Representational Thickness: a quantitative comparison between physical, CAVE and Panorama environments

Michael Mullins and Tadeja Z. Strojan
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This study compares aspects of spatial perception in a physical environment and its virtual representations in a CAVE and Panorama. To measure accuracy of spatial perception, users were asked to look at identical objects in the three environments and then locate them and identify their shape on scaled drawings. Results were then statistically compared for differences. In a discussion of the results, the paper addresses three hypothetical assertions — that depth perception in physical reality and its virtual representations in CAVE and Panorama are quantifiably different; that differences are attributable to prior contextual experience of the viewer; and that design professionals and laypeople have different perceptions of what they see in VR. In conclusion, the concept of ‘representational thickness’ is suggested by the results.
1. Introduction

Contemporary computer technology has made realistic renderings of buildings and environments an integral part of a widely shared public experience. Moreover, contemporary design increasingly employs virtual reality (VR) techniques in participatory design processes with clients and users [see for examples: 1,2]. The opportunities offered by these new possibilities are counterweighted by the dangers seen in previous eras of technological innovation in architecture. There are comparative similarities to the challenges initiated by the rapid development of new production processes, transport and communication networks of the nineteenth century. The subsequent alienation of architects from their traditional domains of operation, were caused, as Habermas has it, by “the contradiction between the democratic demands for universal participation in culture and the fact that ... increasing domains of human activity were being alienated from the creative cultural forces” [3]. If virtual reality is not to have similar effects on architecture and architects, the ‘creative cultural forces’ of society, research needs to be addressed to the increasing application of VR tools in public participatory projects.

2. Prior research

A 1977 Swedish research project into improved clarity and communication in the presentation of public planning proposals for the built environment, reported by Wikforss [4], established that the simulation of three dimensions conveys more information of the anticipated environment or designed object. The report made recommendations for comprehensible illustration without loss of precision, where “it is important that illustrative material allows the reader to identify known places, that they can orientate themselves with the help of illustration and that they can appreciate the scale that is involved” [italics]. In this regard, it concluded that axonometric drawing was the best option for representation, as it meets these conditions better on average than others and conveys a better understanding of the proposal than aerial photography or conventional plans. However, the Wikforss report’s conclusion is negated by contemporary practices of VR and internet communication. In the contemporary fields to which planners and architects contribute, virtual worlds and digital representation introduce new factors to consider, as for example that scanned and rasterised axonometric drawings for use on the internet are not scaleable in any precise manner on the computer screen. The authors’ research has previously been directed into a quantitative and qualitative description of differences in how the lay public and professionals perceive and understand architectural representations in a broad range of presentational media across the internet. Drawing from Bosselman’s categories of ‘experiential’ and ‘conceptual’, an initial
experiment tested for differences in accuracy and efficacy between these two categories of representation as used on the internet [5]. The representations included a broad range of representational types normally available to professionals ranging from the conceptual abstraction of sketch plans, to drawings that realistically attempt to represent our spatial experience of buildings. In summary, it was concluded that experiential representations are more useful for internet presentation in which the lay public participates as they convey architectural ideas more efficiently than conceptual representations. 'Efficiently' in this context means that the intended information was conveyed more accurately and in less time. The lay public also showed decided preferences for the experiential category and the results indicated that architectural intentions and lay public expectations coincide more closely through the means of experiential media.

This experiment was conducted on small-screens, but by reintroducing space and spatial representation of form, immersive virtual environments advance architectural representation to a closer, more immediate expression and communication of architecture as the creator of place. As these environments should thus provide better forms of experiential representation, attention will here be turned to representation in VR. A number of studies provide prior knowledge in this field.

Söderman has experimented with non-immersion VR on conventional desktop computer equipment, using focus group interviews with 5-7 participants in each group. He compared the preference ratings for two consumer products represented by 2D hand-made sketches in black and white, ‘3D’ desktop-VR and the physical products in real space and inconclusively found that “comparing the sketches and the desktop-VR, there seemed to be small differences in the participants’ understanding of the products” [6]. It may be inferred from this lack of conclusive results that it is not the medium of technology that is of overriding importance, but rather the choice of representational illustration; the sketch conveyed as much (or as little) information as the computer VR.

