How non-designers understand the architecture design project: a comparative study using immersive virtual reality.

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Abstract. This study focusses on how people who are not familiar with the traditional methods used to represent architecture understand architecture design projects. The main objective of the study was to assess the client's level of comprehension of a design project presented using traditional representation methods in comparison with a method based on the use of immersive virtual reality. Two experiments were conducted, involving architects, design projects and real clients. In both experiments an architecture design project was presented using two different methods: i) the traditional method, ii) the immersive method, using virtual reality, viewed by means of a Head Mounted Display. The results were used to address the questions posed during the study regarding comprehension of architecture design projects. They confirmed the hypothesis that individuals who are not familiar with architectural representations have a better and more accurate perception of a project after viewing it using immersive virtual reality rather than looking at technical drawings, renders and scale models.

Keywords: Representation, understanding architecture, immersive virtual reality, comparative study.

1 Introduction

The research presented here deals with architecture representation methods and focuses on evaluating how these methods affect the understanding of design projects by people who are not familiar with architecture representation codes (henceforth described as "laypersons"). People who are not trained to visualize abstract graphic representations of space, e.g. orthogonal projections, have a hard time interpreting this type of drawing correctly, which may result in misconceptions of the design project, often meaning that it does not meet their expectations.

Over the years, various tools have emerged that alter the way in which an architectural design is represented and presented to the client and the general public. Nowadays virtual reality technologies are evolving rapidly, offering an immersive experience of space when used with devices such as the Head Mounted Display

(HMD) and CAVE facilities. Virtual reality devices, particularly HMDs, are increasingly being used as tools for architectural representation and experimentation, facilitating dialogue between the various stakeholders [1]. By allowing the user a feeling of experiencing a real-scale space, enhanced by the existence of interactive and animated elements, virtual environments provide a rich experience that is more recognizable as a natural space.

As a consequence of the above developments, two research questions were posed: i) To what extent do clients perceive the architecture design they have commissioned from the architect when it is presented using traditional architectural representation methods? ii) Does the use of immersive virtual reality systems increase the client's understanding of the project?

The main objective of this research was to identify and analyse the differences in the perception of space by laypersons when confronted with traditional architecture representation methods (floor plans, sections, elevations and physical models) and with a viewing involving the use of immersive virtual reality. The work focuses on the architect's clients and on how they can be better informed about their design projects at the conception stage.

The research hypothesis is defined as follows: the client has a better understanding of an architecture design when they visualise the project using Immersive Virtual Reality (IVR) instead of traditional representation methods (technical drawings, physical models, and even renders).

2 Representation and Communication in Architecture

2.1 Architecture representation tools

Over the years, certain architecture representation tools have been developed while others have been forgotten or abandoned.

The best means of communication for architecture is through the use of graphics, which includes images as hand-drawn designs, sketches, photography, photomontage, digital design and renders. In addition to serving as a representation tool, this is also a way of thinking about and creating architectural ideas [2]. This study focusses on analysing technical design, a selective means of representation, since it allows architects to represent only what is required and uses a specific system of values [3]. Within the sphere of digital images, renders are important in terms of visual awareness of the architecture that is being designed. A render is a photorealistic image created from a digital 3D model exposed to virtual light and similar conditions to reality, thus simulating a photograph. Observation of the render may serve as the basis for making decisions relating to the design, since the spatial and construction characteristics are visible and not hidden or disguised by different drawing capacities [4].

A project begins with an idea which is then usually put down on paper in the form of sketches and perspective drawings. However, this is not sufficient, since detailed drawings are essential for the design and construction work [4]. Detailed drawings are produced by using representational codes that are specific to the construction industry and are only, or essentially, understood by those who work in this field. This means that laypersons who do not understand these codes may find the drawings difficult to interpret and may even misunderstand them.

In addition to images, the physical model is also an important tool for architects, since it enables ideas to be explored in three dimensions in a physical and material way, which is not possible with other tools. It is also important for presenting the project, since it represents the architecture on a small scale, thus enabling the viewer to examine it from different angles.

2.3 Spatial perception

Spatial perception or spatial awareness is a research topic that has engaged philosophers, psychologists and neurophysiologists for a long time. Their studies, which became central to the modern scientific vision of nature during the seventeenth century, focus in particular on visual perception and spatial properties [5]. Eimer notes that the dominant role of vision in spatial perception affects other multisensory links, such as auditory and tactile events, and that all the senses are inextricably linked [6].

