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LONG PAPER

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 mouse 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, the authors 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 and 5 used keyboard + mouse. The main conclusion is 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 initial expectations of the authors, the least stable mouse, Space Navigator, produced the best feedback.

Keywords Second Life · 3D mice · 3D controllers · Space Navigator · Space Pilot · 3Dconnexion

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1 Introduction

Three-dimensional (3D) virtual worlds have seen immense growth in user base in the past 5 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 and 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], and various technologically similar platforms powered by Open Simulator have sprung up in several hosting providers. While sometimes confused with games, virtual worlds such as Second Life and spaces based on Open Simulator 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 soft keyboards [9] or vocal joysticks—Yuan et al. [10] provide a good overview. Their adequacy depends on the level of disability of each user and on the 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 not necessarily time-critical.

For instance, Folmer et al. [11] proposed a single switch navigation method for an avatar in a 3D world; Hansen et al. [12] 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 [13].

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 wand-based, tracker-based and many other approaches [14], including devices that provide 3 or 6 degrees of freedom in motion [15].

Such is also the case of the devices in this study, 3Dconnexion's Space Pilot and Space Navigator, for which the company announces in its site: "Move, fly, and build effortlessly" [16] (the selection of these devices for study was a matter of opportunity since they were already available at the researchers' institution) (Fig. 1). There is some (albeit limited) research literature reporting the use of these devices for virtual worlds or motor-unimpaired users, e.g., an early adaption effort [17], a usability test with non-disabled users [18], and an account of their use in computer-aided drawing tasks and simulations [19]. However, informed decision-making supporting purchasing decisions of hardware, by people with disabilities or the professionals working with them, lacks research on detailed impacts of the use of such devices. Moreover, some tests with non-disabled users actually put into question the purported advantages of such devices [20].

Following previous work by some of the authors on planning of a usability test for 3D controllers in virtual worlds [21], this paper presents 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 to establish the feasibility of such claims by manufacturers. It is an expanded version of the work presented at the DSAI 2012 conference [22].

3 Planning the usability tests

The usability of a machine or system can be established by analyzing 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 [23]. Its purpose is to ensure that user interaction is more effective, efficient, and satisfactory [24]. This requires a

Fig. 1 The input devices used in this study: Space Pilot (**a**) and Space Navigator (**b**)—images from www.3dconnexion.com

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 among authors. In the plan that was applied, proposed by Dias et al. [21], 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. Dumas and Redish [25] highlight two main factors defining whether a product is easy to learn and use:-

- how long it takes for the user to perform the intended task;
- how many steps are required to complete the task.

Under this perspective, a product is only successful if it helps the user in completing his/her tasks. The plan proposed by Dias et al. [21] followed Dumas and Redish task selection criteria:

- 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, a new location was selected (in http://maps.secondlife.com/secondlife/Moneta/), and their tasks adapted accordingly, within the overall goal of encompassing an efficient navigation with 3D devices within the Second Life world.

Adapted tasks are presented in Table 1 and illustrated in Figs. 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13 and 14. The main change was to task number 10, which involved zooming in/out the camera while on a moving pad. The new version of task 10 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. It was also decided to drop Dias et al.'s task 11 altogether (using keys/buttons to gain speed while on a swing), due to lack of a similar context. This was one of the tasks originally classified as "easy".

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. [26] point out that the "careful choice of the user group and task level is the basis for establishing goals and metrics for usability". Nielsen [27] 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 is important to check, for instance, if the user is comfortable with using the mouse, as well as with 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 have one less obstacle to overcome while navigating the system or environment.

