Designing for 3D User Experience in Tablet Context

Design and Early Phase User Evaluation of Four 3D GUIs

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Abstract—**This article focuses on a possibility to have a personal three dimensional graphical user interface inside a virtual environment on a tablet device. We describe the visual design process and early phase user experience evaluation of four 3D GUIs in a virtual environment. A user evaluation was conducted by using a structured pair evaluation procedure, where we adapted the concept walkthrough method with non-functional visually high quality prototypes. In addition, we conducted a self-expression task, where participants were able to draw their idea of a 3D GUI on a touch screen tablet device. This evaluation provided us a lot of user feedback for the design, which we utilized in the final iterated designs. In addition, we point out many design issues relating to the visual design of the personal GUI in virtual environments in a touch screen context. Our user evaluation indicated that participants would like to have their personal 3D GUI in a virtual environment. However, the visual design of the 3D GUI should create a secure and private feeling for them. Also, participants did not want the GUI to occlude excessively with the background. The visual indication is needed also when a user transfers items from a personal GUI to the virtual environment and for showing the user's active position between the GUI and virtual environment. We took all of these and other aspects into account when we designed the final iterated designs, which are also introduced in this article.**

Keywords- visual design; user experience; 3D GUI; touch screen tablet device; HCI; self-expression method.

I. INTRODUCTION

Three dimensional (3D) user interfaces (UIs) have been studied from the late 1970s. Prior research has focused on PCs with several input devices [10] and larger touch screen devices [20][42][23], but there is not a large amount of research in the area of 3D UIs on mobile touch screen tablet sized devices [38]. There is a need for user experience based information because of the increasing amount of 3D applications, such as 3D games [33], developed for touch screen tablet devices, e.g., Apple iPad. Also, there have been interest in bringing 3D collaborative virtual environments (CVEs) such as Second Life (SL) [28] to the tablet devices. The first attempt is Lumiya, a 3D viewer for SL for Android tablets [30] which also has a limited view to the 3D virtual environment. In 3D CVEs there are a lot of 3D objects and avatars present in a 3D space. The challenge from a user experience point of view is that in current 3D CVEs, it is not possible to carry out other activities, such as reading personal emails, browsing files or playing games, in parallel. To do activities like that, a user needs to switch to another application, which may weaken the 3D environment experience.

In this article, we explore a different approach to that problem by focusing on a possibility to have a personal 3D graphical user interface (GUI) inside a VE. By a personal GUI, we mean a private user interface (UI) showed only to the user, not visible publicly, in contrast to embedded elements in VEs which are visible to all users.

This article investigates users' subjective experiences of a personal 3D GUI in a collaborative VE in the early design phase and offers user feedback on visual design of 3D GUIs. Article extends our previous work from the ACHI 2013 conference paper by Pakanen et al. [1]. In this article, we discuss more designing for user experience, extend the design phase description and present new findings gathered by using the Self-Expression Template method [8]. Finally, we present new iterated concepts.

First, in Section III, we present the visual design of four 3D GUI metaphors and preparation of user experience (UX) evaluation material. In Section IV, we describe the UX study conducted with 40 participants by using non-functional visually high quality prototypes and the Self-Expression Template method. In Section V, we report the findings and factors that participants pointed out while evaluating our designs. In Section VI, we present our four iterated 3D GUI designs, based on our findings in the UX evaluation. Then, in Section VII, we discuss topics that designers should consider when designing 3D GUIs for CVEs on touch screen tablet devices. Finally, in Section VIII, conclusion and future work are presented.

II. RELATED RESEARCH

The research with 3D UIs and VEs have been extensive and is studied over many decades with PCs using several input devices. Touch screen technology has extended the research to new device areas, such as on larger touch displays on tables [20][42] and on the wall [23]. Despite of this, there is only little research done with tablet devices [38]. Bowman et al. [10] define a 3D UI as a UI that involves 3D interaction, which means human-computer interaction (HCI) where a user performs tasks directly in a 3D context. Based on this definition, a 3D interaction can be defined so that it comprises navigation, object manipulation, application

control [10][21][45] and visual design [14]. The focus of prior research has been on several topics. As 3D UI allows a larger set of items to be displayed at the same time in the UI space than 2D UIs, many earlier studies have focused on 3D file browsing and displaying hierarchical information [25][37][15]. Also different kinds of 3D menus [17] and metaphors have been investigated a lot over the years [2][17]. According to Gotchev et al. [19], the most popular 3D metaphors for mobile 3D media are: tree, mirror, elevator, book, art gallery, card and the hinged metaphor. As tablet devices have been used for reading books and magazines, a bookshelf metaphor [13] has become quite popular for displaying content, for example, in the Apple iPad [3]. Also 3D carousel metaphors have been under a large interest, both in industry and academy [23][36][48]. Different kinds of 3D and 2½D desktops have been designed and studied as well [2][27][41].

CVEs are social in their nature, but if there are personal items in a CVE, then their privacy should be clearly visualized to the user. Culnan [16] defines privacy as: *"The ability of individuals to control the terms under which their personal information is acquired and used"*. Privacy is a large research topic, but in this article, our emphasis is only on visual indication of the privacy in CVEs and VEs. The prior research has focused mainly on e-commerce applications for selling either real world products or virtual products for avatars [39] or for information exchange between avatars [26]. Butz et al. [12] introduced two visual indication practices (vampire mirror and privacy lamps) for indicating which items are shared and which are private.

Even though there has been an extensive amount of research in 3D UIs within the areas of navigation, application control and manipulation, the impact of visualization as a part of the 3D user experience is the least explored in the research. Also the research of personal 3D GUI elements, such as menu items, applications and files in a collaborative virtual environment is still lacking from the visual design, user experience and mobile tablet device points of view.

III. DESIGNING FOR USER EXPERIENCE

ISO 9241-110:2010 [22] defines user experience as: "*person's perceptions and responses resulting from the use and/or anticipated use of a product, system or service*". Aesthetic aspects have become one of the largest parts of the UX with the modern tablet touch screen UIs, as the screen quality has improved within last years. Norman [32] claims that aesthetic design of objects can have a larger influence on user preferences than usability of the product. Also De Angeli et al. [18] found in their study with web pages that users preferred a more attractive webpage interface even though it was not as usable as the not so attractive version of it. Arhippainen's [4] 9th user experience heuristic says: "*Go for a perfect visual design*". She explains that visual design can both make the UI aesthetically pleasurable and improve usability of the UI by making it more understandable, consistent and guiding [4]. Therefore, the visual design should be carefully understood and done by a visual designer. User experience cannot be designed, because it is in people, but it is possible to 'Design for experiencing' [40].

