Collaborative Navigation in Virtual Worlds: How Gender and Game Experience Influence User Behavior

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Figure 1: *360 degree panorama image from collaborative language learning application, Berlin Kompass.*

Abstract

There exists a large base of evidence for gender differences in human navigation. However, there is not much research on gender differences in collaborative aspects of navigation, including the interaction of individuals during collaborative wayfinding tasks in virtual environments. In light of this, we present a study of a collaborative virtual environment, Berlin Kompass. The goal of this study was to find out the main differences between genders in collaborative wayfinding. The application was evaluated in the context of foreign language learning in schools with over 200 students, where the users navigated through cityscapes while interacting verbally with each other. We collected and analyzed interaction logs, questionnaire data and audio and video recordings to gain insights into gender-related differences in wayfinding in virtual worlds. Our findings suggest that several differences that are evident in single user systems are not present when the collaborative aspect is added. Male users were more immersed during the task than females. One of the explaining factors for this might be video game experience. Genders also communicated differently – males spoke in longer utterances whereas females had more, shorter utterances. Males referred more to relative directions and dynamic landmarks such as cars and pedestrians while navigating. Males with more video game experience also provided more positive subjective user experience feedback on the application.

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1 Introduction

With the technological advances we have seen in the last years, virtual environments have become prominent in several domains, and these applications have been utilized especially for the educational purposes [Mikropoulos & Natsis 2010]. With the sufficient level of realism, the performance in these applications can be comparable to real world situations [Witmer et al. 1996]. Therefore they are useful tools for measuring real life phenomena such as wayfinding in a controlled environment.

It has been reported in several studies that males and females utilize different wayfinding strategies in real world scenarios [Lawton & Morrin 1999]. In spatial cognition, gender differences are generally considered among the largest differences in all cognitive abilities [Halpern 1992]. Men are more likely to refer to directions and distances but women, on the other hand, refer more to landmarks when finding their way in the environment [Miller & Santoni 1986; Ward et al. 1986]. These differences should be taken into consideration when designing both 2D and 3D virtual worlds, since these potentially subtle differences in wayfinding strategies can often be magnified, with males often outperforming females in virtual environment wayfinding [Waller et al. 1998]. Virtual environments have been used for wayfinding studies on several occasions, as they provide a good way to control the environment where the user, or users, are interacting. The representation of space in these applications varies, ranging from simple 3-dimensional models [Astur et al. 1998] to photorealistic panoramic images [Waller et al. 2004]. Interaction techniques in these virtual environments varies from traditional arrow keys on a QWERTY keyboard [Lin et al. 2013] and joysticks [Hurlebaus et al. 2008] to full embodied interaction utilizing the Kinect device [Kallioniemi et al. 2013].

To date there has been very little research on collaborative wayfinding scenarios, and barely any that concentrates on gender differences in said scenarios. Working together with teachers and students of local elementary and high schools, we explored the gender-based differences in collaborative virtual navigation in the context of foreign language learning. This study was designed to look into the differences between males and females during collaborative navigation in virtual environments and whether they use different wayfinding strategies while navigating in the application. In our study the participants completed a collaborative wayfinding task with another student in a virtual learning environment called Berlin Kompass in which the users must collaborate and verbally interact in order to reach the goal by navigating through 360 degree panoramic images (see Figure 1). In this application one user takes the role of a tourist and the other acts as a guide, who helps the tourist along the route until they find the goal.

This study was conducted using mixed methods and for the results we analyzed the questionnaire and log data and transcribed, analyzed and categorized the contents of the audio recordings in order to gain insight about some of the gender-related differences related to wayfinding in virtual worlds. Our main research question for this study is as follows: “What are the main differences between genders in collaborative wayfinding, and more specifically, are there gender differences in interaction patterns during wayfinding task completion?”

Our findings suggest that there are several differences between genders in collaborative wayfinding in virtual environments. Males referred more to relative directions (e.g. “Turn right from the shopping mall”) and also referred more to dynamic objects such as cars and pedestrians during the performance of the task. The VAD (Voice Activity Detection) analysis of audio transcripts showed that males and females spoke close to same amount percentage-wise, but that males spoke in longer utterances on average. From this we can also predict that females had higher number (but shorter in length) of total utterances. The questionnaire data showed that males felt more immersed during the task and had more experience with video games than females. Video game experience also affected the subjective feedback, as those female users who acted as guides and played less video games tended to give more negative feedback on the user experience questionnaire than other user groups. Video game experience and the feeling of immersion could be some of the explaining factors for the differences between genders in collaborative wayfinding tasks in virtual environments.

