The Effects of Virtual Museum Tools on Kinetic and Cognitive Processes

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Abstract: Re-considering 'space' has gained importance once again, especially in the context of virtual spaces that have developed in the last century. Virtual technologies aiming for a lifelike experience have tried to imitate the processes taking place in physical space and adapt them to virtual spaces. Just as in the physical world, spaces formed by interconnected areas bring the necessity of navigation. The importance of navigation increases in virtual museums in terms of systematic knowledge transfer as well as spatial experience. Navigation in virtual tours can be evaluated within the framework of the tools offered by the interface. Tools aiming to support cognitive processes should also be considered. The conducted research explores the effects of using virtual museum tools for navigational processes, focusing on Troya Museum virtual tour. In the field study performed with 20 people, the participants were given 4 tasks to complete. Besides participant answers, observational and verbal data has been collected during the fulfillment of the tasks. The outcomes revealed the inadequacy of the floor plan tool, Mattertag tool and the viewpoints in fully satisfying the cognitive processes of the users. Additionally, the limits of the 3D walkthrough and the absence of the zoom in-out tool are examples demonstrating the insufficiency of the kinetic tools effecting navigational processes. In the light of the outcomes, suggestions have been made to increase the adequacy of the tools in the context of kinetic and cognitive processes.

Keywords: virtual museum, navigation, way-finding, virtual museum tools, Troya virtual museum

Introduction

The concept of 'space' is greatly influenced by technological developments along with social, economic and political innovations. In the traditional sense, space has been defined within physical limits. The technological innovations of the recent years such as virtual spaces have made it necessary to reconsider the concept of space. Moreover, rethinking further concepts that gain meaning by space has also become crucial. 'Experience', 'travel-movement', 'navigation' are some keywords which are also important for the content of the research. For the occurrence of spatial experience, virtual spaces should be able to provide some features that physical spaces contain. The interfaces provided by virtual reality offer highly developed tools for imitating architectural spaces and modeling them in a realistic way (Henry & Furness, 1993).

In the book 'The View from the Road', the required criteria for perceiving motion are as follows: the movement of the user that expresses speed and direction, the movement of the field of view, and finally spatial features of the environment (Appleyard et al., 1964). Considering kinetic processes, the first two criteria are crucial to be fulfilled for the virtual spaces that offer spatial experience. Spatial character, on the other hand, effects processes such as way-finding and orientation to support the cognitive map formation.

Museums are places where kinetic and cognitive processes gain importance. Spatial arrangement and circulation in museums aim to provide the visitor with systematic information and sustain spatial experience. Museums aim to promote, offer experience and provide information to remote visitors under the name 'virtual museum' and/or 'virtual tour'. The interface realized in line with these purposes aim to shape the experience with the tools it offers.

Navigation processes of way-finding and orientation is provided by various tools offered in virtual museums. Could these tools support users' kinetic and cognitive experiences? What are the shortcomings?

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The advancement in technology has made possible that physically non-existent spaces are virtually created, and that existing spaces are reproduced in virtual environments. For the purpose of the research, the focus will be on virtual museums that offer spatial experience. Within this sub-group, commonly used technology among virtual museums is QTVR which produces virtual panoramic views of existing space. Examining virtual museums offered by the Ministry of Culture of Turkey has shown that QTVR technology is being widely used. Compared to other museums, Troya Museum was preferred for the field study mainly due to the clarity of the circulation scheme of its physical spaces, as well as the historical importance of the embodied heritage. The aim of the research is to understand the effects of the virtual museum tools on kinetic and cognitive processes of the visitors while navigating the virtual space.

Navigation in Virtual Space

The Concept of Navigation

Way-finding practices may presumably develop in spaces that kinetic and cognitive processes are supported. A primary source in way-finding studies is 'The Image of the City' written by Kevin Lynch. In order to perceive the environment, human beings first tend to disassemble, then group the information obtained by the surroundings. Likewise, imageability of a city depends on the ability to break the city into elements and group them accordingly. Elements that make up the city such as paths, edges, districts, nodes and landmarks work in harmony to guide the user who travels in the environment (Lynch, 1960).