Also, material design for the evaluation should be carefully done by the designer and an effort should be made to make sure that examples are understandable and approachable to the evaluation participants. As Löwgren and Stolterman [31] stated, a designer has to be able to make his/her ideas "visible" to the evaluation participants so that subjects can "see", analyze and evaluate them. If participants cannot understand a new idea or a vision, it does not matter how good it is [31].

To 'design for experiencing', we used the industrial design process [44]. First, we explored approximately 40 existing 3D UIs and concept designs. Then, based on this benchmarking, literature and lessons learned from our earlier studies [6][38] with 3D UIs, we identified three design goals. *1) Design a 3D GUI in a collaborative virtual environment.* The idea was to be able to use a 3D UI while spending time in a virtual space. *2) Support the use of multiple applications within the 3D virtual environment.* In current touch screen tablet UIs, it is not possible to handle multiple applications within the same view. The aim was to make it possible to handle multiple parallel applications in a 3D UI within a VE. *3) Design for 3D interaction on a touch screen.* The idea was to make it possible to select objects from the back rear of a carousel UI.

In the following sections, we describe the design phase of our 3D GUI metaphor designs. We had two design phases in our design process. The first phase included a preparation of the visual theme boards, one group design session, one individual design phase and expert evaluation of the concepts. The second design phase included an individual design phase, evaluation and expert evaluation for selecting the final ideas to the 3D modeling phase. Then, we also developed a Self-Expression Template method [8] for the UX evaluation. The aim of the template method was to get participants to express their ideas of 3D UI topic other way than just commenting on our designs. And finally, we prepared all material for the UX evaluation.

A. The First Design Phase

We started the first design phase with the preparation of five different styled *Visual theme boards* to help us create visuals for the concepts. Visual theme boards are almost as similar as *Mood boards* [29] and they are both used within the industrial design discipline as idea generation tools. For the preparation of visual theme boards, different kinds of inspirational images from the Internet were browsed through. When browsing through hundreds of images, we found interesting looking images of forms that could help us to create new visual styles for the 3D GUI. Each image group was named to represent the forms in the images. The given names were: Futuristic, Minimalistic, Natural/ Organic, Steampunk and Cartoon (Fig. 1). Futuristic images had smooth and streamlined forms with a little edge (Fig. 1, A). Minimalistic images had plain and simple forms and an idea of 'less is more' (Fig. 1, B). In the Natural/ Organic group, images had forms from nature, such as honey comb (Fig. 1, C). Steampunk style had gimmick, utopian and nostalgic forms (Fig. 1, D). Cartoon had sketch like, funny,

unexpected and exaggerated forms (Fig. 1, E). After selecting images to the groups, we built collages of the images on A4 sized boards to represent the titled visual style.

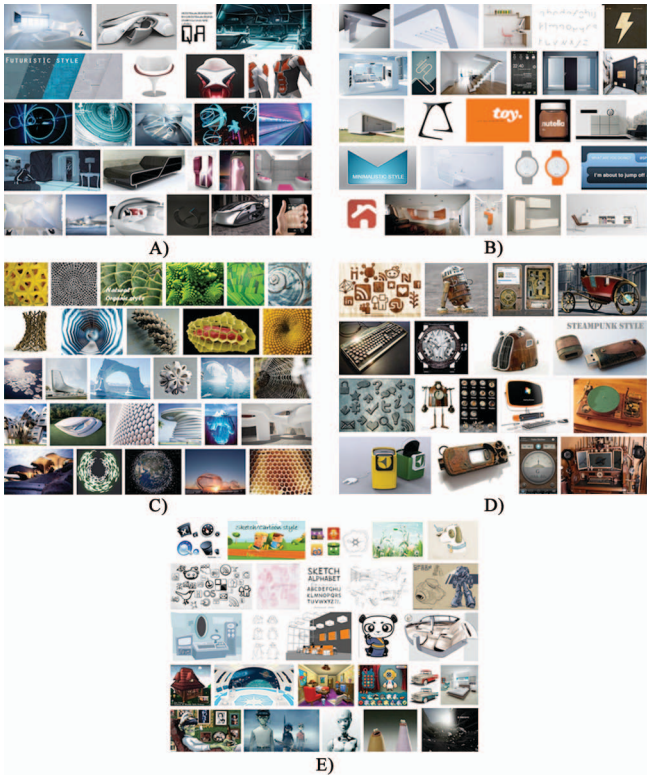


Figure 1. Visual theme boards: A) Futuristic, B) Minimalistic, C) Natural/ Organic, D) Steampunk and E) Cartoon.

Figure 2. 1st expert evaluation.

Then, we started the designing. We started with a brainstorming session utilizing the visual theme boards with two industrial/interaction designers and a UX researcher. During this session, we wrote down different kinds of ideas, advice and needs for a 3D GUI. Next, we had a one- week individual sketching phase. Within that one week, we produced over 100 sketches of 3D GUI metaphors.

Then, we had an expert evaluation of the concepts with eight project members. Each one marked five of the most promising ideas with sticky-notes and wrote on it a short explanation (Fig. 2). The most promising ideas were categorized to the five groups and named them as: 'Carry with you', 'Organic', 'History', 'Real life', 'Transparent' and 'Living' (Fig. 3). The names were given based on the content of the sketches. Sketches in the 'Carry with you' group looked like they could be carried in hand or in a pocket (Fig. 3, A). The 'Organic' category had natural forms and organisms, which grow from the ground when, for example, receiving an email (Fig. 3, B). The 'History' group had navigation signs and things faded out when the UI depth grew (Fig. 3, C). In the 'Real life' group, sketches had ideas of room based metaphors and things from real life, such as a letterbox (Fig. 3, D). In the 'Transparent' group, the sketches offered transparent and translucent solutions for 3D UIs (Fig. 3, E). The main idea was to be able to see through UI elements and being able to have a lot of items showed in parallel. In the 'Living' group, there was a lot of transitions and the form of the UI evolved as a reaction for user touch (Fig. 3, F).

