Spatial Updating is Facilitated by Purely Visual Cues in a Virtual Environment

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1 BACKGROUND

Memory for the spatial layout of objects in a 3D environment must encode both the objects identity and its relative spatial location. Previous studies have shown that this encoding is view dependent in the sense that changes in viewing position away from the initial learning viewpoint result in deterioration in performance (e.g. Shelton & McNamara,1997; Diwadkar & McNamara, 1997). Subsequent studies have also shown that such poor performance in spatial layout tests is eliminated if the change in viewpoint is the result of the subjects own movements (Simons & Wang, 1998). This is attributed to a process known as spatial updating in which proprioceptive information originating from the subjects movement is used to update a mental representation of what the configuration of objects should look like at any moment in time during the subjects movement.
We identify three key components in the ability to recognise spatial layout from any given position in space.

1) The original appearance of the objects is encoded.
2) The original relative orientation of the observer with respect to some fixed reference frame is known.
3) The new relative orientation of the observer is known.

There is no reason why the information required in (3) should only be derived through proprioceptive sources. For instance, spatial updating may be facilitated by any visual and non−visual source that specifies changes in the spatial location of the observer.

To explore whether purely visual information can facilitate spatial updating we used a desktop virtual environment simulation of observer movement around spatially distributed objects.


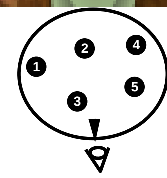
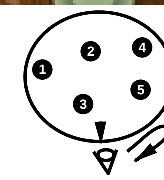

Figure 1
Mean RT = 1534ms (250)
Mean d’ = 3.1 (SE 0.27)

GROUP A
different view
same position


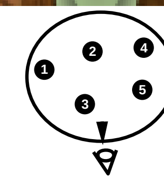
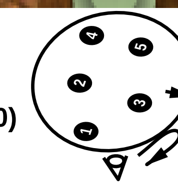

Figure 2
Mean RT = 2042ms (290)
Mean d’ = 1.9 (SE 0.27)


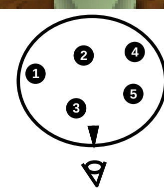
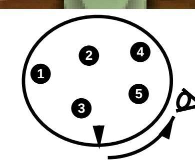

Figure 3
Mean RT = 1500ms (250)
Mean d’ = 2.0 (SE 0.21)

GROUP B
same view
diff. position


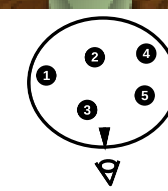
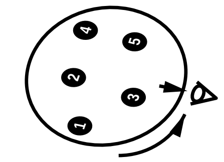

Figure 4
Mean RT = 1510ms (240)
Mean d’ = 2.5 (SE 0.25)

2 METHOD

Stimuli: A virtual environment consisted of a polygonal representation of a richly decorated interior with realistic illumination. A simulation of movement around the scene was achieved using the IRIS Performer software API on a SGI Octane workstation.

Task: Subjects had to memorise the position of 5 objects placed randomly across a table. The objects were derived from a set of twenty−five 3D models of common objects.

Subjects: Twenty−eight men and women volunteered for the experiment. They were randomly assigned to one of two groups (see Procedure). The experiment was divided into 5 blocks and 5 new objects were chosen for each block. Each block consisted of 12 trials. At the beginning of each block subjects used a 3D space mouse that allowed them to move around the simulated interior in order for them to become acquainted with it.

References
Diwadkar, V.A. & McNamara, T.P.(1997) View dependence in scene recognition. Psychological Science, 8 (4), 302−307.
Shelton, A.L. & McNamara, T.P. (1997) Multiple views of spatial memory, Psychonomic Bulletin & Review, 4(1), 102−106.
Simons, D.J. & Wang,R.F. (1998) Perceiving real−world viewpoint changes. Psychological Science, 9, 315−320.

Procedure: The experimental procedure was similar to that used by Simons & Wang (1998). Subjects were divided into two groups as follows:
Group A: Subjects viewed the objects for 3 seconds. The objects were obscured. The subjects experienced a simulated rotation around the table of approximately 28.5 degrees and were then rotated back to their original view of the objects. This took approximately 7 seconds. The curtain was raised and subjects had to determine if one of the objects changed its position on the table during the interim period.
Group B: Subjects viewed the objects for 3 seconds. The objects were obscured. The subjects experienced a simulated rotation around the table of approximately 57 degrees to a new viewpoint. This took approximately 7 seconds. The curtain was raised and subjects had to determine if one of the objects changed its position on the table during the interim period.

Subjects responded YES or NO to the question *’Did one of the objects change its relative position on the table’*. On 50% of the trials the correct response was YES. Also on 50% of trials the table and the objects were rotated in the direction of the observers simulated movement by a full 57 degrees. This meant that on this occasion
Group A saw a completely different view of the objects whereas
Group B saw the same view of the objects but from a new position.

3 RESULTS AND CONCLUSION

Reaction time (RT):
Group A required on average 500msec more time (t(13)=−5.14;p<0.0005) to make a response when the objects were rotated.
Group B were just as fast in their responses regardless of whether objects were viewed from a rotated angle (t(13)=−1.08;p=0.29).
Sensitivity (d’):
Group A performed best, when the table and objects did not rotate (Fig. 1). Performance deteriorated after table rotation (Fig. 2).
Group B performance was best when the table rotated to the new orientation producing the same retinal projection of the objects (Fig.4); although the difference between the two conditions was not as pronounced as for Group A subjects.
ANOVA: For d’ there was no significant effect of group, but a significant effect of view [F(1,26)=22.76,p<0.00005] and a trend towards interaction between group and view [F(1,26)=3.56,p<0.07]. In terms of RT there was no significant effect of group, a significant effect of view [F(1,26)=21.67,p<0.0005] and a significant interaction between group and view [F(1,26)=19.3,p<0.0005].

Conclusion: The perception of simulated movement around a scene can support spatial updating in the sense that there is no cost in response times associated with the change of the observers viewpoint.
In performing spatial tasks people can overcome changes in view brought about by their own movement better than those changes brought about by independent forces. The information that facilitates this ability appears, from the current experiment, to be derived from any source that specifies the observers position in space with respect to the area of interest.