The Effects of Color Coding on Users' Wayfinding Performance in a Virtual Shopping Mall Environment

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Abstract

This study was designed to understand the effect of color coding on users' wayfinding performance in complex buildings such as shopping malls. The experiment was conducted in a virtual environment with two environmental settings; consisting of color coded and neutral schemes. Thirty-two undergraduate and graduate students resident in Ankara were randomly chosen as participants for this study. Participants have equally divided in terms of having a background of visual training and knowledge about color and design issues, and the remaining half have not. There were asked to perform free walk process starting from the entrance to end point in the generic shopping mall in virtual environment. They have been observed in terms of time, route selection, and number of the errors. A clear conclusion could not be derived from the effect of color coding on users' wayfinding performance but it is inferred that color-coding has no significant effect on users' wayfinding performance.

Keywords: wayfinding, color coding, zoning, virtual environment

1. Introduction

The built environment tends to give its users easily accessible information about itself in order to influence their performance positively. Different spatial factors such as layout, landmarks, signage, color etc. affect the ease users perceive the environmental information, influencing their wayfinding abilities. Finding one's way around is a purposeful and motivated activity (Golledge, 1999). The ability to perform this activity in a short time, without experiencing negative feelings such as stress or spatial anxiety helps users' flow in complex buildings. Reaching the desired destination by understanding the environmental information can be supported by one of the basic and easy manipulating design elements such as color (Janzen, 2006). Color has its own language in terms of hue, Chroma, value, and brightness. Using color in layouts of buildings by creating zoning plays a significant role in wayfinding process. Color contribution is considered to be influential in terms of codifying spaces and helping to create visual memory (Spence et al., 2006). The aim of this study is to explore how effective color is as an architectural element towards wayfinding process in a virtual shopping mall environment.

2. Literature Review

2.1 The Definition of Wayfinding

Wayfinding is defined as a process of accessing a certain destination in an acquainted or unacquainted environment (Arthur & Passini, 1992). This process plays a significant role in shopping malls, known as leisure spaces in which negative feelings such as stress, anger and anxiety should be avoided. Wayfinding is also seen to be a mental process in terms of creating a cognitive representation of the perceived environment by using spatial characteristics (Darken & Peterson, 2002). Primarily, the representation of the environment is generated in the mind, then the itinerary is determined and the cognitive process is performed (Ely et al., 2013).

"Wayfinding refers to the various ways people orient themselves to their environment for the purpose of choosing their path" (Carpman & Grant 1993). Users need information to make the right selection of the route carrying them to the desired destination (Helvacıoğlu & Olguntürk, 2011). Information provided by environmental elements, landmarks, signage etc. helps users' wayfinding (O'Neill, 1991). Literature suggests that horizontal signage systems on floors was more effective than vertical wall mounted systems especially in complex buildings such as hospitals and shopping malls (Vilar et al., 2014). On the other hand, landmarks play a crucial role in the development of wayfinding abilities and spatial cognition performance (Osmann & Fuchs, 2006). They help in acquiring the necessary route knowledge for finding their way back, a short cut and making a detour. (Helvacıoğlu & Olguntürk, 2011). In order to measure wayfinding performance from experiments and obtain quantitative data Ruddle & Lessels (2006) proposed VE metric system by considering participant' task performance such as time taken, distance travelled, and number of errors made. The system measures how well a participant performs a task. Wayfinding is the ability to reach a destination in a short time without experiencing fear and stress (Peponis et al, 1990). Error is a miss; occurs when a participant travels within sight of a given location without turning to look at it or takes a wrong turn (Ruddle, Payne & Jones, 1998; Ruddle & Peruch, 2004). Besides, several studies related with the effect of gender on wayfinding perfomance indicated that men tend to be more successful in wayfinding (Cutmore et al., 2000; Kimura, 1992; Lawton, 1994; Linn & Petersen, 1985; Malinowski & Gillespie, 2001; Voyer, Voter, & Bryden, 1995)

