out). Weightlessness played an important role in this stage (which is I guess is irreverent to the purpose of this study). If one defines fear as something that hinders curiosity and ruins amusement, it can be associated with the dark space surrounding the "playground". Once getting lost into this space it was not that easy finding your way back.
PP2(F)	The environment seems like an island lost in the empty space. No people can live there, only pointed objects. Not really dangerous but not comfortable because nothing is soft or warm there. The color is also cold on the black surface. Curiosity for sure, but sometimes confusion took over passing over different levels of the environment was not leading to clarity. I am Interested anyhow to explore these boundaries and understand the general view or shape of the space.
PP3 (M)	I was not fully comfortable with the controller since I could not easily distinguish between moving forward/backward and rotate upward/downward. I improved during the test but was not fully satisfied. While moving in the virtual environment I felt curious at the beginning but after a while I felt the need for an objective or a task to accomplish, because I was "just moving around". I focused on "building-like" elements on the left, but I would be more involved if I had something to find, or a purpose, alongside free exploration. So I tried to "give a meaning" to the environment by first having overall views and then focusing on details.
PP4 (M)	The environment reminded, in some of its aspects, a common building or a common house in which rooms and corridors can be identified even if these are not clearly defined. In some other aspects it was like a ruined building where the corridors were interrupt and the floors were destroyed. It wasn't clear where the environment ends and I had to be careful to not lose myself. The prominent feeling was one of curiosity to understand the environment configuration and in which way a real person could navigate in it and if there was some logical construction and it was possible to navigate in it as if I were walking in a real palace. Navigate through the walls and fly over the environment has been a funny experience.
PP5 (M)	Before going through your experiment I imagined something different: a more colored and dreamlike environment. Instead I found a quite dark and well-ordered architecture. Anyway my prominent feeling during the whole experiment was curiosity. During my exploration I tried to figure realistic architectural components: gates, stairs, flats etc.
PP6 (M)	The experiment is very interesting and I am very curious about the results. Is an unconventional-spatial environment really effective to stimulate creativity? Did immersive VR really influence the user's status? From the environment point of view, I found it very captivating. The disorientation was for a very few moments, after that I was very interested in finding out a path towards an incredible 3D space. As said I was very curious to discover the environment while I was also trying to rationalize it.
PP7 (F)	The non-common environment, which I was asked to navigate through, is very strange and confusing: the absence of orthogonal planes and classic perspective creates disorientation. The main structure appears like a post-apocalyptic environment, a wooden world after a cataclysm or a giant-size of pick-up sticks. While I was navigating, I felt the necessity to search and follow a clear path, moving along what seemed to me more "stable", avoiding the intersecting structures. The main problem of that strategy was the unexpected interruption of those elements and the consequent access into the darker zones. Then my principal intent became to reach the main structure again. I don't know exactly why, maybe the reduced interest to that darker part or maybe the sense of vacuity.