Visual perception works from the global to the particular, since “the overall structural characteristics are the primary data in perception” [7]. Therefore, “perception begins by capturing the most obvious structural aspects.” [7]. When we look at something, we do not register everything in our field of vision since, unlike a camera, a great deal of detail is ignored. Human beings who have access to technology and have become accustomed to images can easily recognise most of what they see in photographs or drawings, but if they are not familiar with photography, as may be the case with a tribe that has no modern technology, they find it difficult to identify human figures in the image, even though they are used to seeing humans.

Regarding depth, we can perceive that an object is a body with volume which always has one side that cannot be seen, namely the side opposite the point from which it is viewed. Multisensory knowledge, two- vs three-dimensional perception and the perception of depth and distance are fundamental in research into spatial perception. There are many variations in the relationship between physical stimuli and perceptual representations of space. As an example, Hatfield [5] refers to the perception of size and how spatial properties of objects that are experienced differ from those represented in the retinal image.

Oblique lines are often seen in images, since they suggest an idea and perception of the depth of an object within the space in which it is represented. However, not all oblique lines create an idea of depth, as it is necessary for them to be “deviations from the normal vertical and horizontal structure.” [7]. One example which illustrates this is a drawing of a cube. If we draw it with three visible surfaces, one of which is its true size, a square will serve as the front and does not need to be deformed as there is no deviation on this plane. When we add the other two faces, they give depth to the drawing of the cube due to the use of oblique lines. Although the drawing represents a cube to us, in reality this is erroneous since when we observe the front of a cube depicted in its true size, we are unable to see any other surface. The drawing is only a means of representing a cube, by giving it depth and distinguishing it from a square in a way most people understand. Moreover, the hidden rear faces of objects are perceived amodally, as observed by the Gestaltists, proving that it "is possible to perceive spatial structure in the absence of physical stimulation." [8, p. 134]

The movements made with our eyes or limbs are transmitted to the brain and the "feedback" we receive concerning these actions influences visual perception. Kinaesthetic perception may be described as the awareness of body and limb position and movements in space. Together with tactile perception, meaning the sense of touch, they are referred to as haptic and provide information about the qualities of objects, bodily movements, and their interrelationships [9]. Authors such as Rudolf Laban, with his theory on Choreutics, studied how body movements can be a means of self-expression and influence perception of space [10], [11].

The fact that the brain knows the head is moving also means that our sense of vision attributes this movement to the head rather than the surrounding environment, perceiving the latter as static. When watching a film, "it is seen as moving on the screen, mainly because the viewer receives kinaesthetic information telling him that his body is at rest." [7]. However, with immersive virtual reality (see section 2.2) a different phenomenon occurs, since we are more "immersed" in the virtual environment and "when enough of the entire environment is seen as moving, the visual input will prevail over the kinaesthetic." [7]. This means that we can feel dizzy if we are in a high virtual location or scared if something frightening appears, even though we are in a totally safe place and merely using an Immersive Virtual Reality (IVR) device such as an HMD.

Obviously, a video does not transmit the same sensations as reality. In the real world, we are surrounded by our environment and subject to the elements that exist in it, whereas with video we usually sit in a chair and watch what has been recorded, experiencing a completely different sensation. In the case of cinema, for example, we are seated in front of a clearly defined screen and have a clear idea of the reality around us. Even when using an audio-visual IVR, although we are deeper "inside" the environment on a visual level, we do not experience the same sensations as in the real world, such as wind, warmth, cold or physical contact with the various elements, including the ground itself. Nevertheless, IVR is the medium which best enables us to "experience a real environment when reality is not present.

2.2 Immersive virtual reality

Virtual Reality (VR) is a technology which enables the user to totally immerse himself in a virtual environment that has been generated entirely by computer technology [12]. This reality links the user to the computer, simulating an environment that may already exist or be entirely imaginary, and allows participants to interact with this environment [12].

