User Experience Study of Concurrent Virtual Environments with 2D Tab and 3D Portal UIs

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Abstract

3D virtual environments have long been proposed as a means for collaborative work and communication. Many current implementations usually require that a user has one presence in one virtual world, which has an effect of limiting the possible actions a user has in some areas such as education and business. In this paper, we support a users' presence in multiple concurrent virtual environments and provide a user interface which makes it easier for them to move from one world to another. We evaluate the work by conducting a user experience study to obtain users' feedback on our solution. Our current implementation supports four concurrent client server connections. User feedback states that using multiple concurrent connections is visually pleasant, entertaining, fun, easy and fast to use.

Keywords

3D user interface, portal, concurrent, virtual environment, user experience.

1 Introduction

Network virtual environments (VEs) have been proposed as a means to carry out collaborative work and communication for many years [Greenhalgh & Benford 1995], [Manninen 2001], [Messinger *et al*. 2009]. The design of most network virtual environments usually assigns each user a single 'presence' in the virtual space, usually represented by an avatar [Zahorik & Jenison 1998]. However, when working, most users face multiple tasks and must therefore allocate their time as users shift their attention between ongoing tasks [Benbunan-Fich *et al*. 2011]. In practice, this means that users are not always fully present on the task in a virtual environment [Greenhalgh & Benford 1995], but rather are trying to maintain a presence across a number of different activities. In the case of education with virtual environments, pupils, students and teachers highlighted the need to have multiple different kinds of 3D spaces to conduct private and public work (e.g. group and classroom work) [Arhippainen *et al*. 2011]. They regularly need to maintain these in parallel and move data from one space to another.

Currently, supporting this level of work concurrency in a virtual environment means opening up separate independent client viewers. However, this has a number of usability and performance issues. For usability, the user must manage multiple separate windows. From a technical point of view, multiple 3D clients require a great deal of memory and processing power, most of which is redundant software components. In this paper, an implementation of concurrent virtual environments is presented which:

- supports up to four concurrent client server connections: the connections can be to the same server, or to four different servers,
- saves significant resources in memory and processing power, but not on bandwidth,
- provides two different user interface (UI) techniques (2D Tab and 3D Portals) for maintaining a presence in multiple spaces, navigating between spaces.

This paper contributes to the research community by proposing a solution to support multiple concurrent connections for 3D environments and presenting user experience (UX) findings.

2 Relation to Existing Theories and Work

The development of virtual environments has a number of application areas, including entertainment, teaching and training, simulation, meetings, collaborative working. Of these, computer gaming is perhaps the largest market area, expanding to 12 Billion in 2012[1]. A large number of research has also gone into training and simulation, which is particularly used by military training, war gaming or other simulations. In each case, however, the user is expected to have a presence in the virtual world, i.e. a sense of being there [Zahorik & Jenison 1998]. This immersive aspect has a very strong effect on all aspects of virtual environments, which in some cases can mean that the user is totally encased in cockpits and cut off from surrounding stimuli. In practice, users need to multitask. Multitasking is a critical aspect of work, i.e. how users manage their presence across a number of tasks [Benbunan-Fich *et al*. 2011]. This need to multitask caused users to divide their attention - and consequently presence - across a number of different applications. Early research tried to detect these situations of attention loss and reflected these in the avatars. However, the inherent design of virtual environments does not naturally support this approach. While it is technically possible to split a screen, e.g. console games will use split screens to have multiple point of views, each user still only has one presence. In virtual environments, prior work on helping the user organise multiple tasks often focused on using a 'room' metaphor. The room metaphor for multiple virtual workspaces is used to divide the users' workspace into a suite of virtual workspaces, using statistics to divide the objects amongst the different rooms [Henderson & Card 1986].

2.1 User Interface Design for Concurrent Virtual Environments

With traditional UI elements such as tabs, textual lists or buttons, it is awkward to navigate through different VEs or respond to various events. Portals can help a user in navigating the virtual worlds because of the visual presentation of the target space [Kotziampasis *et al*. 2004]. Kotziampasis *et al.* experimented with CurlSpace portals and compared them to VRML anchor links [Kotziampasis *et al*. 2003]. A CurlSpace portal is an object (e.g. open window or door) in the virtual world. It displays the destination in a realistic 3D manner before the user traverses through the portal. Compared to the VRML anchor link, the portal helps the user to maintain focus on where he is going and from where. The VRML anchor link is just an icon and user has to memorize where it is leading to.

Portals have also been used as object transfer devices before but only in 2D environment. Voelker *et al*. demonstrate 2D surface portals where documents and 2D shapes can be transferred or mutated through portals on a surface display [Voelker *et al*. 2011]. This implementation does not include virtual environment border crossing. This means all the objects actually reside in the same 2D virtual space although they can reside in different surface displays. This eases the object transfer, because no communication has to be made between different servers [Roden & Parberry 2005].