POST EXPERIMENT FEEDBACK	
PP8 (M)	First of all, thank you for having involved me in your experiment, it has been great! I have been fascinated by your experiment mostly because I was allowed to freely navigate in a 3D environment, which was completely new for me. The entire environment resembled a giant contemporary architecture and I was mostly attracted by the light grey shapes because they were like the parts lit by the sun. The other part on which my eyes focused a lot was that one modeled like a kind of footbridge because I was attracted by the parallel lines. I found the navigation system easy to use and understand, but two or three times I lost my way trying to look around me because of a low velocity on the rotation around the vertical axis of the 3D mouse. I am a curious person so I was excited by the chance to navigate in a completely new environment. I was not frightened nor confused by the modeled structure, but I am really convinced that my feelings would be different with another background color, maybe a light one. But I have to say that the dark grey background helped me to recognize shapes, shadows and volumes.
PP9 (F)	I already had experience with 3D environments and the use of 3D mouse, therefore it wasn't something completely new. Anyway, I was not used to navigate in an unstructured 3D scene. After a quick initial exploration of the 3D environment, the navigation was a bit boring because I couldn't find a goal to lead my movements in the space.
PP10 (M)	I found the experiment curious, annoying, disorienting and relaxing. In the first part of the trial, I was curious to navigate inside the environment understanding what it was and I wasn't able to. With the time elapsing I felt a bit annoyed because of a sense of disorientation (entering some area too dark I lost the orientation) and of a decreased sense of presence (since I could pass through objects). Then I decided to watch the environment from the outside and I found it relaxing.
PP11 (F)	I think that the experiment is very interesting and innovative. During the navigation, (after understanding how to use the joystick!), I felt very curious about the environment, and I didn't feel frightened or confused. I also noticed that, at the beginning of the experiment, I tried to relate the shapes of the virtual environment with the shapes of the real world which are, of course, more familiar to me. But then, since I wasn't able to find an association for every virtual object, I only continue to navigate without this kind of "preoccupations" and it was really funny, mainly because It seemed like I was flying! I wished for the experiment to last longer!
PP12 (F)	I would like two mention 2 comments about the experiment performed yesterday. On the one hand, I want to highlight my particular interest in the colors of the environment. I don't know if these were intentionally selected but I guess that they influenced my feelings when I was moving around these colors. I associated the white color as a possible exit point, so I focused on trying to find possible paths for getting out of there. So I think that I can I can use the word anxiety to describe what I felt in the experiment. On the other hand, I will like to mention that the devices used to perform the experiment, specially the glasses are heavy and uncomfortable, I think that these might have some influence in the experience of walking around the environment.
PP13 (F)	While I was navigating, my prominent feeling was curiosity. I thought I was going into a building and I was discovering how it was made. Some details in your structure made me think there were conventional elements in it, like stairs, windows, walls, etc. Because of this feeling, what I intended to do was try to discover if what I thought to be a specific buildings element (stairs for instance) was that element indeed. Of course, I realized that none of them was something conventional. Therefore, I navigated to try and identify how these unconventional structures were made. I think it is a nice experiment, and it stimulates my curiosity. It was challenging to try to find out how the structure was built.

>>>

POST EXPERIMENT FEEDBACK	
PP15 (M)	Before doing the experiment I was sceptic about the virtual environment (also because of ignorance about the specific research field), mainly because it made no sense to me, with all those strange shapes apparently assembled together in a chaotic way. During the experiment I put aside these thoughts and just navigated while concentrating on exploring this new world as an archeologist does the first time he visits a new cavern. The feeling was curiosity and "contemplation", let the mind absorb what it is actually seeing and feeling. I found that, whatever my orientation and /or navigation direction were, there were always geometrical shapes that made my actual orientation "correct" or, better. It was a sort of property of "isotropy of the feelings" maybe caused by the space. In my opinion it would be useful/interesting to build a more extended virtual environment
PP16 (F)	In my personal experience, I felt very relaxed and curious to discover the virtual environment, I sometimes lost my orientation and got lost in the space but maybe this was because I was curious to discover the environment around me. I hope that this account of my experience will be useful for you.

TABLE 7.1 Post experiment feedback

§ 7.1.5   Specification of the tools for the experiment

§ 7.1.5.1   3D projector

The projector used in this experiment was EX762, XGA - 4000 ANSI Lumens.

Using the inherent speed of DLP technology, The Optoma EX762 can output video and images at rate of 120Hz, allowing one to show full screen, full color, and stereoscopic 3D. The 3D effect is generated by splitting this signal into two standard video streams, one for each eye. Using DLP® Link™ technology, the 3D glasses synchronize with the image on the screen to filter each stream to the correct eye. The brain then combines the two streams. The 3D features of the EX762 can only be used with compatible 3D content.

FIGURE 7.4 3D stereoscopic projector

3D goggle

DLP (Digital light processing) technology uses millions of microscopic, digital mirrors that reflect light to create a picture for projectors. This imaging technology is so fast, it can actually produce TWO images on the screen at the same time: One for the "left" eye and one for the "right" eye. To create the 3D effect, you need 3D Glasses that combine the two images. For the sake of this experiment we decided to use XPAND 3rd generation of DLP® Link™ 3D Glasses: XPAND Edux 3 3D Glasses (X103-EDUX3 / X103-EDUX3-R1).