2.2 Color Contribution to Wayfinding

Color is an ideal design element to provide environmental information and help users by enhancing their wayfinding abilities (Read, 2003). Several researchers have noted color has a positive outcome on wayfinding (Arthur & Passini, 1992, Helvacıoğlu & Olguntürk, 2011, Evans et al., 1980; Rosenstein, 1985; Stone, 2003; Valdez& Mehrabian, 1994). Color can help structuring the space in a hierarchical way and act as a signage for the building (Dalke et. al, 2005). In complex building such as hospitals and shopping malls zoning is applied to differentiate spaces due to their functions. This zoning can be generated by the use of color coding. Color coding can be achieved by coloring the walls or floors of different areas in different colors. (Helvacıoğlu & Olguntürk, 2010). In order to prevent confusion during wayfinding not more than four colors should be used in color coded buildings (Dalke et al., 2005). Previous studies demonstrated that users who are unfamiliar with settings in a color-coded environments made fewer mistakes in wayfinding behavior than users in a non-color-coded environments (Evans et al., 1980). It is inferred that color can be considered an important influential architectural element in the wayfinding process. Apart from this, color contribution is seen to be effective in terms of codifying spaces and helping to create visual memory (Spence et al., 2006). As mentioned, colors have their own characteristic in terms of hue, Chroma, value, and brightness. Therefore, warm colors make people focus outwards and increase their awareness; whereas cool colors turn people inward and help them focus on visual and mental tasks (Stone, 2003). Blue was perceived more positively and was seen to be more effective than orange in shopping decisions. (Babin et al. 2003). Spaces having white and gray (neutral) colors were considered as sterile and boring by users, whereas spaces with warm (red) colors showed a high level of attractiveness (Mahnke, 1993). Color takes a significant role while encoding and recognition processes thus, it supports to create visual memorization of the environment (Spence et al., 2006). This pilot study purports to understand if color-coding helps users finding their way, through a continuous route.

2.3 Wayfinding in a Virtual Environment

Desktop virtual systems, used usually to observe the cognitive processes of spatial cognition, simplify the investigation of spatial knowledge by easily creating environments of varying complexity and online measuring of the desired parameters (Peruch et al., 2000). Also according to Duarte, Rebelo, and Wogalter (2010), computer generated worlds (VE) have become widely used in researches of different fields. The key feature of VE is its flexibility. That is why it is chosen as a methodology for the present study. The Semantic Environment

Description Scale has been used to compare the experience of a virtual reality model versus the experience of a real building. The results suggest that a virtual reality model provides a fairly accurate representation of a real building (Westerdahl et al., 2006). And also virtual environments have the potential to assist ergonomics in systems analysis and development (Wilson, 1999). By using VE it would be able to design a generic shopping mall and have higher variable control on it. Color zoning is much easier and faster in VE than in real ones. All changes in the experimental environment can be achieved with low effort, cost and less time. Many studies related to wayfinding have been generated through VE (Cubukcu & Nasar, 2005; Omer & Goldblatt, 2007). Even though participants don't feel as though they are in a simulation they are not able to observe the VE as they would in a real one because they have a reduced field of view (Vilar et.al 2014). Apart from this, considering the advantages, immersive VE provides controlling environmental features as well as pragmatic ones.

3. Methodology

3.1 Hypotheses

H1: Color enhances visual memory in wayfinding process; warm colors are more memorable during wayfinding.

H2: Users in color-coded environment settings make fewer errors in wayfinding process.

H3: Users in color-coded environments reach their desired destination by spending less time.

H4: There are expected to be differences in the use of color as a wayfinding element between visually trained users and not.

H5: There are expected to be differences in participants' wayfinding performance according to their gender.

H6: There are expected to be differences in route choices between color coded and neutral environments.

3.2 Participants

Thirty two undergraduate and graduate students carrying their studies in Bilkent University and Middle East Technical University were chosen to participate in this pilot study. Half of the participants have a background related with visual training, more specifically meaning they have knowledge about color and design issues, and the remaining half have not. The

population of study consists of 16 males (50%) and 16 females (50%) equally distributed across the experimental settings and ages between 18-29 years. They have normal sight or use corrective lenses and no color vision deficiencies. They have no physical or mental conditions that would prevent them from participating in a VE simulation.

