Exploring Direction Estimation in Virtual Environments

Nurul MOHD NOOR[a] and Corina SAS[b]
[a] *Department of Computer System & Technology, University of Malaya, Malaysia*
[b] *School of Computing and Communications, Lancaster University, UK*

Abstract. Environmental spatial abilities are key for moving around in large spaces, and direction estimation is a common task for assessing such skills. Two key factors impacting on such skills is the complexity of the environment and pointing angle. We report on an experimental study with 40 participants in virtual environments to examine the effect of pointing angles and environment complexity on egocentric pointing judgments. Findings indicate that pointing accuracy performance with target locations at orthogonal angles is significantly higher than with non-orthogonal angles. We discuss our findings with respect to the Orthogonal Framework.

Keywords. Direction estimation, virtual environments, spatial frameworks

1. Introduction

Environmental spatial abilities are key for moving around in large spaces, and direction estimation is a common task for assessing such skills. The complexity of the environment such as number of turns [1], and pointing angle [5] are two key factors that impact on environmental spatial abilities [10] but such factors have been limitedly explored together. Direction estimation tasks is the egocentric estimation in a straight line direction to an unseen target location, and performance in egocentric pointing judgments can be accounted for through two organizational frameworks for egocentric spatial knowledge such as Spatial Framework [2][3] and Orthogonal Framework [6], both of which capture errors for different direction of pointing angles. The first model conceptualizes space along three axes (head/feet, front/back, and left/right) and argues that response times for pointing judgments is the fastest for pointing to head and feet, then front/back, and slowest for left and right. The second model argues that response time for the front is faster than for the back, followed by left and right. The left/right axis is particularly difficult and confusing because the body itself is bilaterally symmetric.

2. Method

We report on an experimental study with 40 participants in virtual environments to examine the effect of pointing angles and environment complexity on egocentric pointing judgments. We varied the exposure to the environment (route vs map learning), pointing angles (90˚& 45˚), and complexity level (1, 2 & 3 turns).

3. Results

The data was analysed using mixed repeated-measures MANCOVA (Multivariate Analysis of Covariance) with the Complexity and Angle as a repeated measure factor, the type of exposure as between-subjects factor, and gender [7] as covariate. For route learning, findings show a significant main effect of pointing angles ($F(1, 12)=6.055$, $p< 0.05$), with the mean absolute errors for non-orthogonal angles ($M=45.01$) being significantly higher than for orthogonal angles ($M=32.73$). We discuss our findings with respect to the Spatial, and Orthogonal Frameworks, and how our data supports the latter. We also explore how our findings start to unpack the relationship between the complexity of the environment and the pointing angles. Our findings confirm that pointing accuracy has the greater number of errors at non-orthogonal rather than at orthogonal angles [2][4][5][6] but they extend these outcomes by showing also that pointing accuracy in simple environments is less error-prone than in complex environments. This work contributes to the broader agenda of assessing and training spatial skills [9][10] in virtual environments [8].

References

[1] Cubukcu, Ebru, Nasar, Jack. 2005. Relation of Physical Form to Spatial Knowledge in Large Scale Virtual Environments. Environment and Behavior, 37, 397-417.

[2] Franklin, Nancy, Tversky, Barbara, 1990. Searching Imagined environments. Journal of Experimental Psychology: General. 119 63 -76.

[3] Hintzman, Douglas, O'Dell, Carla, Arndt, David. 1981. Orientation in cognitive maps. Cognitive Psychology, 13, 149-206.

[4] Montello, Daniel, Lovelace, Kristin, Golledge, Reginald, Self, Caroline (1999). Sex-related differences and similarities in geographic and environmental spatial abilities. Annals of the Association of American Geographers, 89, 515-534

[5] Montello, Daniel. R., 1991. The measurement of cognitive distance: methods and construct validity. Journal of Environmental Psychology 11, 101–122.

[6] Sadalla, Edward. K., & Montello, Daniel. R., 1989. Remembering changes in direction. Environment and Behavior, 21, 3, 346-363.

[7] Sas, Corina. 2004. Individual differences in virtual environments. In *International conference on computational science*, 1017-1024. Springer, Heidelberg, 2004.

[8] Sas, Corina, and G. M. P. O'Hare. 2003. Impact of cognitive style upon sense of presence. In *Proceedings of HCI International*, pp. 696-700. 2003.

[9] Sas, Corina, Greg MP O'Hare, and Ronan Reilly. A connectionist model of spatial knowledge acquisition in a virtual environment. 2003. In *MLIRUM'03, Workshop*

[10] Sas, Corina, Gregory O'Hare, and Ronan Reilly. 2005. Virtual environment trajectory analysis: a basis for navigational assistance and scene adaptivity. *Future Generation Computer Systems* 21, no. 7 (2005): 1157-1166.

[11] Sas, Corina, Nurul Mohd Noor. 2009. A meta-analysis on the correlation between measurements of spatial tasks and standardized tests of environmental spatial abilities. *Cognitive processing* 10, no. 2: 297-301.