CHAPTER SEVEN
Conduct of the Experiments

In this Chapter, the conduct of the wayfinding experiments is described in five sections. It begins with a brief account of the preparatory work carried out for the experiments and is followed by a summary of the participants, a description of the implementation site of the experiments and the equipment used. The conduct of the two sets of wayfinding experiments in two different urban settings is then presented in accordance with the experimental design discussed in Chapter 6. Finally, the procedures of multi-source data capture during the experiment are described.

7.1 Preparation for the experiments

Before conducting the experiment designed for this research, extensive preparatory work was carried out. First of all, an information sheet was written to inform potential participants about the background to the experiments, including the broad objective of the research, the general procedure, as well as the site and equipment used in the experiments. In addition, prospective participants were assured that all of the information provided and collected during the experiments would be treated in strict confidence and that they would not be individually identifiable in the results in any way. Also included in the information sheet was a statement on their right to withdraw from the experiments at any time and without giving any reason. A consent form was prepared for signature by participants in accordance with UCL regulations for using the VR lab. This was to ensure that participants had understood all of the information given, any risk that might occur during the experiments and their right to withdraw. A copy of the information sheet and the consent form can be found in Appendix I. Furthermore, data protection and ethic approval forms were completed by the investigator. Approvals were issued by UCL Records Office and UCL Committee for the Ethics of non-NHS Human Research respectively for recording participant contact data and using the VR lab for experiments.

Having anticipated that the period required to complete the experiments on all participants would last a few months, a procedure and a check list was drawn up for the investigator to ensure that the experimental procedures used for each participant would be consistent. The procedure listed all the steps in the process which should be followed by the investigator before, during and after each experiment. The process steps included preparing for the experiment, such as by ensuring that VR models and equipment were ready, that participants

were informed and that correct experiment procedure would be followed in the correct sequence. The check list included all the materials needed for the experiments such as all the questionnaires, task sheets and necessary equipment in the VR lab.

7.2 Participants

The length of each experiment necessitated the use of an opportunity sample of volunteers who were willing to devote the necessary time and effort, often at short notice due the booking constraints of the VR lab. Within this situation, an effort was made to include participants from a range of age groups, different backgrounds and different disciplines. Participants received no payment or any form of incentive for their participation.

A total of 30 participants, who had not been involved in any of the pilot experiments discussed in §6.5, were recruited to take part in the final experiment. There were 14 females and 16 males. One female decided to terminate the experiment after the first task in the first test setting. Another two participants, one male and one female, only completed 5 out the 6 tasks in their first test setting because of motion sickness and VR lab booking time. However, these two participants did complete the part 1 of the post-experiment questionnaire. These two questionnaire responses were included in the analysis in §8.3. The other data collected from these two participants were not included in the data analysis. This reduced the total number of completed participants to 27 with 12 females and 15 males. The mean age of the participants was 33, with ages ranging from 23 to 52 years. Among the full participants, were 12 British and 15 non-British. All but two of the participants (who were visitors with knowledge of UK) were residents of the UK. 20 participants were White (including British White, European White, non-European White) with 7 non-White (including Asian, Orientals and Mixed). For educational background, all participants had a university degree. Participant occupations included university researcher, PhD student, police officer, lecturer, project manager and artist; educational backgrounds included GIScience, geography, planning, computer science, architecture, social science, arts and humanities. All participants had knowledge of using the Internet and searching travel information via the Web, but few of them used a PDA frequently. None of them had previously used a mobile device as a navigation assistant in wayfinding tasks. In addition, none of the participants had any previous familiarity with either of the two urban test settings. A general summary on all participants is shown in Table 7.1 below.

Participants	No.	Males	Females	Average age	British	Non-British
Included in the result data	27	15	12	33	12	15
Excluded (because partially completed tasks)	2	1	1	29	1	1
Excluded (because withdraw from the experiment)	1		1		1	

Table 7.1 Participants characteristics (small number data suppressed).

