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Usability test of 3Dconnexion 3D mice versus keyboard+mouse in Second Life undertaken by people with motor disabilities due to medullary lesions

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Abstract

The use of keyboard and mouse combinations to navigate 3D environments of virtual worlds requires the coordination of both hands in order for the 2D degrees of motion of the mice to transform into the variety of motions available in a 3D space. Such coordination may pose a challenge to people with motor disabilities. 3D controllers known as "3D mice" are presented by manufacturers as significant interface alternatives. To establish the feasibility of such claims, we have conducted a usability test of two 3D mice marketed by 3Dconnexion, in parallel with a keyboard+mouse test. The 10 participants had motor disabilities due to medullary lesions on vertebrae C5-D11, and performed 13 different tasks in the Second Life virtual world: 5 participants used 3D mice, 5 used keyboard+mouse. We have concluded that 2-3 of the 5 most challenging tasks in the keyboard+mouse combination become less challenging using 3D mice. Participants' feedback was more positive regarding 3D mice, but with significant differences between mice. Contrary to our initial expectations, the least stable mouse, Space Navigator, originated the best feedback.

Keywords: Second Life; 3D mice; 3D controllers; usability; Space Navigator; Space Pilot; 3D connexion

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1. Introduction

Three-dimensional (3D) Virtual worlds have seen immense growth in user base in the past five years. Albeit partly shadowed by the bursting of a media hype cycle that between 2007 and 2008 focused in the virtual worlds of Second Life [1] and World of Warcraft [2], the number of virtual worlds and virtual world users has kept increasing. Hundreds of different platforms have been created and/or abandoned, most of which without having been subjected to research beyond its inner group of developers. Some organizations have been monitoring and tracking such platforms: depending on how one defines what a virtual world is, there are between 300-400 different platforms and circa 1,700 million user accounts [3;4]. Currently, the Second Life virtual world sustains a medium user concurrency of 50,000, significantly more than during the media hype of 2007-2008 [5]. While sometimes confused with games, virtual worlds such as Second Life are not games, but rather 3D social environments for user interaction. They do not involve typical game mechanics such as storylines, lives, goals, etc. Users, including those with various kinds of disabilities employ this kind of virtual worlds for a variety of purposes, such as education [6], social interaction [7], and self-expression [8].

2. Input devices

Various input devices exist to enable people with motor disabilities to use game-like environments. These include switch inputs, brainwave controllers, head trackers, eye controllers, mouth controllers, one-handed controllers, and software solutions such as vocal joysticks [9]. Their adequacy depends on the level of disability of each user, and on actual interaction requirements of an environment. A game requiring fast feedback or precise control presents significant differences from an environment such as Second Life where 3D orientation and movement are critical, but are not necessarily time-critical.

For instance, Hansen and his colleagues [10] refer the case of a cerebral palsy user which is seen in a YouTube video using Second Life with a head wand (http://www.youtube.com/watch?v=CBlaiBV_yJs), and report on the advantages of socializing outweighing the inconveniences of the interface. In the same paper, these researchers report on various other cases of adapting devices to enable Second Life use by motion-impaired users, such as various headsets. Another group of researchers has also focused on high-level motor disabilities, exploring the concept of gaze-based interaction [11].

Some devices, while not adequate for people with high-level disabilities, may possibly be adequate for low-level or mid-level impairments, such as those of people with C and D vertebrae medullary lesions. Their marketing materials typically purport that they simplify the 3D interaction and navigation (for unimpaired people). Such is the case of the devices in our study, 3Dconnexion's SpacePilot and SpaceNavigator, for which the company announces in its site: "Move, fly, and build effortlessly" [12]. There is some (albeit limited) research literature reporting the use of these devices for virtual worlds or motor unimpaired users, e.g., an early adapation effort [13], a usability test [14], and an account of their use in computer-aided drawing tasks and simulations [15].

Following previous work on planning of a usability test for 3D controllers in virtual worlds [16], we present in this paper a usability test of 3Dconnexion 3D mice in Second Life in parallel with a keyboard+mouse test with people with motor disabilities due to medullary lesions in order establish the feasibility of such manufacturers claims.

3. 3. Planning the usability tests

The usability of a machine or system can be established by analysis of the performance of predetermined tasks by a user, while interacting with the said machine or system, in particular by noting expressions or cues of satisfaction [17]. Its purpose is to ensure that user interaction is more effective, efficient, and satisfactory [18].

This requires a plan to gather enough detail to conduct testing sessions in terms of objectives, requirements for the selection of participants, procedures to be adopted by test conductors, the tasks to be performed, the data to be collected, the execution order of tasks, the steps of the test session, and the required resources.