The user in motion collects experiential data by moving through relatively static elements of the environment. In the mutually developing process, the user gains familiarity with the environment resulting in the ease of movement. Therefore, navigation depends not only on the users' cognitive knowledge of the environment but also on the physical movement of the individual.

Sebok, Nystad, and Helgar (2004) summarize the cognitive and kinetic tasks performed during navigation: orientation, way-finding and travel. Before proceeding to detailed descriptions of the tasks, the relationship between navigation and way-finding should be interpreted. Navigation is the movement towards a target, containing the processes of travel and way-finding (Montello, 2005).

Going back to kinetic and cognitive tasks suggested by Sebok et al., orientation can be described as the realization of one's own position and direction, and additionally the preparation step for way-finding (Sebok et al., 2014). Way-finding is the ability of determining a destination and planning the steps to reach it (Montello, 2005). The final task of navigation is physically moving towards the destination.

Way-finding in large-scale environments rests on three elements: landmarks, route knowledge and spatial configuration (Siegel & White, 1975). As Lynch (1960) states, landmarks identify a location and form a reference point for the users of that area. The task of orientation is supported as the users identify their point in space with the assistance of landmarks. Route knowledge and way-finding contain similar processes that may improve as one gains experiential knowledge of that environment.

Grasping the position and distance of the objects in space result in the development of survey knowledge. Clearly labelled maps including place names along with a 'you are here' sign, can be considered as a fundamental source in the assistance of way-finding (Gibson, 2009). Apart from maps, symbols, signs and color usage are important micro-scale approaches to way-finding systems.

The mentioned tools introduce visual communication that aims to be a guidance for members that do not share a common language (Arthur & Passini, 1992; Gibson, 2009). The interconnected aspects that the research focuses on can be seen in Figure 1. Furthermore, numerous sources of information such as navigation devices, photographs and verbal information contribute to landmark, route and survey knowledge (Thorndyke & Goldin, 1983).

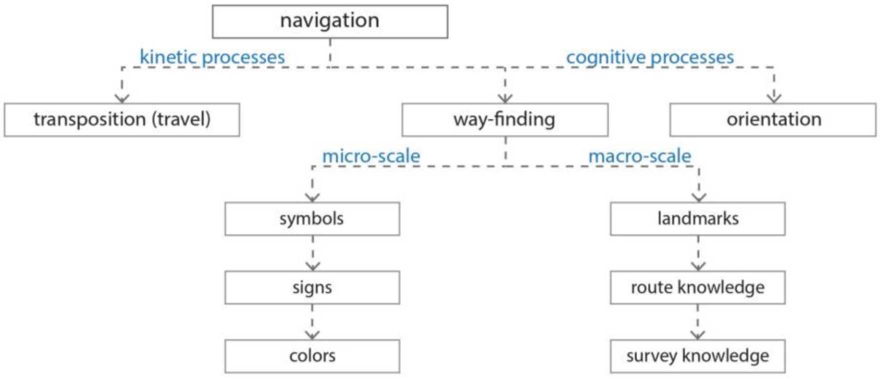

Figure 1. The Frame of Navigational Processes

Kinetic and Cognitive Processes in Virtual Space

Navigation in virtual space depends on one's ability to form a cognitive map as in the case of physical space (Darken & Sibert, 1996). Virtual space users should be able to obtain perceptual knowledge about the environment, determine a destination, generate a route and move towards it. As in physical space, virtual space also consists of cognitive and kinetic processes during navigation.

Spatial information in virtual environments relies primarily on landmark knowledge (Sebok et al., 2014). Landmark knowledge implies the increase in familiarity to surroundings, resulting in the development of route knowledge. The common technique used to emphasize landmarks in virtual environments is to place the predetermined viewpoints in a drop-down menu (Sebok et al., 2014). In this way, the destination can be reached by clicking on the viewpoint. This target-based process is generally carried out by teleportation. Although it may be perceived as a fast and easy way to get from one place to another, teleportation may prevent the user from forming a cognitive map of the environment (Bowman et al., 2001). A way to eliminate the shortcoming may be enabling the user to experience the transitional route (Bowman et al., 2001).

