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# JUDGMENT AND DECISION-MAKING ASPECTS ON THE USE OF VIRTUAL REALITY IN VOLUME STUDIES

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**Abstract.** The most common reason for using Virtual Reality (VR) as a communication medium in urban planning and building design is to provide decision makers with access to a shared virtual space, which can facilitate communication and collaboration in order to make better decisions. However, there is a risk that judgmental biases arise within the virtual space. The displaying of the VR-models and its content could be one way of changing the settings for the visual access to the virtual space and could thus influence the outcome of the decision making process. For that reason it is important to have knowledge of how different settings in and around the VR-medium influence the experience of the shared visual space that the VR-medium strives to achieve. In this case the decision-making process, perceptions of space, and the cognition process of decoding of information in the visual space are important. This paper investigates how reference points influence judgments of a volume study of a building and furthermore what visual cues that are used for spatial reasoning about volumes. The results show that the initial visual information has a profound impact on the decision, even when this information lacks in validity.

**Keywords.** Virtual Reality; spatial perception; judgment; volume study; urban planning.

## 1. Introduction

The use of Virtual Reality (VR) has been seen by many as having potential for increasing the effectiveness and improving communication in the decision making process in urban planning and building design (Kjems, 2005; Westerdahl et al., 2006). The most common reason for using Virtual Reality (VR) as a visualization and communication medium in urban planning and building design is to VR can give decision makers access to a shared virtual space, which can facilitate communication and collaboration in order to make better decisions. VR can facilitate processes so that participants can better understand, identify and analyse problems collectively in order to enhance decision-making and improve the future urban environment. However, this virtual space could result in a decision-making process that is not bias free. The displaying of the VR-models and their content could be one way of changing the settings for the visual access to the virtual space and therefore the outcome of the decision and thus the future physical space in the real world. For that reason, knowledge of how different settings in and around the VR-medium influence the experience of the shared visual space is important. Previous studies (Kjems, 2005; Westerdahl et al., 2006) have investigated usability issues related to the VR-medium. One conclusion has been that VR inspires to a more dynamic decision making process where different actors can communicate and discuss alternatives (Kjems, 2005). Moreover, visualization can provide actors with a greater sense of certainty of that they are not making poor decisions. However, to our knowledge no studies have investigated the impact the VR-medium can have on the judgment and decision-making process. Furthermore, there are also a number of actors in the planning process that have their own agendas (Ambrose, 1994). If the stakeholders involved in the design of the VR-model have agendas, that are more or less hidden agendas and an interest in a specific outcome of the decision-making process. The VR-medium can be used as a tool to influence the decision-makers towards making decisions in line with these agendas. Moreover, spatial-perception also relies on viewers/stakeholders earlier experience and background (Biederman, 1990; Kosslyn, 1999). It is therefore important to have knowledge about how different viewers decode or recognize the different visual cues in the VR-model and how they use these during spatial reasoning.

The objective of this paper is therefore to investigate which visual cues that are used by the viewer for conducting spatial reasoning about the visual virtual space in the context of a urban planning and how they influence decision making, with a focus on reference point and anchoring effects (e.g. Kahneman, 2002).

- What visual information is used during spatial-reasoning of the volumes?
- How do visual reference points and anchoring points influence how the visual environment is experienced?
- To what extent can reference points in the VR-medium, manipulate the outcome of the decisions in the context of urban planning and building design?

In order to investigate these questions we choose to use material from real urban planning studies. In the next sections related theories concerning decision-making and cognition will be reviewed.