7.3 Experiment site and equipment

The study areas were two urban areas which had been created as VR models (discussed in §6.2.1), referred to here as urban setting 1 (U1) and urban setting 2 (U2). These covered areas of approximate 48 hectares and 35 hectares respectively. The two urban VR models were implemented in an Immersive Projection Technology (IPT) VR laboratory located in Department of Computer Science at University College London.

This CAVE-like IPT system was used to generate the virtual environment for the experiments. It was powered by a Silicon Graphics Onyx2 with eight 300MHz R12000 MIPS processors, 8GB RAM and four Infinite Reality2 graphics pipes (Swapp, 2004). This machine processed all the graphics input pertaining to the system. The images were projected onto three 3 metre by 2.2 metre walls (front, left and right wall) and a 3 metre by 3 metre floor (Figure 7.1 (a) and (b)). Participants wore CrystalEyes stereo glasses during the experiments. The stereo glasses incorporate tracking devices (Figure 7.2 (a)) that can record participant locations using an Intersense IS9000 system with 2mm accuracy, with an end-to-end latency of 50ms. The IPT system runs at a maximum refresh rate of 45Hz in stereo. In this experiment, participant locations within the VR models were recorded once every second with 0.1m accuracy. In addition, a joy-stick like device was used to control movement in the VR environments, as shown in Figure 7.2 (a). Although participants could physically move in the 9 square metres of VR laboratory space during the experiments, the 'walking' and 'moving around' in the VR environments were actually controlled by using the joy-stick device. In the VR test environments, participants could turn their head to the left or to the right in order to view the surrounding environments. The view was not restricted to a narrow angle. Figure 7.1(a) illustrates a close-up view of a participant navigating using a joy-stick device in test urban setting 1 (U1) with projected images on the floor and the walls of the VR laboratory, whilst Figure 7.1(b) shows a more general scene with a participant in test

urban setting 2 (U2) with projected images on the three walls and the floor. Other scenes from both urban settings are given in Appendix III.

(a)

(b)

Figure 7.1 Scenes of the experiment settings in the VR laboratory; the PDA can be seen on top of the tripod to the right in (b).

(a)

(b)

(c)

Figure 7.2 Elements of equipment used in the experiments:

(a) stereo glasses, joystick and track device; (b) a general view of the equipment in the CAVE;

(c) the PDA placed on a small platform.

Another set of equipment used in the experiments comprised a Personal Data Assistant (PDA) and a tripod with a small platform for placing the PDA (Figure 7.2(b) and Figure 7.2(c)). The model of the PDA was an HP Jornada 568 (donated by Hewlett Packard Labs, Bristol) with a 240 by 360 pixels screen and 63.32MB ARM SA1110 processor. A stylus was used to activate programmes or to select items by tapping the screen. The information for assisting wayfinding could be accessed through the PDA using a standard Internet Explorer interface. In addition, a small platform with a wooden edge and felt surface was specially made for the experiments, shown in Figure 7.2 (c). This small platform fixed on top of a height adjustable tripod allowed participants to easily place the PDA within reach (Figure 7.2 (b)). This was done to reduce the inconvenience that participants might feel since they would have to hold the joy-stick during the wayfinding tasks.

Additionally, a laptop computer was used for running the observation recording program which was created for this research (discussed in §6.2.3). This program used a purpose-built clickable interface and was installed in the laptop as an interface to a Microsoft Access database. The laptop was used solely by the investigator, in the background, to record the direct observations of participant actions during the experiments.

7.4 Experimental procedure

Prior to the on-site experiments, an email or a printed letter was sent out to all recruited participants. Provided in the email/letter was the information sheet and the consent form discussed in §7.1. The pre-experiment questionnaire (see §6.1 and Appendix I) was also attached with the email/letter. All participants were required to complete the questionnaire before the experiments, and to bring the completed questionnaire and the consent form with them when attending the experiments. In addition, a map was included giving the location of University College London and Department of Computer Science building where the VR Lab is located, together with a written instruction on how to get the VR Lab.