Dave has more recently carried out a small sample (two groups of 3 subjects each) experiment comparing small-screen displays to immersive environments, a term he applies to the ‘CAEV’ environment at the University of Melbourne [7]. Dave concludes from this study of differences in spatial judgments by subjects while working in traditional and immersive environments that: “The summary results appear to indicate that CAEV-like displays may be useful to explore certain spatial attributes e.g. visual occlusion, visceral responses, etc., whereas for measurable properties of spatial attributes such as dimensions, etc., there may not a significant difference between different display environments” [7]. This conclusion is surprising when comparing the apparent scale of models shown on small and big screens – one might expect that the larger representations would
have significant affects on the judgement of dimension, shape and depth. However, the study, like the previous examples, lacks a statistical analysis which could convince of significant results. It is also to be questioned whether sampling error made evident by an application of statistical confidence levels would negate the resultant analysis on the small population sample presented.

A recent experiment to investigate spatial aspects of representation was carried out by Schnabel and Kvan at the University of Hong Kong in 2003 [8]. 24 architectural students first studied a 3D volume composed of interlocking cuboids represented either by conventional 2D plans; screen based virtual environments or immersive virtual environments. They were then asked to rebuild the cuboid using a physical model. Results from the three separate samples were then compared for accuracy. The process was observed in order to relate the degree of spatial-understanding achieved to the media used. It was noted that the highest degree of accuracy was achieved by those who studied the 2D plans. These participants however, analysed the cube as a stack of 2D layers without relating this to the spatial composition of the eight cuboids. This is perhaps not particularly surprising – the only input to solve the problem given to this group of participants was represented as a series of sectional layers. The report concluded however that “designers’ understanding of complex volumes and their spatial relationships is enhanced within a VE setting” [8].

What may be drawn from this latter study is that the students recreated the object in accordance with the information given them. The immersive environments enabled a fuller understanding of the spatial qualities of the object, precisely because it is spatial qualities that are transmitted in those environments. We may say that decisions which affected the built object derived from its design representation. In more general terms, the representational environment may thus have direct influence on the built environment, by way of the transmission of spatial information that is determined by the media itself.

3. Variables

The experience of built environment by its residents constitutes a knowledge base from which any development or intervention among those residents should proceed. An enquiry into VR must necessarily bear in mind that reality as ordinarily perceived is somewhat different from that reality conveyed in digital contexts [9]. Where facilities like the CAVE and Panorama simulate spatial experience of an existing environment, they both represent the residents’ situated knowledge [10] and add to it. This entails an enquiry into the representation of situated knowledge and reinforces the need to refine the methods used to represent architectural intentions in virtual reality.

To this end, the variables uncovered in the exploration for further

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testing can be broadly summarised in the following three categories:

1. The context of Physical, CAVE and Panorama environments;
2. Design professionals and laypeople;
3. Situated knowledge of the physical environment being represented.

4. Methodology

4.1. VR geometric 3D-modelling and physical context

The existing buildings, drawings, digital model and VRML model of the VR Media lab, Aalborg University, were used for the experiment. Specifically, the foyer area of the building and models were used as the context for the experiments questions.

Digital models were previously (in 2000) prepared by employees of the university using '3DStudio Max'. Test objects were placed into this model at precisely defined positions and sizes. The model was then translated to 'Division' software in the CAVE and 'VR4Max' in the Panorama for animation and interactive visualisation.

At the time of the experiment, both the CAVE and Panorama arenas in the VR Media Lab were driven by an ONYX IR2 'super computer' with 16 parallel CPUs, 2 GB Ram, 288 GB Hard Drive in a Raid3 system transferring 100 Mbit/sec. and 6 graphic pipes. The VR Media Lab has subsequently installed a Linux driven PC cluster, comprising three Intel P4, 1.7GHz CPUs with NVidia GeForce4 Ti4600 graphic cards and 1GB memory.

