Effect of Environment Size on Curvature Redirected Walking Thresholds

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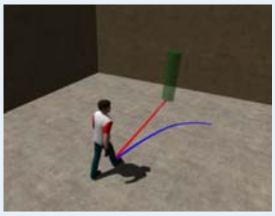
innovation center virtual reality

1 Introduction

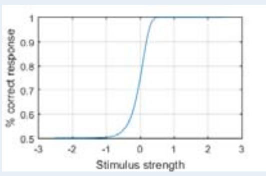


Compared to walking-in-place, or using navigation devices such as game controllers, real walking in a virtual environment (VE) has been proven to have better fidelity and immersion [1]. However, the problem with real walking arises when the VE is larger than the available physical space. A solution to this problem was proposed by Razzaque et al. [2], in which the mapping between the virtual and real trajectories is manipulated. These proposed techniques, quantified as Redirected Walking (RDW) gains, are applied on different aspects of walking such as curvature, translation, rotation. When applied within certain thresholds, these manipulations are not perceptible and immersion can be maintained. Nevertheless, thresholds found by different groups have quite high variance and could depend on factors such as individual difference in perception trait and context settings such as walking speed, cognitive load, environment design, etc. Among these factors, **environment design** plays an important role in how much redirection could be performed. While there exist studies on the effects of environment texture [3, 4], no formal study has been performed on the effect of **environment size**, though there had been remarks that users tend to notice the manipulation more in a narrow aisle compared to a wide open area [5].

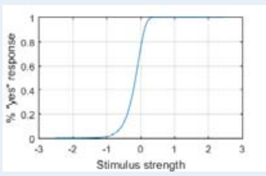
2 Methodology and Experiment

Threshold identification

• **one vs. two stimuli**: When only one stimulus is presented, users could be asked the question *"Did you detect the stimulus?"* (yes/no task) or *"Did you go to the left or right?"* (a variation of 2AFC task). However, there is a high risk of response bias: e.g. tendency to say *"yes"* or *"left"/"right"* when unsure. Due to this bias, in our pilot study, some subjects have a right curvature threshold that is a left radius, which is not applicable in real application. Therefore we used the **2AFC method with two stimuli**. There are two runs per trial, where the stimulus is only presented in one run, and the question is: *"Was the stimulus in the first or second trial"?*



2AFC with two stimuli

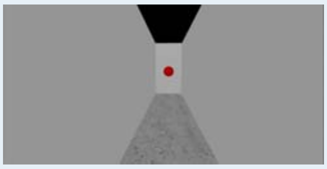


yes/no or 2AFC variant

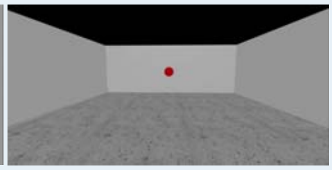
• **Constant stimuli vs. adaptive**: CSM fits the whole psychometric function based on users' responses at a pre-selected range of stimulus. Many stimulus levels are required and a high number of repetition is usually needed. Adaptive methods select the next stimulus level based on the previous response(s) of the users. It only identifies the thresholds and/or the slope but is much more efficient. In our experiment, we adopt a **Bayesian method called QUEST** [6].

Speed Regulation

In a previous experiment, walking speed was controlled by the subjects following and maintaining a distance to an object moving at constant speed. However, it is not known how such task distracts the users visually from the main task of detecting curvature redirection. Therefore, in our experiment we



2m wide



10m wide

control the users' speeds using **nonvisual method** by having them following certain audio step rhythms. Step frequency was calculated using the following equation:

$$v = \left(\frac{f}{1.57} * \frac{h}{1.72}\right)^2$$

Experiment Design

Two room size conditions were designed to be as plain as possible to remove any confounding effects of optical flow. Both scenes contain a red target located 7.5m from the user, four surrounding walls with simple shading and no texture.
For each room condition, each user has to walk with **two speed conditions**: 0.75m/s and 1.25m/s following the step rhythms. We also identify the **left and right thresholds** separately for each user, resulting in four threshold values of four psychometric functions to be found per user.

Participants

60 subjects (30 men, aged from 18-35 (M=25.1, SD=3.9), right-handed, normal or corrected to normal vision). 30 subjects were exposed to the 2m room, and the other the 10m room.

3 Result and Discussion

It was surprising to find out that **room's dimension does not significantly affect curvature gain thresholds**. One possible explanation for this finding could be that it is not the room dimension, but the amount of optical flow generated by the scene or the combination of room dimension and optical flow that affect curvature gain thresholds. Since we had no texture on the walls, the amount of optical flow generated in both cases was mostly similar. It could still be possible that there is a small effect that can not be recovered in a between-subject design since there is a high variability in individual thresholds. The **negative correlation between speed and curvature thresholds** could be reproduced using nonvisual method of speed regulation.

4 References

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