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The Effects of Using On-Screen and Paper Maps on Navigation Efficiency in 3D Multi-User Virtual Environments

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ABSTRACT

This study aims to analyze the effects of using on-screen and paper maps on navigation efficiency in 3D MUVEs. There were 48 participants in the study, which has a randomized true experimental design. The researchers administered a demographics questionnaire and the spatial visualization test to the participants and formed three groups by checking a variety of independent variables, the On-Screen Map (OSM) group, the Paper Map (PM) group, and the Coordinate System (CS) group, which did not use any kind of map. The participants completed three tasks with increasing difficulty levels. There was a statistically significant difference between the methods for the completion times of the first task and aggregate tasks. This difference was between CS and PM as well as between CS and OSM. Participants got confused and lost the most in the CS group and the least in the OSM group. The CS group took longer to complete the tasks and got lost more frequently. Navigational aids that included visual tips about the environment increased the navigation efficiency of the participants using the MUVE.

KEYWORDS

3D Multi-User Virtual Environments, Efficiency, Gender, Maps, Navigational Aids, Wayfinding

INTRODUCTION

With the widespread use of the Internet, social networks, and three-dimensional multi-user virtual environments (3D MUVEs) in every field, interest in 2D and 3D graphics has increased. The transfer of our living environment to the Internet by use of rich and realistic graphics has resulted in the emergence of new concepts such as simulations, virtual reality, and virtual worlds. Since the world we live in is three-dimensional, it is more intuitive to use three-dimensional features when creating virtual realities in the computer environment. Since the designs created with the use of three-dimensional artifacts are closer to reality, they attract more attention than web sites including two-dimensional images and animations made of texts, pictures, and vector graphics. Designers can present visualizations that

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are closer to reality thanks to three-dimensional technology. These visualizations are used in many different fields such as business, education, art, and design (Uğur, 2002).

A MUVE can provide exploration, interaction, and immersion affordances when users navigate and do activities in a virtual environment and communicate among themselves at the same time (Tüzün & Özdinç, 2016). MUVEs, in particular, can be used to reveal the effect of navigation on spatial perception. In these environments, individuals can navigate like they do in real life with the help of the avatars that represent them. These three-dimensional environments include many contexts or places where users can navigate and communicate with each other. However, it becomes more difficult for users to navigate as the environment becomes more complicated and the number of contexts increases (Ballegooij & Eliens, 2001). Besides, it may become more difficult for users to recognize the context and the people around them if they see a context in the virtual environment for the first time without seeing it in reality beforehand. To address these difficulties, the influence of navigational aids on navigation efficiency in 3D MUVEs is worth studying.

RELEVANT LITERATURE AND THEORETICAL FRAMEWORK

3D MUVEs combine textual and audio transfer technologies and enable navigation in realistic three-dimensional virtual worlds. The origin of this kind of environment is the text-based and multi-user games such as Space War, which was a popular game in the UNIX operating system (Tüzün, 2010). For many years, virtual environments have been assigned many names such as Multi-User Dungeon (MUD), Object-Oriented MUD (MOO), Massively Multiplayer Online Role-Playing Game (MMORPG) and Multi-User Virtual Environment (Mayrath, Traphagan, Jarmon, Trivedi, & Resta, 2010).

MUVEs have real-time and open world features. These features make them closer to reality (Fırat, 2008). Although many multi-user games also have real-time feature, players need to perform certain operations and tasks to make progress in these environments. However, MUVEs usually do not include planned tasks. When users enter the environment, their experiences are random. Another aspect of MUVEs is that they are available for creating environments with different levels of complexity, making measurements during interactive navigation and checking the spatial learning parameters (Peruch, Belingard, & Thinus-Blanc, 2000). Navigation in MUVEs refers to reaching a desired object or location by moving in these environments (Raees, Ullah & Rahman, 2019). Virtual environment navigation allows users to control their position and orientation of the virtual camera which they see the virtual world (Galyean, 1995) and to move around, manipulate and interact with virtual objects possible (Geszten et al., 2018).

When navigating in a new environment, a mental image of the place is created in the subconscious. This image is called a cognitive map, and it is stored in the hippocampus of the brain. However, the image in the hippocampus is not the same in every person's brain. Some people very rapidly create spatial knowledge about places they see for the first time and create maps of these places in their minds without any difficulties. Others find it difficult to do so (Çubukçu & Çubukçu, 2006; Green & Bavelier, 2003). Lynch (1960) and Golledge (1999) describe wayfinding as creating a mental image of the physical world in the process of following a road or path and making decisions based on this image. In the process of wayfinding, people create cognitive maps using three different types of spatial knowledge, which are: 1) landmarks, 2) procedural knowledge, and 3) survey knowledge (Bowman et al., 2004). These cognitive maps help people during their navigation.

According to the wayfinding model by Chen, Chang, and Chang (2009), people need to collect spatial knowledge with the help of their senses, combine it with their existing knowledge, and create cognitive maps to understand the environment of their navigation task. The decision-making process depends on the creation of cognitive maps of individual movements and structures for the entire wayfinding plan. Movement to a specific destination is the result of a plan that includes a predetermined path and accurate information about the movements. The plan provides feedback to the memory as spatial knowledge. During navigation, the decisions are transformed into physical movements. Physical movements require the implementation of the decision or movement in the decided path, that is, the navigation. During their movements, users proceed in the planned direction with the help of the stimuli in the environment. In the wayfinding process, users make new wayfinding decisions while creating cognitive maps to reach a goal when they make a decision, the plan is completed, or the plan or the decision goes wrong. Then, they re-create the decision-making process. In these processes, the most important factors that influence wayfinding efficiency are experience, searching methods, differences in abilities, motivation, navigational aids, environmental arrangement, and structure. Without these factors, any person can be disoriented at one time or another. Disorientation is an uncomfortable and unsettling feeling to be unfamiliar with a person's proximal context and unable to determine how to compensate the situation. The goal of navigation research in virtual environments is to create a situation where everyone is oriented properly all the time and knows where they are and how to get there (Darken & Peterson, 2015).