In the following, we first summarize the related work on this topic, which is then followed by a comprehensive description of our prototype. Next, we introduce the methodology used in our evaluation and then report the both qualitative and quantitative results of the study. We conclude the paper by discussing these findings and how they could be used in designing future applications and prototypes that cater for both genders.

2 Background

Both the general principles of three-dimensional wayfinding and gender-related differences in spatial abilities have been studied extensively. In this chapter we describe the previous research in both of these fields.

2.1 Wayfinding in virtual environments

As testing people for spatial cognition at real locations (particularly with large-scale geographic spaces) can be prohibitively difficult for researchers, they have often relied on more conventional method of paper and pencil test that assessed knowledge of relative directions from the participant's viewpoint. This method has been mostly abandoned because of its inaccuracies and problems in relation to the real world scenarios and has been replaced by experiments done in virtual environments (VEs). Witmer et al. [1996] studied the transfer of knowledge between virtual environments and the real world, and concluded that when a sufficient level of realism is provided, performance in VEs is comparable to the real environment. Another study by Waller et al. [1998] came to the same conclusion and even suggested that training in VEs could be superior to training in real world situations.

It has been found convenient to utilize VEs, for example, in examining directional knowledge [Waller et al. 2004] and assessing spatial abilities [Waller 2005]. In the former study, Waller et al. concluded that computerized assessment allows the investigators to measure more dimensions about the participants’ behavior and measure them more precisely and accurately than traditional paper and pencil methods. In addition to the greater fidelity in VEs, they might also be more effective than paper and pencil assessments because they are more interesting and immersive medium with which the participants can engage and interact. The standard for measuring spatial and place learning ability in mammals is the Morris water task, where the subject is required to use the spatial cues outside of a circular pool and swim to a hidden goal platform located in a fixed location. This setting was computerized by Astur et al. [1998] and has been since then used for evaluating different aspects of spatial cognition on humans, including gender differences [Astur et al. 1998], spatial memory impairments [Astur et al. 2002] and effects of exercise on spatial tasks [Herting & Nagel 2012].

As was mentioned earlier, 3-dimensional mazes are often used as virtual environments when evaluating spatial cognition. Lin et al. [2013] used a virtual maze for studying gender differences with local and global landmarks as did Lawton & Morrin [1999] in their research. Waller et al. [Waller et al. 2005], Kallioniemi et al. [2013] and Pihkala-Posti et al. [2014] used photorealistic panoramic environments that referenced real world locations. In addition, these systems used embodied interfaces for the interaction [Kallioniemi et al. 2013] and Head Mounted Displays (HDM) for presenting the visual information during the task [Waller et al. 2004].

Wayfinding in collaborative virtual environment is a rather novel research topic. One reason for this is that only through recent technological development have these collaborative elements become prominent in both research prototypes and computer games [Zagal et al. 2006]. Some earlier studies on the topic can be found - Bruckman [1998] found that game-like VEs enable community support and the development of social interaction and relationships. Kallioniemi et al. [2013] studied collaborative wayfinding in the context of landmark saliency and came to the conclusion that when one is designing and implementing meaningful collaborative wayfinding tasks for virtual environments, careful planning with both the context and contents of the application is required.

2.2 Gender and spatial ability

Kimura [1999] has summarized the known gender differences in spatial abilities and wayfinding strategies, and most of the results indicate male advantage in spatial tasks. A meta-analysis of 286 studies conducted on gender differences in spatial abilities [Voyer et al. 1995] showed that there are significant differences between sexes when evaluating mental rotation (the ability to rotate quickly and accurately 2- or 3-dimensional figures in imagination), spatial perception (the ability to determine spatial relations) and spatial visualization (the ability to manipulate complex spatial information in several stages). Out of these 286 studies, male advantage was reported in 78 studies of mental rotation, 92 studies of spatial perception and 116 studies of spatial visualization.

More recent studies suggest that these differences are even larger when the wayfinding task is evaluated in virtual environments [Astur et al. 1998]. Common method for evaluating spatial cognition in virtual environments is virtual mazes, but they favor males heavily because these mazes often rely on geometrical navigation, rather than landmark cues. Sandstrome et al. [1998] and Waller et al. [1998] have concluded that women rely heavily on landmark-based navigation, whereas men use both structural characteristics and landmarks as wayfinding cues. Gender differences are also evident when studying pointing accuracy in both indoors and outdoors – number of studies have shown that males are more accurate in pointing than females, with mean difference in error of pointing ranging from 4 to 40 degrees [Holding & Holding 1989; Lawton 1996]. Pointing accuracy is closely related to the orientation wayfinding strategies where the users rely more on directional relationships of different landmarks in the scenery. Orientation wayfinding strategies are often favored by men [Lawton 1996]. Pointing accuracy may also play a critical role in less restricted and unfamiliar environment, for example an unfamiliar city (or cityscape in virtual context) [Lawton & Morrin 1999].

