Development of methods for the analysis of movement and orientation behaviour in wayfinding tasks based on the case study „mirror maze“.

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Abstract

Navigation, orientation – to find one’s way – belong to the elementary tasks of everyday life. Do behavioural data retrieved from these scenarios allow for a prediction of whether a subject is anxious, disoriented, determined or satisfied? Can behaviour be predicted on these bases? Insights like this might be of great use, for example for the optimisation of public spaces.

Recent studies have exclusively used punctual measures of movement (photo sensor) or behavioural data. Individual movement or orientation of subjects has received less attention.

Goal of this work is a) the development of methods for the collection of data concerning subject’s movement and orientation and b) the development of helpful descriptive measures, means of visualisation and analysis of this data.

In a pre-study, virtual 3D-rooms have been developed to confront subjects with different experiences and to measure movement and orientation data within this environment.

The main experiment, which is meant to serve as a case study for the development and application of new methods, was conducted in a real world setting. General differences between male and female subjects as well as sex-related effects of restricted field of view were studied in this setting. For that purpose 30 men and 30 women were individually send through the mirror-maze of the Hamburg Dungeon, solving navigation and orientation tasks, while their navigation and orientation behaviour was recorded.

Pre-study: virtual worlds

In a series of pre-studies, virtual 3D-rooms were developed to confront subjects with different experiences (e.g. disorientation, pressure of time, relieve) and to collect the resulting behaviour and orientation data. This experimental setting was implemented with Adobe Atmosphere (advantage of this technology: the developed 3D-setting are accessible through a web-browser plug-in). To test technical aspects and for the explorative analysis of the movement and orientation data, a simple maze was implemented (fig. 1). Additionally, environments used in studies for the analysis of Space Syntax phenomena were replicated (Conroy, 2001) and a supermarket scenario (fig. 2), including various shopping functions, was implemented.

The focus of this work was on developing ways to collect and visualize movement and orientation data. We are now able to automatically collect these data online and to visualize them adhoc (fig. 1 and 3).

Virtual (desktop) environments allow the facil and exact collection of data. But how does the interface influence subjects' behaviour? What is measured in this setting, the navigation behaviour or subjects' competence in operating the computer-interface? In the first tests, subjects with little experience with 3D-environments turned out to have difficulties operating the system, thus focussing their attention primarily on the controls. Based on these experiences, the question of how movement and orientation data can be recorded in a facil, exact and affordable way in real environments came up.

The advantage of real environments is clear: „real-world behaviour" is measured. Up to now, no feasible methods to record movement and orientation behaviour in indoor settings existed. In many cases data collection is imprecise and time consuming or cost intensive.

To better measure and analyse differences in the behaviour in virtual and real world scenarios, a comparably precise and detailed collection of movement and orientation data has to be granted in both environments.

A facile method for recording movement and orientation behaviour in real indoor environments

In case of the method described here, movement and orientation behaviour is recorded by two head-mounted cameras. One camera records the subject's field of vision from an ego-perspective, while the second camera records a compass, which is mounted on the subject's head (fig. 4). With special software (MediaAnalyzer) the information derived from the videos can be transformed into digital coordinates. The subject's position is manually transferred to a 2D-plan frame by frame from the ego-perspective video, while turns of the head (orientation) are automatically analyzed by an eye-tracking software. This leads to a detailed digital representation of the navigation behaviour, which can be used for further analysis. The accuracy of the manual transfer of position data is recently being tested, but seems to be significantly better than in case of recording position data via WLAN technology. The described method is cost saving and applicable in most settings. Still, the analysis of movement data is work intensive. An optimisation of this method is recently being developed, alternative ways of data recording are considered.

Case Study: Differences in navigation behaviour of male and female subjects in a mirror-maze

Sex-based differences in wayfinding and navigation task have received broad attention from researchers. Sandstrom et al. (1998) were able to identify sex-specific performance differences in an experiment in a virtual water maze, if different types of landmarks were present.

Sandstroms study showed, that female navigation performance relied more on landmarks while males used landmarks and geometric information (distance, configuration etc.).

Czerwinski (2002) und Tan (2003) have conducted research on performance differences related to the width of the visual field in virtual environments. They were able to proof, that the weaker performance of female subjects compared to male subjects in virtual environments was compensated when the field of vision was extensively widened.