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

Table 1 Task table (adapted from Dias et al. [21])

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 slight bends	The participant must move along a prescribed route. This route is clearly visible, flat and with only slight bends	Easy
3	Follow a path with flights of stairs (up/down)	The participant must move along a prescribed route, to reach either the top or the bottom 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 fly to reach the proximity of a specific patch of ground and be able to stop flying (land) on it	Difficult
7	Fly and land just in front of an avatar, facing him/her	The participant must fly to reach the location where another avatar is standing and land in front of that avatar, correctly facing him/her	Difficult
8	Control the camera in order to focus on a panel into 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 pane	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 navigate narrow paths, or climb up and down narrow flights of stairs, in situations where the default perspective may require adjustment, zooming in or out. The main objective is to be able to control the perspective while navigating a course	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	Difficult
12	Drive a land-based vehicle	The participant should be able to engage with a land-based vehicle 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 and control it to follow a flying route	Difficult

were at some point living at the Rovisco Pais Center for Rehabilitation Medicine of the Centre Region (CMRRC-RP)—both locations are in Portugal. These participants have a diverse set of limitations regarding the use of the interaction devices used in this test: upper limb motion, lack of upper limb dexterity, lack of balance, and spasticity of the upper limbs and torso.

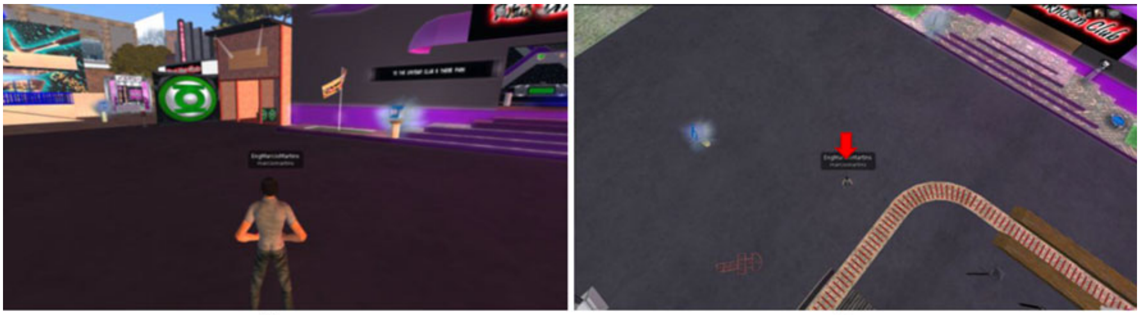
Another relevant aspect is the number of test participants. This is source of significant debate in literature. According to Nielsen [27], the use of at least five participants is suggested, albeit in the context of expert users. Virzi [28] contends that while 80 % of usability problems were detected with four to five participants, 90 % were detected with 10 participants. For this study, to collect qualitative data that can inform larger studies, 10 participants were selected to perform the 13 different tasks (Table 1) in the Second Life virtual world: 5 participants used 3D mice and 5 used keyboard and mouse.

3.3 Location and general remarks on tests

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

The minimal requirements were set as such:

- room with access for wheelchair users;
- adapted toilets nearby;
- adapted table;
- adequately sized room, in order for participants to have enough space for maneuvering wheelchairs and approaching the table; for the researcher (who is also a wheelchair user) to also be able to maneuver and approach the table, alongside the user, in order to observe and if necessary provide clarifications; and for



a b

Fig. 2 Task 1—Getting acquainted and oriented in space within Second Life. Not only what is in front of him/her (**a**) but also its overall position inside the space (**b**). The *arrow* indicates the position of the avatar

a b

Fig. 3 Task 2—Follow a level path, with only slight bends. The participant must move along a prescribed route, from the start (**a**) to its endpoint (**b**). This route is clearly visible, flat and with only slight bends

a b

Fig. 4 Task 3—Follow a path with flights of stairs (*up/down*). The participant must depart from either the bottom or the top of the stairs (**a**) and reach the other end of the stairs, following a prescribed route (**b**)

the person supporting record taking to be able to be positioned at an adequate location.

4 Usability tests

The usability tests were assessed in 3 phases. Initially, a questionnaire was handed out to characterize participants. Then, the participants used the system following the test plan, while being observed by 2 observers. Five participants used the traditional keyboard + mouse combination, and 5 conducted the test twice, one with each device. To lessen experience bias effects, the analysis of results focused on the relative difficulties of the tasks in the test plan, rather than on how each user performed with each device. Furthermore, of these five participants, 3 used the Space Pilot Pro first and 2 used the Space Navigator first, as an added measure to lessen bias (Tables 3–5 show that there is no meaningful difference between participants 1-3-5 and 2-4).