3D MUVEs allow the use of either first-person perspective (egocentric frame of reference) or third-person perspective (allocentric frame of reference) for navigation (Tüzün & Özdinç, 2016; Chen & Chen, 2019). Considering 3D MUVEs, the design of efficient navigation is a problem because users' viewpoint cannot encompass the entire environment. This problem causes disorientation and bad user perception of the virtual worlds' usability. If users cannot find their way to a destination called losing way, they cannot use the virtual world for its desired purpose (Minocha & Hardy, 2016). In the relevant literature, there are many different terms used to describe losing way, such as being lost, getting lost, lostness and disorientation. Karadeniz (2006) uses the term "lostness" to describe users' state of being lost, and the term "disorientation" to describe a general situation including users' failure to orient themselves in the environment. According to Dudchenko (2010), getting lost or disorientation means a person's failure to find their way. Lynch (1960) stated that getting lost was very unlikely when an environment includes maps, street numbers, and path symbols and people are supported by special devices. Karadeniz (2006) describes getting lost in a multimedia environment as users' not knowing where they are, how they have come to a place, and how to go to another place. In other words, users are unable to answer the questions: "Where am I?" "How did I get here?" and "Where will I go?" Dudchenko (2010) reported that users get lost: 1) when they have no familiar users around them, 2) when there are no symbols to help them decide which way to go, and 3) when they cannot reorient themselves by reconstructing their previous experiences. In this study, the researchers define the term "getting lost" as straying from the ideal path.

Altan (2011) and Riis (2016) determined that getting lost in MUVEs is an important issue. Users navigating in MUVEs, particularly for the first time, fail to follow the ideal paths and get lost. Preventing users from getting lost and supporting them with different navigational aids is important for users (Akçapınar, Altun, & Menteş, 2012). These environments use a variety of navigational aids to facilitate their users' navigation. Navigational aids such as flying, spatial audio, breadcrumb markers, coordinate feedback, districting, landmarks, grid navigation, and map view (Darken & Sibert, 1993) help prevent users from getting lost and provide visual hints to users about the ideal path to follow. Maps are one of the most familiar mediators and powerful tools for navigation because they provide wealthy environmental information to users (Darken & Peterson, 2015). They offer intuitive ways to extend the capacities of the human cognitive systems as external representations of the environment with landmarks (McKenzie & Klippel, 2016).

Task completion times in virtual environments are also an important aspect of MUVEs' usability. Individual differences between users along with the design and usability of the aids used in virtual environments influence the accomplishment of tasks and task completion times. Many studies of MUVEs have found that males completed tasks more quickly than females (Astur, Ortiz, & Sutherland, 1998; Lövden et al., 2007; Chen, Chang, & Chang, 2009). A few studies reported no differences between users' task completion times by gender. Studies of the influence of gender on route-learning report that males are capable of meeting the required criteria with fewer errors and difficulties than females, while females are able to remember the landmarks better than males (Galea & Kimura, 1993; Saucier et al., 2002; Tlauka et al., 2007). Cutmore et al. (2000) conducted a study of the influence of the factors of cognition and gender on the navigation in virtual environments and found that males managed to find the exit with less effort. These findings are consistent with the findings of the studies by Moffat, Hampson, and Hatzipantelis (1998) and Sandstrom, Kaufman, and Huettel (1998). The results of the study by Vila, Beccue, and Anandikar (2003) contrast with these studies and indicate that there was no difference between navigation durations by gender. Ross, Skelton, and Mueller (2006) reported that the difference between genders in virtual environments was correlated with the characteristics of the task assigned.

In the light of such information, this study examines the effect of maps, a navigational aid used in 3D MUVEs, on navigation efficiency. Therefore, research questions of this study are: 1) Is there any differences among the use of the Coordinate System (CS) which does not use any maps, Paper Map (PM) and On-Screen Map (OSM) in 3D MUVEs in terms of task completion times?, and 2) Is there any differences among the use of CS, PM and OSM in 3D MUVEs in terms of users getting lost? There are commercial games such as Anarchy Online, which includes in its distribution package paper maps of its worlds; therefore, it is worthwhile to study the effect of paper maps along with on-screen maps.

METHODOLOGY

Research Design

This study has a mixed design. The researchers used a true experimental design, a quantitative research method. The study utilized true experimental matched random design to be able to make the experimental and control groups similar. Moreover, the researchers used observation, a qualitative data collection tool, to analyze the participants' progress with the three methods.