![Figure 1. The CAVE at Aalborg University.](image)

The CAVE is a 2.5 x 2.5 x 2.5 metre room with 6 sides (including ceiling and floor) onto which 3D images are projected. Active stereoscopic shutter
glasses are used to create a spatial representation of a digital model giving an immersive experience for the user. The user employs a hand-held electromagnetic tracking system to enable virtual real-time movement within or around the building. In the experiment itself, participants were invited to spend five minutes familiarising themselves with the equipment, before being asked to take a stationary standing position with their view directed towards the test objects displayed. The interviewer sat outside the CAVE during the questioning.

The Panorama seats 28 people in front of a 160 degree cylindrically curved screen, with a radius of 7.1 meters and a height of 3.5 meters, thereby filling the field of vision of the participants. Three projectors are used with slightly overlapping VRML images. In the experiment, participants were questioned individually and one at a time, seated centrally in the front row of seats. The images were shown in monoscopic vision. Unrestricted head movement was allowed. The interviewer sat at the back of the arena during questioning.

4.2. Visual variables

Test objects in the physical building were cardboard shapes of varying size, colour and texture (see figure below). The objects were chosen as being 'value free', inherently carrying no particular meaning and widely recognisable. These were attached to walls and columns in the foyer at differing distances in relation to the subject. The test objects were arranged so that three objects were visible from three predetermined standpoints in the foyer: Standpoints 'A', 'B', 'C'.

Figure 2. The Panorama theatre at Aalborg University.
With a departure point in Granum and Musaeus’ set of static object properties, test objects were considered in terms of variables for position, pose, size, shape, colour and texture [11]. Observation distance was measured in relation to the size of object, where the standard max. dimension of 100cm of the object = 1 Standard Distance Unit (SDU). Following Granum and Musaeus, a range of important characteristics like inter-object distance and observer-to-object-distance are thus related in a meaningful way to the size property of the objects. Objects had differing sizes to enquire into the effects of observation distance on shape recognition.

The objects were represented in the virtual environments by scaled simulations in precisely the same virtual positions. Objects comprised squares, triangles and circles in 3 sizes each. The different shapes were chosen as, from any one standpoint, only three objects, one each of each shape, could be seen. The perception of size is related to a relative judging of inter-object size against each other in relation to distance; therefore it is desirable that the 3 shapes in view be different to lessen this effect.

The objects were represented on a sketch drawing as in the illustration above which was available to participants in all three media situations, in order to be able to refer to the relevant shape descriptions.

4.3. Sampling procedure

The participants in the experiment were to comprise two groups in roughly equal numbers: Group P: professionals and students, who create, use and deal with architectural representations and are educated to understand them; and Group L: the lay public and students with limited experience of
such representations. Financial limitations to the study determined that the accessible population were drawn from in and around the city of Aalborg.

An initial sample of 10 subjects was used for the pilot phase. A sample of 80 was then selected from the remaining 112 volunteers, so that half were in the professional category and half in the layperson category. Of these 11 either withdrew or did not keep their appointed times and were dropped from the experiment; 1 result was omitted due to technical problems with the CAVE during that participant’s interview, giving the final sample of 68 subjects.

4.4. Procedure

Subjects were questioned individually. Each was given a specified time to meet in an adjacent building. The interviewer met each at the appointed time and led them to the place of experiment. Here, they were shown a 1:20 scaled drawing of the test objects which were described and explained where necessary. Participants answered general demographic and basic questions about age, education and profession. They were then led to the appropriate standpoint and the actual experiment commenced.

Subjects examined the arrayed objects without asking questions – that is to say that they were to attempt to answer the questionnaires from their own ability and with no assistance from the interviewer.