3 Research Approach

This section briefly describes the research methods used, implementation of the experiment and the testing setup. This study uses a multidisciplinary approach combining constructive research methods of software development and user experience evaluation methods. An iterative design

[1] SUPERDATA 2012. http://www.superdataresearch.com/global-mmo-games-spending-exceeds-12bn/

approach is used where the first iteration focused on user experience studies of virtual environments for music and education, which were presented in prior work [Arhippainen & Hickey 2011], [Arhippainen *et al*. 2011]. The results of that work was fed into the second iteration, the design of concurrent virtual environments which is the topic discussed in this paper.

The design focused on a constructive methodology that a) implemented a communication and memory management algorithm, and b) a user interface design to facilitate presence and navigation between the concurrent virtual environments. The design of the user interface elements, 3D Portal and 2D Tab, was implemented and its operation validated for correctness.

Then, a user study was carried out which focused on the users' subjective experiences on the difference between two methods for developing the user interface, 3D Portals and 2D Tab browsing. We were especially interested in how users perceive the 2D Tap and 3D Portal UIs and which elements they like in these solutions. Because user experience is dynamic, context-dependent and subjective [Law *et al*. 2009], it is important in UX studies to use several methods together in order to achieve a comprehensive understanding of users' thoughts, wishes and experiences. ISO standard [ISO DIS 9241-210:2010] defines user experience as: "*a person's perceptions and responses that results from the use and/or anticipated use of a product, system or service*". User experiences should be evaluated before, during and after the use [Vermeeren *et al*. 2010]; therefore, we interviewed and observed during the use, and used questionnaires and adjective card selections after the use of both UIs. Test methods of this study are described thoroughly in subsection 3.2.2.

3.1 Technical Implementation

The implementation of the concurrency on a single 3D viewer client required the introduction of an abstract layer inside the client which allows for the establishment of multiple unique connections to different environments, as shown in Figure 1. The use of this unique connection identifier allows us to multiplex the data into different scenes, making sure that data is not sent to the wrong destination. Additionally, it was also necessary to ensure that user input events, such as mouse clicks could be properly routed towards the correct virtual environment.

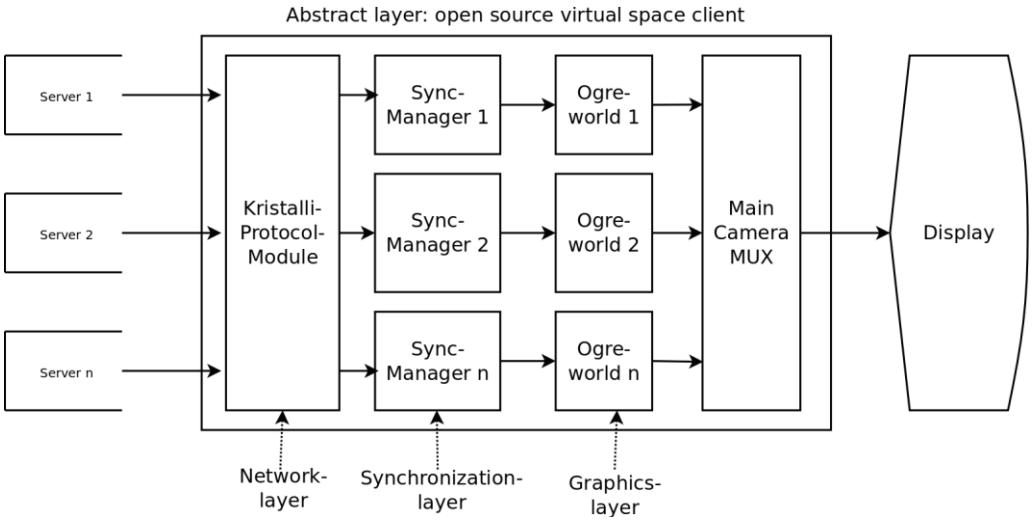

Figure 1: Concurrency abstraction architecture in the client viewer.

This abstraction layer was hidden from the user and the manipulation of the different scenes was handled solely by user input methods, called the tabbed browsing and portal user interface. The Tundra2 realXtend virtual world viewer was used as an experimental setup platform for portals. Tundra2 is based on a client-server type architecture and it uses Entity-Component (EC) model [Alatalo 2011]. Client-server architecture means all entity actions, which are supposed to propagate to all clients, need to be authored by the server. Locally, a client can practically do anything he or she wants but if changes are meant to be replicated to the other clients, it needs

the server authority to confirm the changes. This architecture also forces a client to go through the full login procedure just to get the real-time image for the portal surface. There is no interface to query the vision from the server without a proper login.

3.1.1 2D Tab and 3D Portal User Interfaces

The 3D Portal UI provides an ability to have four client-server connections in parallel, which are presented to the users as four parallel views to the VEs (Figure 2). The portal area (circle on the back wall) shows an image from a concurrent virtual environment. The portal mesh contains a Render-To-Texture (RTT) component, which constantly refreshes the image on the specified surface of the mesh with the view captured from the other virtual space. The image is captured by placing a RTT-target component on the camera observing the concurrent virtual environment. The image created by RTT on the mesh surface is a 2D projection from the observing camera view. In this experiment, portals had predefined target environments which they link to. Users were given textual sign indicators above the portals to clarify what virtual environment this specific portal connects to when clicked [Karhu *et al*. 2012].