3D Multi-User Virtual Environment

This study used an educational game called Quest Atlantis (QA). This game is based on the Active Worlds (AW) MUVE infrastructure. AW offers real-time and three-dimensional content with interaction (ActiveWorlds, 2015). Furthermore, AW has different pre-designed and used environments for educational purposes. Researchers think that designing a new environment could cause different usability problems that would affect the research results. Therefore, an existing virtual world design in QA on AW has been used in the study. Another reason for selecting QA is that it can be edited by researchers to determine tasks' coordinates. All objects in AW are stored in a grid of 10 by 10-meter cells. Locations correspond to the longitude and latitude coordinates that are encountered within the AW. For example, a location located at 11S 3E would be located 11 cells south and 3 cells east of the "ground zero" cell (i.e., the cell located at 0N 0W). By default, the current location of a user's avatar is displayed on the AW browser title bar, and this is the only navigational aid users can use while navigating within the virtual environment (Figure 1). In Quest Atlantis, an OSM navigational aid is located in the upper right corner of the environment. It allows users to see both their location and a bird's eye view of the virtual environment in real-time (Figure 1). This OSM can be turned off by users.

Data Sources

Demographics Questionnaire

The questionnaire has three sections: one about the participant's gender, year of birth and Grade Point Average (GPA), one about their computer and Internet use and one about their use of MUVEs and computer games.

Figure 1. View of the virtual environment

Spatial Visualization Test

This test was created by Winter et al. (1989) and translated into Turkish by Yıldız (2009). The test includes 15 multiple-choice questions, and each question has five options. Five questions concern aerial views of isometric images of the structures made with cubes. The other questions are about views of cubes from the right, left, front, and behind. The highest possible score on the test is 15, and Yıldız (2009) found its reliability coefficient to be 0.971.

Observation

The researchers observed the routes taken by the participants and their difficulties when they got lost.

Participants

The participants of this study included 125 Instructional Technology students at a large-scale public university in the Eastern Turkey. The researchers conducted this study in this context because the students were familiar with these kinds of environments since their curriculum included the use of OpenSim, a 3D MUVE, for design purposes. Based on data collected from the participants, 16 of them were assigned to the pilot test, and 48 of them were assigned to the implementation.

Three participants with the same year of birth and gender were matched by similar GPAs, spatial visualization scores, years of playing games, weekly hours of playing games, and years of using the computer and the Internet. As the computer skill of the participants and their age-related reaction times would affect the results across groups, it was aimed that participants with similar computer skills and ages existed in all 3 groups. For this purpose, the researchers planned to include 16 participants in each group (48 participants in 3 groups) due to logistic limitations. Overall, two groups of three males and two groups of three females from each year of birth were matched. The demographic data for the participants in these matched pairs are presented in Table 1. It was not possible to match participants

Table 1. The distribution of groups according to the independent variables

Trios	Participant	Year of birth	Gender	Grade	Spatial visualization score	Years of playing games	Weekly hours of playing games	Years of computer use	Years of Internet use	Method Assigned
1	P32 P35 P58	1993	M	2.21 2.39 2.47	11 13 12	4 3 3	6 6 4	4 2 4	3 2 2	CS PM OSM
2	P40 P61 P52	1993	M	3.50 3.26 3.53	6 4 6	4 1 0	1 2 0	4 3 2	3 2 2	CS PM OSM
3	P47 P31 P62	1993	F	2.76 3.00 2.83	11 8 11	0 0 0	0 0 0	2 2 4	1 2 4	CS PM OSM
4	P63 P54 P38	1993	F	3.10 3.26 3.35	4 2 4	3 0 2	5 0 1	2 2 2	1 2 1	CS PM OSM
5	P51 P93 P122	1992	M	2.25 2.35 2.36	3 5 4	3 2 2	2 4 6	3 1 1	3 2 1	CS PM OSM
6	P79 P65 P72	1992	M	2.92 2.62 2.98	8 7 7	1 2 4	6 1 3	2 2 4	2 1 3	CS PM OSM
7	P34 P76 P80	1992	F	2.88 2.90 2.79	3 4 4	3 2 2	6 1 2	3 2 2	2 2 2	CS PM OSM
8	P87 P45 P69	1992	F	3.09 3.29 3.27	10 10 12	0 6 0	0 2 0	1 2 2	1 1 2	CS PM OSM
9	P53 P29 P121	1991	M	2.38 2.62 2.70	6 4 4	0 4 0	0 2 0	3 4 1	3 4 1	CS PM OSM
10	P118 P100 P108	1991	M	3.11 3.44 3.51	6 5 4	0 3 1	0 1 2	2 3 2	2 3 2	CS PM OSM
11	P105 P109 P92	1991	F	2.80 2.96 2.75	10 8 10	0 0 0	0 0 0	3 2 1	2 2 1	CS PM OSM
12	P64 P71 P124	1991	F	3.53 3.28 3.40	12 11 11	4 2 0	5 6 0	2 2 2	1 2 1	CS PM OSM
13	P88 P25 P125	1990	M	2.53 2.60 2.43	6 5 4	0 2 3	0 4 5	3 3 2	2 3 3	CS PM OSM
14	P18 P82 P9	1990	M	3.04 3.10 3.11	11 11 9	0 2 2	0 1 1	3 2 2	3 2 2	CS PM OSM
15	P112 P23 P101	1990	F	2.70 2.98 3.00	8 9 7	0 0 0	0 0 0	2 2 4	2 2 2	CS PM OSM
16	P24 P4 P116	1990	F	3.67 3.79 3.81	6 10 6	0 0 0	0 0 0	2 3 3	2 2 2	CS PM OSM

with perfectly identical features for all independent variables. Thus, the researchers embraced the independent variables with the closest values. Participants in each of the trios were randomly assigned to one of the three methods (CS, PM, and OSM). One-fourth of the participants were born in 1990, one-fourth were born in 1991, one-fourth were born in 1992, and one-fourth were born in 1993. Half of the participants were females, and the other half were males.