FIGURE 7.5 XPAND 3D Goggle

§ 7.1.5.3 **3D stereoscopic interface**

For creating stereoscopic environment, we applied GIOVE. GIOVE stands for: "Graphics and Interaction for OpenGL-based Virtual Environments" and is a set of software libraries (SDK Software Development Kit) written in C and C++ for developing applications that use real time 3D graphics. ITIA-CNR (National Research Council: Institute of Industrial Technologies and Automation) of Italy developed the interface for its own research but since various research projects within ITIA typically have different targets and applicative contexts, it was difficult to focus on just one commercial platform for development. GIOVE is an internal "product", it does not have any licenses, it is not open source either. GIOVE is based on OpenGL (www.opengl.org) and it works with Windows operating system. It can load 3d models in .3DS and .Obj format. The FBX and DXF formats are under development depending on the demand of the projects in progress.

For utility purposes an application called "GIOVE-Viewer": an application for loading 3D models and that allows various basic operations including navigating in the scene, positioning/rotating models, taking screenshots, add lights, customize observers point of views, enable real time shadows and so forth was used.

3D navigation tool

3Dconexxion was employed to navigate the virtual environment. Commonly utilized in CAD applications, 3D modeling, animation, 3D visualization and product visualization, users can manipulate the controller's pressure-sensitive handle (historically referred to as either a cap, ball, mouse or knob) to fly through 3D environments or manipulate 3D models within an application. 3Dconnexion patented 6-degrees-of-freedom (6DoF) technology for smooth and intuitive control of 3D models and environments. The appeal of these devices over a mouse and keyboard is the ability to pan, zoom and rotate 3D imagery simultaneously, without stopping to change directions using keyboard shortcuts or a software interface giving the participants a clear sense of immersion in virtual space.

FIGURE 7.6 3DConexxion mouse

8 Conclusion

The research focused on cognitive aspects of creativity, including thinking patterns, conceptual blending, idea expansion and tolerance of ambiguity instead of personality and behavior of creative people, their mood, state, temper, motivation and so forth.

It was also found that "conceptual blending" and "tolerance of ambiguity" are related to creativity. Multiplicity of experiences may help for divergent thinking and indirectly affects creativity.

Starting the design from a higher dimension (3D interface) may yield to more creative ideas comparing to lower dimension (2D pen and paper), due to the fact that 3D interfaces provide a better perception of non-Euclidean geometry.

It is also found that the brain function is different in different environments. More creative parts of the brain activates while the brain tries to perceive an "abstract" environment in comparison with "fully or semi" designed environments.

Each of the above finding is discussed in detail by answering the research questions:

This section gives detailed answers, firstly to the sub research questions and subsequently, to the two main questions posed in chapter 1.

To narrow down the widespread topic of creativity and focus on creativity in architecture, the research ignores aspects of creativity which focus on personality and behavior of creative people, their mood, their state and their temper, intelligence vs. creativity, motivation and so forth. Instead, the research focuses on cognitive aspects such as thinking patterns, conceptual blending, idea expansion and tolerance of ambiguity.

§ 8.2.1   **Question number 1 (answered in chapter 2)**

What are the effective parameters correlated with creativity in architectural design?

The chapter expanded upon the understanding of creativity and narrowed down upon a definition of creativity pertaining to the scope of this research. The Chapter also, discusses where creative ideas come from in accordance with theories of David Jones. The Chapter further, elaborates upon types of creativity and correlates it with the architecture discipline. A clear focus on cognitive aspects of creativity such as thinking patterns, conceptual blending, idea expansion and tolerance of ambiguity have been focused upon. In short, it can be summarized that the following parameters are correlated with [spatial] creativity:

1. Multiplicity of experiences helps in the process of idea expansion and divergent thinking. The same Divergent thinking is directly related to creativity.

2. Conceptual blending is influential in training the brain to blend remote ideas. The more remote ideas are available for blending, the more the chances of generating creative ideas.

3. Tolerance of ambiguity, helps in postponing one's judgment and allows for considering as many parameters as possible. This ability is pertinent to creativity.

4. A change in thinking pattern is emphasized on. This implies shifting from probabilistic creativity towards impossibilistic creativity.

§ 8.2.2   **Question number 2 (answered in chapter 3)**

Are tools and changing the dimension of design process (from 2D pen and paper to 3D interface) effective in the enhancement of creativity?

Inspired by the book "Towards a new kind of building", written by my promoter Kas Oosterhuis, an experiment was conducted to address this question. In the experiment, the same design task was provided to a group of architecture students [in the last year of their Bachelors studies]. The design task was to design the same spatial environment once using an analogue traditional interface of a 2D pen and paper and the next time using a 3D software platform. A group of 5 experts [University Professors] subjectively decided whether there was any enhancement of creativity in their designs or not.