The technology is based on three essential ideas: immersion, interaction, and involvement. Immersion is the sensation of really existing in a virtual environment, essentially as provided by CAVEs and HMDs. In addition to images, these devices can offer the sounds of the environment, thus ensuring a profound sensation of reality and hence greater immersion. It may be said that immersive virtual reality (IVR) is achieved with the use of this kind of equipment, whereas a computer screen provides non-immersive virtual reality [12]. The levels of immersion and interactivity are the variables which enable us to differentiate between VR systems. They are sometimes determined by the performance of the computer, which may, for example, provide a higher frame rate, and also by the data input and output devices, such as HMD or CAVE, in comparison to a screen.

IVR is a rapidly developing technology used mainly in entertainment, particularly video games. Nevertheless, it is becoming increasingly associated with other areas, such as architecture, history, patrimony, psychology, and industrial design.

Currently, certain devices are available which enable the user to become immersed in a particular virtual environment, the most popular being HMDs and CAVEs (for immersive environments) and Powerwalls (for semi-immersive environments).

One way of enhancing immersion is to use these items in conjunction with other interactive devices such as joysticks or data gloves, the latter equipped with data recognition and movement or tracking sensors that enable the user to interact more naturally with the virtual environment [12]. Immersion may also be enhanced with automatic animations that include sound, temperature, touch, smell and flavour, pre-programmed to trigger certain reactions in the user [13].

In recent years, IVR has been used more widely in architecture, particularly as the price of the equipment has fallen and it has become easier to operate, together with modelling and animation software. These devices, particularly HMDs, are increasingly being adopted as tools for architectural representation and experimentation, thus facilitating the process itself and dialogue with the various individuals involved in it [1], [14].

IVR facilitates studies on space perception due to its ability to simulate and reproduce existing or envisioned spaces. Several studies have been developed to evaluate how spatial configurations are perceived by its users and which emotions they trigger. Leite et al. show that a virtual environment is effective in evoking different reactions for safe and unsafe spaces [15]. Shemesh et. al investigated the geometry of space using VR and electroencephalography (EEG) and concluded that "participants with no expertise in the field of design show a tendency to prefer curvy-shaped spaces and take significant interest in these spaces". [16, p. 123] Carreiro et al also concluded that "curvilinear elements are interpreted as being more pleasant and preferred than sharp ones." [17, p. 1]

3 The experiment

3.1 Experiment settings

In order to test architectural clients' perceptions of space it was decided to carry out a set of experiments in a real design environment involving real users, which would enable us to answer the research questions. Two different conditions were therefore defined: i) representation of the design using traditional methods and, ii) representation using Immersive Virtual Reality with the Oculus Rift Head Mounted Display (HMD).

Two different types of clients, both looking for an architecture design project, were chosen. The first was a couple who had commissioned an architect's office to design their home (the "House" case). The second was a company that had commissioned an architecture studio to design an energy interpretation centre (the "CINERGIA" case). The first sample consisted of a couple whose aim was to build their own home. They had a fairly informal relationship with the architect and communicated directly and personally with him. The second sample comprised ten people representing the client ADENE as decision-makers, individuals involved in the project on behalf of the client, or future users who had been requested to comment on the centre.

The house design experiment was carried out at the Correia Monteiro architect's office during one of the project meetings with the clients. In fact, this was the first meeting between the architect and the clients organised to present the architect's proposal and was therefore the first time the clients had the opportunity to visualize their future house. The interpretation centre experiment was carried out at the ADENE premises where most of the participants work and where the centre will be built, and therefore also provided a relaxed environment. These participants had different experiences of the project, since some already knew a great deal about the centre and were actively involved in the project, others had seen designs and some had only heard others talking about the future centre. Twelve people – six men and six women - took part in the experiment. In each case, the participants were equally balanced in terms of gender i.e. five men and five women were involved in the "CINERGIA" category and one man and one woman in the "House" category. With regard to the age of the participants, 50% were in the 21-30 age group and the remaining 50% in the 31-40 age group.

The experiment was carried in the following stages: i) during the first meeting the architect gave a presentation of the project to the clients as usual; ii) the clients answered the first questionnaire (Q1); iii) the researcher showed the clients how to use the HMD; iv) the experiment with the HMD was carried out; v) the clients answered the second questionnaire (Q2). In stage i), floor plans, sections, elevations and printed renders were used (on paper in the House case and as images projected on a screen in the CINERGIA case), as well as a physical model (in the House case). In stage v) Immersive Virtual Reality was experienced using Oculus Rift and interaction with a mouse.