The field of view in physical space changes with every movement of the body and head resulting in data collection with every motion. An ordinary eye can scan a horizontal area of 120 to 140 degrees. However, field of view in virtual space changes between 60 to 100 degrees with larger degrees resulting in distorted or panoramic views (Ruddle et al., 1997). Narrow field of view reveals the need to turn constantly which may obstruct orientation. Certain virtual environments offer auxiliary tools such as a map that determine the user's position, orientation and movement in virtual space (Sebok et al., 2014; Gabbard, 1997).

Besides cognitive tasks, formation of a cognitive map of the environment necessitates kinetic processes in virtual space. It is quite difficult to gain knowledge about the surroundings when the user remains static (Darken & Sibert, 1996). Even small-scale environments may not be perceived from a single vantage point. Therefore, in order to be able to discover the surroundings, movement acquires great importance. In general, the tools enabling kinetic processes are motion in various directions, rotation, sweeping and zooming, with each tool having a particular speed. The main aim of virtual environments is to execute kinetic processes with minimum effort (Campbell, 1996). Navigation can be supported directly with the help of signs, maps and compasses or indirectly by the properties of the environment (Bridges & Charitos, 1997). Therefore, spatial knowledge can increase with the time spent in the setting and/or with the tools offered by the interface.

Troya Virtual Museum Tools

The Troya Virtual Museum interface produced by the company Matterport has been widely used to create virtual museum experiences of physical museums in Turkey and many other countries. The 3D Camera provided by the company is placed on scan points at approximately 2 meter intervals inside the physical museum space. After the scanning process is complete, a virtual walkthrough of the physical space is produced (Matterport, n.d). The field of view for the walkthrough is a panoramic vista estimated to scan 120 degrees on the horizontal plane. Furthermore, the company develops various tools that can be embedded in the interface. Although the tools in these interfaces are mostly similar, slight differences appear in several virtual spaces created in countries other than Turkey. For instance, in Dali Theatre-Museum, a scaling tool exists that is not found in virtual tours of museums in Turkey (The Dali Theatre-Museum, n.d). This section will examine merely the tools that are available in Troya Virtual Museum where the field study has been carried out (Troya Museum, n.d).

The tools offered in Troya Museum virtual interface can be found either on the pull-down menu or directly placed inside the 3D walkthrough (see Figure 2). The pull-down menu presented in Troya Museum consists of viewpoints, floor plans, an axonometric plan tool and a floor selection tool. Compared to virtual museum examples in other countries, domestic museums including Troya lack in diversity of viewpoints.

The axonometric plan is a tool that enables the user to see all the floors at once from various angles that can be controlled. Floor plans, on the other hand, offer a top view of the selected floor. The user location is indicated by a small red point on the floor plan. The floor selection tool sorts a list of floors that the user can select from. When the selection is made, the user is transferred to the selected floor by a vertical movement. This vertical movement between floors occur without teleportation.