Procedures

For the pilot test and the implementation, the researchers used one control group (CS) and two experimental groups (PM and OSM). The control group did not use any maps, and the participants were asked to use the default coordinate system (CS) to perform the tasks (Figure 1). One of the experimental groups was asked to use the on-screen map (OSM) (Figure 1) to perform the tasks. The other experimental group was asked to use the paper map (PM) with an aerial view of the environment, while the OSM was turned off. Both maps are 2D top-down view maps and were used as navigational aid to facilitate users' navigation. Furthermore, they provided visual cues about the environment. PM was presented to users as a static map, while OSM showed where they were. The researchers gave an orientation text to the participants. The text included information about the methods, tasks, locations, and destinations. In the Turkish cultural context, cardinal directions such as north, south, east, and west are rarely used in daily life by ordinary citizens, and relative directions are used for reference. For this reason, the orientation text also included a compass rose to remind the participants of the cardinal and inter-cardinal directions.

The participants were assigned three tasks for each of which they were required to find crystal artifacts placed in different locations in the virtual environment: "Your current coordinates are 0, 0. Your first task is to find the crystal artifact at 9N, 5E," "Your current coordinates are 9N, 5E. Your second task is to find the crystal artifact at 9N, 10W," "Your current coordinates are 9N, 10W. Your third task is to find the crystal artifact at 11S, 3E." The participants were required to go from O to 1 for the first task, from 1 to 2 for the second task, and from 2 to 3 for the third task (Figure 2). The tasks progressively became more complicated and longer to complete as the participants accomplished the tasks.

Figure 2. Display of participants' tasks in the virtual environment

Sixteen participants took part in the pilot test. Afterwards, the researchers held interviews with the participants, identified the problems with the tasks, the orientation text, and the environment, and fixed them. The researchers did not use the data from the pilot test for the analyses.

After the pilot test, the implementation took 12 days to complete. Each implementation was completed with a single participant. Before the implementation, the researchers gave the orientation text to a participant and task completion times were recorded with a chronometer. The researchers also observed and took notes about the routes taken by a participant. All participants completed all the tasks in the implementation.

Certain technical arrangements were made to ensure that the groups performed the tasks in the AW environment under the same conditions. Only the arrow keys could be used for movement. Key combinations such as running with Ctrl key and walking through the objects with Shift key were turned off. The chat window and web browser window were closed, and the three-dimensional virtual environment was used in the full-screen mode. The participants were provided with a first-person perspective of the virtual environment.

Data Analysis

The researchers conducted one-way ANOVA to determine any differences between the groups by their GPAs, spatial visualization scores, weekly hours of playing games, and hours of using MUVEs. In addition, the researchers conducted the chi-square test for independence to identify any differences between the group's experience with games, computers, and the Internet. To compare the task completion times of the groups, the researchers used descriptive statistics, two-way ANCOVA, Fisher's exact test, Levene's Test, and Fisher's LSD Test. Fisher's exact test was also used to determine whether the groups got lost. The significance threshold for this study's statistical analyses was 0.05. The observation data were analyzed using content analysis.

RESULTS

A Comparison of the Groups by the Independent Variables

The descriptive statistics regarding the groups' GPAs, spatial visualization scores, weekly hours of playing games, and the duration of their MUVE uses were shown in Table 2.

Table 2. Descriptive statistics of the groups according to the independent variables

	Group	N	Mean	SD
Grade point average	CS	16	2.90	0.43
	PM	16	2.99	0.39
	OSM	16	3.01	0.43
Spatial visualization score	CS	16	7.56	2.99
	PM	16	7.25	3.22
	OSM	16	7.19	3.17
Weekly hours of playing games	CS	16	1.94	2.62
	PM	16	2.13	2.30
	OSM	16	1.50	2.00
Weekly hours of using MUVEs	CS	16	2.63	2.80
	PM	16	2.69	2.60
	OSM	16	3.63	2.42

According to ANOVA results, there was no significant difference among the groups' GPAs (F (2, 45) = 0.31, p = 0.73), spatial visualization scores (F (2, 45) = 0.07, p = 0.94), weekly hours of playing games (F (2, 45) = 0.31, p = 0.74), and weekly durations of using MUVEs (F (2, 45) = 0.74, p = 0.49). The chi-square test for independence was conducted to see any differences among the groups' experiences in playing games, computers, and the Internet. Fisher's exact test was administered when the number of cells smaller than 5 was above 20% of the total number of cells. According to the test results, there was no significant difference among the groups' experience with playing games (X^2 (8, N = 48) = 10.83, p = 0.16), experiences in using computer (X^2 (6, N = 48) = 7.25, p = 0.29), and experiences in using the Internet (X^2(6, N = 48) = 7.14, p = 0.24). These results suggested that the groups of 16 participants were similar in terms of the independent variables.

A Comparison of the Groups' Task Completion Times

The data should have a normal distribution to conduct parametric tests, and the variances of the different groups should be equal. The normality of the dependent variable was observed using histograms for each group (CS, PM, and OSM), and Levene's test was conducted to determine the homogeneity of the variances. Although the researchers tried to match the groups by considering their characteristics, and their age and gender distributions were equal, other characteristics differed. The variables that differed were taken as covariates, and the covariates assumed to be associated with the tasks were checked while comparing the task completion times. All participants completed all the tasks reaching the determined goals. Table 3 presents the completion times of the tasks by both methods and genders. A visualization of these data is presented in Figure 3.