These differences are reduced according to the task requirements. In a study by Bia et al. [1997], female participants responded faster than their male counterparts in a 2D matrix navigation task when landmark instructions were provided. Previous research by Levy et al. [2005] seems to show no gender differences in the use of different spatial strategies when navigating through water or radial arm virtual mazes.

Figure 2: *Berlin Kompass application used by the researcher in laboratory environment. In this scenario the researcher is pointing at a hotspot which is highlighted in red on the screen.*

3 Berlin Kompass application

We implemented a collaborative virtual environment called Berlin Kompass for the evaluation. In Berlin Kompass, two remotely located users are communicating via audio connection and collaborating in order to find their way through sequential 360 degree panorama images. During the task, one of the users takes the role of a tourist while the other user acts as the guide, trying to instruct the tourist along the route until they reach the goal. Each user has their own view in the application and they can look around freely but only the tourist can move along on the route in accordance with the guide's instructions. The application view is shown as a projection in the front of the user (see Figure 2). In this chapter we describe the interaction design and system architecture of Berlin Kompass and finally describe the wayfinding scenario used in the application.

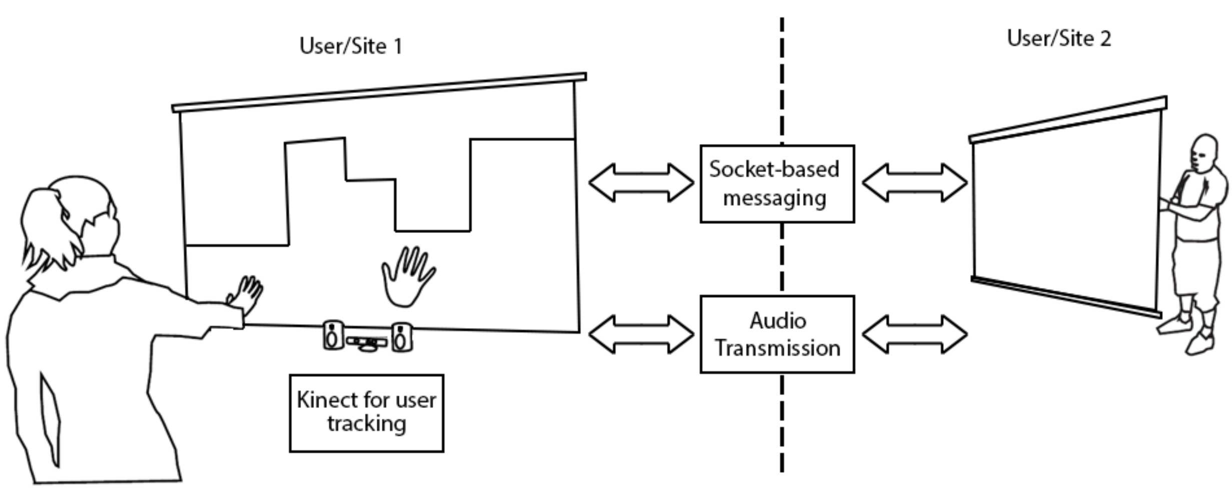

Figure 3: *Application architecture. Users are in remote locations and interact via audio connection. The application states are transferred via socket-based messaging.*

Figure 4: *Participants using the application. The user on the left is acting as the guide (the correct route is indicated with the line) and the one on the right is going through the route in the role of a tourist. The participants are communicating via audio connection.*

3.1 Interaction Design

A general overview of the Berlin Kompass application architecture can be seen in Figure 3. Interaction with the system is done with the user's body. The user can pan the panorama view by turning their shoulders to either left or right to look around the scenery. This gesture emulates the turning of the upper body when one is looking around their surroundings. The user who acts as a tourist can move to the next panorama once he/she finds a green arrow which indicates an exit. This movement is done by walking towards the screen. By activating one of these exits both users are moved to the next panorama. The user interaction and gestures are detected with the Kinect device which is positioned in the front of the user.

The application also detects pointing gestures. Once the user points at the screen, a hand icon is shown indicating the pointing location. The user can point at different hotspot objects that are scattered around the panoramas. These hotspots give out dialogue support and vocabulary for the users and they are always overlaid on landmarks such as store fronts, billboards and residential buildings. Once a hotspot is activated, a synthesized voice is played. This information is also shown as a text to support the adoption of the given term. The hotspot information is usually a description of the pointed landmark and it can be a single noun or adjective or a longer description. The default field of view used for the panorama view was 90 degrees but this could be extended by utilizing multiple screens or projections. Berlin Kompass application provides a reasonably realistic virtual environment by presenting photographic panorama images of real world geographic locations. When combined together with motivating tasks that encourages the users communicate and collaborate with each other it provides an effective method for language learning and wayfinding studies, especially when combined together with embodied interaction and a large projection or screen size.