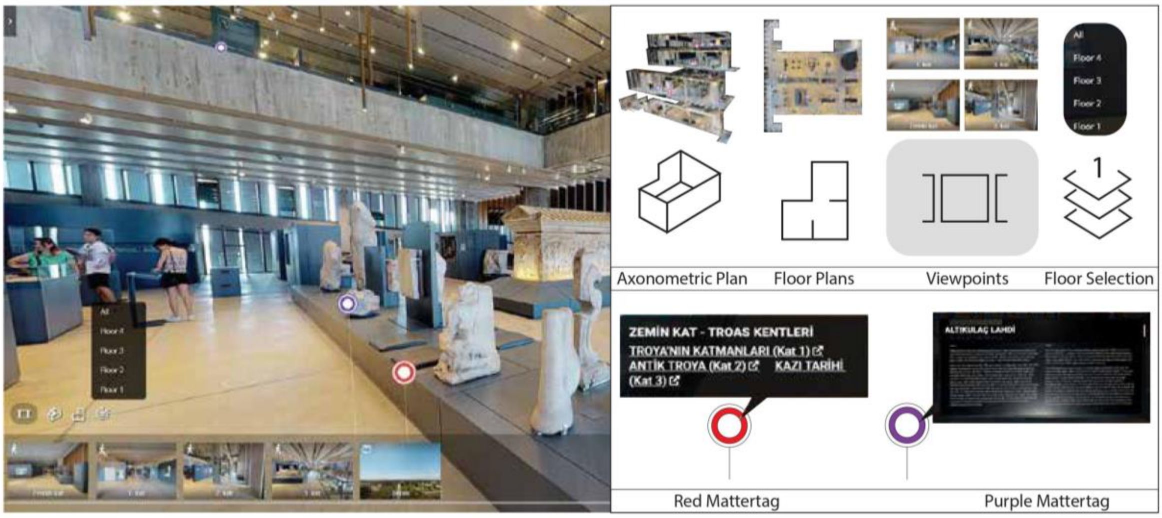

Figure 2. The Tools of Troya Virtual Museum

Tools that are placed inside the 3D walkthrough are mobility tools and Mattertags. Forward and backward movement is supplied by translucent white rings placed on the virtual museum floor (see Figure 3). These rings also indicate the positioning of the scan points where the 3D Camera was situated. Although movement can be achieved by clicking anywhere on the floor, the ability is relatively limited compared to the use of rings. Thus, it is foreseen that the user moves with the help of these rings. Movement in the vertical and horizontal planes occurs by swiping and rotation.

The zoom in and out tool is not available in Troya Virtual Museum, whereas it does exist in virtual museum examples in other countries created by Matterport. The last tool to be discussed is Mattertags. Although the virtual museums in other countries contain diverse types, in Troya Virtual Museum there are only two types of Mattertags separated by color codes (Mildrew et al., 2016). While purple Mattertags placed in-front of certain objects provide additional information about the objects; the red dots placed on the movement paths provide links that direct the user to another area inside the museum. This movement happens with teleportation.

The museum consists of various parts; a souvenir shop, workshop area, temporary and contemporary exhibition area and more. The virtual museum on the other hand is limited to only the permanent exhibition area on each floor and the immediate surroundings. The entrance and main circulation ramp can only be seen visually but the movement remains within the permanent exhibition area. The virtual museum situates the user to a point of departure on the ground floor as marked in Figure 4.

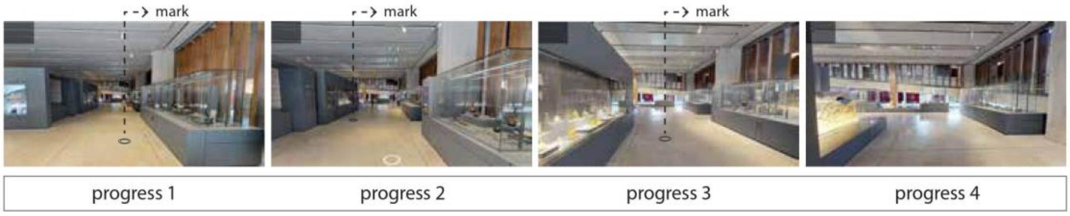

Figure 3. Movement in the Virtual Museum

Figure 4. Virtual Museum Limits on the Ground Floor of Troya Museum

Method

The main purpose of the study is to investigate the effects of virtual museum tools on navigational processes. The field study was carried out with 20 participants. The participants were architects, urban planners and civil engineers; professions that are familiar with design and plan drawings. Four pre-determined tasks were completed by the participants where each task was aiming to investigate the effectiveness of tools during kinetic and cognitive processes.