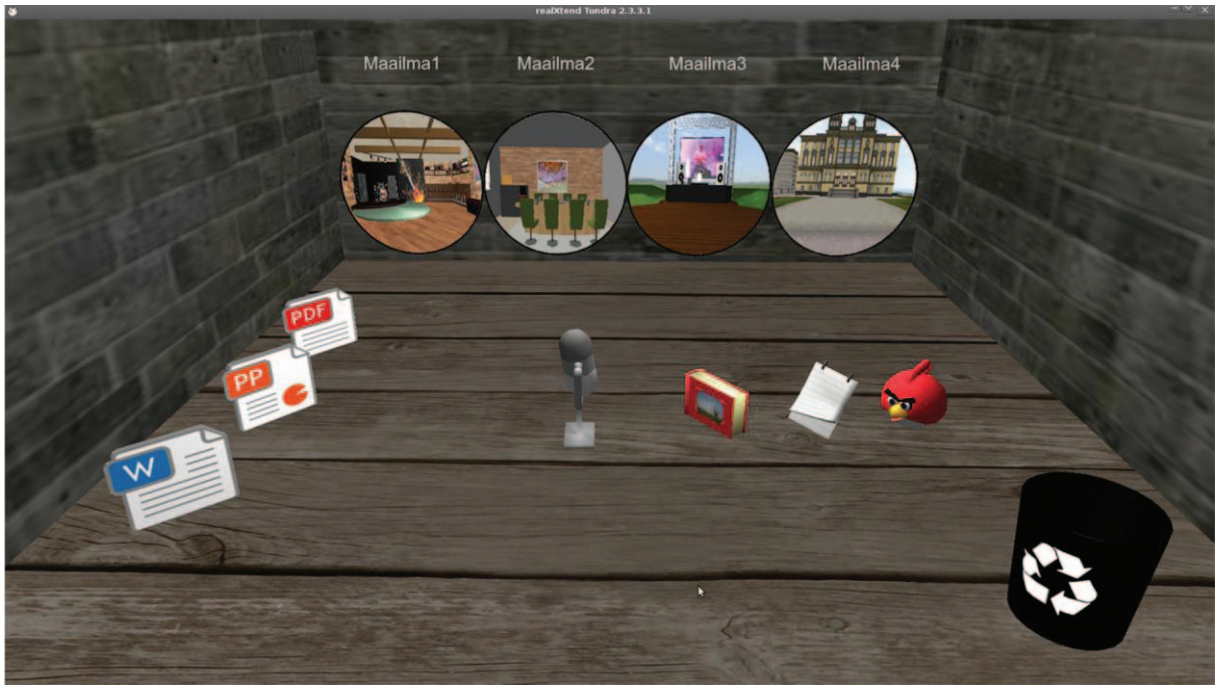

Figure 2: 3D Portal UI for entering to the multiple virtual environments.

In Figure 2, the usage of 3D Portal UI starts with the user loading a private space, which is where he/she can view all of the scenes. When the user wants to specifically concentrate on one task, he/she can click on the virtual environment of choice. In this case, a Miniportal is created which allows the user to move back to the private area, as shown in Figure 3.

Practicality, the tab view is similar in to the portal view, but the user cannot see what is going on in the other concurrent sessions, as shown in Figure 4. The 2D Tab user interface also uses an explicit login phase, while the 3D portals use pre-defined login actions for a one click login. Otherwise, both user interface schemes operate in the same manner.

Figure 3: The Miniportal (shown in the left down corner) for returning to the 3D Portal space.

Figure 4: 2D Tab UI for multiple concurrent connections (highlighted on the top left).

3.1.2 Four Virtual Environments for the Experiment

The virtual environments chosen for the study are completely different from each other so users can feel they are connected to completely different servers (Figure 5). A user can switch to any of these virtual environments at any given moment to emphasize concurrent nature of the VEs.

Four example virtual environments are Music Club, Office, Outdoor Music Club, and City. We selected different types of VEs (e.g. context, size) in order to study privacy aspects as well, for instance, do participants perceive the space as public or private.