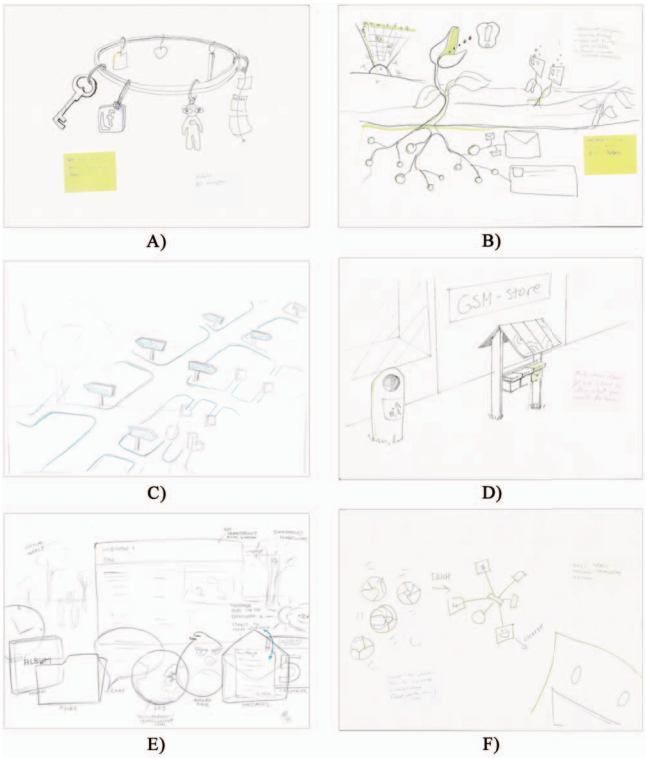


Figure 3. Example skecthes of an each skectch group: A) Carry with you, B) Organic, C) History, D) Real life, E) Transparent, and F) Living.

B. *The Second Design Phase*

The second design phase was started with an individual sketching period. We developed the selected concept groups of the first design phase further and in more detail. In this phase, we also paid attention to user interaction steps, e.g., how the UI behaves if a user selects or taps something in it. Then, the sketches (approximately 50) were evaluated by eight UI and UX professionals. The evaluators were asked to give their vote or votes to the most interesting concepts according to their intuition. Intuition is often used in the design field for selecting the best concept. After evaluators

made their selections, they also discussed together to find out the best concepts for the user evaluation. Finally, the four 3D GUI metaphors: *Room*, *Shelves*, *Pie*, *Keyring* (Fig. 4, A-D, on the left) were selected for the 3D modeling and user evaluation phase. *Room* (Fig. 4, A) and *Shelves* (Fig. 4, B) metaphors have a similar visual style and both of them had a binder metaphor for files but a different amount of icons and depth of space. *Pie* (Fig. 4, C) and *Keyring* (Fig. 4, D) are both examples of the carousel metaphor, but with different visual style, hierarchy level structure and amount of icons. *Room* and *Shelves* concepts were examples of the 'Real life' UI metaphor group. *Pie* and *Keyring* were examples of 'Carry with you' UI metaphors.

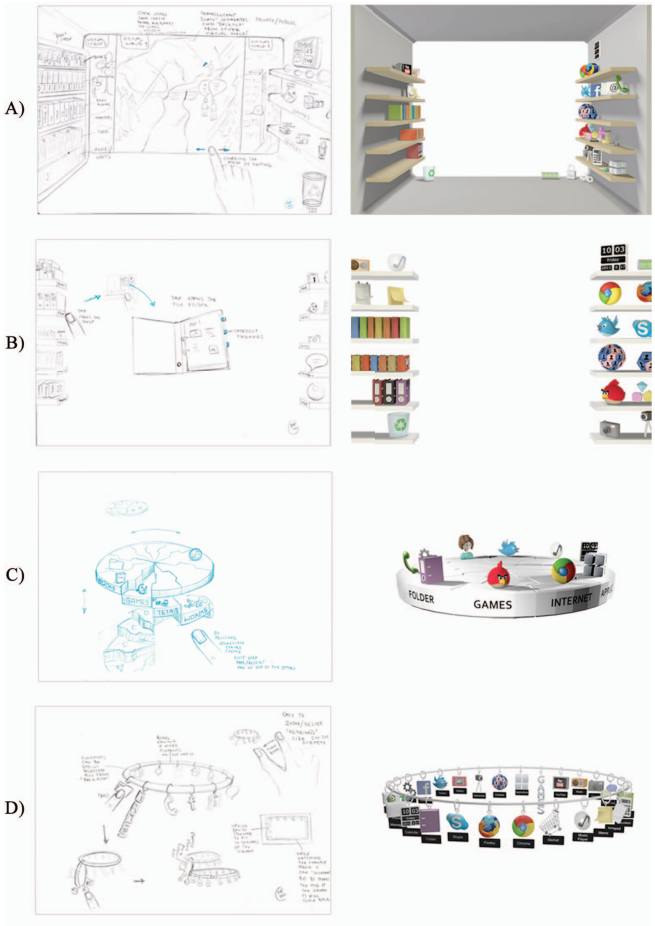


Figure 4. The four selected GUI concepts: A) Room, B) Shelves, C) Pie, and D) Keyring. Sketches on the left and 3D models on the right.

C. File Searching and Sharing Use Cases

As our sketches included hierarchical structures in the GUIs, therefore, we designed also a step-by-step use case (file searching and sharing) for each concept presented in Table I. The idea of the use case was to search for a PDF file (named as PDF 2), copy and share it to a pre-named contact.

D. Modeling of 3D GUI Metaphors and 3D Icons

The 3D models of the selected concepts were created by using the Blender program. First, we designed and modeled the GUI elements and 3D icons for the 3D GUIs. We selected applications that can be used in the tablet context (e.g., mail, phone, messaging, notebook, radio, maps, contacts, books, browsers, gallery, folder, trashcan, calendar, camera, games, music player and social media services). We had a set of 33 icons to be used in our GUI metaphor designs. The amount of icons in every design varied, because we wanted to have a different evaluation setup for each concept in order to evaluate the UI hierarchy structures and the amount of objects displayed in the UI metaphor and on the screen at once. There were 31 icons in the *Room* concept's first view, but in the *Shelves*, there were only seventeen, which are either fully or partially shown icons. The *Keyring* concept included 28 icons and *Pie* ten icons in the first menu hierarchy level (Fig. 4, A-D, on the right). Finally, we made compositions for 'file searching and sharing' use cases by moving and duplicating modeled UI menu elements.

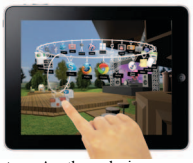
E. Preparation of the Prototypes

We decided to evaluate our four designs as non-functional visually high quality prototypes at an early design phase as possible to get user feedback for the next iteration of our concepts with a fast, easy and cost-effective way. Because we were interested in finding out the user experiences of the visual aspects, it was important to make as high quality looking evaluation examples as possible [31]. Based on our design goals, we wanted to evaluate how users perceive the 3D GUIs in a virtual environment (Table I). Therefore, we selected one 3D model of a collaborative looking outdoor music VE from our earlier research work [6] and rendered out one image of it from Blender. Then, we rendered each image of the metaphors with the step-by-step use case and placed them on a VE background in Photoshop. We then added an authentic-sized 10 inch tablet frame around the images. Finally, we added images of hands, which were representing the touch gestures on top of the use case images (Table I) and saved the image series as PDFs.