The research of sex-specific differences was primarily focused on performance differences (e.g. time to reach a goal) so far. Less attention was paid to detailed differences in behaviour or strategy. What could be an explanation for longer latency-times in performance tasks of female subjects for example? Are they just slower or do they use different strategies than men? The anticipation of a robust effect of sex and the opportunity to study detailed differences in behaviour and strategy of male and female subjects made the study of sex-differences an ideal case study. In addition to general strategic differences, the consequences of a reduction of the field of vision were tested. An interaction of reduced field of vision and sex of subject was expected to occur. Female subjects were expected to react to the reduced field of vision with a higher rate of compensational head turns.

The mirror-maze of the Hamburg Dungeon, designed by Adrian Fischer (Adrian Fisher Mazes Ltd), was used as a test-setting (fig. 5). 30 men and 30 women ages between 18 and 40 were tested, half of the subjects with and half of them without experimental glasses reducing their field of vision (fig 6). Subjects had to fulfil different tasks. During the experiment, subjects' activities were recorded with the camera system described above. Additionally, subjects were instructed to think aloud during the experiment.

Procedure

Survey before experiment

Before the experiment was conducted, socio-demographic Data, visual and auditory impairments, body-size and IT- knowledge of subjects were measured. Additionally, subjects filled out questionnaires concerning self-efficacy, self-assessment of orientation ability and mood.

Experiment

All subjects were equipped with a walkie-talkie in addition to the camera equipment to enable communication with the instructor and the exchange of further instructions during the experiment.

1. Exploration: First, subjects were asked to *„explore the maze as well as possible, because you have to sketch a plan of the maze at the end of the experiment"*. The exploration phase was ended after 4 minutes and subjects were asked to return to the entrance of the maze, but not to leave it.
This task was meant to induce explorative behaviour.
2. Acoustic signal: Subjects were informed, that they were about to hear an acoustic signal and that they had to *„find its source as fast as possible, to turn the signal off "*. The length of this episode was variable, resembling a performance test. The time needed to fulfil the task varied between 1 and over 10 minutes.
This task was meant to induce goal-oriented search under moderate time pressure.
3. Search for the exit: After subjects had turned off the signal, they were asked to find the exit of the maze which was not identical to the entrance. Subjects were informed, *„that the exit can be just about everything"*. If subjects did not manage to find the exit within 4 minutes, they were instructed to leave the maze through the entrance.
Due to the fact, that the exit was hidden behind a mirrored sliding door, it was not found in most cases. This task was meant to produce moderate frustration and helplessness.

Postexploration

At the end of the experiment, subjects were asked to fill out a second questionnaire concerning their current mood. Additionally they were instructed to sketch the ground plan of the maze and to name the strategies they used during the different tasks.

Data analysis: Preliminary results

Detailed results are not yet available at this point (Nov. 2004). During the experimental phase, first hints were gathered, indicating that reduction of field of vision indeed has greater impact on female subjects. Still, male as well as female subjects show a high variability in performance. Interestingly, female subjects show the tendency of attributing difficulties in performing the task to their own abilities,

while male subjects tend to seek responsibility for failure in situational factors, assuming for example that no exit exists.
Currently, movement and orientation data are analysed and proper scales and means of visualizing the data are explored (fig. 7).
Crucial for the test oft the hypothesized consequences of reduced field of vision is a clear distinction between body turns and turns of the head, to make sure that head movements can be clearly identified an counted.

Other potentially helpful measures are listed in the following table and will be discussed in future work.

orientation data (turns)	**movement** (position data)
Rate Direction lengths of „orientation units“	frequency of positions („Heatmap“) speed and acceleration changes of direction and decisions Stopping points and times paths of movement and patterns

References:

Conroy, R. A. (2001). Spatial Navigation in Immersive Virtual Environments. Department of Architecture. London, University College London: 249.

Czerwinski, M., Tan, D.S. & Robertson, G.G. (2002). Women take a wider view. In Proceedings of CHI 2002, Human Factors in Computing Systems, pp. 195-202, ACM press.

Sandstrom, N. J., Kaufman, J., & Huettel, S. A. (1998). Males and females use different distal cues in a virtual environment navigation task. Cognitive Brain Research, 6, 351-60.