Figure 3 shows that the male participants completed the first task faster using the OSM, while the female participants completed the same task faster using the PM. The participants completed the second and third tasks faster when they used the PM, while they completed the same tasks more slowly when they used the CS. The male participants completed the tasks faster when they used the OSM, while the female participants completed the tasks faster when they used the PM. Participants completed the tasks more slowly when they used the CS method. Analysis of the participants' task completion times indicated that males completed the tasks more quickly.

The researchers also tested the equality of the variance among the groups for the first, second, third tasks, and all the tasks. It was found that the variance among the groups was equal for the first task (Levene's test F = 2.83, p > 0.05), the second task (Levene's test F = 1.46, p > 0.05), the third task (Levene's test F = 2.15, p > 0.05), and for all the tasks (Levene's test F = 1.27, p > 0.05). Table 4 shows the results of the covariance analysis. This analysis was conducted to consider the gender variable, which might affect the methods used in the tasks. The researchers also checked the GPAs, spatial visualization scores, weekly durations of playing games and using MUVES, which were taken as covariates. The results indicated a statistically significant difference between the methods for the first task's completion times (p < 0.05). For the other tasks, the difference in methods was not statistically significant (p > 0.05). The difference between the methods for the completion times of all three tasks was statistically significant (p < 0.05). The influence of the interaction between the method and gender on the completion time of the first task, the second task, the third task, and all the tasks was not statistically significant (p > 0.05).

The researchers conducted Fisher's LSD test to find out which groups differed from each other by method for the first task (Table 5). The results showed that the differences between the CS and PM methods, as well as the CS and OSM methods, were statistically significant (p < 0.05). The difference between the PM and OSM methods was not statistically significant (p > 0.05).

The researchers conducted Fisher's LSD test also to determine which groups differed by aggregate task completion times and method (Table 6). The results showed that the differences between the CS and PM methods, as well as the CS and OSM methods, were statistically significant (p < 0.05). The difference between the PM and OSM methods was not statistically significant (p > 0.05).

Table 3. A comparison of the completion times of tasks 1, 2, 3, and all the tasks by method and gender

	Method	Gender	Mean	SD
Task 1	CS	Female	347.38	219.05
		Male	266.88	225.46
		Total	307.13	218.73
		Corrected Total	313.15	38.06
	PM	Female	151.63	89.76
		Male	172.88	173.83
		Total	162.25	134.10
		Corrected Total	173.17	37.96
	OSM	Female	193.50	117.53
		Male	73.63	24.69
		Total	133.56	102.77
		Corrected Total	116.62	38.28
Task 2	CS	Female	286.00	135.36
		Male	200.38	75.30
		Total	243.19	114.68
		Corrected Total	244.89	22.08
	PM	Female	207.87	85.91
		Male	157.63	66.31
		Total	182.75	78.55
		Corrected Total	180.08	22.03
	OSM	Female	212.88	78.23
		Male	180.50	57.33
		Total	196.69	68.33
		Corrected Total	197.66	22.21
Task 3	CS	Female	300.62	179.97
		Male	226.63	112.99
		Total	263.63	150.11
		Corrected Total	262.14	33.44
	PM	Female	250.75	92.77
		Male	178.88	58.12
		Total	214.81	83.49
		Corrected Total	221.28	33.36
	OSM	Female	277.00	204.06
		Male	206.00	93.60
		Total	241.50	157.69
		Corrected Total	236.52	33.64

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Table 3. Continued

	Method	Gender	Mean	SD
Total	CS	Female	934.00	289.93
		Male	693.88	306.42
		Total	813.944	313.72
		Corrected Total	820.18	61.16
	PM	Female	610.25	213.20
		Male	509.38	207.28
		Total	559.81	209.70
		Corrected Total	574.52	61.00
	OSM	Female	683.38	308.54
		Male	460.13	117.20
		Total	571.75	253.23
		Corrected Total	550.80	61.52