F. Self-Expression Template Method

Involving users to the design of the user interfaces has become quite popular [49][24]. Prior research has shown that different self-reporting methods are good tools for gathering users' experiences, ideas and wishes for product development [4][6][43][24][5]. Therefore, we created a Self-Expression Template method to our UX evaluation. As we are studying tablet devices, we needed to make the template look realistic enough for the participants. Therefore, we placed an image of a real 10 inch tablet frame in the center of the A4 sized paper (21 x 29,5 centimeters) [8]. Self-Expression Templa tes were printed on heavy weight paper (200 grams). In the self-expression task, we gave to the participants color pencils for drawing their ideas on the template.

TABLE I. A FILE SEARCHING AND SHARING USE CASE IN EACH 3D GUI METAPHORS.

Steps	Room	Shelves	Pie	Keyring
File searching	**User:** Zooms in with a pinch zoom gesture.  **User:** Taps the PDF binder icon.  **System:** Opens the binder in the center of the screen. **User:** Taps the 'PDF 2' index marker  **System:** Turns the page and the intended PDF is in sight.	**User:** Tap the PDF binder icon on the shelf on the left side of the screen.  **System:** Activates and moves a shelf (that the binder is located on) near the center area of the screen and opens the binder in the center of the screen.  **User:** Taps the 'PDF 2' index marker  **System:** Turns the page and the intended PDF is in sight.	**User:** Taps the binder icon which was located on a one piece of the Pie.  **System:** The tapped piece of Pie drops one step down and the system opens three sub-pieces of the Pie on the same horizontal level. Three icons are located on top of the pieces; W (Word), PP (PowerPoint) and PDF (2nd hierarchy level). **User:** Taps the PDF icon.  **System:** Sub-pieces opens under the Pie GUI in the format of a hierarchical helical stairs (3rd hierarchy level).	**User:** Taps the binder icon which hangs from the Keyring.  **System:** Vertically orientated sub-ring with three icons; W, PP and PDF appears to hang from the original ring. **User:** Tap the PDF icon.  **System:** Another sub-ring opens horizontally to the icon's place. **User:** Zooms in (pinch zoom gesture). 
File copying	**User:** Long press the PDF icon **System:** The copied file icon appears on top of the PDF file. 	Copying is made similarly as in Room GUI. 	Copying is made similarly as in the Room GUI. 	Copying is made similarly as in the Room GUI. 
File sharing by dragging	**User:** Drags the copied file to the other side of the Room to the contact object (ball), and finally to the chosen contact.  **System**: Camera follows the file dragging and zooms in to the contact ball. 	**User:** Drags the copied file on another shelf on the other side of the screen with two contact objects (balls) on.  **System:** Moves the shelf with contact objects to the center area of the screen and closes folder. **User:** Drags the copied file to the contact ball, and finally to the chosen contact.	**User:** Drags the copied file on a contact piece in the Pie.  **System:** Opens sub-pieces in hierarchical helical stair format, where all the contacts are located on the steps of the 'stairs'. **User:** Drags the copied file to the chosen contact. **System**: Camera follows the file dragging. 	**User**: Drags the copied file to the contact object (ball) at the rear of the first hierarchy level ring.  **System**: Camera follows the file dragging and zooms in to the contact object. **User:** Drags the copied file to the chosen contact.
Feedback indication to a user	**System:** Shows a tiny version of the icon beside the contact, which disappears when it is sent. 	The system indication for sending is done the same way as in the Room GUI. 	**System:** Shows a tiny version of the icon beside the contact on the step of the stair, which disappears when the file is sent. 	The system indication for sending is done the same way as in Room GUIs. 

IV. USER EXPERIENCE EVALUATION

As we were interested in participants' subjective experiences, we conducted the study by using semi-structured pair evaluation settings, where we studied our four 3D GUI concepts as a part of a mixed methods evaluation procedure. Table II presents the contents of the whole evaluation procedure, which lasted from 90 to 120 minutes. This article focuses on findings gathered from the tasks number 2 & 3: four 3D GUI concepts with use cases and task number 7: self-expression task. Findings from the other tasks are presented in other publications. Subjects' preferences for 3D icons (task 1) can be found from [34]. How the participants perceived the depth of 3D space (task 5) is presented in [7]. Four 3D GUI concepts were studied by adapting the design walkthrough method in a controlled setting, which lasted from 25 to 59 minutes. In the end of evaluation session, the participants performed a Self-Expression Template drawing task, which lasted from 10-24 minutes. We used different methods to gather user feedback and experiences: video recording, semi-structured interviewing, and observing with user comments written down. First, in the beginning of the evaluation, subjects filled up a short background questionnaire, which had questions about the subjects' gender, age, prior touch screen and 3D experience.

The actual design walkthrough was conducted as follows for each 3D GUI concepts: Showing the 3D GUIs on a 3D VE with the 'file searching and sharing' use case on an authentic-sized tablet frame as a PDF from a laptop where the moderator changed the image and led the discussion. She asked participants to comment freely about what they are thinking and also asked additional questions every now and then. After the concept design walkthrough and other tasks, we had a self-expression task. Participants were given the Self-Expression Templates and color pencils and they were asked to draw or write a 3D UI for a touch screen tablet device. After participants finished their drawings, they were asked to explain their drawings.

TABLE II. THE UX EVALUATION PROCEDURE AND USER TASKS.

No.	Task
1.	2D/3D icon comparison tasks
2.	**Four 3D GUI concept evaluations**
3.	**Four 3D GUI use case evaluation tasks**
4.	Contact and Square UI evaluations
5.	3D UI space and depth level selection tasks
6.	Other 3D UI concept evaluations
7.	**Self-expression task**

A. Participants

In our user evaluation, we had 40 persons of which 63% were male. For recruiting participants, we used an online test user environment [35] and also sent email invitations to friends and colleagues to be distributed. The criterion for selecting participants was that each of them should have at least two months' experience [11] with touch screen devices (mobile phones or tablets). Almost all of the participants (93%) had prior touch screen experience with smart phones and 85% of them had tried or used tablet devices. The subjects' age varied from 23 to 52 years, with a mean of 35.