3.2 System Architecture

The Berlin Kompass application is composed of four components: the Central Logic, Graphics and Voice Service, Kinect Service, and Audio Transmission Service. The Central Logic controls the overall program logic and receives and sends messages from and to all the other services. It also handles the communication with the other user's instance of the application, sending messages whenever exits should be activated.

For the Kinect Service the Microsoft Kinect SDK is used. This service provides the physical locations and skeletal joint data of tracked users. The skeletal data is then used to control panning gestures while location of the user is used to active exits. For the pointing a relative method is used where the hand location of the user relative to the body is translated into screen coordinates. For this a physical interaction zone from the Kinect SDK was used [Vassigh et. al., 2011] The Audio Transmission service can be used to record audio from any local microphone. This is then sent as UDP packages to the other site where it is played back. The Graphics and Voice Service is built on top of Panda3D graphics engine and it displays cylindrical panoramic images with 90 degree field of view [Kallioniemi et. al., 2013].

3.3 Wayfinding Scenario

In the application one of the users takes a role of a tourist who has just arrived to a new and unknown city and wants to find a local tourist attraction. In the beginning the tourist can select one out of the three routes (DDR Museum, Hackescher Höfe or Pergamon museum). All three routes share same panoramas, but Hackescher Höfe and Pergamon museum routes have two extra panoramas. In order for the tourist to find their way to these attractions, they need to ask guidance from the second user who works as the guide and knows the way to the location where the tourist needs to go. Figure 4 shows both user roles in an actual use scenario. The users can communicate freely with each other using with a predetermined language via headsets. Only the user who plays as tourist can move along the panoramas and once they activate an exit, both users are taken to the next panorama. There are three to four exits in each panorama and only one of them is the correct one (takes the users closer to the goal).

Figure 5: *In the dead end situations the tourist describes their location (above) so that the guide can select the correct image out of four different options (below).*

If an incorrect exit is chosen, both users are moved to a dead end panorama, in which the tourist needs to describe their surroundings and the guide needs to find a correct location out of four different images (See Figure 5). After finding the correct location, the guide can activate it by walking towards the screen after which both users are taken back to the previous panorama.

Method

4.1 Participants

95 females (16 ± 8 years old) and 111 males (16 ± 3 years old) students participated in the evaluation after providing informed consent. The participants were from different levels of education, including elementary school, high school and university levels. The experiments were conducted as part of language learning curriculum and those students that attended outside school hours received a movie ticket as compensation. Of the total of 103 pairs, 36 pairs were female-female, 46 were male-male and 21 were mixed gender.

4.2 Procedure

In the evaluation scenario the participants work in pairs and one of the users takes the role of a tourist while the other one acts as a guide. It was up to the participants to decide whom they pair up with and which role they want to take. The users communicated to each other via audio connection and the guide gave out instructions for the tourist on how to go forward along the route. The goal of the task was to find one of the tourist attractions. For the application, three different routes were created: DDR Museum, Hackesche Höfe or Pergamon Museum. There was no time limit for the task. The route selection was done by the guide at the beginning of the task after agreeing on it with the user who acts as a tourist. Both users were given instructions on how to interact with the system in the first panorama and they could also practice the embodied interaction with the system before starting the actual task. The dead end scenarios were described in more detail to the participants only when they made an actual error on route progression and found themselves in a dead end. Evaluations were carried out in two normal, empty classrooms and only the participants and a researcher were present during the task.

4.3 Data collection and analysis

All participants filled out a web-based subjective feedback after they had completed the task. The content of the questionnaire was based on the SUXES [Turunen et al. 2009] which is a user experience evaluation method for collecting subjective user feedback of multimodal systems. The questionnaire consisted of 9 UX related claims to which the participants responded on a 7-point Likert scale, where 1 = "strongly disagree", 4 = "neither agree nor disagree" and 7 = "strongly agree". In addition, the questionnaire consisted of questions about video game experience with a custom scale (with question "How often do you use computer to play video games?" and with answers 1 = Daily, 2 = Weekly, 3 = Every month, 4 = Less than every month, 5 = I do not play video games) and the level of immersion they felt during the task using the same Likert scale as the user experience part of the questionnaire. These results were then analyzed using the two-way analysis of variance.

