

# Factors that hinder and assist learning in virtual environments: An empirical study

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## Abstract:

Working, playing and learning in virtual environments will become increasingly important in the future. Such spaces, it is claimed, allow for realistic social interaction and present opportunities for providing motivational learning environments. For example the School of Computer Science at the University of Hertfordshire have recently established an online campus within Second Life. In this paper we present part of a four year research programme into some of the problems and issues inherent in studying and working in non-immersive virtual environments such as Second Life. We found that many learners experience difficulty with navigation in such spaces and that this may significantly affect task performance and attitude. In the first of a series of studies, important variables that affect navigation in such spaces were identified and their effects on task performance, ability to recall information and attitude to the environments were measured and are presented. In the final part of the paper we discuss how our findings are applicable to learning in virtual spaces such as Second Life.

## Introduction

In recent years, advances in technology and lower hardware prices have made it possible for three-dimensional (3D) virtual environments (VEs) and particularly computer desktop VEs to become popular (Li & Ting 2000, Mills & Noyes 1999), and be used for commercial, social and educational applications. These technologies and their applications are used in a variety of areas such as entertainment, engineering, architecture, medicine and science. A fairly recent development has been the use of the Second Life virtual environment (<http://secondlife.com/>) in education and training. Since its establishment in 2003, many hundreds of organisations have become involved in setting up educational and training applications using this system. For example, the University of Hertfordshire has recently established an online campus within the department of Computer Science which is currently being used in order to support the learning of campus based students. In consideration of the investment necessary in terms of development cost and staff time to set up and manage these systems, it will be important to provide pedagogical justification for the use of such systems. It will also be important to consider the potential risks inherent in such initiatives. These considerations are discussed more fully in the concluding section of this paper.

It seems clear to us that there is a strong rationale for the increased use of virtual systems in education and training. We live and use our senses in a 3D real world environment and are adjusted to interact effectively in one. It has therefore been claimed that, 3D interfaces and VEs which enable 3D interaction provide a more natural manner of interaction with computer applications (Crossley et al., 1997). Whilst VEs, non-immersive virtual environments (NIVEs) and 3D graphical users interfaces (3D GUIs) such as Second Life are becoming more

widespread and have many application areas, they contain problematic design and human factor issues that have to be addressed (e.g. Mills & Noyes ,1999; Stanney et al., 1998). In particular, navigation in 3D GUIs and NIVEs is one of the most important factors directly affecting task performance in these environments.

We present here the findings from part of a four year investigation into the factors that affect task performance in virtual worlds (Haik, 2005). We argue that in order to justify the widespread use of such systems in education and training, we need to understand at the very least, task performance and learner attitude to working in such spaces. In the concluding section we discuss our future plans to extend this work.

## Methodology

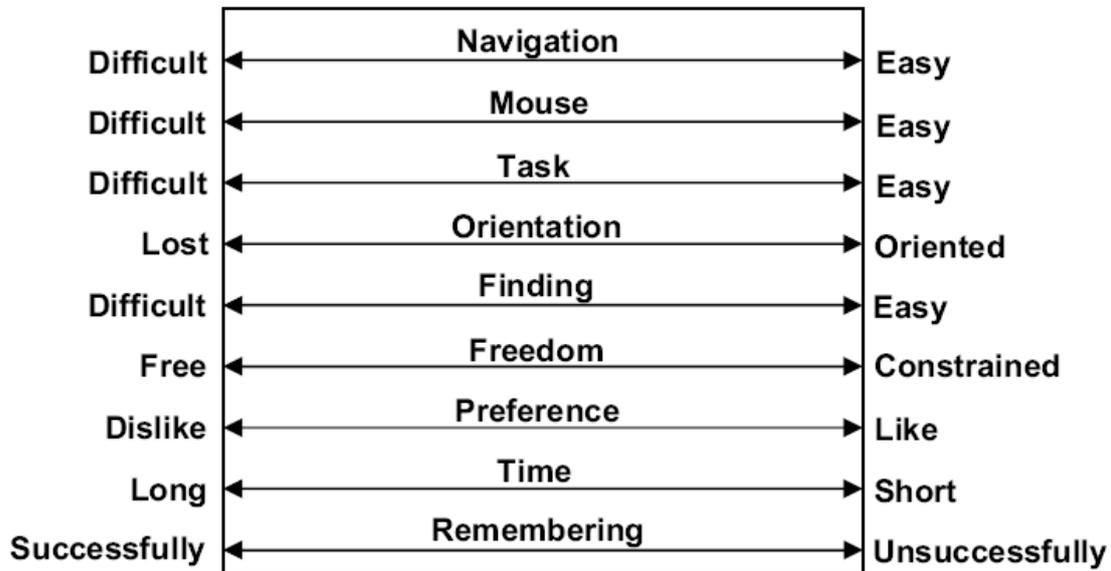
Initially it was necessary to identify those factors likely to be important in working and learning in virtual spaces. This was accomplished by means of a literature survey (Haik, 2005).