V. FINDINGS

All the material was qualitative, which we analyzed by applying the affinity diagram method [9]. We wrote down participants' comments on sticky-notes. Then, we made two analysis rounds for notes and grouped them based on their content. A summary of the analysis is presented in Table III. In the following subsections, we present the participants' perceived aspects and comments on the 3D GUIs in 3D VE and their wishes and needs for 3D GUI in a self-expression task.

TABLE III. A SUMMARY OF HOW PARTICIPANTS PERCEIVED FOUR 3D GUI METAPHORS ("+ "ARE POSITIVE AND " - "ARE NEGATIVE ASPECTS).

UX Factor	Four 3D GUI Metaphors			
	Room	***Shelves***	***Pie***	***Keyring***
Perceived visual appearance	+ homely + things are ordered (garage/storage) + can see all the icons at once - unclear (icons are occluded/ too full) - childish and funny/ toy store	+ clear - shelves are floating in the air (odd) - icons cut in half (ugly) - not possible to see all icons at once - floating in the air (odd)	+ new / exciting / attractive + can see the most important icons at once - bulky / too thick/ chunky - masculine / engineering type / official - floating in the air (odd)	+ new / different / interesting/ fun + can see all the icons at once - full / unclear (icons are overlapping) - feminine/ kitsch bracelet / swinging - floating in the air (odd)
Perceived 3Dness	+ 3D space (Room) + enough depth - icons occluded	- not enough depth = 2D GUI - just 3D icons do not make 3D GUI - no occlusion	+ 3D shape (round) + icons occluded + looks rotatable (interaction)	+ 3D shape (round) + looks rotatable (interaction) - icons occluded
Perceived consumption of space from VE	+ distinct from the background VE - consumes too much space from VE	+ light/airy + does not consume too much space from VE	- consumes too much space from VE	+ light/ airy + does not consume too much space from VE
Perceived privacy and safety	+ clear visual separation from VE (walls) - can other users of VE see the content a shared item	- possible to share something to the VE by accident (no walls) - not clear visual separation from VE - can other users of VE see the content of own GUI or a shared item	- not clear visual separation from VE - can other users of VE see the content of own UI and a shared item	- not clear visual separation from VE - can other users of VE see the content of own UI and a shared item
Perceived ease of use	+ looks simple/ easy to use - require more steps than 2D UI - too long dragging - needs camera & zooming controls	+ no brainer to use + no camera controls required + shorter dragging	+ brainless to use - carousals are difficult - menu hierarchy difficult and messy - too many steps (file search & sharing)	- difficult (can accidently select a wrong icon) - menu hierarchy messy and weird - too many steps (file search & sharing)
Perceived utility by customizaton	+ easy to categorize the content + easy to customize the GUI space	+ easy to categorize the content	+ could work as a launcher	+ could work as a launcher + easy to categorize the content

A. Perceived Visual Appearance

The Room metaphor (Fig. 4, A) was considered as a 'homely' GUI where one's own applications are in order. The *Room* metaphor was also called as 'garage' or 'storage', but it was also regarded as childish and funny like 'a toy store'. 18% of the participants thought that the *Shelves* concept (Fig. 4, B) was better, clearer, more approachable and pleasurable than the *Room* GUI. The *Pie* GUI metaphor (Fig. 4, C), in its turn, was perceived as interesting, new, exciting and visually attractive. On the other hand, the *Pie* was regarded as an official, masculine and engineering type of object and was called as 'a disk' or 'hard drive'. The visual style of the *Pie*'s plate was perceived to be bulky, chunky and too thick and it was called 'a concrete plate', 'tray', 'puzzle', 'Battle Star Galactic' or 'puck'. It was even suggested that the plate could be translucent. The visual style of the *Keyring* (Fig. 4, D) was considered to be new, different, interesting and fun. On the other hand, one participant commented that it is: *"a moment's wow"*. Compared to the *Pie*, the *Keyring* was regarded as a feminine object and it was called as a kitsch bracelet. It was also referred to movement, for example, to 'a shower curtain rack', 'coat hanger rack', 'mobile', and 'janitor's key ring'. One person even said: *"I don't like if it's swinging"*.

The participants liked the fact that they can easily get an overview of the GUI with one glance, with *Room*, *Pie* and *Keyring* GUIs. 15% of the participants did not like that all of the icons are not showing in *the Shelves* GUI. Also, it was perceived as odd and ugly that some of the icons on the shelves were cut in half. In contrast, 30% of the subjects liked the tighter view that the *Pie* concept offered even though there was even less content in sight. *Pie* and *Keyring* were perceived to look like launchers for applications. Participants thought that in the *Room* (18%) and *Keyring* (25%) GUIs, there were too many occluding application icons. It was perceived to be unclear and error prone while making selections.

The participants thought that all GUIs except the *Room*, looked weird and distressing with the virtual environment background, because they seemed to be floating in the air, for example, the *Pie* GUI was perceived as a UFO. Also, one participant commented the meaning of the Pie metaphor because of its location in the 3D environment: *"It looks like a tray when it is located near a bar"*.

B. Perceived 3Dness

When the participants evaluated the 3Dness of the concepts, one factor was the depth of the space. Compared to other concepts, in the *Shelves* GUI, there was not enough depth to make it look like it was 3D and it was considered to be only a 2D GUI with 3D icons. As one participant commented on it: *"3D icons do not change the UI into 3D"*. Another factor was the perceived interaction. The *Pie* and *Keyring* had the round shape which made them look rotatable; therefore, they were perceived as 3D. Also the icon occlusion was considered to be an important factor for creating a 3D feeling; thus, the *Shelves* concept was not considered to be a 3D GUI. From the users' perspectives, 3Dness is made from occlusion, the shape of the UI and the depth of the space.

C. Perceived Consumption of Space from VE

The occlusion of the virtual environment by the GUI was evaluated by the participants. The *Room* and *Pie* were perceived to occlude too much from the VE. The *Room* GUI was showing the center area, but it was considered more like a little peak view to the VE. With the *Pie* GUI, the situation was quite the opposite; the plate of the *Pie* blocked the center area. In comparison, the Shelves and *Keyring* GUIs were considered to be lighter and airy on VE.

D. Perceived Privacy and Safety

The participants felt more secure with the *Room* concept, because there were walls separating the private area from the public background area. To create a secure feeling, there should be some kind of separation from the background environment. However, with the *Shelves, Pie* and *Keyring* GUIs, the participants had concerns for their privacy. For example, one participant commented on the *Pie* GUI: *"If I am in a public virtual space, can other people see my UI?"* The *Shelves* and *Keyring* GUIs were perceived as visually unclear and confusing, because behind the icons and UI elements, there were not any visual elements to separate it from the VE. With the *Shelves* GUI, the participants wished for a back plate or curtain behind the shelves.