### 1.1. THEORY FRAMEWORK ON DECISION-MAKING IN URBAN PLANNING AND BUILDING DESIGN

When decision-making takes place in urban planning and building design, it is a very complex, socially structured process, involving both the decisions of individuals and of groups that are influenced by e.g. social, economic, historical, environmental, physical and spatial factors (Maarttola and Saariluoma, 2002). A seminal contribution to the understanding of decision-making is the concept of bounded rationality (Simon, 1957; Gigerenzer and Selten, 2002) that recognizes the limitations of humans when analysing and evaluating decision alternatives. These limitations can be cognitive and information processing related but it is also affected by limitations such as whether it is time-consuming, whether it requires stable and complete knowledge of all the alternatives, preferences, goals and consequences. The decision maker strives to achieve an optimal decision but given the limitations mentioned above will have to settle for a decision that will frequently deviate from the optimal. The most common issue in urban planning and building design is that the information is not presented in a way so that people can understand it (Hall, 1996; Maarttola and Saariluoma, 2002). It is in this context that the VR-medium can be used as a tool in order to facilitate communication and understanding of the planned new environment. This could be achieved if the visualization is less abstract and that people do not have to spend all their cognitive resources on encoding the visual information from the presentation. VR and motion in the model are necessary for a comprehensive perception of depth cues and, in consequence, for ability to perceive the virtual urban environment. In contrast, perspective static images only communicate "part of the picture" and objects might be blocked or the particular perspective might distort the size and position of certain objects. Therefore, the sense of space requires the ability to navigate interactively through the model (Buziek, 2000; Lange, 2005). Studies have shown that spatial perception of VR-models is different from how reality is perceived (Kenyon et al., 2008). In fact there are many features that are processed during spatial reasoning of the 3D space. Nikolic (2007) argued that for VR-based depth perception, there is a combination of unknowns and uncertainties both real-based and virtual-based ones. One of the main reasons is that viewers' experience a difference between the real environment where the experiment is performed and the virtual one suggested by displayed images. This could be because of low rendering fidelity or photorealism (Sigurdarson et al., 2012) and visual cues and landmarks (Loomis et al., 1999; Riecke et al., 2002; Foo et al., 2005). The display system and their Field of View is also an important factor (Nikolic, 2007). All these factors are dependent on how the VR-medium is set up and the content in the VR-model. The visual cognitive process contain object recognition process that tries to sort the information into patterns, which are then combined and associated with objects that the user has experienced earlier in life (Biederman, 1990; Kosslyn, 1999; Nikolic, 2007). These associated objects are then used in the spatial reasoning process of the 3D space. During this reasoning process the mind tries to create an understanding of the visual space within two parallel systems, i.e. a self-centred *egocentric* reference frame and an environment-centred *allocentric* reference frame (Plank et al., 2010). Both systems interact during this processing and retrieval of spatial knowledge (Plank et al., 2010). In the egocentric reference frame the viewer compares him/herself with the objects in 3D space and in the allocentric reference frame the viewer compare relations between object-object or environment-object.

Kahneman and Tversky (Kahneman, 2002) have investigated how changing reference points influence the outcome of a decision. All judgments made are made relative to something, whether making judgments of wealth or making perceptual judgments. The underlying processes, being in essence of basic perceptual kind. For instance, how you perceive colour is not only dependent on the current stimulation but to a very large extent dependent on previous perception. The same objective colour can thus be experienced very differently depending on what colour that you were exposed to before. The same holds for practically all-visual perception including the perception of width, height and volume. Kahneman and Tversky have also introduced the important concept of heuristics and biases. Humans have been shown to employ simplifying heuristics in order to make judgments. Kahneman and Tversky observed that the reliance on the heuristics could give rise to systematic errors of judgment, so-called biases. One of the heuristics that was identified is the Anchoring and adjustment heuristic (Kahneman, 2002). The anchoring effect is the common human tendency of making judgments starting out with an initial value or a starting point, (the anchor), and adjusting from this starting point when additional information is made available. The problem is that people frequently adjust insufficiently (Kahneman, 2002). This insufficient adjustment means that the initial anchor (information), regardless of its validity, will have a strong influence on the final judgment.