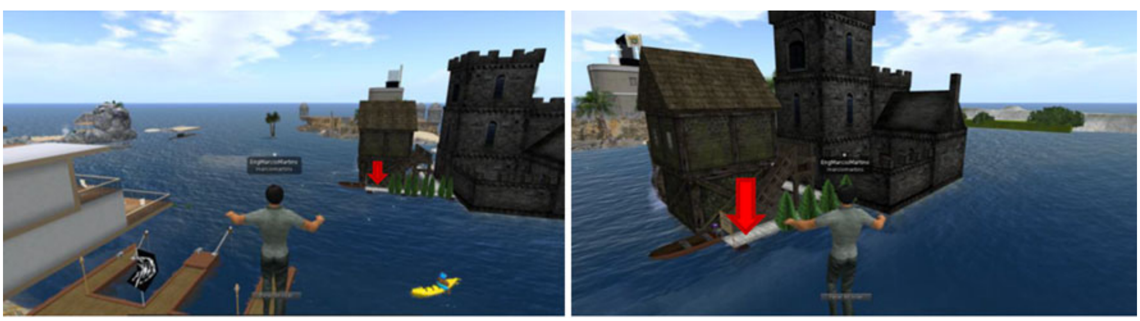
Finally, a questionnaire was handed out for participants to perform a self-assessment of the difficulties they experienced.

a b

Fig. 5 Task 4—Move along an obstacle course on a level path. The participant starts outside the course (**a**) and must navigate it (**b**) while avoiding touching objects or straying too far away

a b

Fig. 6 Task 5—Fly around a particular feature. Starting from a location where a large object or landscape feature is visible (**a**), the participant must navigate the prescribed course (**b**), flying around the object without straying too far away



a b

Fig. 7 Task 6—Fly and land on a specific area. The participant must fly toward a specific patch of ground (**a**—Identified by the *arrow*), and after approaching it (**b**), be able to land on it

4.1 Participants' profile

The pre-test questionnaire focused on participants' prior experience with 3D computer environments, the Second Life virtual world, 3D devices, and their specific medullary lesion. The results are summarized in Table 2. Readers interested in replicating this work may find the questionnaires at the following Web address (in Portuguese: http://pt.scribd.com/doc/95436698/Usabilidade-de-controladores-3D-da-3Dconnexion-no-Second-Life%C2%AE-com-PNE).

Table 2 shows 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. Regarding 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.

4.2 Observations

Mostly, participants were able to complete the 13 tasks proposed (Table 1). Only in very few cases (registered as "0" in Tables 3 and 4, below) were participants unable to complete the tasks. Throughout the execution of the tasks,

a b

Fig. 8 Task 7—Fly and land just in front of an avatar, facing him/her. The participant must fly to reach the location where another avatar is standing—identified by the arrow in (**a**) and land in front of that avatar (**b**), correctly facing him/her

a b

Fig. 9 Task 8—Control the camera in order to focus on a *panel* into read its contents. The participant will have to focus the camera on the *panel* (**a**) and position the camera in a way that enables a clear reading of the content of the *panel* (**b**)

a b

Fig. 10 Task 9—Control the camera in order to focus on the face of a neighboring avatar. The participant is nearby another avatar, initially seeing its full body (**a**) and will have to position the camera so that the face is clearly visible in detail on the screen (**b**)

the observers recorded their observations (the original records – in Portuguese – are available at http://pt.scribd.com/doc/95436698/Usabilidade-de-controladores-3D-da-3Dconnexion-no-Second-Life%C2%AE-com-PNE).