There should also be a clear visual indication for showing the user's active position between the personal 3D GUI and collaborative virtual environment. This could be done with color or dimming effect on the non-active UI area. The participants thought that a possibility to interact between spaces and share content directly to a friend in the VE was good. On the other hand, they were concerned about a possibility to share something into the VE by accident. This could be prevented by giving a user a visual indication with a highlight color when something is moved from their personal GUI to the collaborative VE. There were also concerns such as, 'can someone else see a shared file and to whom it is shared to'. The shared content should be invisible to other users and it should look like it is protected for the user who is sharing it and who is receiving it. For example, as one participant suggested: *"Shared file could be protected with a folder?*"

E. Perceived Easy of Use

Even though we did not have a functional prototype, participants commented a lot how they perceived the usability aspects of each GUI metaphors with the 'file searching and sharing' use case. The participants thought that the *Shelves* GUI (Fig. 4, B) was better than other GUIs from the usability point of view. It was perceived to have shorter dragging, simpler hierarchy, fewer steps and camera movements, such as view rotation and zooming in too near to the UI elements. Also, one person said that in the *Shelves* GUI the interaction can be done more *"brainlessly"*.

Even though a tablet has a gestural interface, the participants did not like long dragging, because it was perceived as difficult and prone to errors, such as an item is dragged to a wrong place. 15% of the participants suggested that instead of long dragging, a copy could be moved to a 'pocket' or virtual USB-memory stick and kept there until sharing. 15% of the participants suggested that the GUI could be intelligent, for example, the target object (in this case a contact), could automatically open beside of the binder while copying.

With the *Pie* and *Keyring* metaphor concepts, the 2nd and 3rd hierarchy levels were found to be distressing, because there were too many items illustrated at the same time and it looked too messy. When the 3rd hierarchy level opened in the *Keyring* GUI, 30% of the given comments were negative. As one participant commented: *"More and more jingling"*. Also, the orientations of the sub-rings was found to be irritating, against the laws of physics and foolish. Therefore, it was suggested that rings could open horizontally either under the original ring, replacing it, or earlier opened rings could move deeper into the space when the new ring opens. With the *Pie* GUI, the 3rd hierarchy level opening as a form of helical stairs was unexpected by the participants and over 50% of the given comments were negative For example, one participant described it: *"It exploded, went broken"*. It was perceived as difficult, hard, complex and distressing. 13% of the participants commented that it looks like endless stairs. The helical stairs structure was perceived to prioritize the content. For example, with contacts, it creates a feeling that some of the contacts are more important than others. With PDF files, the structure was not that irritating, but the amount of items was considered to be critical for the controllability of the GUI. The participants suggested that instead of the 2nd and 3rd hierarchy levels in the *Pie* and *Keyring* GUIs, there could be a similar binder metaphor as in the *Room* and *Shelves*. Other suggestions for the *Pie* included: a drawer opening from it or another *Pie* could open under the first one. With the *Keyring*, there could be a binder metaphor or file cabinet instead of the 2nd and 3rd hierarchy levels.

F. Perceived Utility by Customization

The participants found customization interesting and useful within all of the GUIs. The smallest and simplest thing with the UI customization is to let the users adjust the amount of icons, change their places in the UI and categorize the GUI contents. For example, with the *Keyring*, the participants wanted to categorize icons in groups or pile them in stacks. With the *Room* and *Shelves* GUIs, the participants would have liked to organize their icons by placing work and leisure items on different sides of the room or on different shelves. Also, with the *Room* GUI, 30% of the participants were eager to change the overall visual style of the GUI, for example, with wallpapers.

G. Drawings on Self-Expression Template

Most of the participants (93%) drew on the Self-Expression Template, the rest of them wrote their needs for the 3D GUI (Fig. 5). The participants who did not draw their ideas explained that they did not have skills to draw or did not know how to draw their ideas.

The participants had different ideas of 3D GUI on a touch screen tablet. 45% of them presented 3Dness in the UI by placing objects in either a room space (Fig. 6, A) or a realistic looking 3D world. 28% of the participants drew a carousel type of structures into their UI, so for them, the possibility to rotate makes a 3D GUI. 15% of the participants piled objects in the depth. So for them, a 3D GUI means adding the depth (z-axis) to the UI. The rest of the drawings were either 2D UIs with a 3D virtual environment background (Fig. 6, B) or 2D UIs with one 3D item in it. Also, the content of the drawings varied; 68% of them were based on our 3D GUI designs. The participants often combined our ideas, such as they drew a carousel with shelves. Also, there were other 3D objects combined with carousel GUIs, for example, in one drawing, there was a ball menu in the second hierarchical level of a *Keyring* GUI (Fig. 6, D). Most of the drawings (57%) included different applications and layout needs for the UI. In 38% of the drawings, there were rotatable UI elements presented, for example, in one drawing the whole GUI was rotatable (Fig. 6, C). Also in 15% of the drawings, there were some kinds of hierarchical structures showed, for example, Fig. 6, C and D.

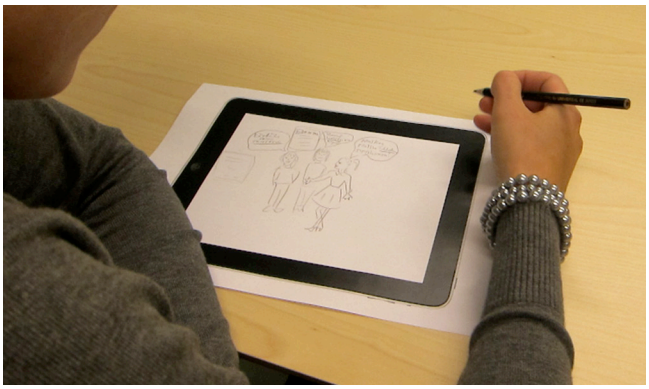


Figure 5. A participant drawing on the template.