HMDs function as data input as well as output devices when they contain sensors, for localisation and rotation for example, which can identify the natural movements of the user and reproduce them in the virtual environment via data sent to the computer, thus making the experience more realistic and immersive [18]. This type of device is one of the most popular interfaces for VR as it is the one which best isolates the user within the virtual environment and does not allow him to see or hear what is happening in the real world that surrounds him.

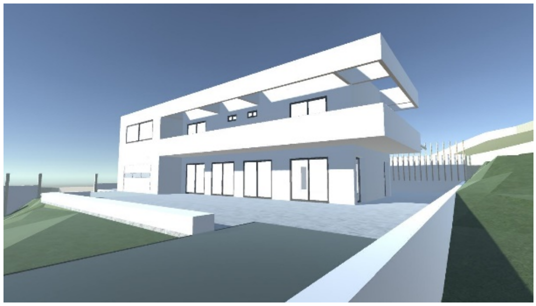

Fig. 1. Condition 1 House, start of navigation.

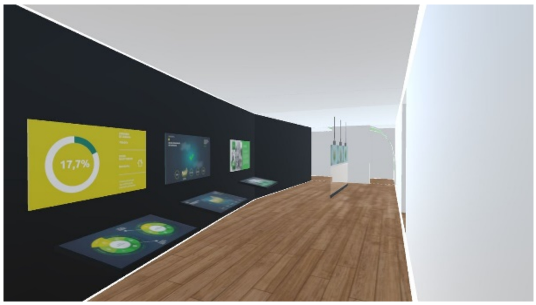

Fig. 2. Condition 2 CINERGIA, exhibition area in the middle of the experiment.

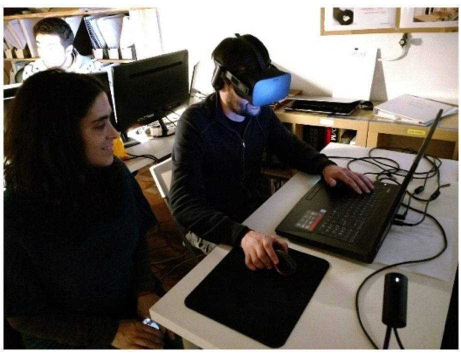

Fig. 3. Experiment in condition 1 House. Participant interacting with the virtual model while navigating with the Oculus Rift.

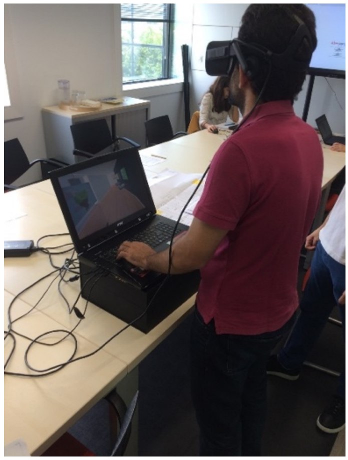

Fig. 4. Experiment in condition 2 CINERGIA. Participant interacting with the virtual model while navigating with the Oculus Rift.

Fig. 5. Experiment in condition 2 CINERGIA. Participant interacting with the virtual model while navigating with the Oculus Rift.

3.2 Results

The questionnaire completed by each participant was divided into three parts which were answered at different times. The first part, defined as "Questionnaire 1 (basic data)", corresponded to basic data and was completed before any presentation. The second part, defined as "Questionnaire 2 (traditional method)", was completed after the first presentation given using traditional representation methods and corresponded to the participants' perceptions of the design visualised using traditional methods. Finally, the third part, defined as "Questionnaire 3", was completed after all the presentations had been given and was divided into three sub-categories, namely, "Questionnaire 3 - presence SUS", "Questionnaire 3 - presence W&S" and

"Questionnaire 3 - perception". This paper will only address the results of "Questionnaire 2" and "Questionnaire 3" concerning perception.

The fact that some people felt sick or dizzy meant that it was also necessary to conduct a qualitative analysis of the quantitative results that may have been negatively influenced for this reason.

Table 1. Results from Questionnaire 2 "traditional methods".