The time required for users to learn the operation required for executing each task varied between 2 min and 5 min, both for the 3D devices participants and for the keyboard + mouse participants. Regarding the task execution speed, the observers recorded higher speed with the use of 3D devices over traditional keyboard + mouse; however, since the groups of participants were distinct, this difference may be too dependent on individual differences and was not used in assessment. Between both 3D devices, however, a higher speed of task execution was also recorded when users employed the Space Navigator, which may be significant in view of the results described ahead, but which was pursued further. Regarding the number of errors, participants using keyboard + mouse also yielded more errors per task and more requests for assistance in order to complete the tasks: with 3D controllers, participants produced on average 1.6 errors per task, while using keyboard and mouse, the average was 2.4 errors per task.

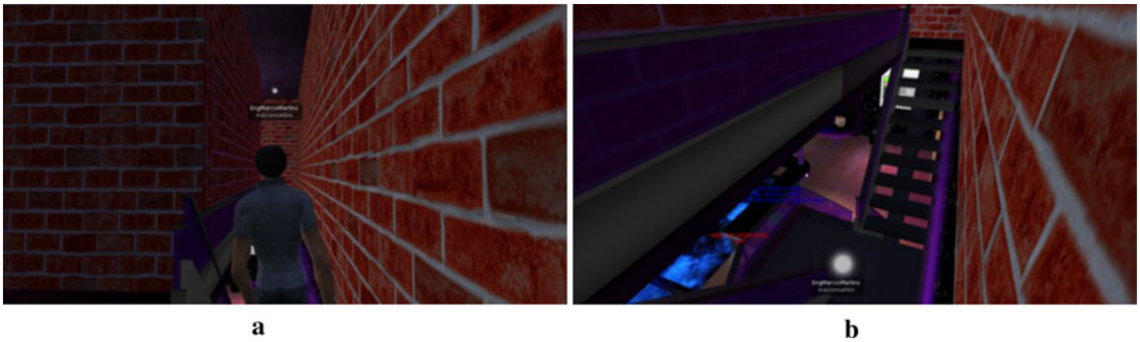


Fig. 11 Task 10—Move along narrow paths with flights of stairs (*up/down*) and zoom in/out the camera. The participant must navigate narrow paths (**a**), or climb up and down narrow flights of stairs, in situations where the default perspective may require adjustment (**b**), zooming in or out

Fig. 12 Task 11—Drive a nautical vehicle. The participant should be able to engage with a nautical vehicle (**a**) and control it to follow a water-based route (**b**)

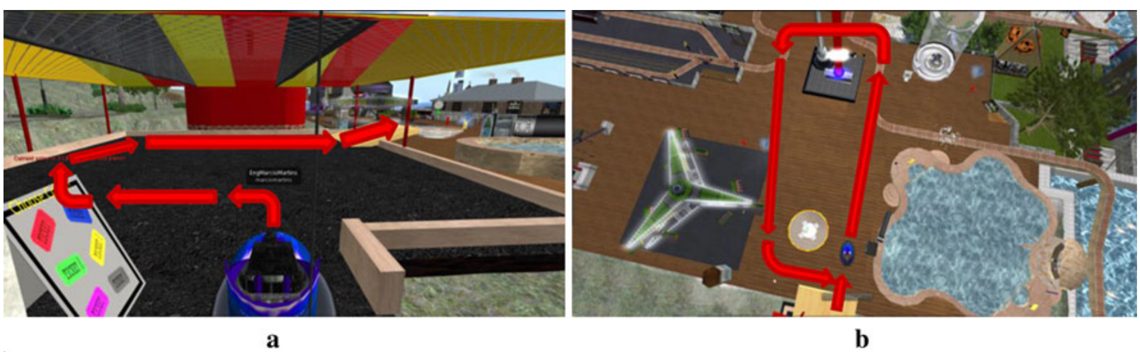


Fig. 13 Task 12—Drive a land-based vehicle. The participant should be able to engage with a land-based vehicle (**a**) and control it to follow a land route (**b**)

The number of assistance requests of participants using 3D devices was half of what was recorded for participants using keyboard and mouse. Given that these differences may also be attributed to individual participant differences; however, the relative difficulty of the tasks was also analyzed.