## 2. Method

### 2.1. PARTICIPANTS

The participants consisted of architecture (n = 18), civil engineering students (n = 36) and researchers (n = 6) at Chalmers University of Technology, Sweden. The respondent groups were selected primarily because of their knowledge of and work with urban planning and building design, which is the focus of this study. Thirty-six of the respondents were male and 24 were female. The respondents' ages ranged from 20 to 61 years, with an average age of 26 years (SD = 6.0).

### 2.2. PROCEDURE

Participants were introduced to the Xbox Kinect interface, which was used to navigate in the Virtual Environments freely using their body (Roupé et al., 2012).

The study was divided into three sub-experiments and in each experiment the participant had approximately 3-8 minutes to explore the different VR-models before answering a questionnaire when in predetermined view points, see Figure 1. The task was to judge the volume of a new building, which is a similar task that is often presented to the city planners and decision makers in the urban planning process. This experiment is actually taken from a real volume study that was conducted in 2008 by the city authority of Gothenburg, Sweden. In the real volume study, the City planners and the local politicians were presented with four different volumes that they had to judge and then decide on which of volume alternatives that the architect would be asked to continue to design. However, in these experiments we have chosen to use 1a and 1b from the real study together with the volume 3 that is currently being built (Figure 1). We also created two new smaller volumes that would represent a smaller alternative to the volume.

During the trials the respondent, with the help of an experiment leader, filled out a web-questionnaire. The experiment leader read the questions to the participants

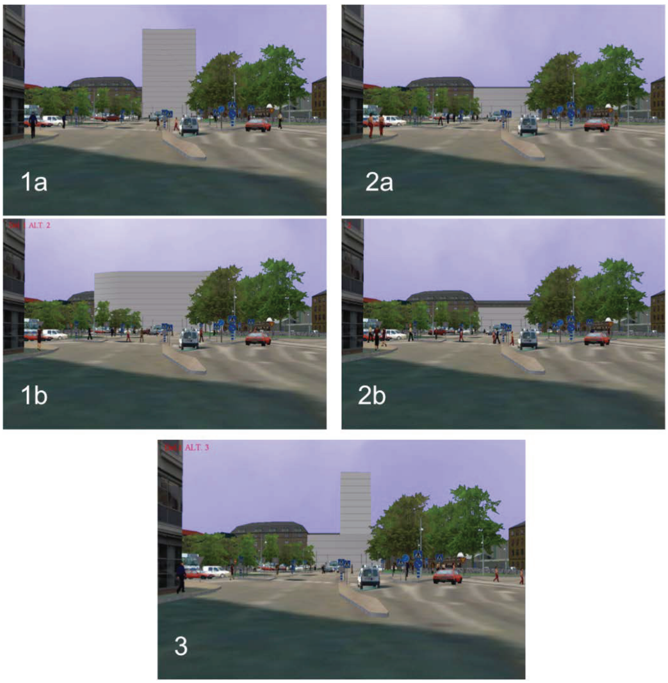


*Figure 1. The participants were sub-divided into three groups and had to conduct a volume study of a new building. The first group saw building volume 1a, 1b and 3, the second group saw building volume 2a, 2b and 3, and the third group only saw building volume 3.*

and explained the questions in more detail if the respondent did not understand the question. The discussion, answers and explanations on the questions were recorded in order to gain more insight into the user experience. Participants were instructed to think out load during the experiment in order to gain an understanding of how they reasoned when answering the questions. Participates also had the opportunity to see the scales and questions on the left to the displayed VR-model were the projected questions were shown. The questions in the questionnaire were related to: user-experience of the navigation; spatial-perception and architectural experience of 3D-models; and finally decision-making in the virtual environments. The questionnaire included in total 54 variables and questions. The study was conducted with a celling mounted projector with a screen size of 1,65x1,25 m with a Field-of-View of 40,25 degrees.