Tan, D.S.,Czerwinski, M., & Robertson, G.G. (2003). Women Go with the (Optical) Flow. In Proceedings of CHI 2003, Human Factors in Computing Systems, pp. 209-215, ACM press.

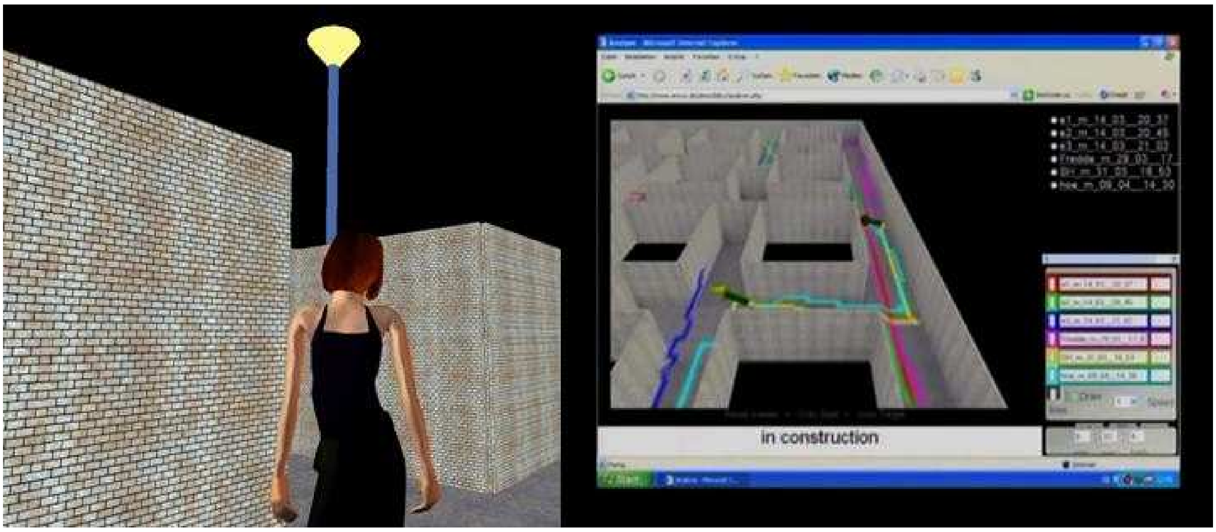

Figure 1: 3D maze and adhoc visualisation of position data, both accessible online.

Figure 2: Complex online scenario with different interactive functions (shopping function).