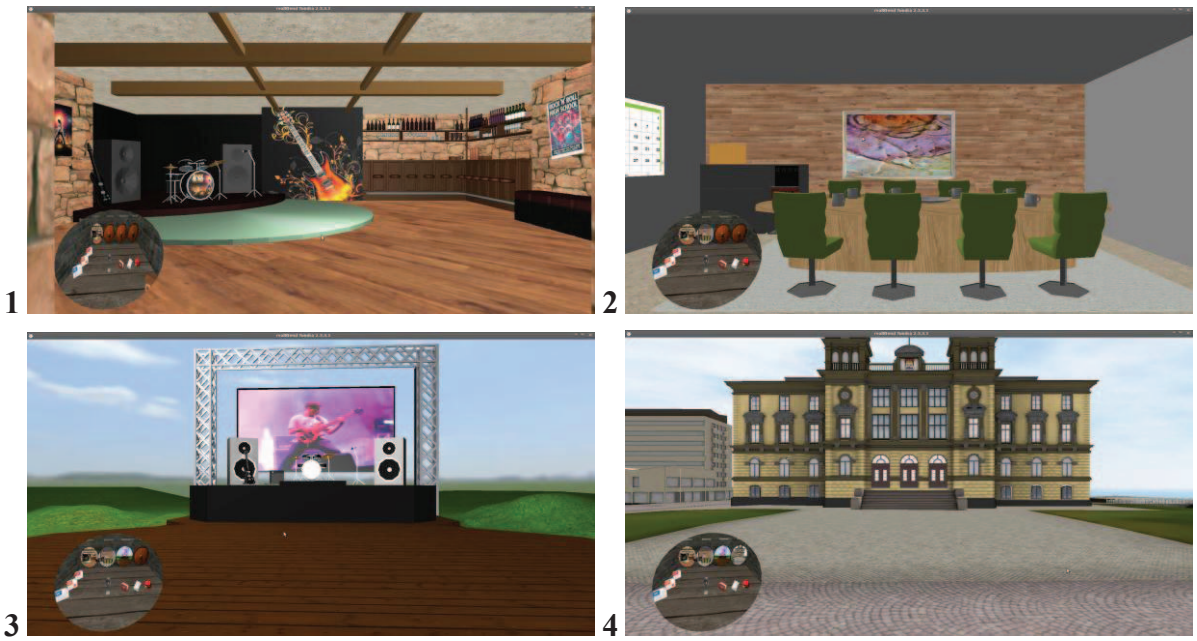

Figure 5: Four example virtual environments with the 3D Miniportal: 1) 3D Music Club, 2) 3D Office, 3) 3D Outdoor Music Club, and 4) 3D City.

3.2 User Study

In this section, the empirical small scale user study is presented. The aim of the user test was to investigate the following issues: how users experience the 3D Portal UI paradigm and do they prefer it more over to the 2D Tab UI solution. In the study, we had 12 subjects, whose age varied from 20 to 40 years (Mean 28). The ratio between males and females was 1:1.

1. Concurrent connection using the 2D Tab UI

a) Login into the worlds 1-4: write user name and server address, press connect button.
Comment what kind the opened world is and what it is meant for.
b) Switch between the opened worlds (using tabs).
Comment how you know in which world you are (indication)
c) Close the connections (click the x in the tab).
d) Select 4/24 adjective cards that depict your experiences relating to the 2D Tab UI.
Comment your selections. (Figure 8A)
e) Fill the questionnaire (10 statements)

2. Concurrent connection using the 3D Portal UI

a) Enter to the 3D Portal environment (click the application icon on the desktop)
Comment do you consider the 3D portal UI as public or private and explain why.
b) Open worlds (doors) 1-4 (left mouse click).
Comment what kind the world it is and what it is meant for.
Comment do you consider the virtual worlds as public or private and explain why.
c) Switch between the opened worlds.
Comment how do you know in which world you are (indication).
d) Close the connections (doors): (the right mouse click).
e) Select 4/24 adjective cards that depict your experiences relating to the 3D Portal.
Comment your selections. (Figure 8B).
f) Fill the questionnaire (15 statements)

3. Compare the 2D Tab and 3D Portal UIs

a) Select which one you preferred 2D Tab or 3D Portal UI and explain why.

Figure 6: User experience test procedure and user tasks.

3.2.1 User Scenario and Test Setup

The procedure of the test and user's tasks is described in Figure 6. At beginning of the test, users were introduced to the virtual environments and portals by small tasks. Participants first used the traditional way to connect to a virtual environment; therefore, they needed to log in to the world by giving user name and server address (Task 1). Users were able to open several environments and they all were opened into the one browser, where the worlds were separated by tabs (the same solution that exists, for instance, in current web browsers). After establishing concurrent connections by 2D Tab views, users were asked to select four out of 24 adjectives to depict their experiences relating to the 2D Tab UI (Task 1d). After that, users filled in the questionnaire. Then, they were asked to use the 3D Portal UI and conduct Task 2. After using both 2D Tab and 3D Portal UIs, they were asked to compare which one they prefer more (Task 3).

3.2.2 Test Methods

In this study, we used a mixed method approach; therefore, we collected user experiences by interviews, observation, adjective card selections and Likert Scale questionnaires. The adjective card selection method in this study included twelve positive and twelve negative adjectives (Figure 7). After the use of both prototypes (Task 1 and Task 2), users were asked to select four out of 24 adjectives which depict their experiences relating to each prototypes (Figure 8). Our first version of the adjective card selection method is presented in [Sunnari *et al*. 2012]. We have created this method based on the ideas in the Product Reactions Cards method [Barnum & Palmer 2010].

