Cognitive Map Formation in a 3D Visual Virtual World

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INTRODUCTION

Active movement is important for spatial memory formation in both animals (O'Keefe & Nadel,1978) and humans (e.g. Feldman & Acredolo, 1979). This experiment tested spatial memory in a 3D visual virtual environment in order to:

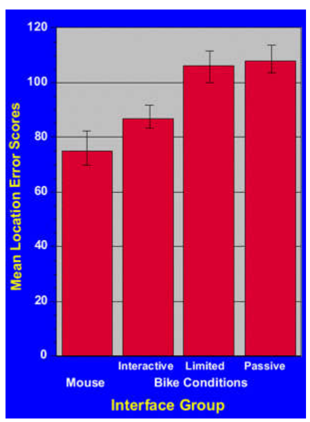
1. Assess what aspects of active movement contribute to spatial representation. This was done by varying self-directed motion (the ability to choose one's route) and locomotion feedback (motor output associated with movement) across conditions.
2. Compare the effectiveness of immersion virtual reality with ordinary mouse interfaces.
3. Evaluate the utility of virtual reality (VR) for psychological research.

TECHNICAL SPECIFICATIONS

Virtual worlds were rendered on a 4d/310GTX Silicon Graphics Workstation using custom-made software ("Cerebral Voyager") and were presented via a monitor or a Cyberface 3 light weight head-mounted LCD display. The bike interface consisted of a stationary mountain bike with an optical sensor attached to the rear wheel and a potentiometer connected to the handlebars to respectively convey peddling rate and angle of steering information to the computer. Dynamic real-time viewpoints were presented based upon actions on the mouse or bike interface such that movement appeared self-controlled.

METHODS

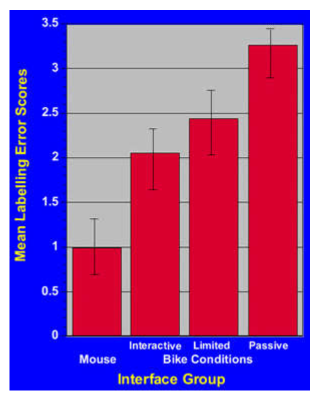
Subjects travelled through a large-scale virtual world under one of four interface conditions. Mouse condition subjects directed their movement with a mouse controller and received visual feedback from a monitor. In the three bike conditions, subjects received visual information from a head-mounted display and used an immersion VR bike interface. Fully interactive subjects could control their speed and direction by pedalling and steering as on a real bike. Limited locomotion subjects could steer but could only travel at a fixed speed by pedalling beyond a low threshold rate, otherwise they remained at a standstill; therefore visual feedback regarding speed was decoupled from pedalling rate. Passive subjects were guided along a preprogrammed path obtained from yoked fully interactive subjects. After visiting five recognizable objects in the virtual world, subjects marked remembered object locations on a 2D map test. For the 3D navigational test, subjects had to manoeuvre through the virtual world with the five objects deleted, stopping where they believed each object was previously located.



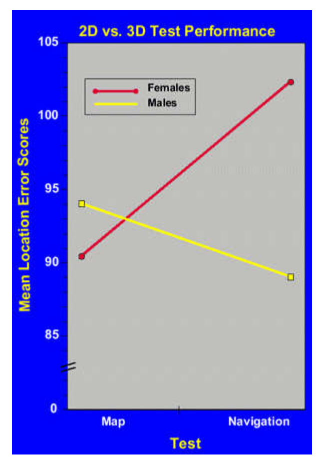
Mouse and fully interactive groups showed significantly better memory for spatial location than limited locomotion and passive groups. (ANOVA, $F(3, 48)=7.69$, $p<.0005$, Neuman Keuls, $p<.05$).

RESULTS

All subjects easily adopted the modified bike as a familiar mode of self movement within the virtual environment. The subjects reported that their motion within the virtual world was similar to motion in the real world and the occurrence of motion sickness was rare. Active (interactive) exploration resulted in significantly better scores in the memory tests than passive (non-interactive) exploration. Performance on these two measures were highly correlated. Subjects could often recall that some object was in a particular location, but failed to recall its identity.



Mouse subjects made significantly more correct object-location associations than all bike subjects, and fully interactive subjects performed better than the passive subjects. (ANOVA, $F(3, 48)=7.05$, $p<.0005$, Neuman Keuls, $p<.05$.



Unlike males, females performed better on the 2D map test than on the 3D navigation test, suggesting that spatial encoding strategies may vary as a function of sex. (ANOVA,$F(1, 48)=3.855$, $p<.0554$)

CONCLUSIONS

1. Self-directed motion is sufficient for accurate spatial representation whereas passive movement leads to impaired spatial memory.
2. The mouse interface produced less realistic virtual movement, however, it was as effective in promoting spatial learning as fully interactive immersion VR.
3. Gross locomotion feedback, therefore, is not important for spatialmemory formation.
4. Decoupled locomotion feedback impairs spatial memory. This suggests that incoherent visual-motor information may distort spatial representation.
5. Findings correspond to real world spatial memory studies (e.g. Froeman, Foreman, Cummings & Owens, 1990) which suggests that VR can adequately model certain visual-spatial aspects of reality. VR may therefore prove useful for psychological research.

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