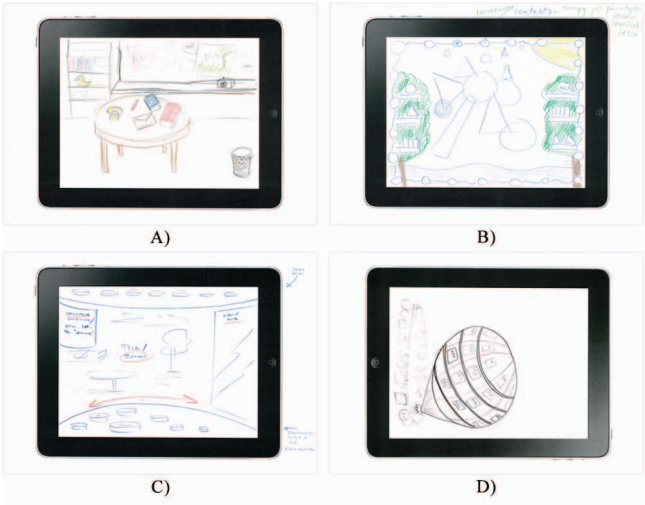


Figure 6. Participants' drawings A-D on the Self-Expression Templates.

VI. FINAL UX BASED DESIGN

Based on the participants' experiences on our designs and their own drawings in the self-expression task, we made design iteration for our earlier 3D GUIs. As the aim of UX studies is to help in selecting the best design solution and make sure that the development is on the right track [47], we made changes that we thought to be best for each GUI. One big change needed based on the participants' comments on the shown four GUIs was the need for a flat hierarchy structure. We needed to solve how we could display a lot of sub items in the *Pie* and *Keyring* concepts without hierarchical structures. In the following sub-sections, we go through all four 3D GUIs and how we iterated their design.

A. The Final Room GUI

The *Room* metaphor was iterated a little to make it more approachable and easier to use. Therefore, the floor plan was changed from a square to a circle to make it easier to see the content on the shelves and ease touch interaction with the content (Fig. 7, on the left). Also, we increased the view area to the virtual environment. Likewise, we decided to ease the interaction with the copied file by providing possible target objects beside the folder when the copy has been made (Fig. 7, on the right). Also, when files are browsed in the center of the screen, the view to the VE is dimmed, because we wanted to increase security and prevent accidental sharing to the VE. The dimming is automatically removed when a user stops browsing items in the center of the screen. If a user needs to share items from his/her private GUI to the virtual environment during the dimming effect is used, he/she just needs to drag an item on the dimmed area and then the visual indication is showed, a flash of light in the dimmed area, and then the item moves through the dimming effect to the virtual environment. We added a possibility to rotate the view with a swipe gesture with three fingers. We also made it possible to hide the GUI totally from the view by swiping with four fingers towards the screen corners and by doing vice versa to make it come back in sight.

Figure 7. The finalized design of *Room* GUI. On the left start view and on the right target objects (trashcan and contact balls) provided when a copy has been made.

B. The Final Shelves GUI

The *Shelves* GUI was not perceived as a 3D GUI in the user evaluation, thus we needed to make it to look more 3D. Therefore, we decided to add a little depth in it. Therefore, we rotated shelves according to z-axis. We also add the translucent white back plate to the shelves to make it distinct more on the background and make it also more secure to use, e.g., users would not have to be worried about that they accidently share their private items to the public virtual environment (Fig. 8, on the left). We did not want to change the possibility to pull just one shelf at sight, because we believe that works best in touch screen context. Also, then the GUI will not occlude too much with the view to the virtual environment. Also, with *Shelves* GUI, we decided to ease the interaction with the copied file by providing possible target objects beside the folder when the copy has been made (Fig. 8, on the right). Also, when files are browsed in the center of the screen, the view to the VE is dimmed, because we wanted to increase security and prevent accidental sharing to the VE. Also in *Shelves* GUI it is possible to share items to the VE even if the dimming effect is used. This was designed in the same way as in the *Room* GUI. As in the *Room* GUI, we made it possible to hide the *Shelves* GUI totally from the view by swiping with four fingers towards the screen corners and by doing vice versa to make it come back in sight.

Figure 8. The finalized design of *Shelves* GUI. On the left start view and on the right target objects (trashcan and contact balls) provided when a copy has been made.

C. The Final Pie GUI

The *Pie* GUI needed quite a lot of changes. First, we removed all the hierarchical helical stairs structures. In replacement for those, we decided to use drawers. The way how content is presented in the drawer depends on the content. For example, for files, there can be a file cabinet drawer (Fig. 9, on the right), and for games, there can be a normal drawer where the games are laying. To limit the occlusion of the VE by the GUI, we made the *Pie's* plate less thick. We also made it possible to move the GUI's place and scale the size of it (Fig. 9, on the left). Also, to avoid accidental sharing of items in the rear of the GUI and to make GUI feel more private, we decided to add a dimming effect to the background when a user is interacting with the personal GUI (Fig. 9, on the right). The dimming effect on the *Pie* GUI is used when a user is interacting with the VE (Fig. 9, on the left). Moving between the GUI and the VE is designed to be easy by long pressing the dimmed UI to make it active. Sharing items into the VE was designed to be possible even if it is dimmed. If a user needs to share something from his/her private GUI to the virtual environment, he/she needs to drag an item on the dimmed area and then the visual indication is shown, a flash of light in the dimmed area, and then the item moves through the dimming effect to the virtual environment.

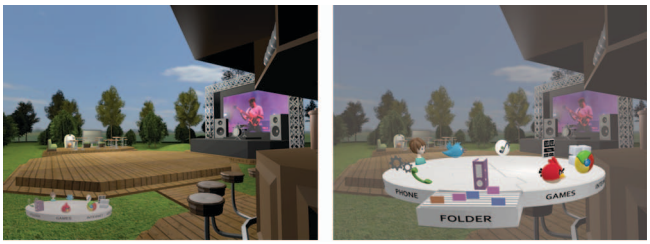


Figure 9. The finalized design of *Pie* GUI. On the left a view when user's focus is on the VE. On the right a view when user's focus is in the *Pie* and files.

D. The Final Keyring GUI

For the *Keyring* GUI, we removed all the hierarchical structures. Instead of presenting subrings, we decided to use different ways for presenting hierarchical information. For example, we used a similar folder for the files as in the *Room* and *Shelves* GUIs (Fig. 10, on the right). We decided to use a similar dimming effect as in the *Pie* also in the *Keyring*, as it was difficult to make it feel a private GUI without heavy additional structures (Fig. 10). Also, sharing through the dimming effect was designed in the same way as in the *Pie* GUI. To prevent the *Keyring* blockin the view to the VE, we made it possible to move the GUI's place and scale the size of it.