Based on the review of the literature several factors were selected as being potentially important in the context of this study. These included navigation, mouse-usage, orientation and freedom. Additionally, it was necessary to examine other factors that were important in using computer applications in general for real tasks. These include task completion time, the ability to find and remember location of information, and user attitude to the environment. The following describes in more detail each one of the investigated factors:

- **Navigation** – The ability to move efficiently in the environment is an important factor for 3D GUIs and NIVEs. However, navigation in these environments is often difficult.
- **Mouse** – The use of the mouse, a 2D device, to navigate in the 3D space is known to be problematic, where users often experience difficulties. The user's concentration could be distracted by problems experienced with the mouse.
- **Task** – This refers to the overall difficulty in performing the tasks. This could be related to different factors such as difficulties with orientation and use of the mouse.
- **Orientation** – The users' ability to know their location with regard to the environment is an important issue that can affect various factors. Users often experience problems with orientation. This could clearly affect the ability to find information and perform tasks effectively.
- **Finding** – The ability to find information in the environment is crucial to successfully completing tasks. How efficiently one can find information could be affected by the efficiency of other properties such as orientation, navigation and use of the mouse.
- **Freedom** – The degree of sensation of freedom or constraint that the users experience is part of the 3D navigation experience that could affect performance. Sensation of freedom could be affected by other factors such as the orientation and navigation. For example, when users experience frustration with navigation they might feel more constrained.
- **Preference** – This is concerned with the overall users' subjective preference and attitude regarding the ease of the different conditions.
- **Time** – The time taken for users to complete the tasks directly reflects general effectiveness of navigation. When users experience problems, efficiency in performing the tasks is reduced and task performance time is increased.

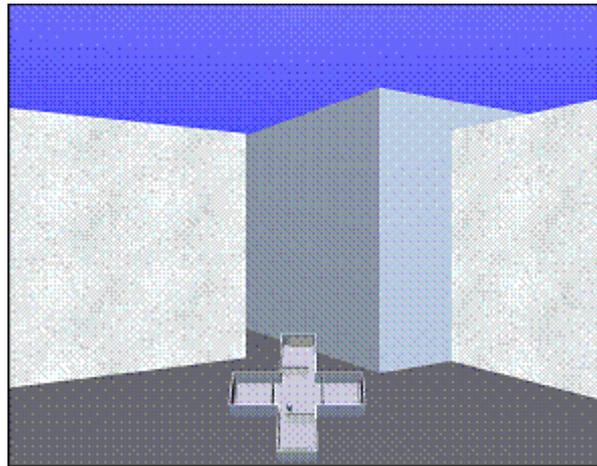
- **Remembering** – This refers to the users’ ability to remember the location of the information after finishing the tasks in each condition. This provides some information about the users’ cognitive load.

The factors identified from the literature likely to be important in task completion in NIVEs are presented in Fig. 1 below.