Figure 3. Distribution of participants' tasks completion by gender

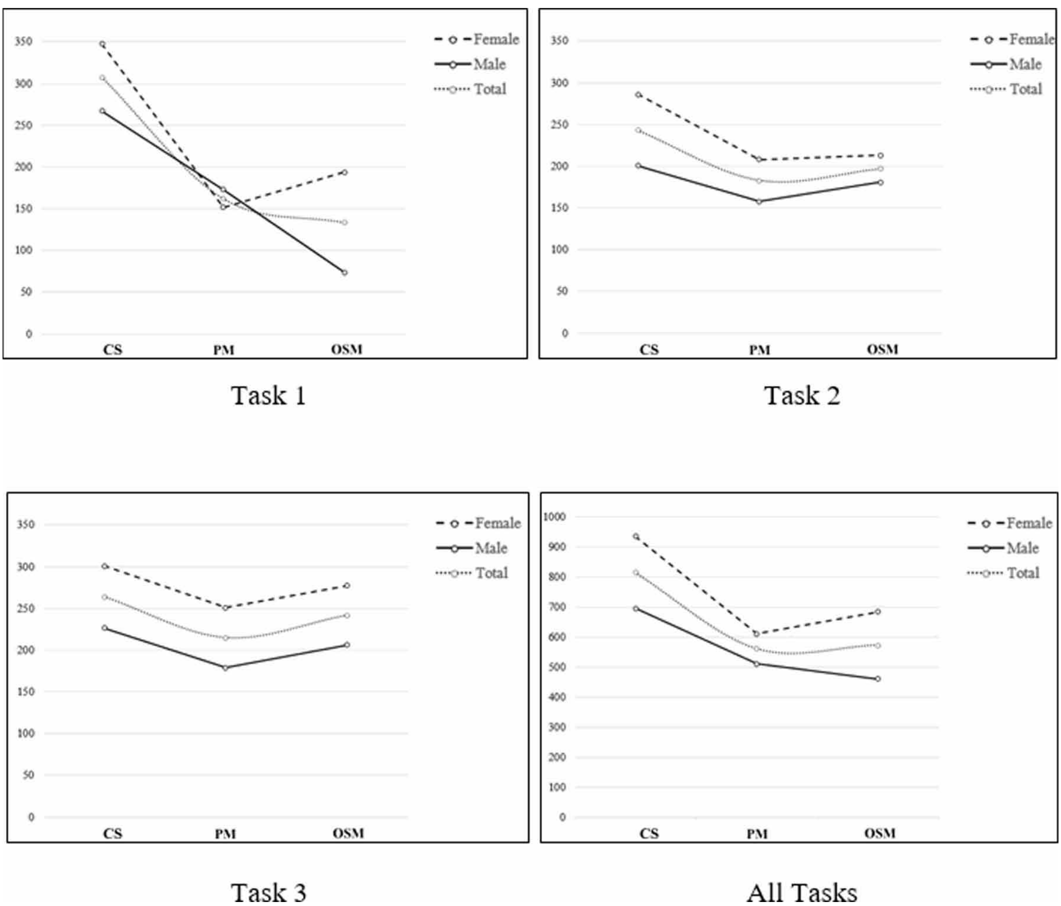

Table 4. The results of the ANCOVA analysis of the average completion times of the tasks

	Source	Sum of Squares	df	Mean Square	F	p	Partial eta Squared
Task 1	Corrected Model	556841.03	9	61871.23	2.72	.02	.39
	Intercept	50352.36	1	50352.36	2.21	.15	.06
	Spatial information score	378.79	1	378.79	.02	.90	.00
	Grade point average	6833.48	1	6833.48	.30	.59	.01
	Weekly hours of playing games	68924.16	1	68924.16	3.03	.09	.07
	Weekly hours of using MUVEs	94489.84	1	94489.84	4.15	.05	.10
	Method	316799.71	2	158399.85	6.95	.00	.27
	Gender	22304.95	1	22304.95	.98	.33	.03
	Method * Gender	53166.14	2	26583.07	1.17	.32	.06
	Error	865925.95	38	22787.53			
	Corrected Total	1422766.98	47				
Task 2	Corrected Model	100416.19	9	11157.35	1.45	.20	.26
	Intercept	310.00	1	310.00	.04	.84	.00
	Spatial information score	4637.90	1	4637.90	.61	.44	.02
	Grade point average	16819.14	1	16819.14	2.19	.15	.06
	Weekly hours of playing games	6301.80	1	6301.80	.82	.37	.02
	Weekly hours of using MUVEs	615.92	1	615.92	.08	.78	.00
	Method	35289.75	2	17644.87	2.30	.11	.11
	Gender	16130.04	1	16130.04	2.10	.16	.05
	Method * Gender	3437.64	2	1718.82	.22	.80	.01
	Error	291501.73	38	7671.10			
	Corrected Total	391917.92	47				
Task 3	Corrected Model	100416.19	9	11157.35	1.45	.20	.26
	Intercept	310.00	1	309.99	.04	.84	.00
	Spatial information score	4637.90	1	4637.90	.61	.44	.02
	Grade point average	16819.14	1	16819.14	2.19	.15	.06
	Weekly hours of playing games	6301.80	1	6301.80	.82	.37	.02
	Weekly hours of using MUVEs	615.92	1	615.92	.08	.78	.00
	Method	35289.75	2	17644.87	2.30	.11	.11
	Gender	16130.04	1	16130.04	2.10	.16	.05
	Method * Gender	3437.64	2	1718.82	.22	.80	.01
	Error	291501.73	38	7671.10			
	Corrected Total	391917.92	47				

continued on following page

Table 4. Continued

	Source	Sum of Squares	df	Mean Square	F	p	Partial eta Squared
Total	Corrected Model	1.520E6	9	168877.36	2.87	.01	.41
	Intercept	217639.19	1	217639.19	3.70	.06	.09
	Spatial information score	47623.25	1	47623.25	.81	.37	.02
	Grade point average	651.16	1	651.160	.01	.92	.00
	Weekly hours of playing games	169146.27	1	169146.27	2.88	.10	.07
	Weekly hours of using MUVEs	109380.14	1	109380.14	1.86	.18	.05
	Method	692584.75	2	346292.38	5.89	.01	.24
	Gender	195686.41	1	195686.41	3.33	.08	.08
	Method * Gender	74996.89	2	37498.44	.64	.53	.03
	Error	2235961.76	38	58841.10			
	Corrected Total	3755858.00	47				

Table 5. The LSD test results of the completion times of the first task by method

Method (I)	Method (J)	Mean Difference (I-J)	Std. Error	p
CS	PM	139.99	53.76	0.01
	OSM	196.53	54.43	0
PM	CS	-139.99	53.76	0.01
	OSM	56.54	54.23	0.3
OSM	CS	-196.53	54.43	0
	PM	-56.54	54.23	0.3

Table 6. The LSD test results of the total task completion times by method

Method (I)	Method (J)	Mean Difference (I-J)	Std. Error	p
CS	PM	245.66	86.38	0.01
	OSM	269.38	87.47	0
PM	CS	-245.66	86.38	0.01
	OSM	23.72	87.14	0.79
OSM	CS	-269.38	87.47	0
	PM	-23.72	87.14	0.79

A Comparison of the Groups' Getting Lost

This study defined getting lost as straying from the ideal route. Table 7 shows the data about participants' getting lost by method, gender, and task.