Category	P8	P9	P10	P11	P12	P13
Condition 1- House						
Mean	7	6	7	N.A.	7	6
Standard Deviation	0	1.41	0	N.A.	0.71	1.41
Condition 2 – CINERGIA						
Mean	6.8	6.3	6.7	6.7	6.3	5.6
Standard Deviation	0.42	0.82	0.48	0.48	0.82	1.18
Total						
Mean	6.83	6.25	6.75	6.7	6.33	5.67
Standard Deviation	0.39	0.87	0.45	0.48	0.78	1.15

N.A. – Not applicable
Questions were answered on a scale ranging from 1 (very little) to 7 (a lot).
P8 – The explanation of the house design was sufficient for me to understand the entire space.
P9 – I understood the sizes of the rooms.
P10 – I understood the connections between rooms.
P11 – I understood how the exhibition in CINERGIA will work.
P12 – I can describe the house/centre if I am asked to.
P13 – I understood the vertical sizes of the house/centre (e.g. height of ceilings, relation between different floors, etc.).

Questionnaire 2 was answered after the first presentation using traditional representation methods and corresponds to the participants' perceptions of the project. Questions such as "I understood the connections between rooms" and "I can describe the space" were part of this first questionnaire. Answers to this questionnaire aimed to measure how well the participants understood the design project. These answers were given on a scale ranging from 1 to 7, in which 7 meant "I totally agree".

The average scores for the answers were all high: they were all above 6 with the exception of P13, which was 5.6. The standard deviation figures were all less than 1, with the exception, once again, of P13. As all the results were close to 7, which corresponds to "I totally agree", the participants appear to have understood the projects presented using traditional methods well.

The averages for the answers show that the participants thought they had understood the project they were presented with well.

Table 2. Results from Questionnaire 3 - perception.

Category	P24	P25	P26	P27	P28	P29	P30
Condition 1 – House							
Mean	7	N.A.	7	R. R.	7	7	7
Standard Deviation	0	N. A.	0	R. R.	0	0	0
Condition 2 – CINERGIA							
Mean	5.9	6.3	6.3	5.9	6.4	6.5	6.1
Standard Deviation	1.29	0.95	0.82	1.29	0.52	0.85	0.88
Total							
Mean	6.08	6.3	6.42	5.83	6.5	6.58	6.25
Standard Deviation	1.24	0.95	0.79	1.34	0.52	0.79	0.87

N.A. – Not applicable. N.C -Not considered. Questions were answered on a scale ranging from 1 (very little) to 7 (a lot), except for Question P29 in which 1 refers to traditional methods and 7 to IMV.
P24 – The House/CINERGIA seems more real in the virtual environment in comparison to what was presented to me before.
P25 – By using Immersive Virtual Reality I understood the CINERGIA exhibition area better than I did after the previous presentation.
P26 – By using Immersive Virtual Reality I understood the sizes of the rooms better than I did after the previous presentation.
P27 - By using Immersive Virtual Reality I understood the connections between the rooms better than I did after the previous presentation.
P28 – I appreciate the opportunity to navigate freely around the virtual reality model.
P29 – Which of the presentation methods made me feel more attracted to the house/centre?
P30 – After the virtual reality house /centre presentation how easy do I find it to describe it, in comparison to the previous presentation?

The above table shows data corresponding to the part of the questionnaire that deals with “Perception”, namely the difference between the traditional and IVR methods, and analyses whether the clients had a better notion of space and which method they preferred in terms of viewing and understanding the project.

Questionnaire 3 measured the difference between the understanding of the design project when presented through IVR in comparison to traditional methods. Questions such as "I understood the room sizes better in IVR than before" and "I understood the connections between the rooms better in IVR than before” formed part of this questionnaire.

In Question P27, the “House” category was removed from the group results because in one case the model was navigated under special conditions. One of the participants felt sick and was unable to navigate alone despite wishing to continue to view the 3D model. In order to offer the best solution for this problem, the participant was simply placed in each room without seeing how she had arrived there or the connections between the rooms and could therefore only view one room at a time independently using Oculus. Since the question was based on a better understanding of the connections between rooms, the response from this participant had to be removed. Hence, in this case, the average and the standard deviation for the House category were not calculated. However, the other participant responded to this question with a 7 and this was included in the total average and standard deviation.

The total averages were all above 6 except for one, which registered 5.83 or, in other words, a score that was close to 6. The standard deviations for the answers varied little.