The steps to evaluate the usability vary amongst authors. In the plan that we applied, proposed by Dias et al. [16], the method set off from two key aspects: the rate of mistakes and the speed of learning to use a system, using the following measures of usability:

- **Settling time**: the time required for the user to analyze system interface affordances
- **Learning time**: the time required for the user to learn the basic operations required to perform a specific task;
- **Speed of performance**: how much time is needed for the task to be completed;
- **Number of errors**: how many errors were made by the user until the task was completed.

As a source of extra data on the nature of the usage described by those measures, the same authors also proposed recording observation data on user attitudes:

- Identification of possible attitudes of frustration;
- Identification of some confusion by users;
- Identification of attitudes of satisfaction;
- Number of requests for help to complete an action.

3.1. Tasks definition

It is essential to choose properly the tasks which are part of the test, as a usability test is a very concise sampling process. The plan proposed by Dias et al. followed Dumas' task selection criteria [19]:

- potential to generate actions with usability issues;
- tasks suggested by earlier experience and concerns;
- tasks that users will likely realize with the system.

This indicates that the tasks must follow a natural flow (from the participants' perspective) and that the most important tasks should take place at the beginning of the test. These guidelines are applied to five types of basic Second Life operations: orientation, ground maneuvers, air maneuvers, adjusting the camera angle/perspective, and zoom in on an environment feature.

Since the locations in Second Life used as examples by Dias et al. ceased to exist, we selected a new location, and adapted their tasks accordingly, within the overall goal of encompassing an efficient navigation with 3D devices within the Second Life world. The adapted tasks are presented in table 1.

Basically, we changed task number 10, which involved zooming in/out the camera while on a moving pad. Our version used a situation where visual perspective is also likely to change unexpectedly: moving through narrow paths with flights of stairs, which will require zooming in and out to regain one's bearings. We also dropped Dias et al.'s task 11 altogether (using keys/buttons to gain speed while on a swing), for lack of a similar context. This was one of the tasks they had classified as "easy".

Table 1. Task table (adapted from Dias et al. [16])

Task	Description	Objective	Difficulty level (expected)
1	Getting acquainted and oriented in space within Second Life.	The participant should be able to understand their environment and orient himself/herself in space, using the 3D controller. Be able to look around, recognizing spaces and/or buildings.	Easy
2	Follow a level path, with only	The participant must move along a prescribed route. This route is clearly	Easy

	slight bends.	visible, flat and with only slight bends.	
3	Follow a path with flights of stairs (up/down).	The participant must move along a prescribed route. Participants using the 3D controller should be able to reach the top of the stairs.	Medium
4	Move along an obstacle course on a level path.	The participant must navigate the prescribed course, going all the way while avoiding touching objects or straying too far away.	Difficult
5	Fly around a particular feature.	The participant must navigate the prescribed course, flying around an object without straying too far away.	Difficult
6	Fly and land on a specific area.	The participant must navigate the prescribed course, flying, and be able to stop flying (land) on the marked spot.	Difficult
7	Fly and land just in front of an avatar, facing him/her.	The participant must navigate the prescribed course, flying, and land in front of another avatar.	Difficult
8	Control the camera in order to focus on a panel in to read its contents.	The participant will have to focus the camera on the panel and position the camera in a way that enables a clear reading of the content of the panel.	Difficult
9	Control the camera in order to focus on the face of a neighboring avatar.	The participant will have to focus the camera on an avatar and position the camera so that the face is clearly visible in detail on the screen.	Medium
10	Move along narrow paths with flights of stairs (up/down) and zoom in/out the camera.	The participant must climb up and down flights of stairs, and zoom in or out the perspective. The main objective is to be able to climb up and down flights of stairs and control the perspective for this purpose.	Medium
11	Drive a nautical vehicle.	The participant should be able to engage with a nautical vehicle and control it to follow a water-based route (we are planning to use a water motorcycle).	Difficult
12	Drive a land-based vehicle.	The participant should be able to engage with a land-based vehicle (we are planning to use a car) and control it to follow a land route.	Difficult
13	Drive a flying vehicle.	The participant should be able to engage with a flying vehicle (we are planning to use a hang glider) and control it to follow a land route.	Difficult

3.2. Selection of test participants

The selection of participants is crucial to the success of the actual testing process. This involves the identification and description of relevant skills and knowledge required of users who will use the 3D devices: for instance, Shneiderman et al. [0] point out that the "careful choice of the user group and task level is the basis for establishing goals and metrics for usability." Nielsen [0] deems necessary to analyze individual user differences, and then register the experience of users under three dimensions:

- General computer use experience: participant's computer experience may vary from minimal to intense. It's important to check, for instance, if the user is comfortable with the mouse and concepts such as scrolling.
- Experience with the system: this may vary from no experience to expert users; whether the user will be comfortable to start navigating the system or environment may depend, partly, on his/her previous experience with that system or environment.
- Domain knowledge: this may vary from ignorant to knowledgeable; people more accustomed with the specific domain has one less obstacle to overcome while navigating the system or environment.