When the participants came for the on-site experiments, the investigator checked with them if the pre-experiment questionnaire had been completed. Then the experiment procedure and the equipment were further explained to the participants. All questions concerning the procedure were answered. Items in the consent form were also explained to make sure that the participants fully understood their right to withdrawn from the experiment and the possible potential risks (e.g. motion sickness) caused by using VR environments. No information was given on the real towns upon which the VR urban models had been based. All participants were satisfied with the information provided about the experiments. The consent form was signed by all participants. This process took approximately five to ten minutes.

At the beginning of the wayfinding experiments, a training session was provided to all participants inside the VR environment. Figure 7.3 (a) shows the map of the training area, whilst Figure 7.3 (b) and (c) shows two views of it. One aspect of the training session was to familiarise the participants with navigating in a VR environment. The participants, wearing a pair of stereo glasses, were shown how to use the joystick to 'walk' around inside the VR training area. They were informed that they could move their head left or right / up or down to view the surroundings as in the real world. They were also informed that they could physically move around in the 3m by 3m lab floor area, but that the movement in the VR environment was controlled by the joystick. In addition, all participants were advised to

'walk' along the road network, rather than roam amongst the buildings or across the lawns which would be parts of residents' garden areas. The participants were then allowed to practice navigating inside the VR training area for approximately 5 minutes. Another aspect of the training session was to instruct the participants on how to access the information using a PDA when attempting the wayfinding tasks. All options were shown to the participants for acquiring maps, text and voice information; and they were informed that they could choose any available information from the PDA during the experiments, at any time according to their preference and needs in completing the wayfinding tasks. The participants were given about a further 5 minutes to practice. The total training session took approximately 15 minutes.

(a)

(b)

(c)
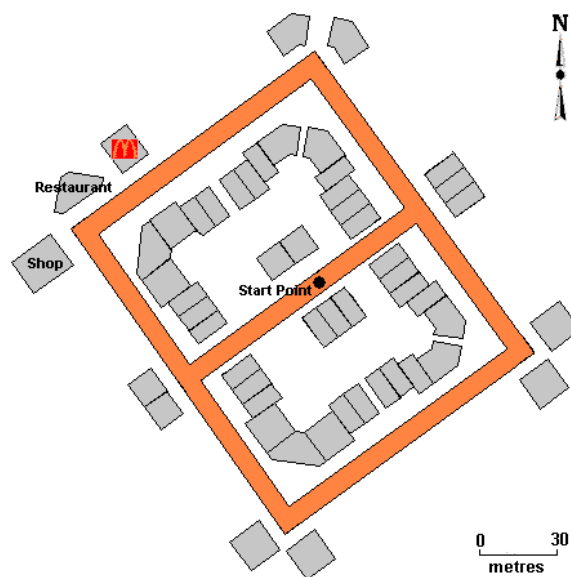
Figure 7.3 The training area: (a) map of the area; (b) and (c) views of the training area.

The main wayfinding tasks were carried out in two VR urban models: urban setting 1 (U1) and urban setting 2 (U2). All participants were required to complete the pre-described wayfinding tasks in both settings. Half of them started the first set of wayfinding tasks in U1, whilst the other half started in U2, thus alternating the setting in which the participants started and finished their tasks (Table 7.2). Before the experiments were started, the participants were advised and encouraged to voice their thoughts and emotions during their wayfinding activities. However, the participants were not interrupted or reminded to do this during the experiments. During the experiment for each urban setting, an A4 page was provided on which all pre-described wayfinding destinations were printed in sequence. This paper, which was fixed on the top of the tripod, can be seen in Figure 7.2 (b). No required time limit was set for the participants to finish the wayfinding tasks.

The urban setting used for the first part of wayfinding tasks	Participants
Urban setting 1 (U1)	P01, P03, P05, P07, P09, P11, P13 P15, P17, P19, P21, P23, P25, P27
Urban setting 2 (U2)	P02, P04, P06, P08, P10, P12, P14 P16, P18, P20, P22, P24, P26

Table 7.2 Sequence of urban settings used for each of the participants.