The results were therefore clearly satisfactory in terms of perception of space using IVR. Given these results, it can be verified that the participants understood the project better when using IVR and also felt more attracted to the project with this mode of representation. The answers also show that after visualizing the project using IVR, they felt more able to describe the project.

One of the factors that justifies these results is that some traditional representation methods, namely technical drawings, are based on codes related to a specific field of knowledge – architecture – which are known to experts and designers but not laypersons and non-designers. This normal lack of knowledge by non-designers often leads to misinterpretations of design projects. However, with the use of IVR, architecture can be visualised in a more natural way and the spatial qualities of a project can be perceived [19].

In the case of the experiment involving the ADENE participants, based on comments that were noted during the experiments it can also be stated that the less positive responses to IVR came from participants who had either felt sick during the experiments and/or already knew a great deal about the centre.

4 Discussion

During the conceptual design stage in architecture the visual data, i.e. geometries, colours, and lights are the stimuli most frequently presented to clients. As observed by Eimer, “as a general rule, our sensations tend to be dominated by the modality that provides the most detailed and reliable information about the external world.”[6] Since vision provides highly accurate and detailed spatial information, this stimulus is the one used to guide spatial judgments. Other data, such as textures (tactile data) and environmental conditions including sound, smell, and temperature, are not often presented to clients except verbally, as a narrative. One exception to this is the display of construction material catalogues, enabling clients to touch the textures of wood flooring, a stone wall, or fabrics for curtains, for example.

In the experiment described in this paper only visual data was presented to the participants.

As stated in the introduction, the main research hypothesis for this study was that clients have a better understanding of an architecture design when they visualise the project using IVR instead of traditional representation methods (technical drawings, physical models and renders).

This hypothesis was tested essentially by drawing on Questions P29 and P30. It should be emphasised that in the House case study, where the meeting was the first occasion on which the clients were presented with the project, both participants answered the two questions with a score of 7, expressing a clear preference for the virtual reality representation. The less positive responses for virtual reality came from participants who had more extensive previous knowledge of the CINERGIA project. When the data for Questions 25, 26 and 27 was added in, a very solid conclusion could be reached regarding the hypothesis. It can be seen that participants did have a better understanding and perception of the project as a whole and in terms of various details after viewing it using IVR in comparison to their experience with traditional methods. Visual perception is seen as a multistage process in which the individual starts with a 2D sketch in the retina and it is only after depth information is added that a 3D model is finally generated [20]. Traditional drawings only provide the full process for people who understand architectural drawing codes. In fact, as noted in the state of the art, one of the factors which justifies this data was the fact that certain traditional methods, namely technical drawings, are based on representational codes that are specific to this field and are essentially only understood by professionals. This makes interpreting technical drawings (floor plans, cross sections, and elevations) for projects more difficult for laypersons, sometimes resulting in erroneous ideas and misinterpretations. As a technique for demonstrating an object, lines on paper fail to realize the properties of the objects and such representations can actually create illusions due to mistaken spatial judgments [5].

Moreover, renders and model buildings differ from reality in terms of depth and size. In relation to renders, which are sometimes used in architecture presentations and are produced from virtual models, it can be seen that IVR is able to offer a more natural environment for the participants than virtual models viewed in 2D (two dimensions) [19]. In fact, the addition of movement and bodily presence provided by IVR allows those participating in this kind of experience to be "actively and intentionally directed toward its surroundings, as something that skilfully copes with things and pragmatically 'knows how' to encounter the environment" . As a *quasi-real* experience, and given the fact that the participants can freely move in space, IVR enables the body to know "how to encounter the environment, and the intertwining between body and environment is just always there." [21, p. 103]

Even in the case of the participant who felt sick and was not able to freely navigate through the entire space, the results of the questionnaire showed that the House was nevertheless perceived amodally and the spatial perception afforded by IVR was enough to form a mental representation of the spatial structure .

Hence, with IVR digital architecture can be used in a more natural way as a tool for understanding the spatial qualities of a project [19].

Without aiming to replace traditional methods, by introducing a new way of seeing and understanding a project IVR helps the user to interpret the designs better, thus supplementing the existing methods. As can be seen from the data obtained from this experiment, it aids and improves the way in which a project is presented by the designer to laypersons, whether clients or simply individuals who need to be informed about it.