The Steps Followed by the Field Study

The research was carried out on a one-to-one basis over the teleconference software Zoom. The participants were asked to share their screen during the process, enabling the researcher to obtain observational and verbal data. As a first step, the link of the virtual museum and the page containing the tasks were shared with the participants. The participants were expected to read the task, perform it in the virtual museum and move on to the next task.

The Content of the Tasks

The virtual museum locates the user to a point of departure on the ground floor as mentioned in the previous section. Gibson (2009) argues that way-finding strategies should be applied to a structure starting from the approach and entry of the space. Therefore, the perception of the departure point is estimated to be of great importance for the formation of a cognitive map. The first task asks the participants to detect their access point to the 3D walkthrough on a map. The interface lacks a tool that shows the users location in the virtual space, for this reason the tools that may substitute for cognitive processes will be investigated by means of the first task. The second task asks the participants to find the room that 'Troad Golds' are located and to get information about the golds (see Figure 5). The task requires the use of mobility tools as well as the purple Mattertag located inside the room.

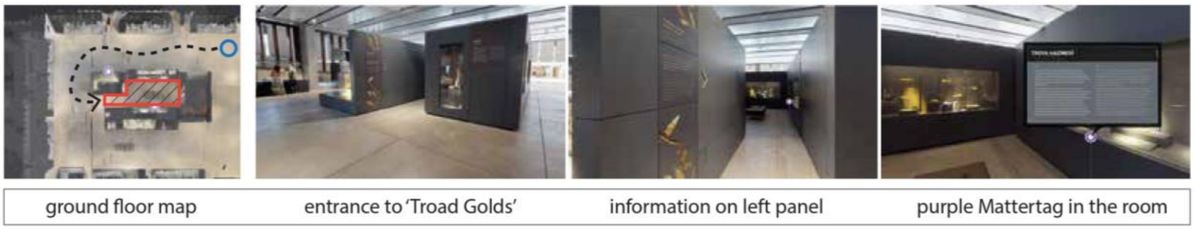

Figure 5. Accomplishment of Task 1

Task 3 and Task 4 aims to compare the effects of vertical movement and teleportation on orientation. In Task 3, the participants are asked to use the floor selection tool to reach the second floor and state the direction of 'Troad Golds' room that they had found in Task 2. Task 4, on the other hand, asks the participants to click the link given in the red Mattertag that teleports them to the fourth floor. Again, they were asked to state the direction of 'Troad Golds' room. As mentioned earlier, in the third task the participants are transferred between floors by a vertical movement; in the fourth task the participants are teleported to the destination. Two different kinds of displacement tools are compared in terms of orientation loss. Each task is assigned to primary navigational processes, and at the same time serve to evaluate other cognitive and kinetic processes (Table 1).

Table 1. Primary Navigational Processes Corresponding to Each Task

Tasks	Descriptions	Primary navigational process
1	Determination of the point of departure	Cognitive map formation
2	Finding 'Troad Golds' room and reaching information	Way-finding, kinetic processes and reaching information about the objects
3	Reaching the second floor using the floor selection tool (vertical movement)	Orientation
4	Reaching the third floor using the red Mattertag (teleportation)	Orientation

Results and Discussion

Task 1

Participants were positioned to a departure point within the virtual museum after opening the link, where the first task was to mark their position on a ground floor plan. The first few minutes were allocated to exploring the kinetic tools offered by the interface. During the fulfillment of the task, participants toured their immediate surroundings while realizing the limits of the virtual tour had restrained them to go beyond certain boundaries. Recorded verbal data consisted of sentences such as 'Where is the entrance?', 'I am not able to move', 'I cannot understand my location'. The general strategy used by the participants was to determine the entrance or a space that may indicate an entrance such as the cloakroom or lobby. The virtual museum presented a view of the entrance but the movement was limited. Thus, the tendency of the participants was to compare the direction of the entrance to the point of departure. Six participants used the floor plan tool to comprehend their position. Commuting between the given plan and the virtual tour a couple of times, the final answers were marked. The distribution of participant answers is concentrated at the entrance of the museum and the departure point of the 3D walkthrough (see Figure 6). The results reveal the tendency of the participants to position themselves towards the entrance.