In addition to collecting subjective feedback, we observed the use of the system and collected audio and video recordings of the participants. The system also logged all interaction by the user during the task, including activating exits and dead ends, pans of the screen, activation of the hotspots and reaching the goal. After investigating the results for individual participants, we analyzed the results for each pair in order to detect any significant effects in male-male, female-female or mixed gender pair interaction during the task. As the routes were of different lengths, the route was considered as a factor in the data analysis.

We also analyzed the audio recordings of 20 randomly selected participants (5 female guides, 5 male guides, 5 female tourists and 5 male tourists) with a VAD (Voice Audio Detection) tool that detected the audio levels. By comparing them to the log data we could detect occurrences of speech and silence during the task and also in each individual panorama. The first panorama and first dead end were removed from the analysis of each task, since the participants used them for practicing the interaction and they also contained speech and assistance by the researchers. Observations were made during the evaluations and they are reported in the results. These findings were confirmed from the video recordings.

After this we also transcribed the actual dialogues for these participants for better understanding of the collaborative wayfinding process. Landmarks referred to were categorized into five different groups and their occurrences counted for measuring the gender differences in landmark-based wayfinding. One interrater was used for this categorization. The categorization was based on a landmark model by Kallioniemi & Turunen [2012]. This model ranks landmarks based on their saliency in three categories: visual, structural and semantic. As the original model was designed for mobile environments and the categorization was based on metadata from maps, and therefore some changes were made so it fits better for virtual environments. Visual landmarks were divided into two categories: residential and office/store front, semantic landmarks were changed into historical landmarks. In addition dynamic landmarks were added. Categories and their descriptions for the landmarks can be seen in Table 1.

Table 1: *Landmark categorization*

Category	Description
Residential	Residential buildings, private housing
Office/store front	Offices and store fronts which often have billboards and/or signs on their façade
Structural	Landmarks that have a major role in the structure of the spatial environment. E.g. roads, traffic signs and bridges.
Historical	Landmarks with cultural and historical importance. E.g. churches and castles.
Dynamic	Dynamic objects in the landscape. E.g. humans, cars and bicycles.

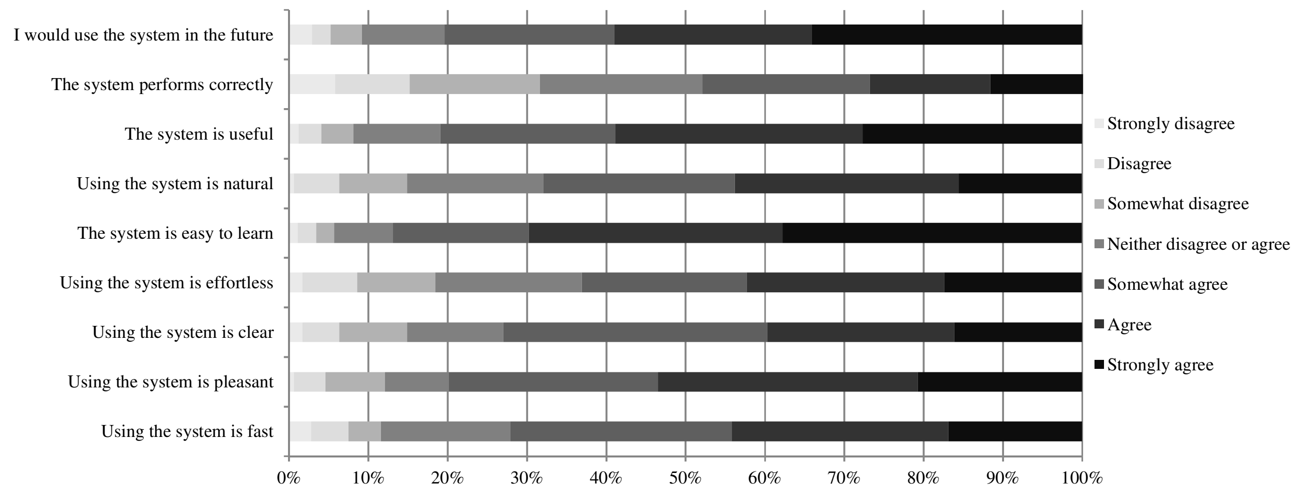

Figure 6: *Distribution of users' experiences with Berlin Kompass.*

In addition to the landmark information, we transcribed any remarks to directions (left/right), references to degrees ("Turn 180 degrees") and also occurrences of hesitation/wayfinding anxiety. In this task, wayfinding anxiety was defined by a simultaneous silence of over 15 seconds of both users.

5 Results

The main research interests in this evaluation were the differences between the genders in collaborative virtual wayfinding. In this section we report both quantitative and qualitative results from the study. This includes data from the logs, our observations during the task, VAD analysis of the audio recordings and transcripts of said recordings.