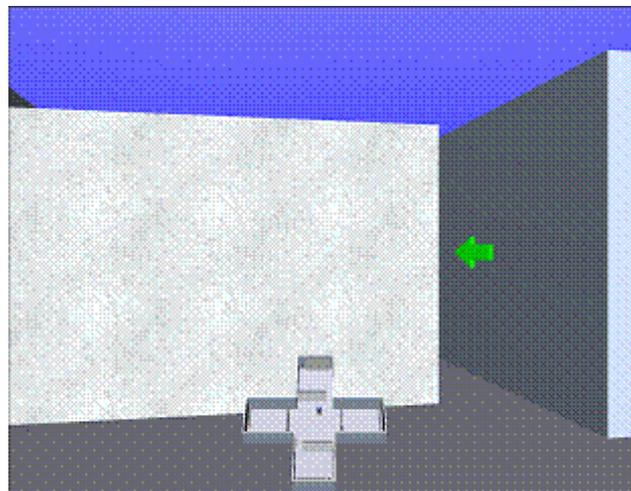
**Figure 1** Factors in NIVE task completion.

In order to test the importance of the factors shown in Fig.1, a prototype NIVE was developed in order to carry out a series of experiments. Several experiments were performed over a considerable period using this system (Haik, 2005), though it is not possible to present them all in this paper due to space considerations. In the first series of trials, effective navigation was tested based on widely accepted metaphors, such as maps which are commonly used for navigation, and arrows, which are commonly used to direct users to a destination. Some ideas from several previous works (Darken & Silbert 1993, Li et al 1999, Stoakley et al 1995), along with new ideas such as use of different metaphors, were employed and investigated. It was suggested that the main problems caused with navigation are due to difficulties with movement, orientation and use of the mouse in the environment. The general concept behind the methods was to provide users with guided or targeted navigation that would direct or restrict them to relevant areas and result in easier navigation. This would be achieved by preventing them from coming across problematic navigational areas (such as corners of rooms), by directing them so they would not, or assisting them if they did. Providing these methods of navigation by simple mouse-usage aimed to prevent the users from experiencing problems with using the mouse for navigation. The investigation included three navigational methods. The first method is a simple map that provides a view in the form of a fixed 3D miniature of the environment, intended for intuitive use and suitability for the environment (Fig. 2). The map is visible to the user along with the VE itself and includes an avatar representation of the user that moves according to his / her movements. The aim was to assist the users with orientation by providing them with indication of their location and direction of movement in the environment.



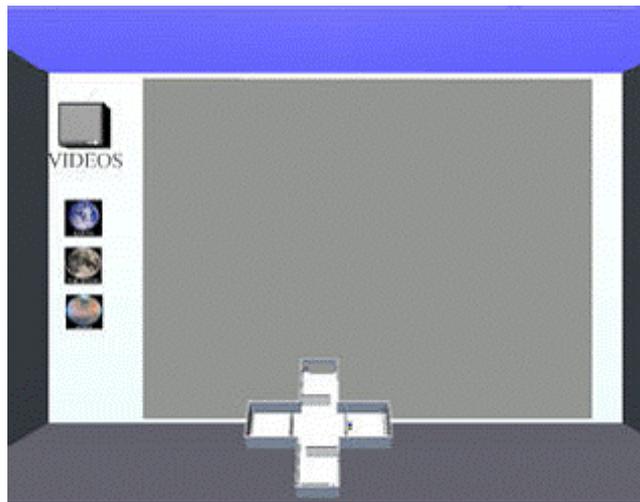
**Figure 2** Method 1 (simple map) Screenshot from the central space of the environment.

The second method was based on the use of navigation arrows and zones positioned in the environment, in predicted problematic areas. Whenever a user enters a targeted zone, navigation aids in form of arrows appear in the VE (Fig.3). Clicking on an arrow animates the viewpoint to an area of interest associated with that arrow. Choosing not to click enables the user to continue with free navigation. This method provides the user with general / exploratory navigation as described by Mackinlay and colleagues (1990), along with support for guided navigation, an idea that was supported for example by Galyean (1995). The guided navigation feature was included to provide the user with simpler navigation that is enabled by simple mouse clicks on the arrows.



**Figure 3** Method 2 (simple map and arrows)

The third method provides the user with targeted navigation (Mackinlay et al 1990) to areas of interest in the virtual interface (Fig. 4). In order to simplify the use of the mouse, the navigation was enabled by simple mouse clicks on the map rather than by pressing the mouse button and moving the mouse. Upon clicking, the viewpoint is animated to the related area and the avatar representation moves accordingly.