The process of conducting the experiments followed the designed wayfinding experiment procedure as discussed in §6.4. For the first set of wayfinding tasks, all participants were

instructed to begin at a car park (marked P in Figure 6.12 (a) and (b)) as the starting point and to then find five destinations D1 to D5 sequentially before returning to the car park (see Table 7.3). Figure 7.4 (a) to (f) and Figure 7.5 (a) to (f) show scenes of the start/finish point and five destinations D1 to D5 in both VR urban settings U1 and U2 respectively. The participants were advised to take rests either at any one of the destinations or any other time when they felt this was needed. During the experiments the participant's exact current position was not displayed on the PDA. The reasons for this are twofold. Firstly, in the real world, although the location of individuals can be identified through location-aware mobile devices, this would be to different levels of accuracy depending on the positioning technologies used (GPS, cellular network based) and the nature of the urban area (high-rise city centre, low-rise suburban). Hence, given current technologies, the location of a mobile device cannot accurately and consistently be expressed as a point in urban areas. Secondly, not providing exact current position puts all participants on an equal footing regardless of whether maps, voice or text are used. However, the starting point could be clearly identified by participants. No participants had problems in locating the start points in settings U1 and U2. During the experiment, all participants used the PDA to access information (route instructions and/or maps of the area) for assisting their wayfinding activities. Of the 30 participants that took part in the first set of wayfinding tasks, 27 completed all of the pre-specified tasks. Among the three participants who did not complete the tasks, one decided to withdraw from the experiment after reaching the first destination D1 in setting U1. This participant did not feel very well yet still wanted to carry on. Later, this participant was advised to stop. The other two participants that did not complete the tasks stopped at destination D5 (one in setting U1 whilst another in setting U2) after finished five wayfinding destinations. Both were ended due to motion sickness caused by navigating in VR. The time taken for completing the first set of wayfinding tasks varied depending on each participant's situation, ranging from 40 minutes to 1 hour. This also included time taken for rests. The post-experiment questionnaire part 1 (discussed in §6.3, see also Appendix V) was given to each participant after he/she finished the first set of wayfinding tasks whether in setting U1 or U2. Participants were led to an adjacent room in order to finish the questionnaire and the investigator was on hand to answer any questions that they might have about the questionnaire. The time for completing the post-experiment questionnaire part 1 was approximately 15 minutes.

	Destinations in U1	Destinations in U2
start	**P** - car park	**P** - car park
D1	✝- modern church	Castle
D2	**PO** – Post Office	✝- Church
D3	MacDonald's	**Mkt** - Market Square
D4	Cinema	Superstore
D5	Monument	**Pub** – public house
finish	**P** - car park	**P** - car park