5.1 Questionnaire

The questionnaire consisted of user experience related questions and questions about gaming experience and immersion. Regarding user experience, 88 % agreed with the statement that the application is pleasant to use (M = 6, SD = 1.29) and 73 % agreed with the statement that the application is easy to use (M = 6, SD = 1.57). 73 % agreed with the statement that the application is easy to learn (M = 6, SD = 1.1). See Figure 6 for distribution of users' experiences with the application. Role and gender had no significant effect on these results.

Regarding immersion, 75 % of the participants who completed the task agreed with the following statement: "When I was guided, I felt like I was actually moving on the streets". For the participants who acted as guides, the statement was "When I was guiding the other user on the route, I felt like they were actually moving on the streets". 63 % of the participants who acted as guides agreed with this statement. Based on the questionnaire results, males were more immersed than females during the task while they were acting as the tourist, $F(1, 95) = 7.257$, $p < 0.05$ but there was no statistically significant difference for the participants who acted as guides, $F(1, 86) = .015$, $p > 0.05$. As was the case with user experience questionnaire, role and gender had no significant effect on the immersion results.

There was also a statistically significant difference on video game experience, $F(1, 216) = 8.215$, $p < 0.05$, where males (M = 2,24, SD = 1.174) spent more time playing games than females (M = 1.78, SD = 0.894). Video game experience correlated with several subjective feedback questionnaire statements. There was a negative correlation amongst females who acted as the guide between video game experience and the statement "Using the system is pleasant" ($r_s = -0.386$, $N = 37$, $p < 0.05$), the statement "Using the system is clear" ($r_s = -0.373$, $N = 37$, $p < 0.05$), the statement "using the system is natural" ($r_s = -0.334$, $N = 37$, $p < 0.05$) and "using the system is entertaining" ($r_s = -0.400$, $N = 37$, $p < 0.05$). These same correlations were not present with male or female tourists or male guides. With male guides, there was a positive correlation between video game experience and the statement "The system performs correctly" ($r_s = 0.291$, $N = 47$, $p < 0.05$) and with male tourists between video game experience and the statement "I would use the system in the future" ($r_s = 0.307$, $N = 46$, $p < 0.05$).

5.2 Interaction data

We compared the effect of three independent variables (gender, role and route) on the interaction action data collected from the log files. This data consists of total time spent on the task, number of dead ends, number of pans and activation of hotspots during the task. The participants were categorized into three different groups: male tourist with male guide, female tourist with female guide and mixed gender pairs.

There was no statistically significant difference on total time spent on the task between all male groups (M = 432.52, SD = 48.269), all female groups (M = 552.95, SD = 57.516) and mixed gender groups (M = 593.11, SD = 70.299). The average total time spent by each group can be seen in Figure 7. Also the selected route had no significant effect on these results. There was no statistically significant difference between the groups on the number of dead ends (male with male: M = 0.78, SD = 0.964, female with female: M = 0.92, SD = 1.628, mixed gender: M = 1.52, SD = 1.750), pans (male with male: M = 63.69, SD = 33.306, female with female: M = 66.22, SD = 43.975, mixed gender: M = 71.05, SD = 26.150), or activation of hotspots during the task (male with male: M = 20.89, SD = 14.257, female with female: M = 23.06, SD = 19.613, mixed gender: M = 15.00, SD = 10.114).

There was a statistically significant difference on how much the user panned the screen between the roles, $F(1, 216) = 7.221$, $p < 0.05$, where the tourist panned the image more than the guide. Another statistically significant difference was found on the activation of hotspots: the users acting as guides activated more hotspots than their tourist counterparts, $F(1, 216) = 6.650$, $p < 0.05$, regardless of gender or the route.