**Figure 4** Method 3 (navigation map)

The following is a summary of the methods:

- **Method 1** (simple map) – A fixed 3D miniature that provides a view of the environment (Fig.2).
- **Method 2** (simple map and arrows) – a simple map (method 1) accompanied by navigation aids in the form of arrows that upon clicking provide guided navigation to associated areas (Fig. 3).
- **Method 3** (navigation map) - A fixed 3D miniature model of the environment that provides targeted navigation, which is enabled by clicking on the map (Fig. 4).

## Aims and Objectives

The aim of the first experiment was to investigate factors that affect navigation and their relationship to task completion within and attitude to the NIVEs. The following objectives were generated:

- Investigate any relationship between navigation, task performance and features of the VEs.
- Investigate any relationship between user attitude and features of the VEs.

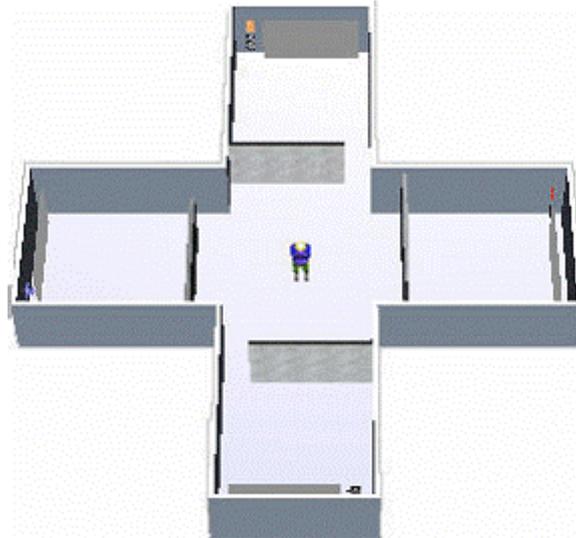
## Hypotheses

It was hypothesised that guided and targeted navigation would result in faster performance. It is possible to summarise the hypotheses as follows:

- Any difference in task performance and user attitude would be related to the navigational method used.
- Environments with navigational assistance would result in quicker task performance and more positive user attitude compared with the control condition.
- The navigation map would result in the fastest task performance and most positive user attitude.

## The experimental environment

It was intended that the environment should provide challenges for navigation and orientation as most NIVEs do. Several authors have employed the 'room(s)' metaphor in their 3D GUI or VE research. The early 3D interface - the Information Visualizer (Mackinlay et al 1992) used virtual 'rooms' for the user to retrieve information in 3D. Li et al (1999) tested their techniques for navigation in VEs, using a room(s)-like environment. Additional examples are Drucker and Zeltzer's (1994) work, and the Task Gallery (Robertson et al 2000), which also employed a rooms / gallery shaped environment in their research. It was therefore decided in this study to base the 3D environment on a 'rooms' metaphor, as shown in Fig. 5 below.



**Figure 5** Layout of the environment: consisting of four rooms and a central space.

## Method

In the following section the stages of the experiment are presented.

- Practice stage - the user is introduced to navigation in a desktop VE and practices navigation.
- Subjects were then presented with the following conditions:
  1. Environment-only, navigation is enabled by mouse movements (control).
  2. Environment with a 3D view map, navigation is enabled by mouse movements.
  3. Environment with a 3D view map and with the navigation arrows. Navigation is enabled by mouse movements and by clicking on the arrows that animates the viewpoint accordingly.
  4. Environment with the 3D navigation map. Navigation is enabled by clicking on the map that animates the viewpoint accordingly.

In addition to randomising the order of the conditions in the experiment, the location of the rooms was presented randomly, the starting viewpoint for each test was randomised and the task order in each condition was also randomised. Pilot studies were undertaken prior to the first run of the experiment proper in order to test the experimental methods and evaluation tools such as questionnaires. It was then possible to make adjustments to the methods in the

light of the experimental work. The results from the pilot studies suggested that the proposed methods and tools were satisfactory.

