자기주도 탐색(Active navigation)이 가상환경 내 대상재인에 미치는 효과

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The effects of active navigation on object recognition in virtual environments

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Abstracts

We investigated the importance and efficiency of active and passive exploration on the recognition of objects in a variety of virtual environments (VEs). In this study, 54 participants (19 males and 35 females) were randomly allocated into one of two navigation conditions (active and passive navigation). The 3D visual display was presented through HMD and participants used joysticks to navigate VEs. The VEs consisted of exploring four rooms (library, office, lounge, and conference room), each of which had 15 objects. 'Active navigation' was performed by allowing participants to self-pace and control their own navigation within a predetermined time limitation for each room. 'Passive navigation' was conducted by forced navigation of the four rooms in random order. Total navigation duration and objects for both navigations were identical. After navigating VEs, participants were asked to recognize the objects that had been in the four rooms. Recognition for objects was measured by response time and the percentage of correct, false, hit, and miss responses. Those in the active navigation condition had a significantly higher percentage of hit responses (t (52) = 4.000 $p < 0.01$), and a significantly lower percentage of miss responses (t (52) = –3.763, $p < 0.01$) in object recognition than those in the passive condition. These results suggest that active navigation plays an important role in spatial cognition as well as providing a better explanation about the efficiency of learning in a 3D-based program.

Keyword : virtual environments, active navigation, passive navigation, recognition

1. INTRODUCTION

In recent years, 3D-based simulated programs that people can interact with and explore in real time are popularly referred to as virtual reality (VR) or virtual environments (VEs).[1] Their potential benefits as training media for optimizing environment– human behavior interactions have been accepted for many years: for example, in flight simulation,[2] battle-field training,[3] and training for disabled children[4] and adults.[5] Specifically, there has been growth in the interest in VEs as tools for investing spatial knowledge of a novel environment[6] ; these interaction systems appear to have significant potential as aids to human learning. For example, exposure to VEs was effective in training people to find their way along a specific route through a large office block[7] and firefighters could apply route knowledge learned in a VE to a mock rescue in the real world.[8] Evidence from these results clearly shows that VEs offer advantages to training with actual equipment and environments, and have ecological validity for acquiring spatial knowledge.

In general, the visual information that can be used to memorize and to recognize, which is essential for learning in virtual environments, can be acquired in a variety of ways; it can be obtained both in the course of active navigation of an environment and during passive one. In addition, one factor that may promote learning in both real and virtual environments is the user's type of navigation.[9] Evidence from real world experiments generally suggests that active navigation is necessary for effective orientation and way-finding.

The demonstration of spatial competence in experimental settings seems to occur most efficiently when the subject has freely navigated the testing environment. For example, 3-year-old children who spontaneously engaged in active exploration showed better understanding of room layout than did less active children.[10] Similarly, there is evidence that active exploration is necessary for effective spatial learning in adults.[11,12] Thus, as suggested in previous studies, self-produced, voluntary movement in space may be necessary for the construction and use of spatial representations.[13,14]

In addition to the findings on active versus passive navigation in experimental settings, evidence from real world experiments suggests that active navigation is necessary for good orientation.[11,12] For example, a study of hundreds of city inhabitants using different types of navigation in an urban area found that car passengers learned less than automobile drivers about the layout of a town route.[12] However, not all studies have shown superiority of activity over passivity.[9,15,16] For instance, there was a small but significant advantage in way-finding ability following active navigation of a VE compared with a condition in which participants passively watched a prerecorded route through the environment.[16] There has also been a failure to find a beneficial effect of active exploration on orientation in VEs.[9] Moreover, a recent study[17] compared experimental conditions which were active, passive, and snapshot, in directing exploration using a driving simulator. Although the continuous visual stimulation was essential for acquiring spatial abilities, there were no differences between the active and passive exploration performances.

These inconsistent results suggest that factors such as the amount of attention directed to the task and the kinds of information available may influence the active-passive navigation.[18] In other words, these studies have failed to show a superiority of active navigation in VEs; the limited driving simulator environment did not test spatial abilities or the amount of attention directed to nonidentifical in each navigation condition (e.g., participants who experienced physical and psychological activity were included in the study, and participants in the active navigation condition were limited to visual and tactile simulated apparatus).[17]

In the present study, therefore, we examine the role of active navigation in the efficient acquisition of spatial knowledge, and further investigate the relative effectiveness of active navigation and passive navigation under consideration previous limitations.