132   **Enhancing [Spatial] Creativity**

TOC

The jury decided that the students who used 3D max platform as their modeling interface had the best results with 83.4 % improvement in their performance. Only 42.9% of the students had improved by choosing Sketch up as their interface and this was mainly due to software limitations for producing complex geometries. Students who applied Revit as their 3D interface gained 66.7% improvement.

In summary, tools have a direct effect on the brain's ability and aid it to think out of the box. Starting design from a higher dimension thus helps the designer to include all the possible design options, both Euclidian and non-Euclidean.

§ 8.2.3 Question number 3 (answered in chapter 4)

Theoretically, how can unconventional virtual environments (UVEs) be helpful for enhancing creativity?

This question has been expanded upon and elaborated in chapter 4. After defining the characteristics of a UVE, the hypothesis has been broken down and discussed in detail. In summary the following arguments have been arrived at:

1. Surfing/Exploring an UVE enhances creative performance and creativity-supporting cognitive processes (e.g., recruitment of different ideas and retrieval of unconventional knowledge);

2. The connection between experiencing UVEs and creativity is most apparent when individuals have had the experience of deeply "immersing" themselves in virtual environments and "interacting" with these environments;

3. Adapting and opening themselves to new experiences and actively interacting and comparing the differences they encounter between unconventional virtual environments and the physical world can boost the benefits of this experience;

4. A weaker relationship between experiencing virtual environments and creativity emerges in contexts where one confines themselves to limitations of the physical world, such as: construction limitations, material limitations etc.

§ 8.2.4   Question number 4 (answered in chapter 5)

Are there any methods to boost [spatial] creativity in architecture?

This question is answered in Chapter 5. In Chapter two, pertinent parameters on creativity have been tested under the unique name: Proto-fuse project. These parameters are 1) Conceptual blending and 2) Tolerance of ambiguity. For each of these parameters a separate experiment has been designed:

1. Navigating in UVEs (aiding conceptual blending mutation)

2. Extracts of local distance (aiding tolerance of ambiguity)

These two experiments not only verified the linkage of these two concepts to creativity, but also clarified how these can be implemented in the pedagogy of architecture to enhance creativity in praxis as well as academia. The Proto-fuse project can help architects to increase their tolerance of ambiguity and expand their inventory of experiences. Improbabilist creativity can turn to impossibilist creativity by applying UVEs to attain the mutation of ideas.

Training students of architecture to enhance their tolerance of ambiguity during the design process, by designing ambiguous experiences and training the mind gradually for more ambiguous situations, can provide a suitable springing board for implementation of the Proto-fuse concept. Providing virtual reality workshops for students, where they can navigate, interact and explore UVEs adds new and unique opportunities to enhance their inventory of experiences, subsequently leading to the generation of novel ideas and should thus be surely encouraged.

§ 8.2.5   Question number 5 (answered in chapter 6)

Is there any difference between perceiving different environments? (E.g. Abstract, semi designed and fully designed environment). If the answer is positive, can we provide an objective empirical evidence for it?

This question is addressed in Chapter 6. A marked difference is observed by analyzing the differences in the perception of different environments. The experiment was conducted with three different environments: 1) Abstract-designed environment, 2) Fully-designed environment and Semi-designed environment. The results show that

the brain activity patterns during perceiving abstract environments is different from the brain activity patterns while perceiving a fully designed or semi-designed environment.

It is also discussed that this difference is [possibly] related to creativity. The difference observed while perceiving abstract virtual environments, owing to its being free from physical rules/world, maybe related to divergent thinking, expanding inventory of experiences, thinking out of the box and in general to different aspect of creativity. The empirical evidences for these claims have been acquired with an electroencephalography (EEG) study.

§ 8.3 Application recommendation based on results:

The designated audiences of this dissertation are architects, industrial designers, (3D) game designers and so forth. The application may thus vary for different target groups. The following applications are nevertheless speculated:

§ 8.3.1 Apply UVE in the pedagogy of architectural education:

UVEs can be implemented in the pedagogy of architectural education, specifically in the early years as part of the curriculum. By designing, navigating and interacting with UVEs, students shall add new data to their unconscious mind. Their brains shall thus witness a higher possibility of conceptual blending and passively becoming more creative.