Therefore for the present usability tests we sought participants with some previous experience of computer use. We also inquired on their experience with 3D environments, not necessarily just Second Life. All participants have some level of motor disability, with medullary lesions varying in level from C5/C6 to D10/D11. They are associated with the Amarante branch of the Portuguese Association of Disabled People (APD Amarante) or were at some point living at the Rovisco Pais Center for Rehabilitation Medicine of the

Centre Region (CMRRC-RP) – both locations are in Portugal.

Another relevant aspect is the number of test participants. This is source of significant debate in literature. According to Nielsen [0], the use of at least five participants is suggested. Virzi [0] contends that while 80% of usability problems were detected with four to five participants, 90% were detected with 10 participants.

For our study, we selected 10 participants to perform the 13 different tasks (Table 1) in the Second Life virtual world: 5 participants used 3D mice, 5 used keyboard and mouse.

3.3. Location and general remarks on tests

We have conducted all tests with individual participants. Two observers registered relevant events during the tests. Since all participants (and one of the observers) use wheelchairs, we selected a room where they felt comfortable, in order to minimize the impact of external factors during the tests.

4. Usability tests

We assessed the usability tests in 3 phases. Initially we handed out a questionnaire to characterize participants. Then the participants used the system following the test plan, while being observed by 2 observers. Finally, we handed out a final questionnaire, for participants to perform a self-assessment of the difficulties they experienced.

4.1. Participants profile

The pre-test questionnaire (available to the public at http://home.utad.pt/~leonelm/mundosvirtuais/) focused on participants' prior experience with 3D computer environments, with the Second Life virtual world, with 3D devices, and on their specific medullary lesion. The results are summarized in Table 2.

From table 2, we can see that the average age is 30.2 years, with the youngest participant aged 23 and the oldest 40. Regarding experience on the use of 3D environments, all participants had some very small experience. And on prior experience with the Second Life virtual world, some had no prior experience at all. None of the participants had prior experience with the use of 3D devices.

Table 2. Participants' profiles (0 = no experience; 5 = frequent use)

Participant	Gender	Age	User experience with 3D environments	Second Life experience	3D controllers experience	Medullary lesion
1	M	40	1	1	0	D6-D7-D10 and D11
2	M	26	1	1	0	D10-D11
3	F	35	1	0	0	D4-D5
4	M	23	1	0	0	C5-C6
5	M	33	1	1	0	C5-C6
6	M	30	2	1	0	D12
7	M	31	1	2	0	D6
8	M	27	2	0	0	D4-D5
9	M	30	1	1	0	C6-C7
10	F	27	1	0	0	C5-C6
Average	-	30.2	1.2	0.7	0	-

4.2. Observations

Mostly, participants were able to complete the 13 tasks that were proposed (Table 1). Only in a very few cases (registered as "0" in the tables below) were participants unable to complete the tasks. Throughout the execution of tasks the observers recorded their observations, which are available to the public at http://home.utad.pt/~leonelm/mundosvirtuais/.

By analyzing the observation records, it is noticeable that the most difficult tasks for the group of 5 participants using the 3D devices (Space Navigator and SpacePilot Pro) were task 12 and task 13 (i.e., driving a land vehicle and a flying vehicle). In the case of the SpacePilot Pro device, we also observed noticeable difficulties on task 7 (flying and landing exactly in front of an avatar). These participants have also expressed some frustration when doing errors or failing to complete a task, but expressed satisfaction when successfully completing them – especially in the case of the most complex tasks. The most common error was running onto objects or walls. We hypothesize that the sensitivity to touch of the devices may contribute to this, but further testing will be necessary to ascertain it. We also noted that participants experienced more difficulties while using SpacePilot Pro. This was contrary to our initial expectations: we believed that the large and heavier base of this controller would render it easier to use, but our observations proved otherwise.

The 5 participants using the conventional combination of keyboard strokes and mouse movements experienced the most difficulties on tasks 5, 6, 7, 12, and 13: flying around a feature, landing on a specific area, landing in front of an avatar, and driving land/airborne vehicles. Similarly to what was observed with the previous group, frustration and satisfaction was expressed during the test, but in this case some participants have not provided emotional feedback. Mostly, errors also consisted in running into objects or walls, but also in not being able to stop flying and landing on intended locations.