2. Materials and Methods

2-1. Participants

Participants were 54 adults in the range of 19–29 years of age (*M* = 22.72, *SD* = 2.5) who were recruited at K University. Nineteen (35.2%) were males and 37 (64.8%) were females; mean ages were 24 years (*SD* = 2.13) and 22 years (*SD* = 2.45) respectively. All participants gave written consent

2-2. Instruments and measures

The virtual environments were created using the Direct X, Pentium IV PC, with an Open CL Accelerator VGA card. The 3D visual display was presented through an Olympus FMD-250W Head Mounted Display (HMD) with resolution of 800 x 600 pixels and a joystick. The virtual environments consisted of four rooms (library, office, lounge, and conference room) (Figure 1). Participants were required to complete a demographic form and a Simulator Sickness Questionnaire (SSQ)[19] designed to measure the incidence of simulator sickness symptoms in a variety of task performance environments (Table 1).

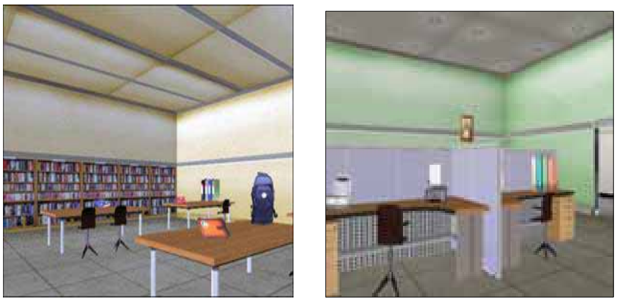

Figure 1. Example of the view during virtual navigation for library (on the left) and office (on the right) in 3D virtual environments

2-3. Procedure

Before the experiment, participants were asked to complete and return their demographic questionnaire. Participants were randomly divided into one of two VE navigation conditions; 22 were in the active navigation group and 32 were in the passive navigation group. The VE consisted of four rooms (library, office, lounge, and conference room), and each room had 15 objects (total of 60 objects). The rooms were identical in size. The participants in the active navigation group were shown how to move around the virtual environment using the HMD and joystick and asked to explore at their own pace within the predetermined time limitation for each room. Participants in the passive navigation group passively explored the four rooms in random order. During the passive navigation, each target object was presented for 2000 ms without motion, and the Inter-Stimulus Interval (ISI) between objects was 5000 ms. The total navigation duration (125 s) and objects for both conditions were identical. After navigation, all participants were asked to complete the recognition task with 60 old items, which had previously been shown during the navigation, and 60 new items, which had not been presented before. The new and old items had been matched on familiarity, emotional valence and arousal dominance in a previous survey. Before the experiment, participants were instructed to complete the Simulator Sickness Questionnaire (SSQ). During the recognition task, stimuli were presented for 500 ms with 2000, 3000 or 4000 ms inter-trial intervals. Participants were asked to use a keypad of two response buttons to indicate if they had seen the stimulus during the previous navigation

2-4. Data analysis

In the object recognition task, we conducted t-tests to compare the response times and the percentage of accurate responses of the active navigation group with those of the passive navigation group. The percentage of accurate response measures included correct, false alarm, hit, and miss.

3. Results

3-1. Response time of recognition

The mean response times on the recognition task for the two navigation conditions are shown in Table 2. The mean response times for correctly identifying old objects and new ones were 734 ms (*SD* = 154) for active navigation and 721 ms (*SD* = 163) for passive navigation. The mean response times for missing old objects were 821 ms (*SD* = 214) and 749 ms (*SD* = 196) for active and passive navigation conditions respectively. The active navigation group had longer overall reaction times than passive navigation group, though this difference was not significant.

3-2. Response percentage of recognition

The response percentages for the recognition task are shown in Table 2. The mean percentage of correct rejection was 43.75 (*SD* = 3.34) for the active navigation group and 44.35 (*SD* = 3.87) for the passive group. The mean percentage of false alarm was 6.14 (*SD* = 3.40) and

5.18 (*SD* = 3.42) for the active and passive groups, respectively. In this analysis, we failed to find a difference between the groups.

The mean percentage of old and new objects correctly identified by active navigation was 35.30% (*SD* = 5.48) and by passive navigation was 28.07 (*SD* = 7.15). The mean percentage of old objects not recognized was 14.51 (*SD* = 5.60) for the active navigation group and 21.38 (*SD* = 7.19) for the passive group. The analysis revealed a significant difference between the conditions in hit and miss response percentages for object recognition. The active navigation group made significantly more hit responses (*t* (52) = 4.000, *p* = 0.000) and fewer miss responses (*t* (52) = − 3.763, *p* = 0.000) than did passive condition.