The researchers conducted a two-way chi-square test (Fisher's exact test) to compare the groups' getting lost by method. The results of the test showed that there was a significant difference between their getting lost in the first task ($X^2(2, N = 48) = 8.18, p = 0.02$), the second

Table 7. Numbers of participants who got lost by gender and task

Method	Lost	Gender	Task 1	Task 2	Task 3	Total
CS	Lost	Male	5	7	8	41 (85%)
		Female	7	7	7	
	Not Lost	Male	3	1	0	7 (15%)
		Female	1	1	1	
		Total	16	16	16	48 (100%)
PM	Lost	Male	3	3	5	28 (58%)
		Female	4	6	7	
	Not Lost	Male	5	5	3	20 (42%)
		Female	4	2	1	
		Total	16	16	16	48 (100%)
OSM	Lost	Male	0	3	5	18 (38%)
		Female	4	3	3	
	Not Lost	Male	8	5	3	30 (62%)
		Female	4	5	5	
		Total	16	16	16	48 (100%)

task ($X^2(2, N = 48) = 8.54$, $p = 0.01$), and the third task ($X^2(2, N = 48) = 7.81$, $p = 0.02$). Using the CS caused the participants to get lost the most frequently, while the OSM caused the fewest participants to get lost. With all three methods, participants got lost more often as they proceeded performing the tasks.

The researchers used a two-way chi-square test to compare the participants' getting lost by gender. For the CS method, there was no difference between males and females' getting lost in the first task (X^2 (1, $N = 16$) = 1.33, $p = 0.57$), in the second task (X^2 (1, $N = 16$) = 0.00, $p = 1.00$), and in the third task (X^2 (1, $N = 16$) = 1.07, $p = 1.00$). There was no difference between genders for the PM method in the first task (X^2 (1, $N = 16$) = 0.25, $p = 1.00$), in the second task (X^2 (1, $N = 16$) = 2.29, $p = 0.32$), and in the third task (X^2 (1, $N = 16$) = 1.33, $p = 0.57$). For the OSM method, there was no difference between the genders in the first task (X^2 (1, $N = 16$) = 5.33, $p = 0.08$), in the second task ($X2$ (1, $N = 16$) = 0.00, $p = 1.00$), and in the third task (X^2 (1, $N = 16$) = 1.00, $p = 0.62$). The researchers used a two-way chi-square test to compare the groups' getting lost by gender. The test results showed that there was a difference by gender in the first task (X^2 (1, $N = 48$) = 4.09, $p =$ 0.04), while there was no difference by gender in the second (X^2 (1, $N = 48$) = 0.78, $p = 0.38$), and third tasks (X^2 (1, $N = 48$) = 0.11, $p = 0.75$).

Observations Related to Getting Lost Using the CS

The researchers observed that the participants failed to follow the ideal route using the CS method on their first attempt and got lost. When using this method, the participants focused on the coordinates on the title bar and did not pay much attention to their surroundings. Some participants used roads they already walked many times. They passed by the goal while changing direction. However, they did not recognize the goal since they were concentrating on the coordinates. Some discovered the goals of the second and third tasks while attempting to perform the first task.

Observations Related to Getting Lost Using the PM

The participants who got lost using the PM method while performing the first task said they did not understand how to use the paper map at the beginning and did not find the bridges. In second and third tasks, they used the PM to get close to the goal, then stopped using the PM and began to use the CS, which caused them to lose their way. Their use of the coordinate system increased as they got closer to the goals. The participants focused on the coordinate system when they were very close to the goal and failed to recognize their location using this method, too. Since there were no indicators on the PM showing their location, the participants had difficulty telling where they were.

Observations Related to Getting Lost Using the OSM

Using this method, the participants noticed that they were going in the wrong direction thanks to the location indicator, and they switched to the correct direction. This indicator made it easy for the participants to find the bridges they were supposed to use particularly in the first and third tasks, but participants could not see them using the other methods. The reason for the OSM task completion times being longer than the PM times was that the participants followed the routes first on the OSM, and then they searched for the crystal artifact without checking the coordinate system. For a majority of the participants using the OSM, it took longer to find the crystal artifact than it took them to get to its location. The participants used fewer routes when they used this method. The participants who used both the OSM and the CS together completed the task faster.

DISCUSSION

This study analyzed the effects of on-screen and paper maps as navigational aids in 3D MUVEs on navigation efficiency. It was found that the method used in the first task and all the tasks influenced the task completion times, and there was a difference between the CS and PM methods, as well as between the CS and OSM methods. The group that did not use any maps completed the tasks more slowly and got lost more frequently. The differences between the CS and PM methods and the CS and OSM methods resulted from the fact that the CS method did not include a navigational aid giving participants visual cues about the environment. For instance, the CS method did not include any visual cues about the bridge they were supposed to cross, which lengthened participants' task completion times. A review of the relevant literature also showed that Tlauka et al. (2005) found that the types of maps used for tasks influenced task completion times. Yokosawa, Wada, and Mitsumatsu (2005) found that participants were more successful in MUVEs when they used methods, which gave them visual cues about the environment.