The users' perception of the departure point is predicted to be of great importance in means of cognitive map formation. The fact that the virtual museum has chosen an undefined location as a point of departure for the 3D walkthrough has negatively affected the cognitive map formation, since the participants had difficulty in detecting their locations. As mentioned above, movement towards the museum entrance has been limited. Cognitive tools such as the floor plan has been consulted at the point where kinetic tools were incapable. Although the floor plan tool indicates the users' position in the environment, a diminutive red dot is used that was not perceivable by the participants.

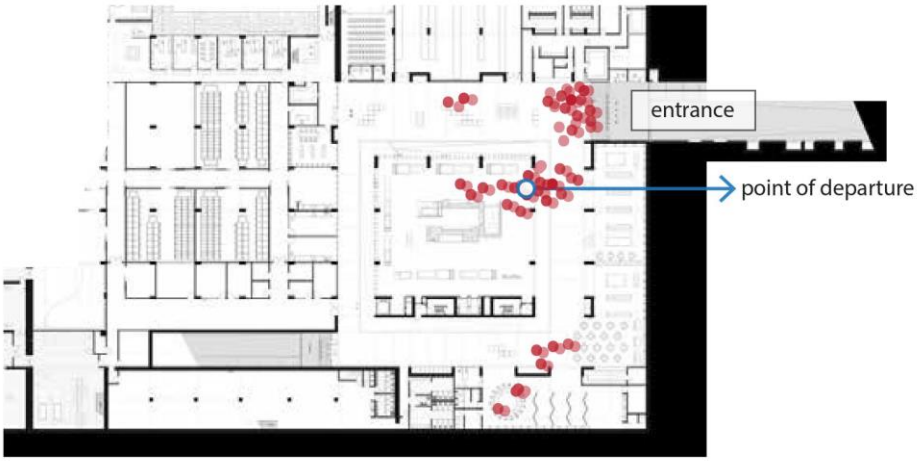

Figure 6. Distribution of Departure Point Estimates

Task 2

The second task aims to evaluate way-finding processes, kinetic abilities and accessing information by the use of tools. Starting from the departure point, the participants are asked to find the room on the ground floor that exhibits the 'Troad Golds'. After finding the room, the participants were asked to get information about the golds. Two kinds of information existed: the first one was a short paragraph located at the left panel of the rooms entrance, the second was the purple Mattertag tool located inside the room.

Finding the room required intensive use of rotation, forward and backward movement. Recorded verbal data contained sentences as 'The movement is very fast.', 'I can't find it.', 'I can't read'. The vast majority of the participants used the mouse and stated that movement became easy once they got used to it. At first, the transparent rings on the ground did not draw attention, thus the participants had difficulty in moving. One participant using a tablet and another using a touchpad had difficulty in moving throughout the whole virtual space. A participant who used the keyboard arrows stated that kinetic abilities of movement and rotation was quite easy. While searching for the room, each participant tried to read the panels located on the sides of the route, as a visitor would do in a physical museum. Almost none of the panels were readable due to the lack of the zoom tool.

Detection of the room has also posed difficulties for the participants. Observations showed that 14 participants out of 20 had passed-by the room without noticing the entrance. As mentioned earlier in the literature review, compared to the vision of the human eye in physical space, the virtual environment has a narrower field of view (Ruddle et al., 1997). In the case of Troya Virtual Museum, the angle was calculated to be around 120 degrees. Although the field of view is nearly the same with a human eye, the room was unnoticed. Some participants tried the floor plan tool which enabled them to locate the room. Participants who are unable to find the room, were supported by the help of the researchers' instructions. Three of the participants stated that the entrance of the room was not comprehendible at all and needed to be emphasized.

The panel on the left of the entrance was recognized and read by each participant. This was one of the few readable panels throughout the 3D walkthrough. The first part of accessing information about the Troad Golds was completed by each person. After entering the room, all of the participants approached the panels inside the room at first, but the panels could not be read. 13 of the participants noticed the purple Mattertag after not being able to read the panels. Figure 7 shows the usage of the two types of information sources included in the task.