## The tasks

In each condition, the users (university students and staff) had to navigate to four rooms of the virtual interface and click on a menu item in each one of these rooms in a pre-defined order. They were required to remember features of the rooms and the menu items. The task order was randomised among the different conditions. This kind of task involves navigation-only operations with simple mouse clicks on menu items and did not include any additional complex or time-consuming operations.

## Data collection

Each section of a task was timed along with the overall time spent to complete the tasks successfully. All participants were observed and notes were taken regarding their performance and actions they made while accomplishing the tasks. Prior to starting the experiment the participants were asked to complete a questionnaire regarding personal details and relevant computer and virtual world experience. At the end of each test users were required to answer questions about the environment and tasks. This also provided information as to their ability to remember location of information in the environment. Finally at the end of the experiment they answered a short questionnaire intended to measure their attitude to the experience.

## Results

The following tables (1,2 and 3) present the results for the four conditions tested. The parametric variables ‘time’ - that it took the user to perform the tasks, and the user’s ability to ‘remember the location of the rooms’ were analysed using an Analysis of Variance (ANOVA) (Tables 1 & 2).

**Table 1** Means of ‘time’ and ‘remembering rooms’ location’ variables in the four conditions

Variable	Means			
	Env. Only	Env. & 3D view map	Env., 3D view map & arrows	Env. & 3D navigation map
Time	273.08 (SD 87.85)	248.16 (SD 168.27)	208.33 (SD 93.09)	101.41 (SD 27.41)
Remembering	2.16 (SD 0.71)	2.33 (SD 0.49)	2.16 (SD 0.57)	2.41 (SD 0.51)

**Table 2** ANOVA of the time and remembering variables

Analysis of Variance			
Variable	F	df	Sig.
Time	7.87	3	.00
Remembering	0.76	3	.53

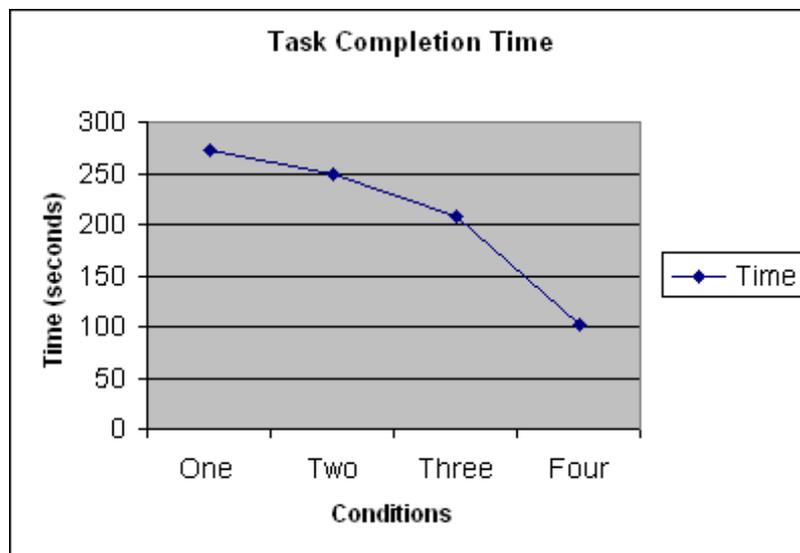
Non-parametric variables consisted of subjective users' feedback, attitude and preferences and were analysed using a Friedman test / mean ranking presented in Table 3 below.

**Table 3** Attitude to environment and Friedman Test results from users' feedback (1-5 Likert scale) in the four conditions

Variable	Mean Rank				Chi-Sqr.	Df	Sig.
	Condition I (Control - env.- only)	Condition II (method 1 - simple map)	Condition III (method 2 - simple map & arrows)	Condition IV (method 3 – navigation map)			
Navigation	3.46	3.04	2.42	1.08	24.88	3	0.00
Mouse	3.33	3.29	2.13	1.25	25.87	3	0.00
Task	3.25	2.83	2.75	1.17	23.11	3	0.00
Orientation	3.33	2.67	2.83	1.17	21.28	3	0.00
Freedom	3.00	2.50	2.29	2.21	3.18	3	0.37 <sup>at</sup>
Finding	3.04	2.67	2.71	1.58	10.62	3	0.01
Preference	3.54	2.88	2.17	1.42	20.27	3	0.00
Overall easiest	3.75	2.92	2.25	1.08	27.40	3	0.00
Overall preference	3.75	2.83	2.17	1.25	24.10	3	0.00

(Env.=Environment, Likert 1-5 rating 1 = good; 5=poor)

Fig. 6 shows below how the time variable was related to each of the four experimental variations in the environment.