By analyzing the observation records, it was established that the most difficult tasks for the group of 5 participants using the 3D devices (Space Navigator and Space Pilot Pro) were tasks 12 and 13 (i.e., driving a land vehicle and a flying vehicle). In the case of the Space Pilot Pro device, noticeable difficulties were also observed on task 7 (flying and landing exactly in front of an avatar). These participants have also expressed some frustration when committing 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. As a hypothesis, the touch sensitivity of the devices may contribute to this, but further testing will be necessary to ascertain it. It was also noted that participants experienced more difficulties while using Space Pilot Pro. This was

Fig. 14 Task 13—Drive a flying vehicle. The participant should be able to engage with a flying vehicle (**a**) and control it to follow a flying route (**b**)

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	–

Table 3 Space Navigator participant feedback on experienced difficulty

Tasks	Participant					% higher or equal to 3
	1	2	3	4	5	
1	2	1	0	2	2	0
2	0	1	0	2	1	0
3	2	0	1	2	2	0
4	1	2	3	2	3	40
5	3	2	0	2	1	20
6	3	3	1	4	3	80
7	2	3	2	5	3	60
8	1	2	2	2	1	0
9	2	2	3	3	1	40
10	3	2	2	3	2	40
11	2	3	2	3	3	60
12	4	3	2	4	2	60
13	4	3	2	5	2	60

Table 4 Space Pilot Pro participant feedback on experienced difficulty

Tasks	Participant					% higher or equal to 3
	1	2	3	4	5	
1	3	2	0	3	2	40
2	2	1	1	2	1	0
3	2	2	1	4	3	40
4	2	2	3	3	3	60
5	4	3	2	2	3	60
6	3	3	2	3	4	80
7	4	3	3	4	4	100
8	3	2	3	3	2	60
9	3	2	3	3	3	80
10	4	2	3	3	3	80
11	4	3	2	4	4	80
12	4	3	3	4	3	100
13	4	3	4	5	3	100

contrary to the initial expectations: the large and heavier base of this controller was expected to render it easier to use, but the 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, although in this case, some participants have not provided emotional feedback. Mostly, errors also consisted of running into objects or walls, as well as 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 posttest questionnaires are summarized in Tables 3, 4, and 5 (the forms are available at http://pt.scribd.com/doc/95436698/Usabilidade-de-controladores-3D-da-3Dconnexion-no-Second-Life%C2%AE-com-PNE). 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".

Overall, participants who used the 3D controllers expressed some frustration when making an error, or finding themselves unable to complete a task. However, the authors emphasize the satisfaction that the participants expressed while performing the tasks, particularly the most complex ones.

The most common error was crashing onto virtual objects and walls. It is possible that a reason for this is their lack of prior experience with 3D controllers, since they are quite responsive to touch. The authors also emphasize that the greatest difficulty in task execution was observed while using the Space Pilot Pro controller, against original expectations, based on weight differences between the two 3D controllers.

In the case of the Space Navigator device, the collected data are presented in Table 3. Participants experienced as most difficult tasks 6, 7, 11, 12, and 13 (landing on a specific area, landing in front of an avatar, driving a nautical vehicle, driving a land-based vehicle, and driving a flying vehicle). The tasks experienced as easiest were tasks 1, 2, 3, 5, and 8 (described in Table 1).

In the case of the Space Pilot Pro device, the data are presented in Table 4. Participants experienced as most difficult tasks 6, 7, 9, 10, 11, 12, and 13 (the same as for the Space Navigator, plus focusing on the face of a neighboring avatar and moving along narrow paths with flights of stairs). The tasks experienced as the most easy where 1, 2, and 3. An overall higher level of difficulty can be noticed.