Time-consuming	Uncontrollable	Useful	Fast	Clear	Difficult to use
Businesslike	Fun	Useless	Empowering	Stressful	Entertaining
Unpredictable	Approachable	Innovative	Desirable	Ordinary	Visually unpleasant
Undesirable	Easy to use	Too technical	Unclear	Boring	Visually pleasant

Figure 7: 24 Adjective cards were presented in alphabetic order (in native language).

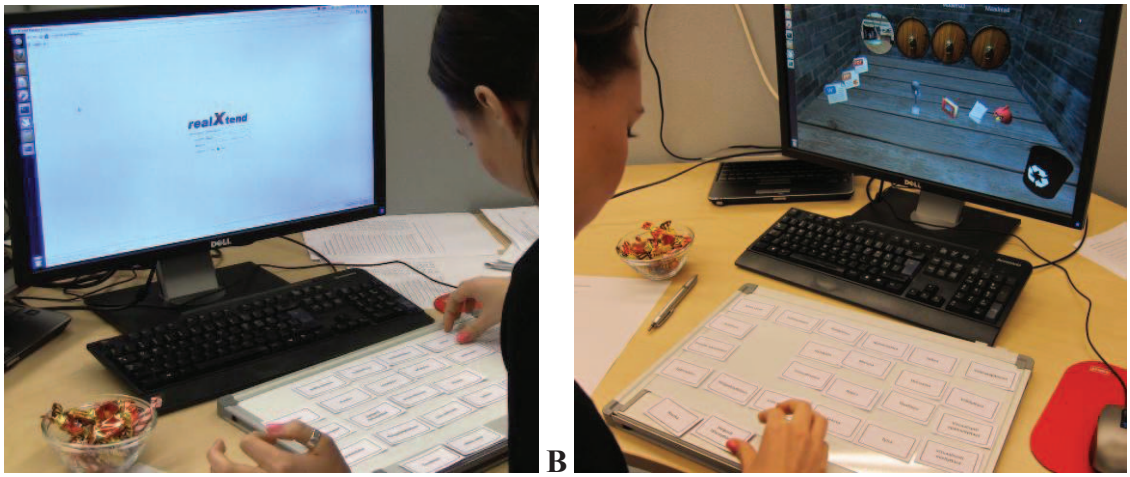

Figure 8: A user is selecting four out of 24 adjectives after using A) the 2D Tab UI (Task 1d) and B) the 3D Portal UI (Task 2e).

4 Findings

This section presents the findings of how users experienced both the 2D Tab UI and the 3D Portal UI. The results from adjective card selections are presented as well. Then findings from Likert Scale questionnaires are discussed and finally the results from the comparison task are presented.

4.1 Adjective Selections for the 2D UI and the 3D Portal UI

Figure 9 presents percentages of users' adjective selections for 2D Tab view and 3D Portal UI. Based on the adjective selections of both prototypes, 2D Tab UI and 3D Portal UI, 83% of the selected adjectives were positive. Positive adjectives for the 2D Tab UI related to usability issues, for instance, users experienced it as *clear* (75%), *easy to use* (67%) and *fast* (42%). Users also thought that this kind of solution is *businesslike* (17%), because it requires the user to log in to the service in the way people are used to. 58 % of the participants regarded 2D Tab UI as *ordinary*. Depending on the users, this adjective was perceived as negative or positive. One person commented that she expected a 3D prototype to be something more than just an ordinary tab solution. Participants thought that the 2D Tab UI is *empowering* (33%) and *useful* (25%). Users' comments revealed that these adjectives (Empowering and useful) related especially to the possibility of concurrent connections. Negative adjectives for the 2D Tab UI related to user experience issues, such as, *visually unpleasant* (8%), *boring* (8%) and *too technical* (17%).

The positive adjective selections for the 3D Portal UI related to user experience issues, such as, *visually pleasant* (67%), *entertaining* (58%), *approachable* (50%) and *fun* (42%). The 3D Portal UI was also experienced as *empowering* (33%) and *useful* (8%) because of a possibility open several concurrent connections.