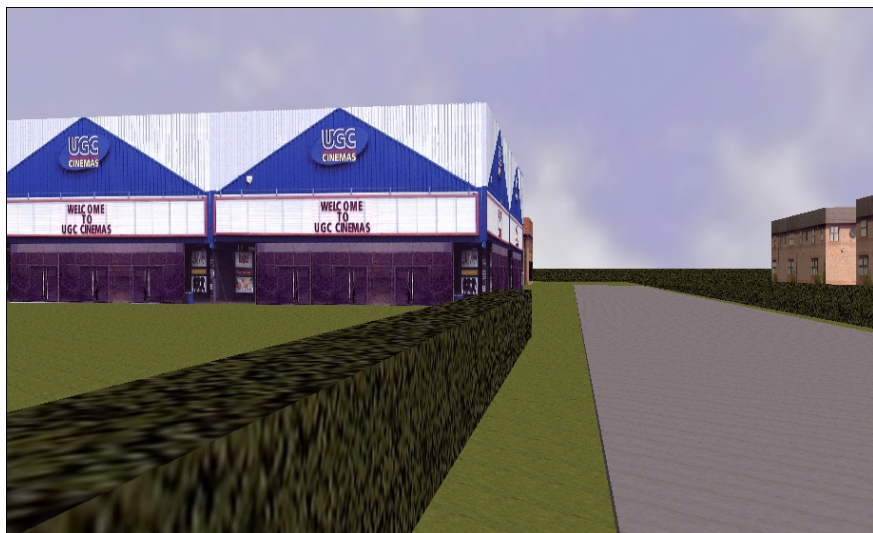Table 7.3 The destinations in urban settings U1 and U2.
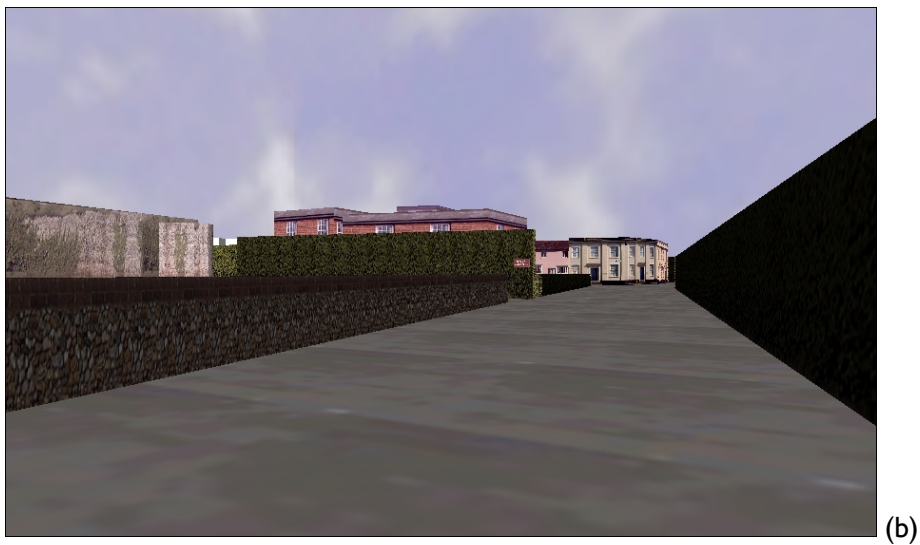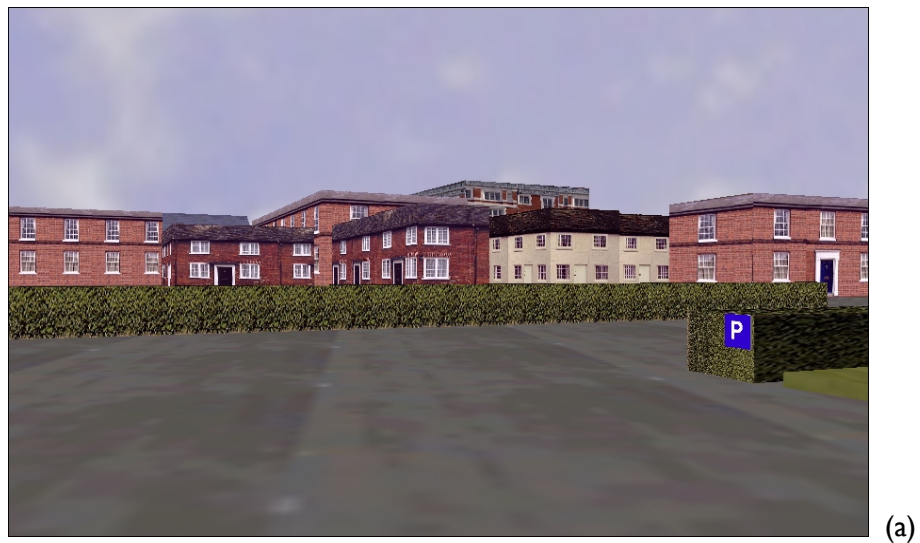

(a)

(b)

122

(c)

(d)

(e)

(f)