4.5. Conditions

The tests were carried out in three environments: the foyer of the VR Media lab, the CAVE and the Panorama. The latter two are situated within the VR Media Lab itself. The tests were to compare depth perception in these three environments. Slater et al. [12] have described the following cues as essential to the perception of depth and thus the primary conditions of creating virtual environments:

**Occlusion:** The test objects were arrayed so that they did not directly occlude each other when seen from the predetermined standpoints; however, as head movement was possible in all three environments, partial occlusion was obtainable in relation to columns, furniture, walls etc.

**Shading:** Shading in the CAVE and Panorama was not “real-time” for the experiment, although the common practice of placing fixed shadows into the models was followed. This lack of interactive shading is therefore an additional variable in terms of the experiment’s aims. However, both CAVE and Panorama are equally lacking in this regard.

**Perspective:** Perspective is present in all three environments. Dynamic perspective; in the CAVE, the position and orientation of the viewer’s eyes are constantly communicated to the computer by means of a
position tracker mounted within the stereoscopic glasses worn by the viewer; the projected image is modified and updated accordingly. This was not the case in the Panorama as tested in the experiment; while the projected image was inherently interactive in real time, it was operated by the interviewer and not by the viewer’s movements.

**Stereo viewing:** To simulate the effects of stereo, each eye must be presented with its own perspective correct image. This is achieved in the CAVE by stereoscopic shutter glasses, so called active stereo, but was not employed in the Panorama. Although technically possible, the conditions emulated those usually used in the Panorama at the time of testing.

**Field of view:** The visual field subtends about 180° laterally and 120° vertically. The test required participants to take a stationary position but allowed for head movement side-to-side in all environments. Thus, although the CAVE and foyer theoretically provide 360 degree horizontal views by turning the bodily position, in the actual test only an approximate 180 degree field of view was utilised, allowing comparisons to the 160 degrees possible in the Panorama.

**Extra-retinal cues:** Proprioceptive information was emulated through the allowed head movement of participants.

Using Slater’s list of depth cues, the environments can be compared in the following table.

<table>
<thead>
<tr>
<th></th>
<th>FOYER</th>
<th>CAVE</th>
<th>Panorama</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occlusion</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Real-time Shading</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Perspective</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Dynamic Perspective</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Stereo Viewing</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Field of View (max. degrees horizontal)</td>
<td>180</td>
<td>180</td>
<td>160</td>
</tr>
<tr>
<td>Non-visual (head movement)</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
</tbody>
</table>

### 4.6. Instruments

Questionnaires were developed and validated to include the identification of specific perceptual references suitable to the investigation. Questions were asked as multiple choices, for example: “From standpoint ‘A’, do you judge the visible square shape to be: S1, or S2, or S3? (Choose only one).” The answer given was recorded on the questionnaire as, for example, “S1”. These answers were measured for accuracy relative to actual shapes in the relevant environment. As a total of 27 questions were answered (3 standpoints with 3 shapes in each of the 3 environments), by scaling scores in this manner, the measurement constructed enabled a ratio variable between participants’ answers for each environment. The questionnaires
were transferred to a database (Microsoft Access) for storage and sorting. Statistical analysis was carried out using SPSS software.

4.7. Pilot phase

To determine whether the questionnaires and procedures would achieve the desired internal validity, a pilot phase using 10 participants was initiated a week prior to the experiment being operationalised.

The test objects were arrayed identically in all three environments and their positions recorded and photographed. It was observed that participants in the procedure P_V group were prone to discount their initial perceptions of size in answering the questions in the virtual environments. Instead, a number of them tended to refer to what they had seen in the physical environment as “what must be right” and adjusted their responses according to their memorised impressions, thus undermining the objectives of the test, i.e. actual perceptions in all three environments.

It was decided therefore to change the test object positions in the foyer, so that they were not identically positioned in relation to the virtual environments. Objects in the virtual environments were not changed. It was also decided to inform all participants at the commencement of each interview that objects were not necessarily in the same positions in all environments, thereby encouraging responses derived from actual perceptions.