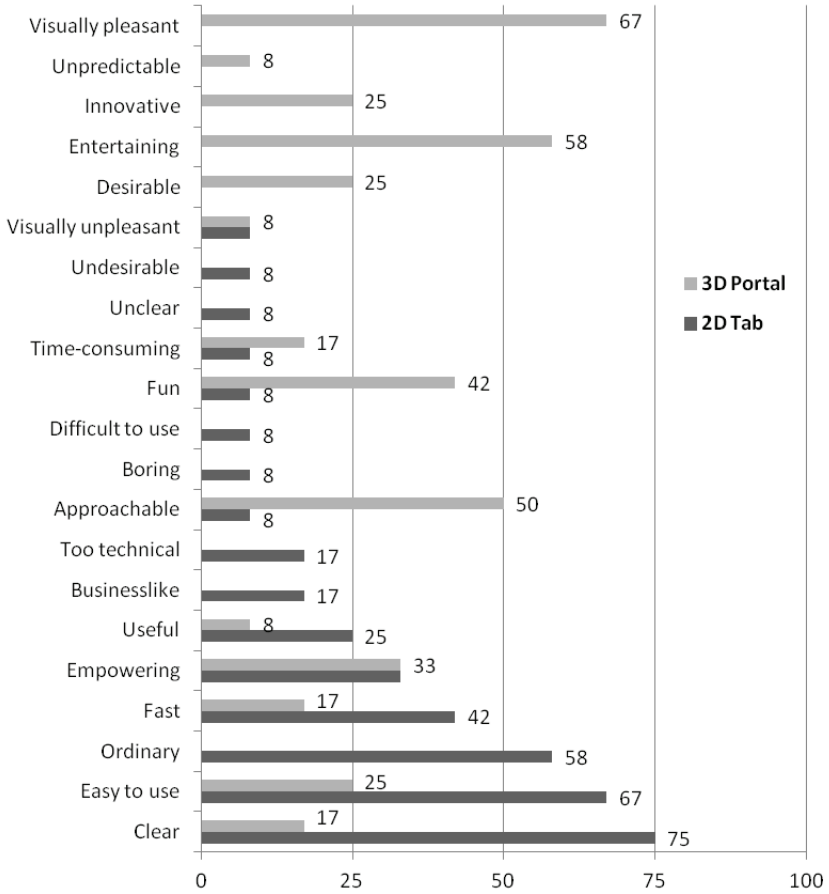

Figure 9: Percentages of users' adjective selections for 2D Tab view and 3D Portal UI.

4.2 Login and Entering into the Virtual Environments

After Task 1, users were asked to fill in the questionnaire with Likert Scale statements. In this questionnaire, we asked how users experienced the login in to the virtual environment by the following statements.

- In my opinion, log in to the virtual environments was easy.
- In my opinion, log in to the virtual environments was fast.
- In my opinion, log in to the virtual environments was laborious.

Figure 10 presents the users experience of the login process to the multiple virtual environments. It was considered to be *easy* (4.6), *fast* (4.4), and it was not perceived as *laborious* (1.8). After using the 3D Portal UI (Task 2), we also asked the users about their opinions on entering the virtual environment with the portal method. The 3D Portal UI did not require the traditional login process; instead, the connection was opened from the 3D Portal space by clicking the doors. Figure 11 presents that users experienced entering to the virtual environments as *easy* (4.9), *fast* (4.4.), *interesting* (4.4.), *fun* (4.3), *familiar* (3.8) and *secure* (4.4).

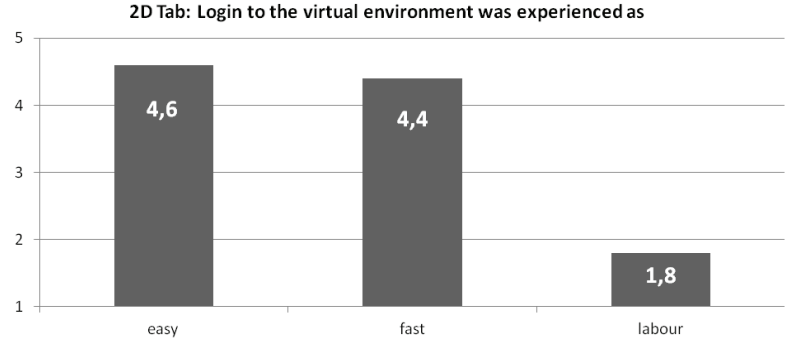

Figure 10: How users experienced login in to the virtual environments by using 2D Tab UI.

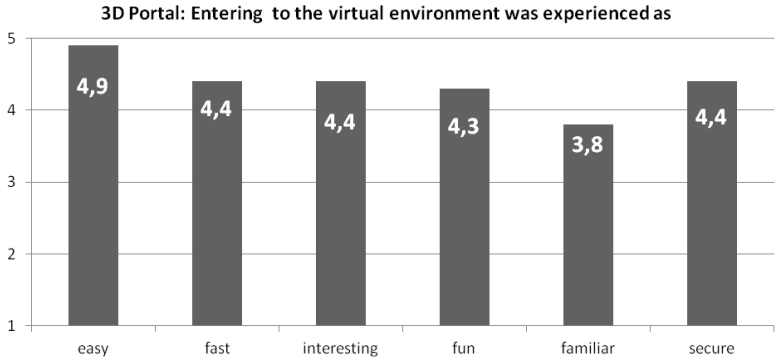

Figure 11: How users experienced entering in to the virtual environments by using the 3D Portal UI.