Figure 7.4 The scenes at the starting point and five destinations in setting U1:
(a) the start/finish point; (b) destination D1; (c) destination D2; (d) destination D3;
(e) destination D4; (f) destination D5.
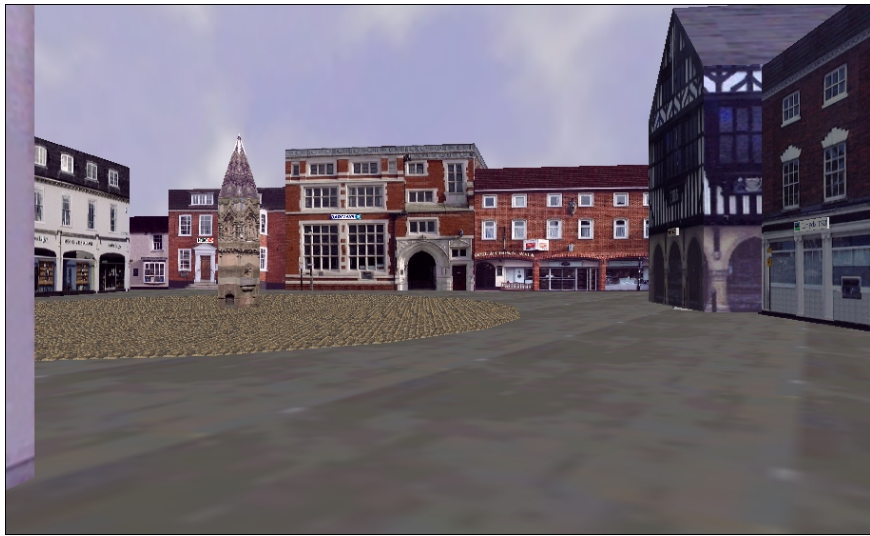

(a)

(b)

(c)

(d)

(e)

(f)

Figure 7.5 The scenes at the starting point and five destinations in setting U2:
(a) the start/finish point; (b) destination D1; (c) destination D2; (d) destination D3;
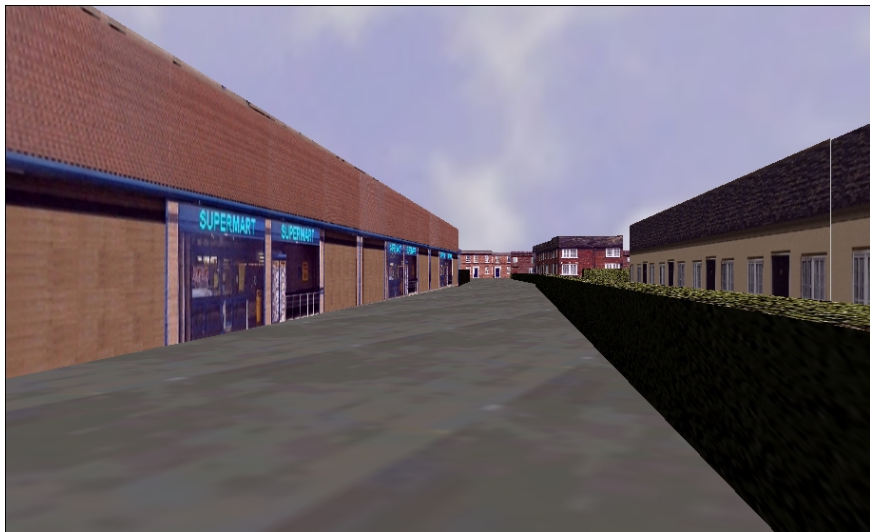(e) destination D4; (f) destination D5.

The procedure for the second set of wayfinding tasks was carried out in the same way as the first, except that it was performed in a different test setting. The 27 participants, who finished the first set of wayfinding tasks, had all completed the wayfinding tasks in the other setting. The time taken ranged from 40 minutes to 1 hour, which also varied from person to person. The post-experiment questionnaire part 2 (Appendix V) was then completed in a similar manner to part 1 by the participants, which took approximately 15 minutes. An approximate five minute informal de-briefing interview was conducted in a conversation style and minuted on paper afterwards by the investigator. The entire on-site experiments took about 2 -3 hours to complete for each participant.