In this study we wanted to investigate if there are any visual framing effects by presenting the volume study in this manner. The task for the respondents was to judge the volume of the building that is being built, see Figure 1 (alternative 3). Judgments were made regarding the size and form. The first group saw building volume 1a, 1b and 3 (Figure 1) where 1a and 1b were large volumes and the second group saw building volume 2a, 2b and 3 which were small volumes, and the third group saw only building volume 3. All of the sub-groups explored and judged their presented volume alternatives. However, it was only the third the alternative that was considered in the questionnaire in this study. The participants then had to respond on questions related to size, form etc. (Table 1).

## 3. Results

Table 1 displays the means and standard deviations (SD) for how the respondents perceived and judged the volume of the building (sub-divided groups, see Figure 1 and above). As can bee seen in Table 1, the respondents seemed to use the volumes that were presented before they made their assessment as a reference point for their judgment of the building volume. This effect was most pronounced for item 1.1 “How do you perceive the volume of the house volume?” Alt1 vs. Alt2 ($t$ = (–4.69 (38) $p < .01$) and Alt1 vs. Alt3 ($t$ = (–3.69 (38) $p < .01$). Although the pattern was in the predicted direction, there were no significant differences for the other items. A notable observation was that they did not think that the other alternative influenced their judgment of the house volume when it clearly did (see item 1.3).

In Table 2, the result from the question related to what visual information that was used to do spatial-reasoning about the new building volume.

During the estimation of height in floors, 17 (28.3%) of the respondents mentioned that they comparing the lower part of the building with the total building

Table 1. Means SD for non-qualitative question (n = 60).

| **Item/Question**<br>**(Seven step scale)**<br>**Number of responses for each sub-group (n = 20)** | **Case 1,**<br>**Alt 1.**<br>**Mean (SD)** | **Case 2,**<br>**Alt 2.**<br>**Mean (SD)** | **Case 3,**<br>**Alt 3.**<br>**Mean (SD)** |
|---|---|---|---|
| 1.1 How do you perceive the volume of the house volume? *(Small = 1, Large = 7)* | 4.051<br>(1.05) | 5.452<br>(0.83) | 5.102<br>(0.72) |
| 1.2 When you made the assessment on the size, to what extent did you compare it to the existing buildings? *(Very low extent = 1, Very high extent = 7)* | 5.55<br>(1.43) | 5.20<br>(1.73) | 5.75<br>(1.41) |
| 1.3 When you made the assessment on the size, to what extent did you compare it to the previous volumes you have seen? *(Very low extent = 1, Very high extent = 7)* | 3.60<br>(2.06) | 3.10<br>(1.71) | – |
| 1.4 How tall do you estimate that the house is in meters? | 42.25<br>(13.52) | 40.79*<br>(10.70) | 41.21**<br>(11.18) |
| 1.5 How many floors do you estimate that the house has? | 12.75<br>(2.61) | 11.85<br>(2.11) | 13.60<br>(1.85) |
| 1.6 How hard is it to estimate the volume of the house? *(Easy = 1, Hard = 7)* | 3.60<br>(1.31) | 4.00<br>(1.69) | 3.20<br>(1.61) |
| 1.7 Does the house volume fit with its surroundings and nearby buildings? *(Very low extent = 1, Very high extent = 7)* | 4.35<br>(1.66) | 3.60<br>(1.70) | 3.90<br>(1.33) |
| 2.1 How appealing is the form of the house volume? *(Little = 1, Much = 7)* | 3.80<br>(1.44) | 3.80<br>(1.51) | 3.60<br>(1.50) |
| 2.2 How stimulating is the form of the house volume? *(Little = 1, Much = 7)* | 3.85<br>(1.35) | 3.20<br>(1.24) | 3.15<br>(1.39) |
| 2.3 How attractive is the form of the house volume? *(Little = 1, Much = 7)* | 3.95<br>(1.39) | 3.55<br>(1.40) | 3.15<br>(1.35) |
| 2.4 How original is the form of the house volume? *(Little = 1, Much = 7)* | 3.75<br>(1.58) | 3.50<br>(1.43) | 3.25<br>(1.41) |