5. Data analysis

Data collected from 68 questionnaires was analysed for correct and incorrect answers. For each participant, 9 questions were asked in each of the physical, CAVE and Panorama environments, giving a total of 27 answers per participant. Scores in each environment were examined for frequencies, normality and homogeneity of variance.

5.1. Hypothesis Test A: Less accurate perceptions will be made in virtual environments of CAVE and Panorama, when compared to perceptions in the original physical environment.

Since data were not normally distributed, a Friedman’s one-way ANOVA, repeated-measures test was performed on the three conditions. Analysis took in the “within-subjects effect”: this is the possible effect of the environment on accuracy of answer for each individual participant. Also possible would be a study of “between-subjects” variables which would be for the professional /layperson grouping (not included in this paper) and the process direction. Results gave a chi-square of 34.36 with an associated two-tailed probability value of 0.001.

These results confirm that significant differences in the effects on accuracy are related to the environment in which they are viewed.
3 pair-comparisons were then carried out between the conditions, physical – cave; physical – panorama; and cave – panorama. Wilcoxon tests on two-related samples show associated two-tailed probabilities as: $p=0.009$; $p=0.001$; and $p=0.001$ respectively, with Z values of -2.603; -5.503; and -3.556 respectively.

It can therefore be concluded that participants made less errors in shape recognition in the physical environment, and more errors under the conditions of the CAVE and Panorama, with the level of error being highest in the Panorama condition. It can also be concluded that such differences are highly unlikely to have arisen by sampling error.

5.2. Hypothesis Test B: More accurate perceptions in virtual environments will be found where there is prior experience of the physical environment.

The data collected from the 68 questionnaires was grouped into two separate randomly assigned participant procedures: From Physical to Virtual (Procedure P_V); From Virtual to Physical (Procedure V_P).

In procedure P_V, participants answered questions starting in the physical environment, followed consecutively by the CAVE and Panorama environments. Procedure V_P was in reverse order. Procedure P_V tests the prior experience hypothesis by enabling a measurement of results in the Panorama when participants have already experienced the physical reality of the simulated environment. These results can be compared to Panorama results in procedure V_P, where participants have not yet experienced the physical environment.

Procedure V_P participants in the Panorama condition obtained fewer correct answers (Mean = 6.90, SD = 1.08) than did the Procedure P_V participants (Mean = 6.42, SD = 1.19). Descriptive statistics showed that procedure P_V participants in the Panorama achieved significantly higher accuracy (median = 7.0) in shape recognition than procedure V_P participants (median = 6.5). The Mann-Whitney U was found to be 416.50
5.3. Hypothesis test C: Professionals perceive shapes more accurately than laypeople in physical and virtual environments.

The scores collected from 68 questionnaires, as described above, were grouped into 'Professionals' and 'Laypeople' for all three environments. Layperson participants in the Panorama condition obtained fewer correct answers (Mean=6.18, SD=1.27) than did the professional participants (Mean=7.00, SD=0.87). A directional independent t-test revealed that if the null hypothesis were true, such a result would be highly unlikely to have arisen (t=3.002, df = 66, p = 0.002). Results for a comparison of two groups' scores in the Physical (t = -0.061, df = 66, p = 0.952) and CAVE (t = -0.515, df = 66, p = 0.603) environments were not significant.

![Table 4. Independent samples test for professional and layperson variable in environments.](image)

It was therefore concluded that professionals perceived the shapes more accurately than laypeople in the Panorama environment. Results were inconclusive for the Physical and CAVE environments.

6. Conclusion validity

In the context of the empirical evidence of this study, we conclude that there is a relationship between the variables of depth perception and virtual environment. Of the two virtual environments tested, accuracy was highest in the CAVE. Accuracy is negatively affected by a decrease in representation of spatial experience.

It was further shown that professionals perceived the test shapes more accurately than laypeople in the Panorama environment and that P_V participants made fewer errors in shape recognition in the Panorama than did V_P participants. These conclusions show further relationships between virtual environments and spatial ability as well as virtual environment and prior knowledge of the physical equivalent.