			Male	**Female**	**Total**
Experimental settings	**Set 1 Neutral**		**8**	**8**	**16**
	Set 2 Color Coded	**Warm scheme**	**4**	**4**	**8**
		Cool scheme	**4**	**4**	**8**
Total			**16**	**16**	**32**

Table 1. Participants according to their gender and setting experience

3.3 Experimental Setting

Virtual environments are usually used to observe the cognitive processes of spatial organization in terms of creating environments in various complexities and measuring the desired parameters (Peruch et al., 2000). Witmer, Bailey, and Knerr (1996) have demonstrated that the values obtained from tests using virtual spaces are nearly equal to those obtained from real world tests.

In the current study, virtual environment of a generic shopping mall with three different color-coding schemes was used. The four story shopping mall consists of retail shops, exhibition areas, food court and terrace. In first experimental setting there was no color coding and the colors were presented as neutral. The other two settings consisted of a color-coded environment in two schemes dominated by warm and cool colors respectively. The colors selected to be used in the experiment were the most well-known colors and used by Turkish people (Ekici et al, 2006). The warm color dominated set was composed of orange, yellow, pink and red while the cool color dominated one had blue, brown, purple and green. All the other spatial elements such as space organization and illuminance level (800 lx) were kept the same in three conditions. The settings were created in Sketch Up and subsequently rendered

in Unreal Engine 4 software which provides realistic simulations of the environment and simultaneously makes a way for controlling the users' navigation in the spaces.

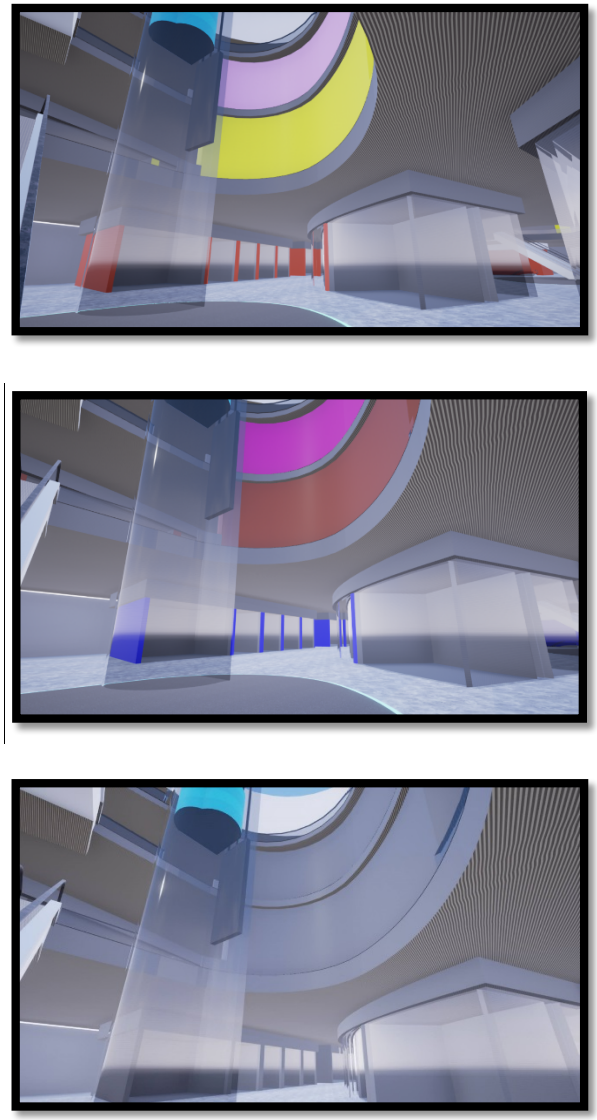

Figure 1. Warm, cool and neutral color-coded settings

3.4 Instruments and Procedure

In order to understand the effect of color-coding on user wayfinding, certain factors were defined as independent and dependent variables. An independent variable is defined as the number of samples from which inferences will be made (Argyrous, 2011). Experimental sets, gender and the bachelor background of the subjects are defined as independent variables. A dependent variable is defined as affected by an independent variable (Argyrous, 2011).

Time spent in simulation (sec), route choices and error numbers are defined as dependent variables.

The experiment was conducted in an artificially illuminated environment (200 lx) in front of a calibrated computer monitor. Primarily, the participants seating in front of the computer were asked about their general demographic information, and then an animated tour of the generic shopping mall they were going to walk through was demonstrated. This tour helped them to become familiar with the environment but none of the spaces were emphasized more than the other in order not to give clues for the following activity.