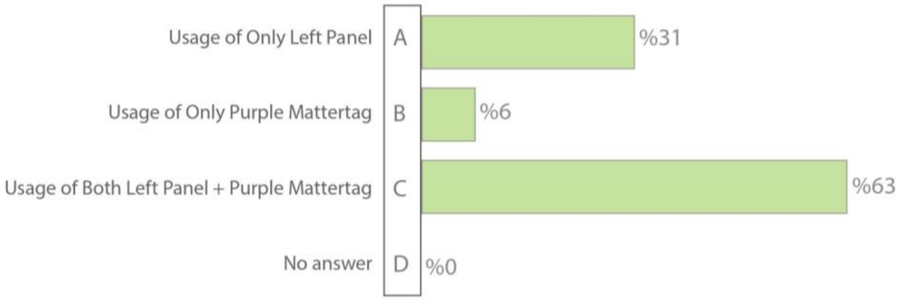

Figure 7. Usage of Two Types of Information Sources

Task 3 and Task 4

The comparison of Task 3 and Task 4 aims to reveal the effects of different displacement tools on user orientation. The participants are asked to use the floor selection tool in Task 3 to reach the second floor. The vertical movement can be experienced when changing floors, just as being in an elevator. Additionally, the direction of the user remains the same. After reaching the second floor, the participants were asked to state the direction of the room (Troad Golds) that they had found in the previous task. The virtual museum lacks a tool that indicates a direction such as a compass or a map. Therefore, the participants considered 'north' to be the direction they were facing.

Task 4 had requested the participants to use the red Mattertag that holds an additional link to the top floor. Contrary to the third task of vertical movement, Task 4 teleports the user to the destination. In most cases, the user direction is also changed after the displacement. The teleported user is asked to state the direction of the 'Troad Golds' room. During the task, the collected verbal data consisted of 'Where am I?', 'I lost my sense of direction.', 'I have no idea'. Three of the participants went back to their previous location and tried to understand how their direction changed. One user tried to use the floor map, unfortunately stating that it was not helpful in understanding the direction. Another participant used the floor selection tool to visit the ground floor where 'Troad Golds' room was located. Since the floor selection tool displaced the user without changing their direction, this participant easily answered the question. Another participant also correctly answered the question, but by guessing. All remaining individuals had great difficulty. The answers presented in Figure 8 clearly show that the participants were able to orient themselves after vertical movement. On the contrary, the comparison of the tasks demonstrates a loss of orientation after teleportation.

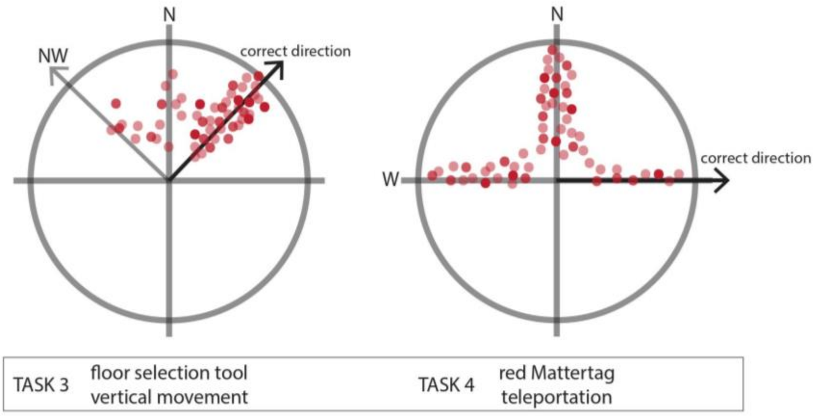

Figure 8. Orientation Loss after Teleportation

Conclusion

The conducted research investigated the effects of virtual museum tools on navigational processes of the users. Although the interface has been found to be sophisticated, the field study results showed that the tools remained insufficient in fully satisfying the cognitive and kinetic processes required for users to navigate in the environment. It has been observed that the participants consulted cognitive tools whenever kinetic tools became insufficient. Thus, the cognitive and kinetic tools regularly supported each other.

