The influence of shape and culture on visual volume perception of virtual rooms

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1 Introduction

The ability of humans to apprehend the overall size or volume of an indoor space is not well understood. Previous research has highlighted a 'rectangularity illusion', in which rectangular rooms appear to be larger than square rooms of the same size (identical volume), showing that the subjective perceived space cannot be explained from the mathematical formula for volume, i.e. length $\times$ width $\times$ height. Instead, the results suggest that one might use the longest dimension of the space as a simplified strategy to assess room size [Sadalla and Oxley 1984].

We ran two experiments to investigate the rectangularity illusion. Our research interests were two-fold. First, can illusions of spaciousness be controlled and modelled using virtual environments? If so, this would provide a methodological advantage: using virtual environments would allow the systematic study of visual volume perception without the need to build rooms or resort to two-dimensional drawings, which were typical methods in previous research [Wise 1988].

Second, are these illusions consistent across cultures? So far, most of psychological research on perception has been conducted on western cultures [Henrich et al. 2010]. The few exceptions to this have found cultural differences in perceptual studies of visual illusions [Segall et al. 1963]. Therefore, we investigated the rectangularity illusion in western culture (Germany) and east-Asian culture (Korea).

2 Experiment 1 – Cultural differences in the rectangularity illusion

The first experiment examined cross-cultural volume perception of virtual rooms when displayed on a laptop screen. We used a two-alternative forced choice psychophysics task to determine how South Korean (Seoul) and German (Tübingen) participants compare the size of virtual rectangular rooms varying on their ratio of length to width, to a constant square room. There were two different viewing perspectives (middle of short wall vs. middle of long wall), one group of subjects was allocated to each. We fitted a psychometric function to obtain the perceived subjective equality (PSE) from each participant, for each length to width ratio.

The results indicated a significant effect of the rectangularity ratio (p=0.001) and viewing perspective of the rooms (p=0.008) as well as a cultural difference between the two populations which interacted with the perspective (p=0.002).

More precisely, cultural differences were found when participants were seeing the room from the middle of the longest wall (p=0.03). Korean participants had little bias toward the rectangularity illusion. At most, their judgement of room size was slightly influenced by the longest dimension of the room when the ratio of room size increased in width (perspective: middle of the long wall, p = 0.07, trend). On the other hand, German participants' results were consistent with the strategy of using the distance to the front (opposite) wall to judge room size, and *not* the longest dimension of the room ($p < 0.05$ for effect of ratio within each perspective). In other words, when seeing the room from the middle of the long wall, Germans perceived rectangular rooms as being smaller whereas Koreans tended to perceive them as being larger.

3 Experiment 2 – Investigating the rectangularity illusion with a Head-Mounted Display

Limitations of the first experiment could be that participants were not surrounded by the virtual room, and the virtual room was not presented in stereo. Therefore we conducted a second experiment (same paradigm) within a head-tracked stereoscopic Head-Mounted Display.

Experiment 2 was only conducted in Germany. Preliminary results were consistent with our findings from experiment 1 using the laptop display; there was an effect of ratio (p=0.037) in that participants reported the room as being smaller in the higher ratio conditions, when viewed from the middle of the long wall.

4 Future work

Taken together, our experiments raise interesting points concerning the processes involved in visual volume perception of indoor spaces. Overall, the results suggest that participants are relying on simplified heuristics. Relying on heuristics is coherent with how we perceive visual volume of objects [Piaget 1968; Raghubir and Krishna 1999]. We can see that Korean and German participants were using different strategies. It is an open question of whether this is due to perceptual difference or to other factors such as spatial language. Finally, our research contributes to the findings of anthropologists showing substantial variation of visual illusions across cultures [Henrich et al. 2010] and adds weight to the debate that psychological studies should not be limited to western cultures.

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