**Figure 6** Task completion time and experimental condition.

Table 2 shows that there was a significant difference ( $p < 0.01$ ) found for task completion time between the environments tested. Fig. 7 summarises the effect of environment on the non-parametric variables tested in the study.

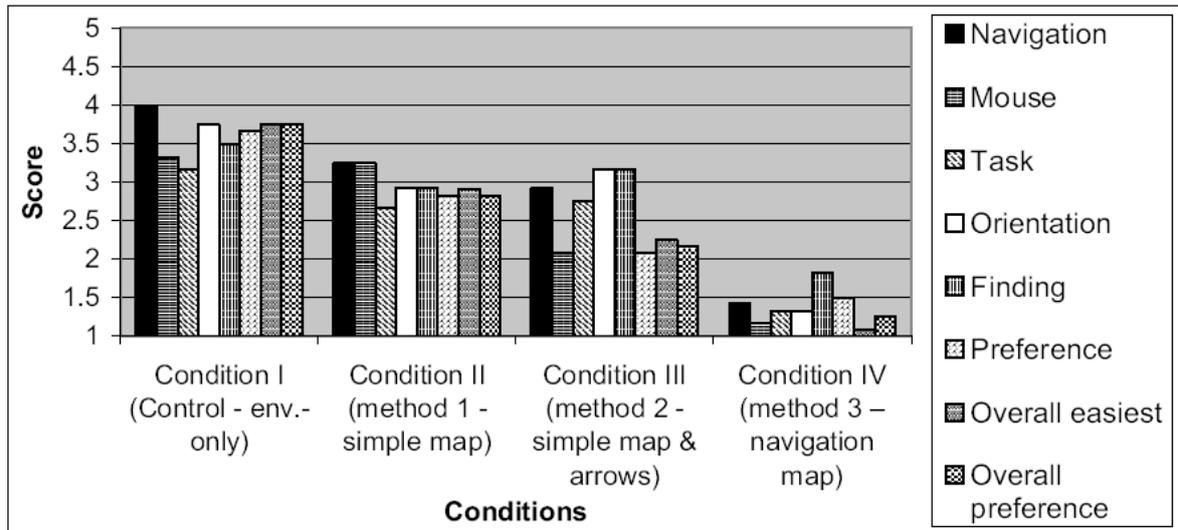


Figure 7 Non-parametric variables and experimental condition

## Discussion

Tables 1 and 2 show that there were significant differences in task completion times that could be attributed to the effect of the environment ( $p < 0.01$ ). Table 3 shows that there were significant differences in attitude to the task performance also due to the effect of the experimental condition. It is interesting to note that, despite significant differences in task completion time and attitude to the navigation method employed, there was no significant difference in the ability to remember information related to locations. This is despite tasks performed under the control condition (i.e. no assistive features) taking almost three times as long to complete as the fastest task completion (navigation map). This is interpreted as being related to the additional cognitive load placed on learners due to the difficulty of navigation in the control condition compared to other conditions. Increased time was spent dealing with the difficulties involved in navigation, rather than performing tasks and remembering. It is also likely that in the conditions with less cognitive load, features of the environment were not better remembered because learners experienced less of the environment, due to the assistive measures removing them from it, leading to decreased task completion times. This finding has interesting implications for learning in such environments. Although assistive measures decreased task completion times and improved attitude to the environment, they did not assist in learning about the environment ( $p = 0.53$ ). We argue that there is a trade off between how much assistance learners are provided with in difficult environments and their ability to engage with and learn about the environment. This was supported by our findings. Environments such as Second Life provide several assistive methods intended to decrease task completion times and improve attitude, such as 'flying' and 'teleporting'. Although these may improve attitude to the environment by speeding up interaction and navigation, they are not likely to help in remembering the environment. Needless to say, the actual *environment* itself is central to what takes place in virtual *environments* otherwise we may ask, why have them? The benefits claimed for such spaces relate in part to the motivational aspects of such worlds. It is indeed paradoxical that in order to overcome the cognitive overhead placed on learners by the complex virtual environment, assistive measures to help navigation remove learners from a large part of the environment itself. Even with such assistive measures, there