7.5 Data capture

Data were captured during the experiment automatically and semi-automatically using different devices. These multi-source data were the positional track through the VR systems, the PDA usage data via cookie files and the observation data recorded by using an Access database with a purpose-built clickable interface.

During the course of the wayfinding experiments, the location of each participant within each urban setting was tracked with a time stamp using the tracking device and the VR system. The VR system was run and monitored by the CAVE manager during the experiments. The entire route of each participant was recorded in a time-location format of (t, x, y). Head

height and head movements were also logged in a format of (z, pitch, yaw, roll). Figure 7.6 (a) illustrates the positional data, whilst Figures 7.6 (b) demonstrates the head movements. These data were captured automatically once every second and saved in text files. A sample of the track data is shown in Table 7.4. The six columns (X_w, Y_w, Z_w, Pitch_w, Yaw_w, Roll_w) are the position data in the VR environment, which include x y z coordinates and head movements. The following six columns (X_t, Y_t, Z_t, Pitch_t, Yaw_t, Roll_t) record the actual position data in VR Lab where individuals physically stand or move, which is not used in this research.
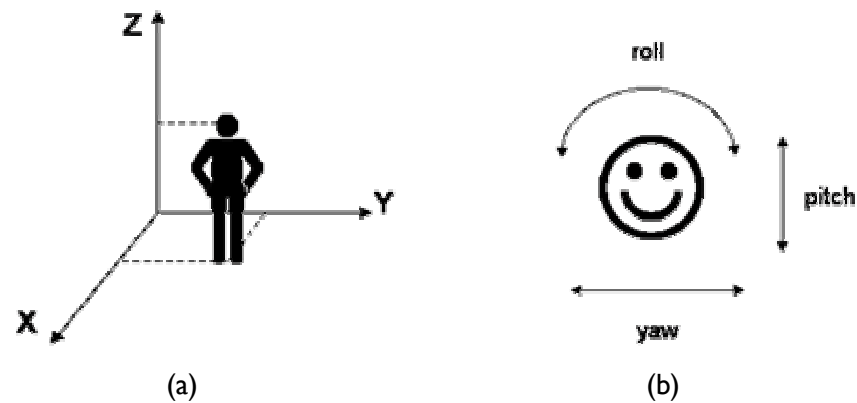

Figure 7.6 Positional data (X, Y, Z) and head movements (Pitch, Roll, Yaw):

(a) positional data; (b) head movement.

Time	X_w	Y_w	Z_w	Pitch_w	Roll_w	Yaw_w	X_t	Y_t	Z_t	Pitch_t	Roll_t	Yaw_t
791.0:	58.4	211.6	1.6	-10.6	8.4	45.0	0.5	-0.7	1.5	-10.6	8.4	-12.2
792.0:	58.4	211.5	1.6	-10.6	8.4	32.6	0.5	-0.7	1.5	-10.6	8.4	-12.2
793.1:	58.2	211.7	1.6	-10.4	8.7	30.8	0.5	-0.7	1.5	-10.4	8.7	-10.7
794.0:	57.2	212.7	1.6	-10.2	8.9	32.4	0.5	-0.7	1.5	-10.2	8.9	-9.1
795.0:	56.0	213.7	1.6	-10.9	7.8	27.1	0.5	-0.7	1.5	-10.9	7.8	-14.3
796.0:	54.9	214.8	1.6	-9.5	10.7	39.3	0.5	-0.7	1.5	-9.5	10.7	-2.1
797.0:	53.8	215.8	1.6	-9.5	11.0	41.7	0.5	-0.7	1.5	-9.5	11.0	0.3
798.1:	52.6	216.8	1.6	-10.4	10.2	36.3	0.5	-0.7	1.5	-10.4	10.2	-3.8
799.0:	52.2	217.3	1.6	-10.5	10.1	26.2	0.5	-0.7	1.5	-10.5	10.1	-4.4
800.0:	51.6	218.0	1.6	-10.0	9.2	31.0	0.5	-0.6	1.5	-10.0	9.2	0.5
801.0:	50.8	219.3	1.6	-10.7	9.1	31.7	0.5	-0.6	1.5	-10.7	9.1	1.2
802.0:	49.9	220.4	1.6	-7.3	9.6	36.6	0.5	-0.7	1.5	-7.3	9.6	6.1
803.1:	49.0	221.7	1.6	-8.9	9.2	34.7	0.5	-0.7	1.5	-8.9	9.2	4.1
804.0:	48.5	222.4	1.5	-39.7	10.3	37.8	0.5	-0.6	1.4	-39.7	10.3	7.2
805.0:	48.2	222.8	1.6	-6.9	7.7	36.3	0.5	-0.7	1.5	-6.9	7.7	5.7
806.1:	47.3	224.2	1.6	-8.9	7.7	36.5	0.5	-0.7	1.5	-8.9	7.7	5.9
807.0:	46.5	225.4	1.6	-8.9	7.7	36.5	0.5	-0.7	1.5	-8.9	7.7	5.9

