Journées Françaises d'Informatique Graphique et de Réalité Virtuelle, Marseille, 12-15 novembre 2019

The scale of virtual environment influences human perception of distance

Antoine HP MORICE*[1], Victor GARRUCHET[1], Nessrine HARBAOUI[1], Cedric GOULON[1],

Martin BOSSARD[2], Daniel MESTRE[1], Franck RUFFIER[1]

[1] Aix Marseille Univ, CNRS, ISM, Marseille, France
[2] School of Psychology, Cardiff University

Résumé
Participants were instructed to reproduce a previously observed distance by travelling passively at a constant velocity into straight textured tunnels in a CAVE. The diameter of the tunnel into which participants travelled and the egocentric distance to be reproduced were manipulated. Participants' distance perception was sensitive to the tunnel's scale, distance being overestimated with the tunnel's diameter increase and underestimated with the tunnel's diameter decrease.

Mots clés : Odometry ; Optic flow ; Scale ; Geometry ; Tunnel ; Virtual Reality ; CAVE

1. Introduction

Tunnel traveling paradigm had generated two distinct flow of experimental research from the ethology and human movement sciences communities focusing on information-movement coupling. From a stimulation viewpoint, a such closed environment indeed allows the manipulation of visual cues available in the optic flow while paralyzing the influence of environmental landmarks. From a motion capture viewpoint, the limited degrees of freedom allow monitoring behavioral responses tiny coupled with perceptual stimulation. It has been evidenced that human travelling in a corridor in virtual reality (VR) tended to diverge from the center of tunnel when the lateral optic flow on the side was modified on a wall relative to the other side [WKZ*01]. More recently, the contribution of view point oscillations due to walking locomotion in the distance estimation have been evidenced in VR [BM18] [BGM16]. Tunnel travelling paradigm was also used to investigate the human perception of ego-motion [OPH*16].

Few experimental works have focused on the influence of tunnels' dimensions on the perception of distance. Compton and Brown [CB06] found that judgment of distance while walking along same-length routes changed in differently scaled real urban settings. Judgment of distance increase twofold or more in a small village as compared with a large city. In an experiment ran in virtual reality [NZP*09], Nguyen et al. found that participants reproducing actively egocentric distance of targets in two successive tunnels overshooted the target's distance when both tunnel's diameter and target size were decreased and undershooted the target's distance when both tunnels and target size were increased. Moreover, they did not observed any effect of changing only the tunnel's diameter on participant's performance. In sum, researches performed with humans underline change in distance perception with change of the scale of real as well as virtual environments. Interestingly, a similar trend was also found in insect. In a seminal work, Srinivasan et al. [SZB97] evidenced that bees trained to travel tunnel tend to overestimate the distance of food in smaller than normal tunnel whereas underestimate distance for larger than normal tunnels. More recently, it has been shown that bees decreased the flight velocity when approaching a narrowing tunnel so as to maintain a constant optical low in their visual system [SMRF08], [SR17].

The understanding of the contribution of the scale factor in human remains thus to be scrutinized.

2. Methods

2.1. Population

Eleven participants (9 males and 2 females, 25.5 *dm* 3.4 years old) volunteered for participating to the experiments. None of them reported any visual impairment. Two additional participants having experienced simulator sickness were excluded from the analysis.

2.2. Apparatus

The figure 1 illustrates the experimental layout used for the experiment. Participant sat on a chair at the middle of a back projected stereoscopic Cave Automatic Virtual Environment consisting of three vertical screens and one horizontal floor screen (3-m deep, 3-m wide 4-m, 1400 x 1050 pixels @60Hz for each eye). The participant's point of view was updated in real-time with eight ART® cameras connected to cluster of ten PC computers equipped with professional graphic cards that generated in real-time the virtual environment and thus ensuring real-time interactivity with the virtual environment. The ICE virtual engine (developed at the Institute of Movement Sciences) was used to design the virtual environment, display the virtual scene, control the experimental procedure and monitor signals.