is a considerable learning curve for even experienced computer users before navigation and task completion become easy in virtual worlds. This is also true for teaching staff who may lack confidence when interacting with student experts in such spaces. Navigation in *fully* immersive worlds is simplified to some extent by our worldly experience. In NIVEs, mouse navigation requires that we keep still and the world moves as we move around in such spaces. This is not natural to us and it is difficult if not impossible for us to obtain the benefits claimed by Crossley and colleagues (1997) related to the naturalness of virtual spaces. We are not able to benefit from a more natural environment, indeed we are hampered by it. Table 3 shows that learners, despite the assistive measures, faster task completion and improved navigation did not feel less constrained because of this ( $p=0.37$ ). This shows that the feeling of constraint and freedom users experience relates more to the frustration of poor navigation than to the ability to roam unhindered. The control environment allowed users to wander freely, yet there was no difference in this dimension from the most physically constrained environment with guided navigation.

It is reasonable then to ask what exactly the pedagogical benefits of learning in NIVEs are. The ability to provide realistic simulation is an important feature of 3D worlds. However, the amount of realism provided by Second Life is quite minimal. In almost all respects it is an artificial world with mouse and keyboard navigation, low resolution graphics, anonymous users with strange names, poor physics, users flying and teleporting and rather strange abilities such as walking through walls and typing as they talk. The possible benefits related to motivation and the feeling of presence in such space however is of interest to us. We intend to investigate these potential benefits in detail with groups of learners at the University of Hertfordshire in the near future.

We have also found in our other studies that individual differences such as gender ( $p<0.05$ ) and approaches to learning ( $p<0.05$ ) have significant effects on attitude and task completion (Haik, 2005). It will be important to continue to understand how such factors affect learning performance in such worlds. Should learners be disadvantaged by such environments, it will be important to understand and to allow for it in some way, possibly by induction measures or the provision of greater assistance.

Given that we find good pedagogical reasons for using NIVEs such as Second Life in learning, there may still be problems of undertaking formal learning in such spaces. The use of web 2.0 technology in learning is a fairly recent innovation that seeks to capitalise on the rapid growth of the social aspects of the internet and apply them to learning. Second Life may be grouped under the web 2.0 banner. Often such services are provided 'free' to learners, and teachers are keen to integrate them into formal programmes. The true cost of this to institutions may be high, including training and support, as well as materials development. Such third party providers are liable to disappear, to commercialise their service, or throw off users, or, as in the case of Woodbury University in the USA, the whole campus. Second Life removed Woodbury's campus for terms of service violations by students.

*"..in violation of the terms of service. These problems include incidents of grid attacks, racism and intolerance, persistent harassment of other residents, and crashing the Woodbury University region itself while testing their abusive scripts. Due to the ongoing problems, Linden Lab has no option but to immediately close the Woodbury University region"*  
(<http://www.secondlifeherald.com/slh/2007/07/woodbury-univer.html>)

The high development cost of creating your own virtual world and the loss of true 'social networking' in university developed systems may be too high for many organisations. Despite much research over the last couple of years, there are few good examples of the pedagogical benefits of web 2.0 in education. Most examples stress the motivational benefits of such systems with little regard to the true cost, the risks, or the actual benefits to learners. It is also important to understand the part that context plays in learning. Distance learners, for example already have significant overhead on their learning. It will be important to ensure that learning in a wide range of contexts and personal situations is not made more difficult by the use of difficult environments with little pedagogical benefit. Our research will centre on finding the pedagogical benefits of such systems and also on the best sorts of assistive measures to provide for learners to ensure a successful and motivational learning experience.

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