The participants were requested to go from the entrance to the bookshop. During this phase they were alone in front of the monitor and were not allowed to ask questions. At the same time, the researcher staying in front of another monitor showing the same desktop as the participant's one, marked down the time duration, the number of errors and route choices of each participant to the data sheet (See Appendix A). When they reached the target destination the experiment was over. In order to measure visual memory, the participants were asked to write down the colors associated with the respective floors. Consequently, a presence questionnaire created by Witmer & Singer (1994) was distributed to them in order to understand the subject's level of presence in the virtual environment (see Appendix B).

All statistical analysis were carried out by using the software SPSS (Version 21, IBM SPSS Statistics) regarding an error probability Type I (α) of 0.05. In order to understand the effect of color coding in their wayfinding performance of users an independent samples t test comparing their time, errors and route choice in two different environments was run. The two different environments in this test stand for the color coded (both cool and warm color coded settings) and the neutral one. Another additive test comparing cool and warm environments was conducted. The consequent analysis regarded the difference in the wayfinding performance expected to be observed between visually and non-visually trained users. The same test was run to understand if there are differences in the wayfinding process of the participants according to their gender. Lastly, in order to find the most memorable colors in the wayfinding process, a cross tabulation giving the number of participants who matched correctly the color and the floor number was prepared.

4. Findings

The data concerning the time, errors and route choice of all the 32 participants who felt present during the wayfinding experiment in virtual environment, was gathered and analyzed to verify the hypotheses stated in section 3.

4.1 Presence Test

All the 32 participants felt present according to the Presence Questionnaire prepared by Witmer and Singer. The cross tabulation of the questions of the questionnaire and their responses, Table 1 showed that all the users felt moderately or completely responsive to the virtual environment.

Table 2: Presence questionnaire and the participants' answers

Questions * Scale Crosstabulation

			Scale			Total
			Not responsive	Moderately responsive	Completely responsive	
Questions	1	Count	0	12	20	32
		% within Scale	0,0%	15,6%	25,3%	20,0%
	2	Count	1	15	16	32
		% within Scale	25,0%	19,5%	20,3%	20,0%
	3	Count	1	19	12	32
		% within Scale	25,0%	24,7%	15,2%	20,0%
	4	Count	1	14	17	32
		% within Scale	25,0%	18,2%	21,5%	20,0%
	5	Count	1	17	14	32
		% within Scale	25,0%	22,1%	17,7%	20,0%
Total		Count	4	77	79	160
		% within Scale	100,0%	100,0%	100,0%	100,0%

4.2 Independent t test comparing wayfinding performance in color coded and neutral environments

Half of the participants were asked to perform their wayfinding activity in a color coded environment, and the remaining in a neutral one. The independent samples t test considering a 95% level of significance compared the three variables (time, errors, and route choice) in these two different environments. No significant difference was observed in the time users need to reach their pointed destination. ($t= 0.864$, $p = 0.394$) The recorded fastest time was 36s and the slowest was 270s. Likewise, there has not been found any significant difference between the numbers of errors users performed in the two environments. ($t=0.855$, $p=0.4$). Moreover, no difference between the route choices of the participants in the two settings has

been observed. (t=0.34, p=0.729). Therefore, the statistical analysis did not verify the first and second hypotheses stating that users in color coded environments would reach the destination faster and by performing fewer errors during the process. Furthermore, the third hypothesis stating that there would be route choice differences between the users in these two environments was not verified.

Table 3: Two sample T test for neutral and color coded environments

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Time	Equal variances assumed	,153	,699	,864	30	,394	16,250	18,798	-22,142	54,642
	Equal variances not assumed			,864	29,010	,394	16,250	18,798	-22,197	54,697
Error	Equal variances assumed	1,041	,316	,855	30	,399	,500	,585	-,694	1,694
	Equal variances not assumed			,855	27,633	,400	,500	,585	-,698	1,698
Route	Equal variances assumed	,446	,510	-,349	30	,729	-,063	,179	-,428	,303
	Equal variances not assumed			-,349	29,982	,729	-,063	,179	-,428	,303

Another additive independent t test has been run to compare the wayfinding performance of users in cool and warm color coded environments. The total number of the participants was 16 (half of the total number). The results of the analysis didn't show any significance difference in terms of time, no. of errors and route choice between the colored environments. (t_{time}= 0.32, p_{time} = 0.748 ; t_{error}=0.001 p_{error} = 1; t_{route}=-1.52, p_{route} = 0.14).