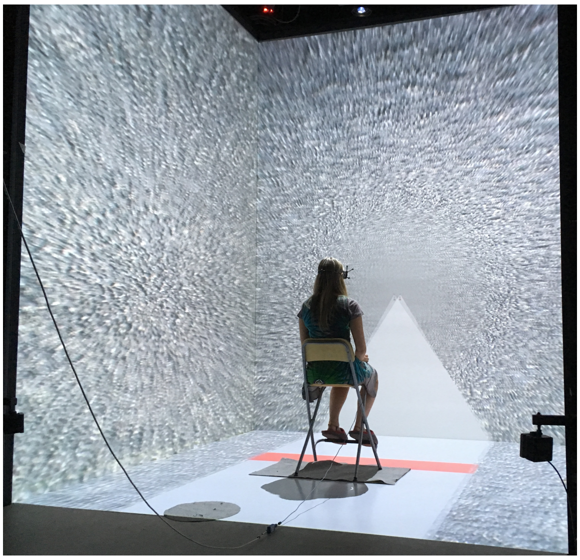

Figure 1 : *Overall view of the experimental setup. Participants sat in the middle of a CAVE system, travelled passively at a constant velocity (XXX m/s^2) and press a button once they though the red line displayed on the bridge reached the previously memorized remote position.*

2.3. Virtual environment

The virtual scene consisted of an infinite straight tunnel with a circular section textured with a nonsingular monochromatic random pattern inside which an uniform colored foot bridge, whose dimensions remained constant along the experiment, was depicted. The tunnel floor is graphically homogeneous and therefore devoid of visual marks that might be used as landmarks. Similarly, no visual marks could be taken in the tunnel due to its nonsingular random texture. Since the eye-height remained constant at 0.8 m relative to the footbridge level and that footbridge width was kept constant across conditions, the splay angle carried by the footbridge and the peripheral optical stimulation remained also constant.

2.4. Protocol

At each trial, participants started by observing a traffic cone of the usual size (40 cm high) laying on the footbridge. Once the cone disappeared, participants were passively travelling horizontally toward it direction at a fixed 1.2 m/s velocity and were instructed to indicate when the thought reaching it (i.e., when they though the red line displayed on the bridge reached the previously memorized remote position) by pressing a button.

2.5. Independent variables

The experiment comprised two sessions. In the first section, the diameter of the tunnel (2, 3 and 4 m) and the egocentric target distance to be estimated (12, 18, 24 m) were manipulated between trial. The figure 3 depicts the independent variables manipulated.

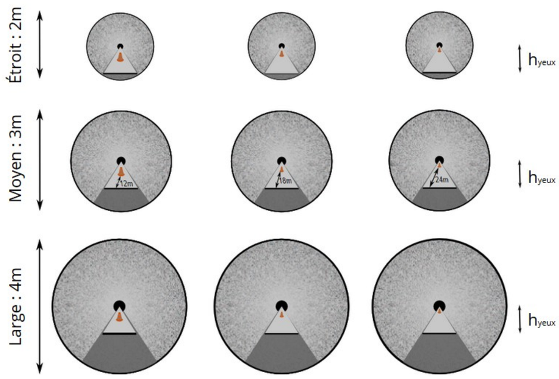

Figure 2 : *Independent variables manipulated during the first session included the scale of the tunnel (in rows) and the distance to travel (in columns).*

In the second session, the egocentric target distance to be estimated remained constant at 18 m but the diameter of the tunnel was manipulated during the unfolding of trials. Tunnel's diameter changed from 3 to 2m or from 3 to 4 m.

In both sessions, participants performed 10 repetitions in each condition. The experiment lasted 45 minutes for each participant.