7. Internal validity

The key question in internal validity is whether observed changes can be attributed to the experiment's program and not to other alternative factors.
explanations. The design clearly allowed for temporal precedence of cause over effect: the accuracy scores were obtained by successive introduction of the participants to the environmental contexts. Co-variance of cause and effect was demonstrated as accuracy of response related to the environment – for example consistently higher scores were achieved in the physical context than were in the Panorama context.

The experiment indicates the clear directional difference, measured in accuracy scores, between moving from the physical environment to the CAVE and thence to the Panorama (procedure P_V), and the reverse, that is, to the physical from the Panorama (procedure V_P). It may be objected that an improvement in scores may be expected as a result of participants learning to recognise the shapes by repetition through 3 consecutive environments. This would predict a relatively higher score in the final environment, being Panorama in the case of procedure P_V and Physical in the case of procedure V_P. The design countered selection-testing threats by randomly reversing the test procedure for half the participants. Moreover, by comparing the two Physical scores from the procedures, the tests show that knowledge gained initially in Panorama and CAVE does not affect Physical scores significantly, as would be expected if the ‘learning hypothesis’ were to hold true.

8. Construct validity

The causal relationship between depth perception and virtual environments has been established on the basis of statistically significant differences in scores achieved in the experiment. In establishing construct validity it is submitted that the operationalisation of the experiment has met the conditions of clear unambiguous semantic meaning of questions – there is little room for misunderstanding in identifying square, triangle or circle, particularly as each was differentiated in colour – the test probed for accuracy of shape/size identification in relation to depth.

The differences in results may also be attributed to various deficiencies in the representations. At the time of experiment for example, real-time shadow creation by the software used was not possible, and this certainly affects perception of depth and shape. Although this situation is already being improved by newer software, the CAVE and Panorama were tested in the state that they were being used for various decision making processes. Moreover, the notion that virtual reality will, at some future time, resemble ‘reality’ exactly is logically absurd, in the case of architectural representation. While it may be argued that VR becomes its own reality as it were, the “establishing of a place which did not exist until then ... in keeping with what will take place there one day” [13], in the applications under consideration an object cannot be the same as its representation. That is to say, there will for architectural professionals most often be an ‘abstraction gap’ of some order between object and its virtual representation, notwithstanding Ivan Sutherland’s early proposition of an “ultimate display”, indistinguishable from
reality [14]. Indeed, one may question if improved realism in virtual environments will significantly increase the accuracy measure employed in this study. This however remains a question to be answered in the future.

9. External validity

Conclusions should be restricted to generalisations based on the characteristics of the sample. The study therefore carries greatest external validity in measuring the "training effects" of people (professional or not) engaging with VR and transferring their knowledge to the real world (or vice versa). In addition, the predominance of students in the sample has not undermined the group definitions of professional and layperson, as clear differences in the response accuracy of the two groups are clearly discernable and statistically significant. It can confidently be claimed that more experienced or older professionals in the sample would have merely exaggerated these differences.

The experiment has simulated knowledge gained via bodily immersion in virtual context. It has narrowly focussed on depth and shape recognition. While the study follows the positivist conventions of statistical testing of empirical hypotheses, it will seek to relate results to a broader context of experience. "There are wholes, the behaviour of which is not determined by that of their individual elements, but where the part-processes are themselves determined by the intrinsic nature of the whole" [15]. The generalisation of the results to describe attributes of the virtual context will be justified in the sense that the experiment describes repeated, part-processes in the context of different 'intrinsic wholes'. By comparing isomorphic part-processes, comparisons may be made regarding the identity of wholes. Results in the two virtual environments tested show consistent and significant differences in how depth and shape are perceived, indicating that VR context is a major determinant of variations in spatial response. The present study thus supports the view that spatial experience is intrinsically related to its context.

It is asserted that perception of shape and distance, made in the 3D virtual contexts of the experiment, display here their fundamental conditions; not those of fortuitously chosen processes, but those that concern the character of the CAVE and Panorama, in which the dialogue between the real and the imagined takes place in the context of virtual spatiality.