Note: Subscripts that differ indicate significant differences at p = .01.
*N = 19 (one outlier, 12 m was removed). **N = 17 (two outliers, 100m and 150m were removed).

height. During this tasks the participants' hade to think-out loud and explain how they decoded the volume. The verbal protocols showed that the judging of the volume was done in different reference plans e.g. the building façade plane. Furthermore, the estimates of the volume was done in both e.g. egocentric and allocentric frame of reference. In this reasoning process they used known objects (e.g. size of the objects and buildings) in the scene. As can be seen in Table 2, the

Table 2. Reported comments about: What kind of visual information did you use to estimate the building's height in meters and in floors?

| Category<br>Number of responses (n = 59) | Visual information for estimate height in meters | Visual information for estimate height in floors |
|---|---|---|
| Surrounding building | 47 (78.3%) | 35 (58.3%) |
| Lines | 35 (58.3%) | 48 (80.0%) |
| Reference objects/details | 20 (33.3%) | 7 (11.7%) |
| Earlier experiences of places/buildings | 5 (8.3%) | 4 (6.7%) |

surrounding existing buildings and their façades was an important feature that was used as a reference during the spatial reasoning. The added objects where also important. The participants that mentioned object, mentioned cars 15 times, people/avatars 11 times and trees 10 times. Furthermore, the lines illustrating floors on the building volume was also used.

## 4. Discussion and Conclusions

The result shows that participants were influenced in their judgments when they were presented with other building volumes before they judged the size of the new building volume. This is observed in case 1 in comparison with case 2 and 3. In case 1, the participants were presented with two larger volumes before their judgment, which made them perceive the volume as smaller then case 2 and 3. The larger volume seemed to provide a visual reference point, which in turn affected their judgment, a result in line with previous research (e.g. Kahneman, 2002). In case 2 where the volumes were smaller than the reference volume as compared to case 3 there was no significant difference. We speculate that this is due to the fact that the existing surrounding buildings are almost at the same level of height as the smaller reference volumes. Another interesting observation is that the respondents did not think that the previous volumes affected their judgment of the building volume, when the results clearly showed the opposite. We claim that this study has demonstrated the effects that reference points can have when conducting volume studies in virtual environments. Clearly, it is important to take this into account when using the VR-medium in real urban planning projects. A failure to do so risks biasing the judgment and outcome of the urban planning process. We acknowledge that this is a strong contention. However, given the fact some of the volumes used in this study have actually been used in real urban planning studies, were the use of the VR-medium was used in a similar way, we feel that this contention is justified. The first initial information, the large alternative, unduly influenced how they reasoned about subsequent information. This result evidently shows that the initial visual information has a profound impact on participants' decisions, even though they know that the initial visual information had no validity. These results have implications for the use of VR-models in in actual decision-making settings. In this type of volume studies it could be agued that a more objective evaluation tool, such as visual impact analyses (Danese et al., 2009), could be combined together with the VR-medium. The visual impact analyses could give objective result of how the different design alternatives influence views and the streetscape. But also what viewpoints that is of important during judgment of the different design alternatives.

When doing volume studies in VR it is important to provide visual cues to the viewer such as the façades of the surrounding existing buildings and familiar details such as cars, people/avatars and trees. The viewer uses these features during spatial-reasoning for understanding sizes, which is in the line with research on spatial-perception (Biederman, 1990; Kosslyn, 1999).

To conclude, the assumption that people perceive and act on information in an un-biased fashion in VR-models being used for urban planning and building design can be seriously questioned. It is our experience that stakeholders and practitioners in this arena are not aware of some of the potential pit-falls associated with this use of this technology. The results from this study have implications for the use of VR-models in actual decision-making settings.

As mentioned in the introduction, the urban planning process has a lot of actors, all having their own more or less hidden agendas and interests. In this context it is important to bear in mind that the VR-medium could also be used as a tool for different actors to achieve different outcomes. All these issues have to be considered before the VR-medium can be seen as comprehensive decision-making tool in urban planning and building design.

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