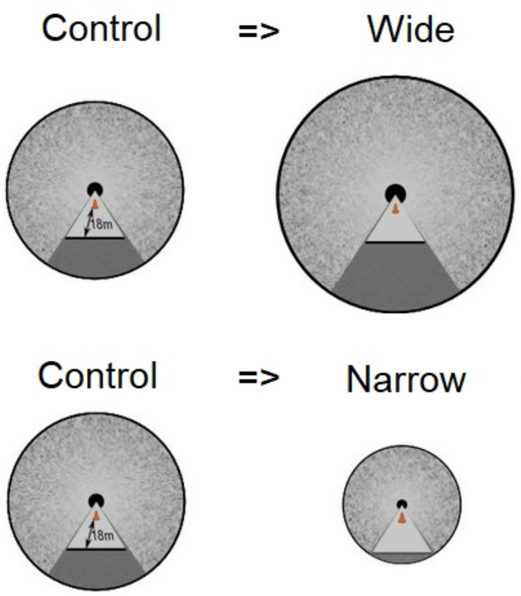

Figure 3 : *Independant variables manipulated during the session session included the scale of the tunnel (in rows) and the distance to travel (in columns).*

2.6. Dependent variables and statistics

For each trial, we measured the distance travelled by the participants. Statistical test were performed with the R software. A mixed statistical model based on the Distance, Diameter, Repetition and participants factors was build and showed that the Repetition factor was not significant. The mean as well as the standard deviation of individual values across repetition for each Distance×Diameter condition were computed.

2.7. Results : Changing tunnel's scale between trials

This section reports the results gained when the tunnel's diameter was manipulated from trial to trial. The figure 4 depicts the pattern of average inter-individual values of the mean travelled distance across repetitions. Participants responded to both target distance and tunnel diameter manipulations by adjusting the between trial average travelled distance. Concerning the target distance manipulation, the average travelled distance increased with the increase of target distance but remained inferior to it in all conditions, suggesting that the target distance was systematically overestimated. Moreover, the overestimation of the target distance (i.e., under-performance) increased with the target distance (12.04±9.97, 18.81±10.61 and 23.42±11.29% for the 12, 18 and 24 m target distance, respectively). Concerning the tunnel diameter manipulation, the between trial average travelled distance decreased in the narrow tunnel in comparison to the control tunnel ($p = 0.1967\%$, 97.17±10.84, 93.82±11.69 and 98.1±14.83% for the 12, 18 and 24 m target distances, respectively) and increased in the wide tunnel in comparison to the control one ($p = 1.441\%$, 102.72±13.18, 101.44±12.93 and 107.41±15.79 for the three target distances, respectively). The travelled distance performed in the narrow tunnel was found to be significantly inferior to the one performed in the wide tunnel ($p < 0.001$).

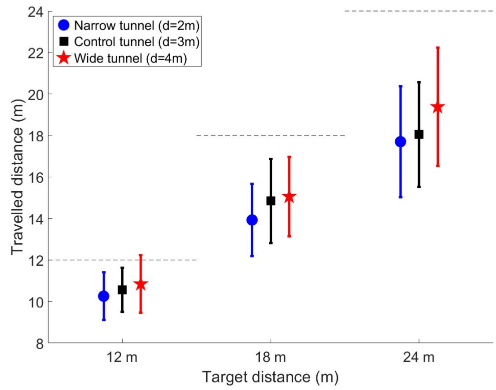

Figure 4 : *Average inter-individual values of between trial average travelled distance (m) across Target distance and Tunnel Diameter conditions. The vertical bars depict the standard deviation of individual values.*

The figure 5 depicts the pattern of average inter-individual values of the mean travelled distance across repetitions. Concerning the target distance manipulation, the between trial standard deviation of travelled distance increased with the increase of target distance (0.97±0.58, 1.48±0.88 and 2.02±1.19m for the 12, 18 and 24 m target distances, respectively).