§ 8.3.2 Start designing from a higher dimension

Unlike the traditional recommendation of architecture schools to start designing with pen and paper in a 2D environment and then shifting to a computer, there should be no obligation on the order or the kind of design tools. It is even recommended to start designs from a higher dimension e.g. 3D computer interfaces or an even higher dimension such as starting a design from a virtual reality point-cloud.

§ 8.3.3 Train the brain to tolerate more ambiguity:

It is recommended to confront one's self with complex ambiguous situations/images/problems and try to suspend making rational judgments as much as possible. Try decoding ambiguity as much as possible from different perspectives. It is suggested that introducing the proposed UVE's based exposure to induce ambiguity in the architectural curriculum can help train students to enhance tolerating ambiguity as much as possible.

§ 8.3.4 Do not mix design and problem-solving modes of the brain:

Opposed to the popular belief amongst designers, that they can think as a designer (for form-finding) and problem solver (technical issues) at the same time, it was observed that the brain cannot perform both tasks at the same time. It is thus recommended to iteratively pursue a design process (form-finding, problem solving), focusing on these two aspects of design one at a time.

§ 8.4 Recommendations:

§ 8.4.1 Recommendation for future research:

This dissertation and its findings suggests two topics for further research:

In the experiment presented in chapter three, two different starting point dimensions were considered: 2D vs. 3D. The comparison was between pen and paper and a 3D interface. Such a comparison would become more interesting if we can compare the same task using another higher dimension: A 3D interface (by using 3D software platforms on the computer) with an interactive 3D point cloud accompanied with 3D goggles and motion detector gloves. It could still be hypothesized that the results of the interactive 3D environment will be more creative as compared to a lower dimension starting point.

The second recommendation is drawn from the experiments in chapter seven. In this Chapter a sample UVE was created and participants interactively navigated in this environment wearing a 3D goggle. It is suggested that one records the brain functions of the participants while they are navigating the UVE. The results would help to see whether the creativity correlated parts of their brain are being activated while the users are navigating the UVE's or not. There are nearly 60 different experiments already conducted in the whole world in connection with creativity and brain function (using EEG, fMRI). The results of such an experiment can be compared to the results of these previous experiments and comparatively analyzed for similarities and differences in the recorded data.

§ 8.4.2   **Recommendation for the market:**

Enhancement of creativity of designers [especially architects] and applying more creativity supporting tools comprised the broader aim of this research. The research thus specifically focused on methods which can passively increase creativity. At the moment there is no specific game engine for designing interactive virtual environments. The next generation of architects will apply creativity supporting tools more and more in their design procedure. Therefore, powerful design engines can be developed in the market which can be of great use for the design community. Moreover, interfaces which can transform a 3D environment to stereoscopic 3D would also be a welcome move from the industry.

Better tools for interacting with virtual environments are also very vital a for the future development of such immersive VR based methods. Next generation of motion detectors, 3D goggle, 3D navigating tools, 3D sound, 3D soundscapes, 3D projectors etc. with intuitive interfaces for a richer experience are thus much needed. It is thus suggested that the industry invests in developing up to date supporting tools for such creative/cutting edge design/pedagogy developing procedures.

§ 8.5   **Value of this dissertation:**

This dissertation has provided a set of unique and original results regarding human creativity, perception and the functioning of the human Brain. These results are driven by scientific simulations, experiments, interviews and observations conducted

in The Netherlands, United Kingdom, Italy and Iran and have been peer reviewed by Internationally reputed scientific Journals.

The most important factor of this research is its multidisciplinary perspective on creativity and design. While there is no consensus on the definition of creativity and each of these disciplines (design, psychology and neurology) has its own approach, definition and associated research, this research managed to cover all three domains.

Architecture is a subjective and context oriented discipline. While there is no global design approach accepted by all architects and each of them have their own approach and design methodology, this research found empirical evidence on brain functions during design procedures, which is not subjective but objective in nature. Such empirical evidence on brain function can help architects to re-design/re-think their methods and approaches via enhancing their creativity.

At the end, this dissertation serves society in general because it helps to improve the creativity of human kind, which, is the fountainhead of human civilization.