During the experiment it was also possible to observe that the individuals directly involved in the projects took advantage of the opportunity to use IVR to comment to their colleagues about various aspects which they liked or others which needed to be corrected. Although they were familiar with traditional methods, these individuals also had a better perception of the project and pointed out various spaces which they had had no notion of before, such as the width of a connection between rooms, the standing positions for the ADENE Centre users, and the impact of the images shown on the Centre monitors.

Further analysis was carried out to understand what kind of influence the experience of IVR might have on factors external to the experiment.

The research questions posed at the start of this study can now be reprised so that, based on the data obtained, certain conclusions may be drawn, and answers formulated. The questions are:

1. To what extent do clients perceive the architecture design they have commissioned from the architect when it is presented using traditional architectural representation methods?
2. Does the use of IVR systems increase the client's understanding of the project?

Regarding the first research question, we obtained some unusual and interesting data.

The scores on the questionnaires are high: the averages for questions relating to satisfaction with traditional methods (Questions 8 to 13) are above 6 with the exception of Question 13, which had an average of 5.67, also a high score and very close to 6. However, the data which followed, relating to the questions comparing traditional methods with IVR (Questions 25 to 30), also revealed averages of over 6, with the exception of Question 27, which had a value of 5.83 and, again, was very close to 6.

This data leads us to conclude that the data for the responses to traditional methods may be biased. This may have been due to the fact that some people were already familiar with the project itself, namely those involved in its development. However, in the case of those with no experience of this kind, it may be due to a variety of factors which might include a desire to show that they were able to understand these methods in order not to feel "inferior" or less able, a wish to please or satisfy the person developing the study in the belief that these answers would help, or the fact that they had no idea of what they had really understood of the project until they compared the first viewing with the use of IVR.

Hence, an analysis of Questions 8 to 13 alone suggests that the participants were able to understand the project well from traditional methods, yet from an analysis of the data from Questions 25 to 30 and the comments made during the IVR experiment it may be concluded that they had not, in fact, understood it in the way the previous data would indicate.

With regard to the second research question, as already noted in the main hypothesis and the analysis of the previous question, the data shows that the users understood the project better when they viewed it using IVR.

On the basis of these questionnaires, after experimenting with IVR the participants were able to understand various aspects better, such as how the exhibition space in the Centre would function, the size of the rooms and the connections between them, and they were also able to describe the project more easily in comparison to after it had been presented to them using traditional methods only.

One possible explanation for this result was also referenced in the analysis of the main hypothesis, namely that the designs were produced using representational codes that were specific to architecture and therefore unknown to laypersons.

5 Final considerations

The problem that led to this study was the difficulties that occur in terms of communication between architects and their clients during the presentation of an architecture project using traditional methods, such as technical drawings, physical models, and printed computer renders. The difficulty that laypersons experience in understanding these representations results in misconceptions of the final building. Often clients only understand the building when it is built, sometimes with a feeling of disappointment that could have been avoided.

The use of IVR is increasing in architecture since it offers a close to natural visualisation of the design project which traditional forms of representation cannot provide. IVR provides the feeling of being immersed in the building and the possibility of interacting with it, in a way that has never been achieved before by any other means of representation. Traditional representation methods will continue to be used, but due to the difficulty laypersons have in perceiving what is represented via these methods, IVR acts as a complement and facilitates perception of the project through an intuitive, interactive, and exploratory experience.

After conducting several experiments and analysing the results, this study has been able to confirm the main hypothesis, which states that participants understand a project better after using IVR. Architects and others involved in designing projects were also able to use IVR and study their projects from a new perspective. They took the opportunity to discuss the design and show it to people working in other areas, such as multimedia, who were also present at one of the meetings. These results are also substantiated by concepts emerging from Kinaesthetics, Choreutics and Gestalt Theory, specifically those related to the presence of the body in space and how the individual perceives space.

Acknowledgments. This research was partially funded by the Fundação para a Ciência e Tecnologia through project ISTAR UIDB/04466/2020 and by EEAGrants Portugal through project FBR_OC1_020 - ISCTE. The authors would also like to thank ADENE, namely Miguel Sales Dias, and the Correia Monteiro architect's office, namely João Correia Monteiro, as well as all the participants involved in the study.

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