In all cases, participants solicited assistance in the most complex tasks, and this was more frequent when using keyboard and mouse. Overall, observations point to keyboard+mouse participants experiencing greater difficulty in conducting the tasks when compared with the group that used 3D devices.

4.3. Participants' perspective

The post-test questionnaires are summarized in tables 3, 4, and 5 (the forms are available to the public at http://home.utad.pt/~leonelm/mundosvirtuais/). The self-assessment feedback on difficulty was graded from 0 to 5, where 0 means "easy" and "5" means "hard/couldn't complete the task".

In the case of the Space Navigator device, the data is presented above in table 3. Participants experienced as most difficult tasks 7, 12, and 13 (landing in front of an avatar, driving a land-base vehicle, and driving a flying vehicle). The tasks experienced as the most easy were tasks 1, 2, 3, 5, and 8 (described in table 1).

Table 3. Space Navigator participant feedback on experienced difficulty

	Participant					
Tasks	1	2	3	4	5	average
1	2	1	0	2	2	1.4
2	0	1	0	2	1	0.8
3	2	0	1	2	2	1.6
4	1	2	3	2	3	2.2

5	3	2	0	2	1	1.6
6	3	3	1	4	3	2.8
7	2	3	2	5	3	3
8	1	2	2	2	1	1.6
9	2	2	3	3	1	2.2
10	3	2	2	3	2	2.4
11	2	3	2	3	3	2.6
12	4	3	2	4	2	3
13	4	3	2	5	2	3.2

In the case of the Space Pilot Pro device, the data is presented below in table 4. Participants experienced as most difficult tasks 7, 11, 12, and 13 (the same as for the Space Navigator, plus driving a nautical vehicle). The tasks experienced as the most easy where 1, 2, 3, 4, and 8.

Table 4. Space Pilot Pro participant feedback on experienced difficulty

	Participant					
Tasks	1	2	3	4	5	average
1	3	2	0	3	2	2
2	2	1	1	2	1	1.4
3	2	2	1	4	3	2.4
4	2	2	3	3	3	2.6
5	4	3	2	2	3	2.8
6	3	3	2	3	4	3
7	4	3	3	4	4	3.6
8	3	2	3	3	2	2.6
9	3	2	3	3	3	2.8
10	4	2	3	3	3	3
11	4	3	2	4	4	3.4
12	4	3	3	4	3	3.4
13	4	3	4	5	3	3.8

Table 5 presents the data regarding the use of a combination of keyboard strokes and mouse movements. Participants experienced as most difficult tasks 4, 6, 7, 11, 12, and 13 (the same as for the Space Pilot Pro, plus moving along an obstacle course on a level path, and flying and landing on a specific area). The tasks experienced as the most easy where 2, 8, and 9.

Table 5. Keyboard and mouse participant feedback on experienced difficulty

	Participant					
Tasks	6	7	8	9	10	average
1	2	3	4	3	3	3
2	2	2	3	2	2	2.2

3	3	3	2	4	3	3
4	3	4	4	3	4	3.6
5	4	3	4	2	3	3.2
6	3	3	4	3	4	3.4
7	3	4	4	4	4	3.8
8	2	2	3	3	3	2.6
9	3	2	3	3	3	2.8
10	4	2	4	3	3	3.2
11	3	3	4	3	4	3.4
12	4	3	4	4	3	3.6
13	4	3	5	5	4	4.2

5. Conclusions and future work

Overall, the participants' assessment is more favorable among those that used 3Dconnexion 3D devices, when compared with the conventional keyboard+mouse combination.

Amongst 3D devices, participants where more positive towards Space Navigator than towards Space Pilot Pro.

This result surprised us, for we expected the heavier base of the Space Pilot Pro to render it more stable and consequently easier to use. Our initial reasoning was that, being lighter, the Space Navigator could be tilted or lifted accidentally.

Keyboard+mouse participants found as most challenging the same tasks of 3D device users, plus two more tasks. It is interesting that one of the tasks that keyboard+mouse user found challenging was one of the tasks that Space Pilot Pro participants found most easy (task 4, navigating an obstacle course on a level path). Also, it was also with the keyboard+mouse combination that a task average experienced difficulty was above 4: task 13, driving a flying vehicle.

An anecdotal account we wish to share is that all participants expressed enthusiasm with the possibility of exploring the 3D world of Second Life. Specifically, they have expressed their interest in creating a personal avatar and start to use Second Life frequently.

We believe that these results point towards the need to ponder the use of 3D devices as a significant approach to ease access to 3D worlds – particularly Second Life and similar platforms, such as OpenSimulator. This test was undertaken by people with disabilities due to medullary lesions, but we believe the results recommend that further testing is conducted, on different levels and types of disabilities.

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