4.2.1 Users' Perceptions on Private and Public Environments

All of the participants thought that the 3D Portal UI was a private virtual environment, because there were private items and files in it (Figure 12). Also, the visual style of the environment (room) looked private, because it was a closed indoor space without windows on the walls; therefore, it almost looked like a cellar. From other virtual environments, all of the participants thought that outdoor places (Outdoor Music Club and 3D city) were obvious public virtual environments, because they are open and meant for a huge amount of people. The 3D City was also recognized as the city where participants live in real-life, so they automatically thought that it is open for all citizens. Indoor virtual environments were not that evidently public. 92% thought that the Music club was public, because it resembled a real-life rock club with many bar stools and band equipment. The Office was perceived as a public environment by 75% of the participants. The reason why some participants thought that it is either private or semi-private

was the context where meeting rooms are used in real-life. Participants thought that there is going to be only a limited amount of invited attendees, because there is a limited amount of chairs in the scene. Also, meeting rooms are normally used for private meetings inside of the company.

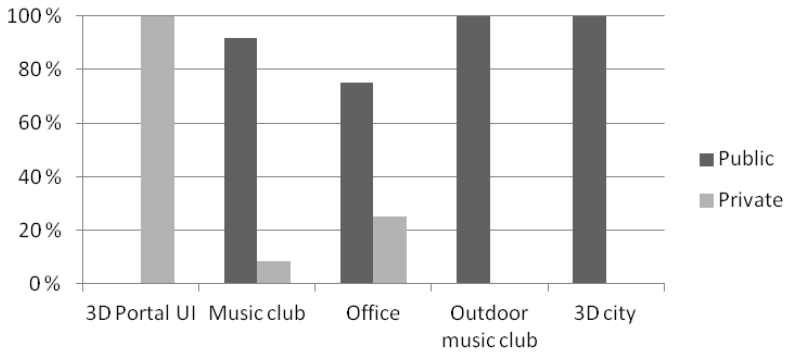

Figure 12: Participants' perceptions about privacy on the different virtual environments.

4.3 Moving between Virtual Environments by using 2D Tab and 3D Portal UIs

After Tasks 1 and 2, we asked users to evaluate how they experienced the moving between multiple virtual environments by using both 2D Tab and 3D Portal user interfaces. Figure 13 presents that user experiences on moving between VEs by using both UIs are quite similar and there are not big differences between them in terms of adjectives: *easy*, *fast*, *fun*, *familiar* and *secure*.

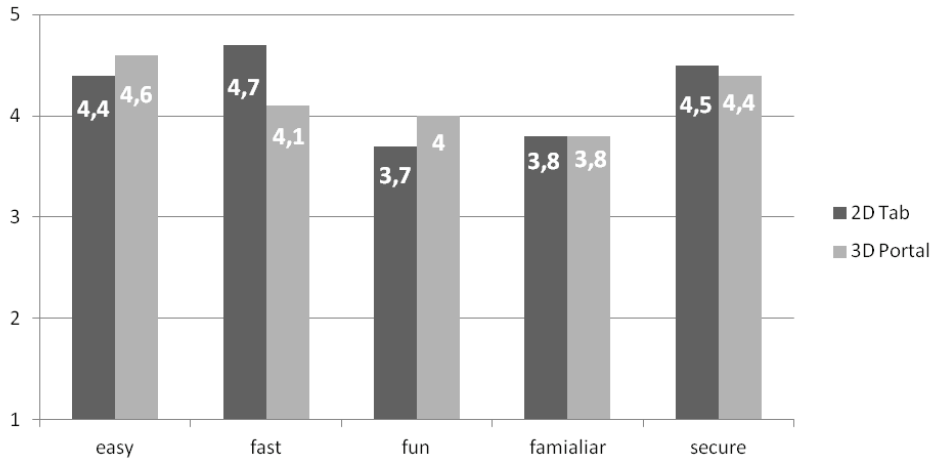

Figure 13: How users experienced moving between VEs by using 2D Tab and 3D Portal UIs.

4.4 Users' Comparison Between 2D Tab and 3D Portal UIs

After participants had used both prototypes, we asked them to compare which one they liked more and explain why. 83% of the users preferred the 3D Portal view. The reasons why they selected the 3D Portal UI were: *visually better*, *more pleasant, faster, funnier*, *more clear, easy to use* and *livelier*. Users also commented that they could use their own 'things' (e.g. applications and files) at the same time when using multiple virtual environments; for instance, they gave examples of the possibility to add Skype and Spotify in the 3D Portal space. There were only two persons who selected the Tab view. From these users, one commented that with keyboard and mouse input this Tab view works better. He thought that the 3D Portal UI could work with touch screen tablet devices. The other person who selected the Tab view commented that moving between virtual environments is faster by using tabs. He would have selected the 3D Portal UI if it had been possible to move directly to other VE's through the Miniportal without a need to enter to the 3D portal space.