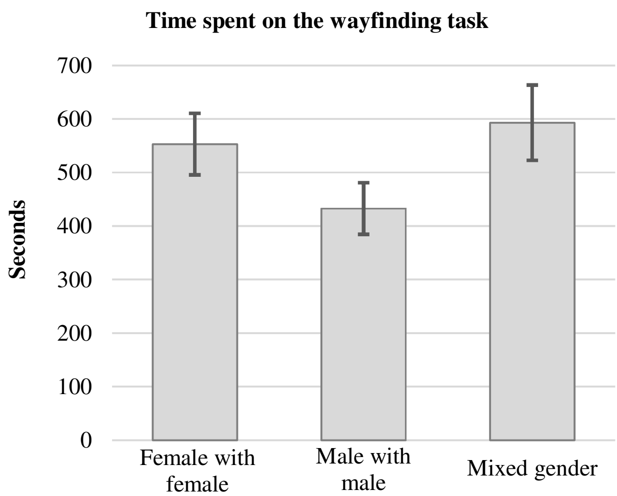

Figure 7: *Total time spent on the wayfinding task by group.*

5.3 Voice analysis

Voice activity detection was performed for a total of 20 audio files recorded during the task. There was a statistical significant difference on the average length of speech segments between the genders, $F(1, 20) = 4.541$, $p < 0.05$. Average length of speech segment was 2.9 (SD = 1.178) seconds for males and 1.7 (SD = 0.719) seconds for females for a total average of 2.3 (SD = 1.34) seconds (see Figure 8.). There was no statistically significant difference on total percentage of speech during the task between genders. On average, males spoke 35 (SD = 12.3) percent of the total time spent on task and females 33.1 (SD = 15.99) percent of the total time spent on the task for a total average of 34.1 (SD = 13.92) percent for both genders. Either age or role had no significant effect on the total percentage of speech.

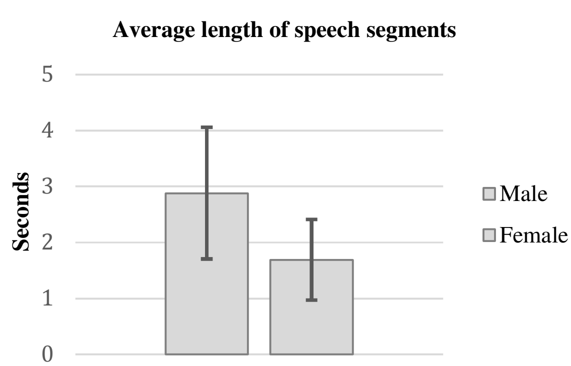

Figure 8: *Average length of speech segments by gender.*

5.4 Audio content analysis

The contents of the audio files were also transcribed and categorized. Males (M = 5.7, SD = 3.860) used more remarks to directions than females (M = 1.5, SD = 2.121), $F(1, 20) = 8.545$, $p < 0.05$, and males (M = 4.2, SD = 0.787) also referred more to dynamic landmarks than females (M = 1.9, SD = 0.787), $F(1, 20) = 5.395$, $p < 0.05$. There was no statistically significant difference in other landmark categories between genders. 30 percent of males used degrees as cues for wayfinding, whereas none of the females did this. Wayfinding anxiety was experienced by 20 percent of analyzed participants from each gender.

5.5 Observations

Based on our observations on the audio content, both males and females used mostly full sentences while describing the virtual environment or while asking for directions and cues. Male participants were active during the initial phase and some started interacting with the system and activating exits before the researcher was finished with the introductory part of the study. There were several ways of coping with wayfinding anxiety, for example asking help from the researcher or using the native language for communication. From total of 20 participants' whose audio content were analyzed, a total of 8 users resorted to using their native language during the task. In most cases, the guide was the more active participant, describing the environment surrounding the correct route to the user acting as tourist, but in 3 of these scenarios the tourist took more active role whereas the guide contented to single word utterances (often "Yes" or "No").

When moving to a new panorama, 4 out of 20 users panned through the whole panorama before continuing the conversation with their counterpart and all of these users were female. Some users used longer and more elaborate vocabulary while conversing which did not necessarily enhance the performance time-wise, but led to some interesting dialogue between the participants. Based on our observations, male participants considered the task more "game-like", and tried to accomplish it as quickly as possible, whereas females concentrated more on the conversation with the other user.

6 Discussion

The results of the study suggest that there exists differences between genders in collaborative virtual wayfinding. Some of these findings are similar to the ones observed in wayfinding tasks performed individually [Astur et al. 1998; Voyer et al. 1995]. Video game experience seems to be an affecting factor with gender differences on the user experience with collaborative virtual environments. This might also be the explaining factor for the higher feeling of immersion for males than females during the task. Those females who acted as guides and had less video game experience felt more negatively about the user experience factors such as "Using the system is pleasant" and "Using the system is entertaining". This indicates that the lack of video game experience affects the user experience among females but not among males. In addition, those male tourists (who usually are in more active role during the task) agreed more with the statement "I would use the system in the future".

6.1 Gender differences in interaction

There was no difference between gender groups in terms of interaction data, but as the context of the application was language learning, the time spent on the task was not indicative of the quality of the learning experience of the student. Our findings were quite different from previous studies with only one user. Based on a study by Coluccia & Louse [2004], males outperform females in virtual environment wayfinding when they have an opportunity to interact actively with the environment and that this is explained by the higher familiarity with virtual environments among males. Males performed faster on average, although these results were within the margin of error. Lin et al. [2012] stated that "males tended to engage in a more exploratory mode of wayfinding" which can be seen from quicker moves but not necessarily optimal routes. They also state that females adopt more conservative strategies where they make more stops and change their orientation and that this strategy leads to "slower moves but not few detours". This was evident in our observation data with the subgroup of 20 participants whose performance was observed during the completion of the task and then verified from the video recordings.