We can therefore maintain that the findings may be generalised to apply to representations in virtual environments, professionals and laypeople distinctions, and to the role of tacit knowledge in perceptions of the built environment.

10. Conclusion

The enquiry into virtual reality environments has allowed for a comparison between Physical/Virtual representations as well as between CAVE/Panorama.
It is argued that generalising from so focussed an experiment, specifically on depth and shape perception in CAVE and Panorama, is justified by the manner in which the experiment has been set up. In the three environments tested, it replicated isomorphic shapes on which there was an a priori consensus, based upon the principle of universal archetypes of form. It thereby released for observation the contextual factors causing the differences in perception that have been recorded. The subject’s responses are thus closely related to the context of the environment in which they are made. This fact is not so much an external/internal, cause/effect on parts of perception, so much as a whole phenomenon of representation, and more particularly the identity of place conveyed by VR environments.

It has been indicated that, by reintroducing space and spatial representation of form, virtual environments return architectural representation to a closer, more immediate expression and communication than conventional media. We conclude that representational media may be categorised in a spectrum which extend into a perspective of increasing distance from physical space: from Cave, Panorama, small-screen, perspective, to 2D drawing at the greatest distance. In this sense, depth perception is a measurable aspect of the ‘metaphoric extension of the body’ referred to by Abel [16] in discussing the identity of place, which, taken as a whole, bestows spatial identity and which is a function of tacit, situated knowing. Where VR represents the built environment and where there is an intention that object and representation correlate to some degree, the VR ‘picture’ represents the situated world as it is intended for this metaphoric bodily extension into place.

Differences arise in professionals’ and laypeople’s perceptions of architectural representation, and this occurs in virtual environments as well. The empirical data gained from the experiments have clearly confirmed that professionals and laypeople have different perceptions of what they see in VR. The significantly less accurate results found in the experiment for laypeople in the Panorama are better understood when seen in the light of spatial ability – the primary quality in differentiating and defining ‘professionals’ and ‘laypeople’. Better spatial ability, narrowly defined from the experiment as a more accurate perception of simulated depth, is gained through education and experience of the ‘codes’ inherent in architectural representation. It follows that increasing spatial ability in participating laypeople will reduce differences between the groups, thereby increasing the quality of participatory decision making. This process is an aspect of architectural training that appears to progress relatively quickly, as shown by the fact that a large proportion of the ‘professional’ group were undergraduate students. However, a scale of years is not practical for training participant public in VR planning processes, which may only last months.

This being the case, CAVE and Panorama are attractive tools for training spatial ability. The observed differences increase in relation to the degree of
abstraction from spatial experience, hence the Panorama is prone to give rise to a wider gap in perceptions between the two groups than the CAVE. With the foyer as a benchmark, the CAVE is therefore a better instrument in this aspect for participatory projects.

In terms of architectural education, an ‘ideal sequence’ for increasing what may be termed the ‘thickness of representation’ may imply a teaching curriculum in for example computer skills, which would start with VR spatial exercise and progress through 3D rendering, lighting and modelling and end with 2D CAD software, a method inverse to those generally prevalent. While the study found that increasing spatial qualities of representation improved accuracy, it also suggests that learning through VR maintain a close spatial integration with physical environments. Not least, in the case of architectural schools, where the potential to accelerate students’ spatial abilities by learning through virtual reality may occlude such considerations as situated knowledge and identity of place. This however remains a question to be answered by future research projects that more specifically address the issue of means to improve spatial ability through virtual reality.

References

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Michael Mullins,
Department of Architecture and Design, Aalborg University, Gammel Torv 6, 9000 Aalborg, Denmark
mullins@aod.aau.dk

Tadeja Z. Strojan,
Faculty of Architecture, University of Ljubljana, Zoisova 12, 1000 Ljubljana, Slovenia
tadeja.zupancic@arh.uni-lj.si