Table 1. *Means and Standard Deviations for Demographics and Measures*

Condition	Active	Passive	*t*
	M (*SD*)	*M* (*SD*)	
Demographics			
Age	23.14 (2.41)	22.44 (2.58)	0.999
Sex	1.55 (0.51)	1.72 (0.46)	–1.307
SSQ			
Nausea	34.69 (32.19)	5.07 (9.99)	4.893**
Oculomotor	23.08 (18.78)	30.79 (17.64)	–1.537
Disorientation	38.60 (46.45)	12.18 (16.11)	2.978**
Total	356.58 (306.67)	177.75 (134.59)	2.923*

Simulator Sickness Questionnaire; Nausea = nausea, stomach awareness, increased salivation, burping; Oculomotor = eyestrain, difficulty focusing, blurred vision, headache; Disorientation = dizziness, vertigo; Total = (Nausea + Oculomotor + Disorientation)*3.7

*p< .05 , **p< .01

Table 2. *Comparison of the Effect of Active and Passive Navigation Conditions on Object Recognition*

Condition	Active	Passive	*t*
	M (*SD*)	*M* (*SD*)	
Response time			
Correct rejection	740.63 (158.03)	681.58 (174.24)	1.270
False alarm	811.15 (227.36)	800.79 (233.31)	0.166
Hit	734.77 (154.81)	721.61 (163.38)	0.297
Miss	812.22 (214.55)	749.16 (196.50)	1.116
Response percentage			
Correct rejection	43.75 (3.34)	44.35 (3.87)	–0.591
False alarm	6.14 (3.40)	5.18 (3.42)	1.010
Hit	35.30 (5.48)	28.07 (7.15)	4.000**
Miss	14.51 (5.60)	21.38 (7.19)	–3.763**

Correct rejection = correctly rejected new items; False alarm = response to new items; Hit = correctly recognize old items; Miss = failure to recognize old items.

*P< .05, **p< .01

4. Discussion

The most important finding in this experiment was the difference in object recognition between the individuals who navigated actively and those who navigated passively. The study was designed to overcome the limitations of previous studies, and the results are consistent with those of previous studies[11,12] that found active navigation of VEs allows more accurate recognition of spatial objects than does passive navigation.

Although we expected the active navigation group to outperform the passive group on the recognition task, only some significant differences were found. In particular, differences between conditions were shown in the hit and miss response percentages, which represent the most accurate responses among subordinate response measures. This implies that active navigation promotes higher performance and more efficient spatial learning. However, the shorter reaction time for recognition from the passive navigation group was not expected. There are a number of reasons why this may have occurred. One possibility is that the emphasis of the study was on investigating memory ability using a recognition task. It may be that the reaction time to this type of task is not influenced by navigation type.

Previous research[20] has shown a relationship between high ratings on the Simulator Sickness Questionnaire and performance decrements. Self-paced navigation and the degree of control are known to affect cyber-sickness. However, we did not find this relationship: although Table 1 showed that nausea and disorientation were troublesome for active navigation participants, it was not related to a decrease in memory performance.

The present results appear to be of some theoretical interest in relation to neurobiological models of spatial cognition and mapping. In influential theory[21], self-initiated movement plays a crucial role in the establishment of cognitive spatial maps by means of processes occurring within the forebrain hippocampus. It emphasized the need for the integration of successively encountered environmental cues into more global spatial representations in the hippocampus, allowing predictions to be made about the consequences of self-initiated movement. The time base for these sequential processes is thought to be the theta rhythm, a sinusoidal waveform prominent in the hippocampal EEG and notably coincident with so-called voluntary behaviors, such as exploratory movements.[22] The results of the present study support the assertion that self-initiated movement is vital for generating hippocampal cognitive maps.

Our results also have implications for the use of 3D-based programs for spatial learning. Although most research has been done using paper and pencil tasks, virtual environments provide a new tool for cognitive research.[23,24,25] Previous and present results suggest that active navigation is generally useful in promoting spatial awareness: walking around a building or city is probably the best way to learn to recognize the related stimulus as well as learn its spatial layout. Those who may benefit include disabled individuals who are unable to establish efficient cognitive maps, or are less able to utilize spatial concepts, due to damage or disease.

In conclusion, we found evidence that active navigation provided a significant advantage over passive navigation under conditions that actually tested spatial abilities, and controlled confounding variables. Active navigation promoted spatial learning. Finally, it is possible to study the extent to which active navigation is beneficial in other kind of VE tasks. Spatial encoding and the memory mechanism underlying active navigation remain to be investigated.

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