4.3 Effect of gender on the wayfinding performance

Another important issue of this study is to find if there exist any difference in the wayfinding performance between males and females. An equally distribution of the 32 participants according to their gender was conducted. The result of the independent t test with a 0.05 alpha significance level showed that there were not any significant difference in the time, number of errors and route choices of the participants according to their gender. (t_{time}= -0.68, p_{time} = 0.501; t_{error}= 0.001, p_{error} = 1 t_{route}=-1.83, p_{route} = 0.076). These findings rejected the 5th hypothesis claiming the existence of differences in the wayfinding performance between males and females. (Table 3)

Table 4: Two sample T test for gender difference in wayfinding

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Time	Equal variances assumed	,011	,919	-,682	30	,501	-12,875	18,885	-51,444	25,694
	Equal variances not assumed			-,682	29,376	,501	-12,875	18,885	-51,478	25,728
Error	Equal variances assumed	,325	,573	,000	30	1,000	,000	,592	-1,208	1,208
	Equal variances not assumed			,000	28,391	1,000	,000	,592	-1,211	1,211
Route	Equal variances assumed	4,061	,053	-1,838	30	,076	-,313	,170	-,660	,035
	Equal variances not assumed			-1,838	29,462	,076	-,313	,170	-,660	,035

4.4 Effect of visual related background on the wayfinding performance in color coded environments

Another independent t test (alpha=0.05) was run to verify the 4th hypothesis pointing out differences between the wayfinding performances of visually and non-visually trained users. There were 16 participants who performed their experiment in color coded environments, and half of them were students whose departments were related with visual studies. The results (Table 4) showed no difference between the performances of these two samples. (t_{time}= -2.67, p_{time} = 0.18 ; t_{error}= -1.49, p_{error} = 0.16; t_{route}=-0.47, p_{route} = 0.64)

Table 5: Two sample T test for differences between visually trained users and not

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
Time	Equal variances assumed	,730	,407	-2,679	14	,018	-54,125	20,202	-97,453	-10,797
	Equal variances not assumed			-2,679	13,843	,018	-54,125	20,202	-97,499	-10,751
Error	Equal variances assumed	2,333	,149	-1,497	14	,157	-1,000	,668	-2,433	,433
	Equal variances not assumed			-1,497	10,658	,163	-1,000	,668	-2,476	,476
Route	Equal variances assumed	,467	,506	,475	14	,642	,125	,263	-,439	,689
	Equal variances not assumed			,475	13,985	,642	,125	,263	-,439	,689

4.5 Color memory

The last part of the conducted experiment for this study was to match the color with the respective floor by the participants who had performed it in colored settings. The cross tabulations (Table 6 & 7) showed that the participants mostly could match and remember the blue and purple color, (7 out of 8 rights) both belonging to the cool colors dominated scheme. The most remembered color in the warm dominated color scheme was red. (6 out of 8 right) These findings disapproved with the first hypothesis stating that warm colors are more memorable than cool ones.

Table 6: Warm colors

Floor * Color Crosstabulation

Count

		Color				Total
		Orange	Yellow	Pink	Red	
Floor	Groundfloor	5	0	0	0	5
	1st floor	0	5	2	0	7
	2nd floor	0	2	4	1	7
	3rd floor	0	0	1	6	7
Total		5	7	7	7	26

Table 7: Cool colors

Floor * Color Crosstabulation

Count

		Color				Total
		Blue	Brown	Purple	Green	
Floor	Ground floor	7	0	0	0	7
	1st floor	1	3	1	1	6
	2nd floor	0	1	7	0	8
	3rd floor	0	0	0	5	5
Total		8	4	8	6	26

5. Conclusion and Discussion

In this study, the effects of color coding on wayfinding performance in a virtual shopping mall environment was explored by analyzing the time spent, route choices and error numbers of the participants. This study discovered three main, significant results. Primarily, it was investigated that color coding is not significantly influential on wayfinding performance in virtual shopping mall environment. Furthermore, there were expected to be differences in wayfinding performance according to gender but no gender difference was found in performance. Besides, it was considered that there are differences in the use of color as a

wayfinding element between visually trained users and not. However, there is no significant difference in the wayfinding performance between visually trained and non-visually trained participants.