The virtual museum interface has specified an undefined area as a starting point which has created confusion for the majority of the participants. The limits of the virtual tour also restrain the movement of the user, failing to satisfy kinetic abilities. The floor plan tool offered by the interface has been referred to while determining location. The tool was found to be incapable since the small red point indicating the user location was not noticed by the participants.

The tendency of every participant has been to try to read the panels in order to gain knowledge of the exhibited objects and the museum. Zoom in-out tool was not available in the interface of Troya Museum, preventing the user from getting closer to the panels. The purple Mattertag could not replace the panels since the tool was only used for giving additional information about a few selected objects. The panels on the other hand contained detailed information throughout the museum. Therefore, the common kinetic tool for zooming in-out has been found to be critical in gaining knowledge and supporting cognitive processes.

The previous section emphasized that the field of view dramatically decreased in a virtual environment. The fact that 'Troad Golds' room was not noticed may demonstrate a shortcoming of a narrower field of view. Nonetheless, this may not be the only reason whereas the 120 degrees' view field is nearly as extensive as a human eye.

The research clearly shows that teleportation has negatively affected the orientation of the participants while the vertical elevator-like movement had not caused any disorientation for the vast majority. As reported in the literature review, previous research indicates that instead of teleportation, the user should follow a route towards the destination (Bowman et al., 2001). Although the floor selection tool has achieved this ability, it has created confusion about another issue. Returning to Figure 2, it can be seen that the floor selection tool has named the ground floor as the first floor. The same acceptance does not exist for the viewpoints tool where the ground floor is named as it is. The situation has led to confusion in some participants, causing questions such as 'Which floor am I on?', 'Which floor was the Troad Golds room on?'.

Finally, observations show that the viewpoints tool consisting of pre-defined scenes from each floor was not referred to at all during the tasks. Compared to virtual museums produced by Matterport in other countries, Troya Museum accommodates a limited number of viewpoints in the pull-down menu. Since the viewpoints only consisted of one view for each floor, it acted as a floor selection tool instead.

Recommendations

The recommendations given below aim to improve the tools offered by the interface towards an enhanced experience of navigation:

- The conducted research revealed the importance to fully perceive the entrance of an environment in order to fulfill the purposes of navigation. The importance of expanding the limits of the virtual environment to include the entrance of the museum has become crucial for the formation of a cognitive map. Moreover, the departure point of the virtual tour could be located at the entrance of the structure.
- As demonstrated in the research carried out by Gabbard (1997) and also suggested by two participants, an additional cognitive tool such as a map showing the location, direction and movement of the user can be placed on the side of the screen.
- The floor plan tool can be improved by replacing the unperceivable red dot with an attractive mark indicating the user location in space.
- The purple Mattertag has been found to be beneficial in terms of accessing knowledge. Increasing the number of Mattertags could be recommended since only a few were provided on each floor. For the tags to be fully comprehendible, the signage 'i' could be placed inside the dot that indicates the purpose of the tool. The necessity of the zoom tool has also been revealed especially in museum spaces where the legibility of the panels is crucial.
- Out of sight spaces/objects may require an additional indication that draws the attention of the users, such as an animated arrow.
- Virtual spaces should be consistent in using the same naming among all the tools placed in the interface.

- Viewpoints should be used to indicate outstanding pieces of the virtual environment, supporting the cognitive processes of the user. The viewpoints in Troya Museum virtual tour could be diversified, focusing on important objects exhibited inside the museum.

Further Research

The conducted research aimed to understand the effects of virtual museum tools on kinetic and cognitive experiences of the user. The emphasis has been made on the methodology throughout the research. The content of the tasks aimed to provide an adaptable methodology for virtual environments that offer diverse tools, as well as alternative virtual spaces. Thus, the executed research aims to constitute a background for further research on the examination of virtual museum tools on navigational processes of the user.

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