Table 7.4 Sample data from of the movement track data.

The second set of data captured during the experiment was PDA usage. On each occasion that participants used the PDA to acquire information, the pages accessed along with the access time were recorded automatically through the programmed Cookies. A sample of the

recorded Cookie data files is shown in Figure 7.7. The first line is the name of the information page that was accessed; and the second line is the time when it was accessed. The subsequent lines record the file directory in which the page was stored and the system expiring time. After the '*' sign, there is another record showing that the same page was accessed again. For the record shown in Figure 7.7, a sketch map page with all landmarks shown (SW-SALL) was accessed twice, once at 16:45:55 and another time at 16:55:10.

```
SW-SALL
16M45S55
~~local~~/\sw-pda\sw-sall\
0
1277165568310792927287755529645113
*
16M55S10
V
~~local~~/\sw-pda\sw-sall\
0
1277165568310792921983808256296451114
*
```

Figure 7.7 Sample data from Cookie data files.

Additional observations for each participant's actions were carried out by the investigator throughout the experiment. These observations were recorded by clicking the relevant action buttons through the observation recording program interface (Figure 6.11). These observations included when participants looked at the PDA for information, where participants got lost, the completion time of individual tasks, any rotation of the PDA in the hand (as if turning the map around) and so on. Participants were encouraged to speak aloud their thoughts and feelings as they progressed through the tasks. Thus, some observations on emotion and the confidence level of participants during the wayfinding tasks could also captured. Figure 7.8 illustrates a part of a recorded observation data table in an Access database file. The action column corresponds to the option buttons in the interface, whilst the time was captured automatically when buttons were clicked.

	count	action	time
	33	Found D2	25/08/2004 11:43:12
	34	Stationary	25/08/2004 11:43:53
	35	Look at PDA	25/08/2004 11:43:54
	36	Voice Inst.- B	25/08/2004 11:43:57
	37	Slow	25/08/2004 11:44:06
	38	ConfidentM	25/08/2004 11:44:28
	39	Intermediate	25/08/2004 11:44:29
	40	Look for Str Name	25/08/2004 11:44:51
	41	Intermediate	25/08/2004 11:44:52
	42	S-Lost	25/08/2004 11:45:04
	43	Look for Str Name	25/08/2004 11:45:08
	44	Look for Str Name	25/08/2004 11:45:14
	45	Stationary	25/08/2004 11:45:16
	46	Look at PDA	25/08/2004 11:45:17

Figure 7.8 Sample data from recorded observation data files.

Throughout the experiments, the multi-source data were captured, including the positional track data, information usage data and observation data. The data could then be synchronised and integrated. The exact position of an individual in VR urban settings at any time could thus be re-traced through the detailed tracking data. Furthermore, the information usage data and observation data could subsequently be explored along with the location and time.

7.6 Conclusion

The final wayfinding experiments including the pre-experiment questionnaire and post-experiment questionnaire and debrief interview were carried out successfully following the designed procedure. A wide range of empirical data was collected through the experiments. In the next Chapter, these data are discussed in detail and analysed.