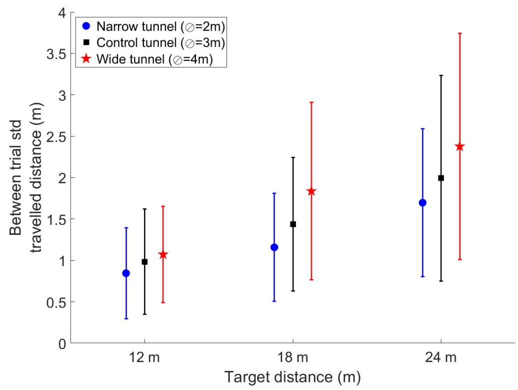

Figure 5 : *Average inter-individual values of between trial standard deviation of travelled distance (m) across Target distance and Tunnel Diameter conditions. The vertical bars depict the standard deviation of individual values.*

2.8. Results : Changing tunnel's scale withing trial unfolding

This section reports the results gained when the tunnel's diameter was changed during the trial unfolding. The figure 6 depicts the pattern of average inter-individual values of the mean travelled distance across repetitions.

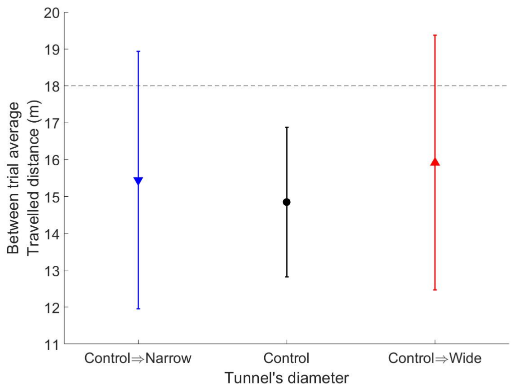

Figure 6 : *Average inter-individual values of between trial standard deviation of travelled distance (m) across Target distance and Tunnel Diameter conditions. The vertical bars depict the standard deviation of individual values.*

3. Conclusion

In this experiment, we aimed at investigating whether the scale of virtual environments influenced the perception of egocentric distance. Participant were instructed to reproduce a previously observed distance by travelling passively at a constant velocity into straight textured tunnels in a CAVE. The diameter of the tunnel into which participants travelled and the egocentric distance to be reproduced were manipulated. We analyzed the distance travelled by participants. The overall overestimation of distances (underperformance) is a well know phenomenon in VR, despite that its roots remains unclear. Participants' distance perception was sensitive to the tunnel's scale, distance being overestimated with the tunnel's diameter increase and underestimated with the tunnel's diameter decrease.

Références

[BGM16] Bossard M., Goulon C., Mestre D. R. : Viewpoint oscillation improves the perception of distance travelled based on optic flow. *Journal of Vision. Vol. 16*, Num. 15 (12 2016), 4–4.

[BM18] Bossard M., Mestre D. R. : The relative contributions of various viewpoint oscillation frequencies to the perception of distance traveled. *Journal of Vision. Vol. 18*, Num. 2 (02 2018), 3–3.

[CB06] Crompton A., Brown F. : Distance estimation in a small-scale environment. *Environment and Behavior. Vol. 38*, Num. 5 (2006), 656–666.

[NZP*09] Nguyen T., Ziemer C., Plumert J., Cremer J., Kearney J. : Effects of scale change on distance perception in virtual environments. pp. 27–34.

[OPH*16] Ott F., Pohl L., Halfmann M., Hardiess G., Mallot H. A. : The perception of egomotion change in environments with varying depth : Interaction of stereo and optic flow. *Journal of Vision. Vol. 16*, Num. 9 (07 2016), 4–4.

[SMRF08] Serres J., Masson G. P., Ruffier F., Franceschini N. : A bee in the corridor : centering and wall-following. *Naturwissenschaften. Vol. 95*, Num. 12 (2008), 1181–1187.

[SR17] Serres J. R., Ruffier F. : Optic flow-based collision-free strategies : From insects to robots. *Arthropod Structure & Development. Vol. 46*, Num. 5 (2017), 703 – 717.

[SZB97] Srinivasan n., Zhang n., Bidwell n. : Visually mediated odometry in honeybees. *J. Exp. Biol.. Vol. 200*, Num. Pt 19 (1997), 2513–2522.

[WKZ*01] Warren W. H., Kay B. A., Zosh W. D., Duchon A. P., Sahuc S. : Optic flow is used to control human walking. *Nature Neuroscience. Vol. 4*, Num. 2 (février 2001), 213–216.