Although the participants in this study had experience in using three-dimensional multi-user virtual environments (3D MUVEs), they did not have any cognitive maps of the environment since they completed tasks in a virtual world they had not seen before. In MUVEs, one of the most important influences on participants' wayfinding performance is their experience in the environment (Sadeghian et al., 2006). This explains why the method used in the first task influenced the task completion time while those used in the second and third tasks did not. In a majority of the studies in the relevant literature, participants were provided with training in the same implementation environment beforehand. This improves participants' cognitive maps of the environment. Thus, the researchers suggest that user orientations should be conducted in an environment that is not used for the implementation.

CS was the method that caused the most participants to lose their way, and the OSM caused them to get lost the least. With the CS method, the participants could not obtain the general information about the environment since they only followed the coordinates on the title bar, and thus, they got lost more often. If the users do not know about the environment spatially and the location of their destination is known, navigational aids such as teleportation tools and GPS can be used to reach the goal accurately and rapidly. In this situation, users' performances will be better since they do not need to explore the environment (Li et al., 2013). When users do not know about the environment and do not have navigation tools to help them reach the goal, they need to explore the environment to find the goal. When users do not have navigational aids providing direct access to the goal in unfamiliar environments, they tend to concentrate on visual information about the environment provided by navigational aids. Users' orientation in the environment depends on analyzing their location and spatial relationships in the environment and requires landmarks, links, and directions to be able to determine their location and intentionally reach their destinations (Özen, 2006). According to Gramopadhye et al. (2014), if maps and directions are placed in the environment for wayfinding purposes, it will both increase the usability of the environment and reduce workloads. Although the same map was used for both the OSM and PM methods, participants easily reached their goals with the OSM thanks to the affordance indicating their real-time location. However, comparing task completion times showed that the PM method was faster than the OSM method and that the OSM method was faster than the CS method. Although the OSM method enabled participants to move towards their goals more rapidly and get lost less frequently, most participants took more time to get there than they did with PM since they did not use it with CS. With the PM method, the participants got lost more frequently than they did with the OSM method since they made navigation errors and incorrectly estimated distances.

With all these methods, males completed the tasks in shorter times than females (except for the first task performed with PM) but this difference was not statistically significant. Males and females got lost at the same rate. This study is one of the few studies that found no difference in rates of getting lost and task completion times by gender (for another example, see Vila, Beccue, & Anandikar, 2003; Török & Török, 2018). Presumably, there was no difference between participants by gender because they were all students in an instructional technology department. In this respect, users' experience plays an important role in their task completion by gender in MUVEs. In particular, task completion times of users may be long in environments that the users experience for the first time. As participants get more familiar with the environment, their task completion times also get shorter. Female participants got lost more frequently than male participants only while performing the first task, which may be explained by this fact. In this study, the researchers did not match male and female participants according to their characteristics, and they suggest that future studies match the characteristics between genders after an analysis of the differences between males and females.

A review of the relevant literature reveals that the characteristics of users influence their navigation efficiency in MUVEs. Darken and Peterson (2015) stressed that users' spatial visualization skills should be known by researchers and that the spatial skills of users who play games will be higher than those who do not. Darken and Cevik (1999) studied the use of maps in virtual environments and found that individuals with strong spatial skills use maps better than those with weak spatial skills in any given environment. Other studies are reporting that spatial ability influences navigation efficiency and is one of the essential parts of navigation (Bowman et al., 2004; Chen & Stanney, 1999; Downs & Stea, 1973; Sjolinder, 1998; Wu, Zhang, & Zhang, 2009). Çubukçu, Çubukçu, and Nasar (2006) claim that playing computer games played a major role in perceiving the space and transforming it into spatial knowledge. Another study found that users who played computer games were more successful at using maps in MUVEs than those who did not play games (Darken & Cevik, 1999). To mitigate the influence of the participants' characteristics on the implementation results, the researchers created groups considering their spatial visualization scores, weekly durations of playing games and using MUVEs and their experiences with games, computers, and the Internet. Then the researchers checked the groups and confirmed that there was no significant difference between the groups by these independent variables. The researchers also suggest that future empirical studies of this phenomenon similarly check this kind of independent variables.

The participants who used the OSM and the CS together completed the tasks the fastest. Thus, the most important implication of this study's findings is that different navigational aids should be located close to each other for optimum navigation efficiency. This means that the coordinate system should be located closer to the OSM or should be integrated with it. It is a common problem that maps cannot be scaled properly for really large virtual environments (Darken & Peterson, 2015). Therefore, users should be allowed to personalize their navigational aids so that they can be resized and the colors on the map can be changed for people with visual disorders such as color blindness. If it is not possible to use another window for the navigational aid when the size of the window is restricted, then the zoom technique should be used.

CONCLUSION AND FUTURE WORK

In this study, there were differences between the methods by the completion times in the first task, while there was no difference between the methods in the second and third tasks. Had the research been carried out on a single task, the result differences between the different tasks would not have been achieved. Therefore, the researchers suggest that future studies in this field include multiple tasks. The use of objective data collection tools for the implementation will make it possible to analyze the navigation in a micro-dimensional way. To do so, future studies could follow and record users' eye movements during navigation using eye-tracking devices. This will yield objective data about the operations conducted by users during their navigation such as their completion times, their routes, and the number of turns. These data can be used to compare different navigational aids. In this study, the spatial experience involved only two dimensions. However, MUVEs can contain information on the Z-axis. Future studies could examine users' navigation efficiency in spaces containing multiple dimensions and the influence of maps on their spatial experiences.

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