5 Conclusion

This paper presented an implementation for concurrent virtual environments with two user interface designs (2D Tab UI and 3D Portal UI). A user experience study was conducted in order to solicit users' opinions on the design and concept. The user study results showed that participants prefer the 3D Portal UI over the 2D Tab UI, because of richer user experiences it provides, such as being visually pleasant, entertaining and fun. According to the user study, both user interfaces were perceived to be equally easy and fast to use. An important finding was that users were interested in the possibility for concurrent connections and they thought that this feature can be empowering and useful. Future work will focus on transfer of data between the virtual environments, e.g. by using drag and drop actions.

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References

Alatalo, T. (2011) An Entity-Component Model for Extensible Virtual Worlds. IEEE Internet Computing, Vol. 15, No. 5, Article 30.

Arhippainen, L; Hickey, S. (2011) Classifying Music User Groups and Identifying Needs for Mobile Virtual Music Services. In Academic MindTrek '11. ACM Press (2011), pp. 191-196.

Arhippainen, L; Pakanen, M; Hickey, S; Mattila, P. (2011) User Experiences of 3D Virtual Learning Environment. In Academic MindTrek '11. ACM Press (2011), pp. 222-227.

Barnum, C; Palmer, L. (2010) More Than a Feeling: Understanding the Desirability Factor in User Experience. In Proc. CHI2010. ACM Press (2010), pp. 4703-4715.

Benbunan-Fich, R; Adler R.F; Mavlanova, T. (2011) Measuring Multitasking Behavior with Activity-Based Metrics. ACM Transactions on Computer-Human Interaction. Vol 18, No. 2, 2011, Article No. 7.

Greenhalgh, C; Benford, S. (1995) MASSIVE: A Collaborative Virtual Environment for Teleconferencing. ACM Transactions on Computer -Human Interaction. Vol. 2, No. 3,1995, p. 239-261.

Henderson, J; Austin, D; Card, S. (1986) Rooms: the Use of Multiple Virtual Workspaces to Reduce Space Contention in a Window-Based Graphical User Interface. ACM Transactions on Graphics. Vol. 5, No. 3, 1986, pp. 211-243.

ISO DIS 9241-210:2010. Ergonomics of Human System Interaction - Part 210: Human-Centred Design for Interactive Systems.

Karhu, A; Vatjus-Anttila, J.H; Hickey, S; Vatjus-Anttila, J.M. (2012) Supporting Multiple Virtual World on a Single 3D Viewer. In Proc. 2012 IEEE/ACM 16th International Symposium on Distributed Simulation and Real Time Applications, Dublin, Ireland, 2012, pp. 145-146.

Kotziampasis, I; Sidwell, N; Chalmers, A. (2003) Portals: Increasing Visibility in Virtual Worlds. In Proc. 19th Spring Conference on Computer Graphics. 2003, pp. 257-261.

Kotziampasis, I; Sidwell, N; Chalmers, A. (2004) Seamlessly Integrated Distributed Shared Virtual Environments. In Proc. 20th Spring Conference on Computer Graphics. 2004, pp. 138-147.

Law, E.L; Roto, V: Hassenzahl, M; Vermeeren, A; Kort, J. (2009) Understanding, Scoping and Defining User Experience: a Survey Approach. In Proc. CHI'09. ACM Press (2009), pp. 719-728.

Manninen, T. (2001) Rich Interaction in the Context of Networked Virtual Environments - Experiences Gained from the Multi-player Games Domain. In Joint Proceedings of HCI 2001 and IHM 2001 Conference, 2001, pp. 383-398.

Messinger, P.R; Stroulia, E; Lyons, K; Bone, M; Niu, R.H; Smirnov, K; Perelgut, S. (2009) Virtual Worlds — Past, Present, and Future: New Directions in Social Computing. Decision Support Systems, Vol. 47, No. 3,

2009, pp. 204-228.

Roden, T; Parberry, I. (2005) Portholes and Planes: Faster Dynamic Evaluation of Potentially Visible Sets. Computer in Entertainment. Vol. 3, No. 2, April 2005, Article 3C.

Sunnari, M; Arhippainen, L; Pakanen, M; Hickey, S. (2012) Studying User Experiences of Autostereoscopic 3D Menu on Touch Screen Mobile Device. In Proc. OzCHI'12. ACM Press (2012), pp. 558-561.

Vermeeren, A; Law, E.L; Roto, V; Obrist, M; Hoonhout, J; Väänänen-Vainio-Mattila, K. (2010) User Experience Evaluation Methods: Current State and Development Needs. In Proc. NordiCHI'10. ACM Press (2010), pp. 521-530.

Voelker, S; Weiss, M; Wacharamanotham, C; Borchers, J. (2011) Dynamic Portals: a Lightweight Metaphor for Fast Object Transfer on Interactive Surfaces. In Proc. ITS'11. ACM Press (2011), pp. 158-161.

Zahorik, P; Jenison, R. (1998) Presence as Being-in-the-World. Presence: Teleoperators and Virtual Environments, Vol. 7, Issue 1, February 1998, pp. 78-89.