The literature survey demonstrated that color could be expected to influence wayfinding performance (Evans et al., 1980; Rosenstein, 1985; Stone, 2003; Valdez& Mehrabian, 1994; Helvacıoğlu & Olguntürk, 2011). However, the results of the statistical tests could not confirm this statement. There is no significant difference in the wayfinding performance in terms of the time spent, route choices and number of errors in color coded environment compared with neutral environment. This situation may be associated with the selected building type. Since, shopping malls have already considerable visual elements and colors in their ambiance; color coding may not take attention in terms of influencing perception of the participants. Additionally, the design of color coding may be reconsidered; not only ceilings but also floors and walls can be defined by using color in order to draw more attention.

Contrary to previous studies (Schmitz, 1997; Waller et al., 2011; Galea and Kimura, 1993), no gender difference was found in wayfinding performance; both genders have presented equal performance. This result was corresponded to study conducted by Helvacıoğlu and Olguntürk.

It was also stated that in literature the memorability of the colors is significantly associated with hues of warm colors (Hidayetoglu et al., 2012; Read 2003, Pile, 1997). Blue and purple belonging to the cool-colored setting are the most remembered colors contrary to these studies. Furthermore, it is confirmed that the most remembered colors are blue and purple (Babin et al., 2003; Crowley, 1993).

Apart from these, it was expected that there are differences in the use of color as a wayfinding element between visually trained users and not. However, there is no significant difference was found in the wayfinding performance between visually trained and non-visually trained participants. This may result from the number of participants because it is observed that there is an inclination; if the population size is more than current size, visually trained participants may make difference in terms of using color as a wayfinding element compared to non-visually trained participants.

Number of participants can be seen as a limitation of this study. As a further study suggestion, larger size of population may be more effective in order to get certain results. Being gamer and non-gamer is also another significant factor in terms of influencing the performance of

the participants. Gamer participants are more likely to present good performance in wayfinding process in a virtual environment.

To conclude, this study would help designers and researchers in order to understand the influence of color on wayfinding process as an architectural element. Wayfinding design is explained as a set of tools making a way for helping people to reach their destination in an unfamiliar environment (Dogu & Erkip, 2000). The use of color in this process may be effective in convenient building types with proper design ideas.

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Appendices

Appendix A

IAED 502 Data Sheet

General information:

1.Name _____

2.Sex Male ☐ Female ☐

3.Department Visually-trained ☐ Other ☐

Wayfinding in VR:

1.Time _____

2. No. Of errors _____

3. Route Choice Long ☐ Short ☐

Notes:

_____

_____

_____

_____

_____

Color memory:

Write the color of the belonging floor number:

1st floor _____

2nd floor _____

3rd Floor _____

4th floor _____

Notes:

_____

_____

Appendix B

PRESENCE QUESTIONNAIRE

(Witmer & Singer, Vs. 3.0, Nov. 1994)* Revised
by the UQO Cyberpsychology Lab (2004)

Characterize your experience in the environment, by marking an "X" in the appropriate box of the 7-point scale, in accordance with the question content and descriptive labels. Please consider the entire scale when making your responses, as the intermediate levels may apply. Answer the questions independently in the order that they appear. Do not skip questions or return to a previous question to change your answer.

WITH REGARD TO THE EXPERIENCED ENVIRONMENT

1. How much were you able to control events?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL SOMEWHAT COMPLETELY

2. How responsive was the environment to actions that you initiated (or performed)?

|_____|_____|_____|_____|_____|_____|_____|
NOT RESPONSIVE MODERATELY RESPONSIVE COMPLETELY RESPONSIVE

3. How natural did your interactions with the environment seem?

|_____|_____|_____|_____|_____|_____|_____|
EXTREMELY ARTIFICIAL BORDERLINE COMPLETELY NATURAL

4. How much did the visual aspects of the environment involve you?

|_____|_____|_____|_____|_____|_____|_____|
NOT AT ALL SOMEWHAT COMPLETELY

5. How natural was the mechanism which controlled movement through the environment?

|_____|_____|_____|_____|_____|_____|_____|
EXTREMELY ARTIFICIAL BORDERLINE COMPLETELY NATURAL