Table 5 Keyboard and mouse participant feedback on experienced difficulty

Tasks	Participant					% higher or equal to 3
	6	7	8	9	10	
1	2	3	4	3	3	80
2	2	2	3	2	2	20
3	3	3	2	4	3	80
4	3	4	4	3	4	100
5	4	3	4	2	3	80
6	3	3	4	3	4	100
7	3	4	4	4	4	100
8	2	2	3	3	3	60
9	3	2	3	3	3	80
10	4	2	4	3	3	80
11	3	3	4	3	4	100
12	4	3	4	4	3	100
13	4	3	5	5	4	100

Table 5 presents the data regarding the use of a combination of keyboard strokes and mouse movements. Participants experienced as most difficult tasks 4, 5, 6, 7, 9, 10, 11, 12, and 13 (the same as for the Space Pilot Pro, plus following a path with flights of stairs and moving along an obstacle course on a level path). The tasks experienced as the most easy were 2 and 8. A higher level of overall difficulty compared to the Space Pilot Pro on the easier tasks can be noticed.

In general, participants who used a keyboard and mouse combination expressed some frustration when making errors or failing to complete a task, but expressed satisfaction when successfully completing them. There was also a minority of participants who has not expressed any reactions.

The most common errors were: running onto objects or walls, and being unable to stop flying (land) on intended spots.

4.4 Statistical analysis

Even though the sample size is quite small, a statistical analysis of the data collected was conducted in order to better characterize the results obtained. Nonparametric tests were employed for differential analysis, since data were obtained using Likert scales.

The Mann–Whitney Unilateral (MW) method can be used to determine whether there is a tendency for a set of observations to present larger median values than another

Table 6 Results for the nonparametric tests used on participant feedback on experienced difficulty

Tasks	Space Navigator versus keyboard + mouse *p* value for MW test 1-tailed	Space Pilot Pro versus keyboard + mouse *p* value for MW test 1-tailed	Space Navigator versus Space Pilot Pro *p* value for MW test 1-tailed
1	0.008**	0.111	0.042*
2	0.016*	0.0475*	0.090
3	0.008**	0.2105	0.051
4	0.016*	0.028*	0.079
5	0.028*	0.274	0.032*
6	0.2105	0.2105	0.282
7	0.111	0.345	0.128
8	0.028*	0.5	0.029*
9	0.155	0.5	0.090
10	0.0755	0.345	0.042*
11	0.0475**	0.4205	0.051
12	0.2105	0.345	0.079
13	0.111	0.274	0.090

*, ** Significance at $p < 0.05$; $p < 0.01$ respectively

set of independent observations. In this case, the particular method was employed in order to compare the difficulties felt while using the Space Navigator and Space Pilot Pro devices, with the ones felt while using keyboard and mouse (Significant *p* values were assigned at unilateral $p < 0.05$ described in Table 6).

Regarding the comparison of the Space Navigator versus keyboard + mouse, it points toward the difficulties felt by keyboard + mouse users being most relevant in tasks 1 through 4, plus tasks 5 and 8. When conducting a comparison of the Space Pilot Pro versus keyboard + mouse, the tasks this test reveals as most relevant are only tasks 2 and 4. This method does not find significant differences for the other tasks.

In order to compare task difficulty between the Space Navigator and the Space Pilot Pro, the Wilcoxon signed-rank (WCX) nonparametric method was used. This method allows the comparison of two related samples to establish whether the population mean ranks are distinct and was performed for a unilateral test significant level $p < 0.05$, described in Table 6. This method was not conclusive due to the reduced sample of only 5 participants on the two different devices. It points toward the difficulties felt in tasks 1, 5, 8, and 10 being greater when using the Space Pilot Pro compared to the experience of using the Space Navigator.

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.

Among 3D devices, participants were more positive toward Space Navigator than toward Space Pilot Pro.

This result was surprising, for the expectation was that the heavier base of the Space Pilot Pro would render it more stable and consequently easier to use. The 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 users 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). 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 one can share is that all participants expressed enthusiasm with the possibility of exploring the 3D world of Second Life. Specifically, they expressed their interest in creating a personal avatar and start using Second Life frequently.

The tests were conducted with a limited number of users, so conclusions are limited in scope until more tests with larger number of users can be performed. The authors believe that these results point toward 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; however, the authors believe the results recommend that further testing is conducted, on different levels and types of disabilities.

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