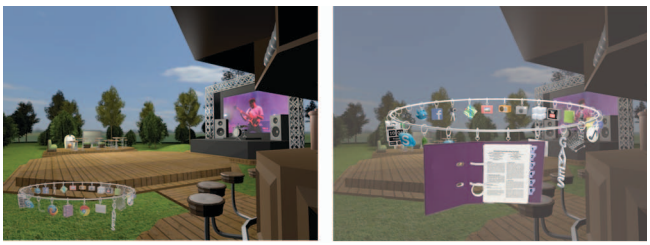


Figure 10. The finalized design of the *Keyring* GUI. On the left a view when user's focus is on the VE. On the right a view when user's focus is in the *Keyring* and files.

VII. Discussion

In this study, we focused on designing 3D GUIs from the user experience point of view. We made a large design process which was focused on designing of personal 3D GUI in a virtual environment. As the outcome of the process, we had four 3D GUIs for the user evaluation. In the concept evaluation, we had also several other tasks and as a final task we had the self-expression template task. Our study provided a lot of user experience based information for the next iterative design phase of the four concepts, but in addition, it helped us to save a large amount of implementing costs and time.

The study indicated that the visual design of the GUI has an impact on the user's experience with the 3D GUIs on public VEs from privacy perspectives. Therefore, when designing 3D GUIs which are used in parallel with collaborative VEs, it is important to create a secure and private look for the 3D GUI. The Room GUI was perceived to be the most secure, because it had walls separating it from the background VE. Participants wished for visual elements, such as walls or curtains, which will distinguish the GUI and its elements from the background environment. However, these elements should not excessively occlude the virtual environment; therefore, they could be also translucent. For the final design, we used a translucent dimming effect for the *Pie* and *Keyring* GUIs and a translucent back plate solution for the *Shelves*. By these solutions, in our opinion these three GUIs are now looking more secure and private.

The study indicated that there should be a clear visual indication for showing the user's active position between the personal 3D GUI and a collaborative virtual environment. Also, when something is transferred from the personal GUI to the public virtual environment, there should be a visual indication shown to the user. In the final iterated designs, we used a dimming of the background or UI for showing the active position and a highlight color for indicating object moving from a private GUI area to a public VE. By using the dimming effect, we believe we were also able to reduce the influence of the background space to the visual design of the 3D GUI. This was because subjects thought that all GUIs except the *Room* looked weird and distressing with the VE background, because they seem to be floating in the air and were unclear looking. With the dimming effect, they do not look anymore as a part of the 3D scene; therefore, the visual weirdness is not that big issue anymore.

From the participants' perspectives, 3Dness in a 3D GUI is made from icon occlusion, the shape of the UI and the depth of the UI space. All other GUIs except *Shelves* were perceived as 3D. Therefore, we needed to add depth to the Shelves GUI to make it look more 3D.

The hierarchy structure does not have to continue similarly through the hierarchy levels; it is more preferable to use flat hierarchy on touch screen devices. Therefore, we replaced deep hierarchical structures from the *Pie* and *Keyring* to the more flat solutions, for example in the *Pie* we used different kinds of drawers.

The study elicited also that users need to have a possibility to organize icons, UI elements and decorate the GUI space as they wish. Therefore, customization is an important aspect of the user experience of the 3D GUI. The shape of the GUI and amount of the icons depend on the user's personal preferences. One user wishes to see all of the applications at one glance and another one would just want to see only the most important applications in their GUI. Therefore, there should be different kinds of GUI designs available to the users.

Even though the procedure of the whole evaluation was very large and included several examples, the topic was interesting for the participants and the rhythm of the evaluation procedure was balanced with the tasks. Therefore, participants were not exhausted after the session. Instead, they were surprised how fast the time went and how much fun they had. Because we studied 3D UIs from several perspectives, it was very important to use a mixed methods procedure with different types of concept examples. Likewise, it was critical that the participants used the drawing template in the final task because they were able to use all showed examples as a source of inspiration for the drawing. Also, this case elicited the fact that a pair

evaluation setting is a good setup for experience elicitation and sharing, because the participant is expressing his/her experiences, wishes and ideas to the other participant (e.g., a friend or a colleague) and not only to the researcher.

Even though this evaluation had limitations from the interaction point of view, it nevertheless provided useful information to us for the next iteration of the four concepts. Although it was not possible to evaluate touch screen interaction with a non-operational prototype, it was possible to show the designed interaction ways and discuss about them with the participants. If we would have not done this early phase user evaluation, we would not have gained this valuable information, nor would we been able to update our designs to the next level. As prior research have shown, it is important to evaluate user experience in different phases of the development [47][4][46]. Also, the meaning of the visually high quality evaluation materials cannot be undervalued. As prior research has shown, for the successful evaluation, the designer need to be able to present his/her designs in the way that participants can understand them and are able to discuss and give a feedback about them [31]. Our study confirms this finding, but it also indicated that the use of visually high quality evaluation material can reveal big problems with visual, interaction and usability aspects, before any implementing and development hours are spend.

VIII. Conclusion and Future Work

In this article, we focused on a possibility to have a personal 3D GUI inside a VE on a tablet device. We started with the visual design process of 3D GUIs with 3D icons and 'file searching and sharing' use cases. Then, we had an early design phase UX evaluation of four 3D GUIs in a virtual environment background with 40 participants. In the evaluation, we used non-functional visually high quality prototypes and a Self-Expression Template to involve participants in the design of 3D GUIs. This evaluation provided a lot of user feedback for the design, which we utilized in the final iterated designs. In addition, we pointed out many design issues relating to the visual design of the personal GUI in VEs in a touch screen tablet context.

We found that the participants liked the possibility of having their personal 3D GUI in a virtual environment. However, they wished that the visual design of the 3D GUI should create a secure and private feeling for them. In this case, the *Room* concept was perceived as the most secure, because it had walls separating it from the background space. For creating as a secure feeling also to other GUIs, participants wished for visual distinction of the GUI and its elements from the background VE. However, participants wished that the GUI should not occlude too much with the background VE. Therefore, we included in the final iterated designs either a translucent back plate or with a dimming effect of the background when a user is interacting with the GUI and vice versa. Also, when items are moved from the personal GUI to the virtual environment, participants wished for some kind of visual indication. Similarly, visual indication should be used for showing the user's active position between the GUI and VE. Therefore, we included in the final iterated design a flash of the dimmed area when a user moves an item through it. In a touch screen tablet context, the participants found deep hierarchical structures distressing and difficult; therefore, they were replaced with more flat hierarchical solutions in the iterated designs.

In future studies, it would be interesting to evaluate the final GUI designs as fully functional prototypes to find out how participants perceive them and test user interaction as well. Especially we need more information about the animations of the final GUIs, e.g., how items will behave when a user is interacting with them. In addition, the dimming effect and indication while moving items between UI spaces need to be studied more.

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