The difference on number of pans between user roles can be explained with the design of the system. As the guide knows where she has to lead the tourist, they usually do not pan much after they have found the correct route. In most scenarios the guides described the environment to the users acting as tourists and looked out for vocabulary cues (e.g. "Can you find the souvenir stand?") which explains the difference in the activation of hotspots.

6.2 Gender differences in communication

Voice activity analysis showed that males spoke in longer utterances on average than females. One of the explaining factors for this could be the immersion. Those immersed during the task might have tendency to communicate more in order to progress. When the results are analyzed in the context of language learning, some interesting observations can be made. A study by Thompson [1975] claimed that there are fundamental differences in the communication between males and females, and that males focus more on competition, status and independence whereas females concentrate more on intimacy and consensus. Our observations support this, as many male users started interacting with the application even before the initial introduction whereas females attempted to maintain a common consensus and strategy with the other user before starting the exploratory part of the task.

As the audio transcripts showed, males referred more to dynamic landmarks during the task. In most of the cases, these were driving or parked cars and in some cases people walking on the street. This is an interesting finding but does not apply to real world scenarios, as these objects are rarely observed twice in the same location and thus are not very good directional cues. Our aim is to create the virtual environment as realistic as possible and therefore these dynamic objects should be removed from the panoramas. Another option would be to create video-based panoramas where these objects were actually moving during the task. In this scenario the videos for both roles should be produced on different times because if the video material is same for both user roles, these objects could still be referred to even though they are moving on the screen.

As the interaction log data shows no evident differences between genders, creating gender-specific guidelines for the interaction is not necessary. The communication-related differences are something that could be taken into account when designing virtual environments where collaboration and communication are key elements. Especially in the context of education, gender should be an affecting factor when the performance is being evaluated, as there are observed differences in how the groups interact with each other. In general, these applications should cater to both genders.

For example, wayfinding anxiety was prevalent in both genders which support the idea that these applications should have some kind of encouraging mechanism for users who remain quiet for a certain period of time. This feature could be implemented with an avatar or just a general text box that encourages the user to communicate more in order to progress with the task. In order to increase the feeling of immersion, some "game-like" elements like scoring system or story-based scenario could be added to the application. Another important addition would be support for different type of learners. Previous performances of users could be used to determine the type of support the application gives to the users, e.g. emphasizing elements that support spatial ability or the user's language skills.

Summarization of this study in a form of gender-related design guidelines for collaborative virtual environments is as follows:

- These applications emphasize the type of communication used. For example, in the context of language learning it could encourage females to speak in longer utterances and males to speak more often
- In order to familiarize the users with the application, it should contain a tutorial where they can practice the interaction. This introduction might also increase the user's level of immersion
- If the system is used for measuring spatial ability and the content consists of photorealistic images, the number of dynamic landmarks (such as cars and pedestrians) should be minimized

In contrast to our original question, "What are the main differences between genders in collaborative wayfinding and are there gender differences in interaction patterns during wayfinding task completion?" we can see some similar patterns to individually performed navigation tasks. Explaining factors for the abundance of male communication might be the higher feeling of immersion or goal-oriented performing from video game experience.

7 Conclusion

This paper studied the gender differences in collaborative wayfinding in virtual environments and then analyzed these results in the light of previous research. Berlin Kompass, a collaborative language learning application was evaluated in schools with over 200 students. We collected and analyzed interaction logs, questionnaire data and audio and video recordings to gain insights into gender-related differences in wayfinding in virtual worlds.

The main findings suggest male groups tend to communicate in longer utterances than their female counterparts in collaborative virtual environments. As males and females communicate close to same amount percentage-wise, this result also indicates that females tend to communicate in shorter utterances but in higher number than males. Males also had higher feeling of immersion while performing wayfinding. Interestingly, those females with less video game experience who acted as the guide gave more negative user experience feedback on the application than the other user groups (male guides, male and female tourists). These findings also indicate that there is no need for gender-specific user interaction design for collaborative virtual environments, but the systems should be specifically designed to cater both genders by supporting their strengths in these scenarios.

For further studies, a type of gaming experience should be categorized in more detail. This should be done because different type of games might affect the performance and user experience differently (e.g. playing Candy Crush on mobile versus playing Minecraft on PC). Also, new methods of increasing the immersion of the users of both genders should be explored.

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