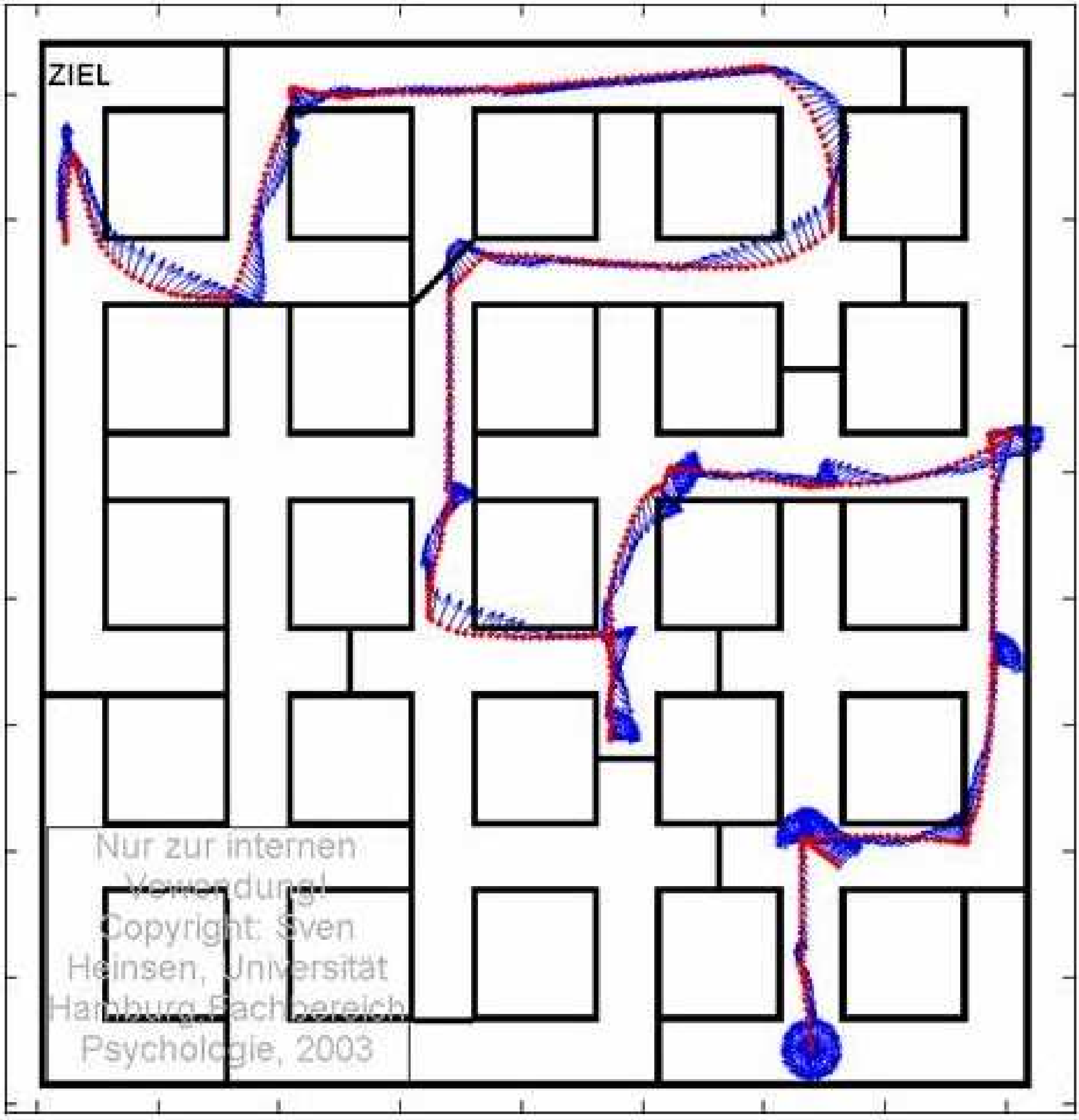

Figure 3: Visualisation of movement and orientation data of the online maze as Quiver-Plot.

Figure 4: Equipment for the recording of movement and orientation behaviour (compass and second camera are mounted in the black box).

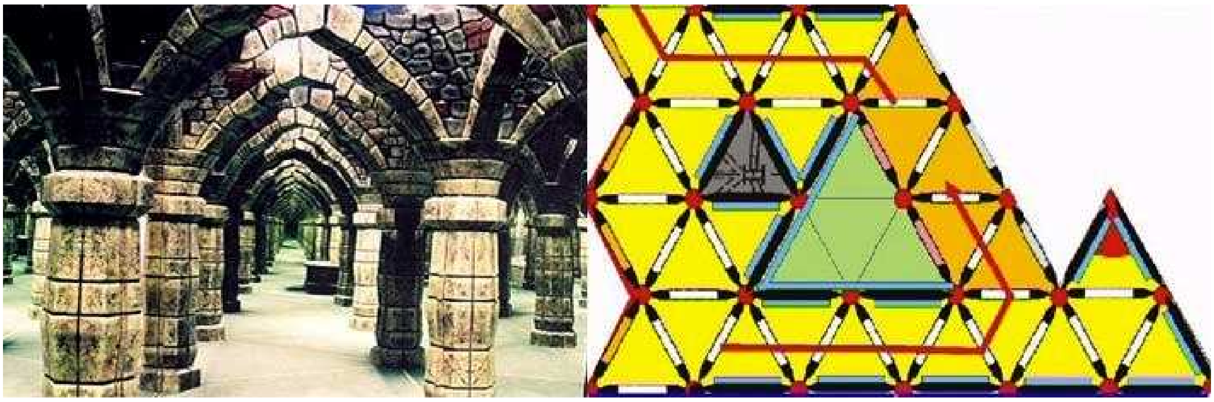

Figure 5: Mirror-maze of the Hamburg Dungeon and its ground plan (copyright: Adrian Fisher Mazes Ltd.)

Figure 6: Two of the four experimental conditions: female subject with restricted field of vision, male subject with unrestricted field of vision.

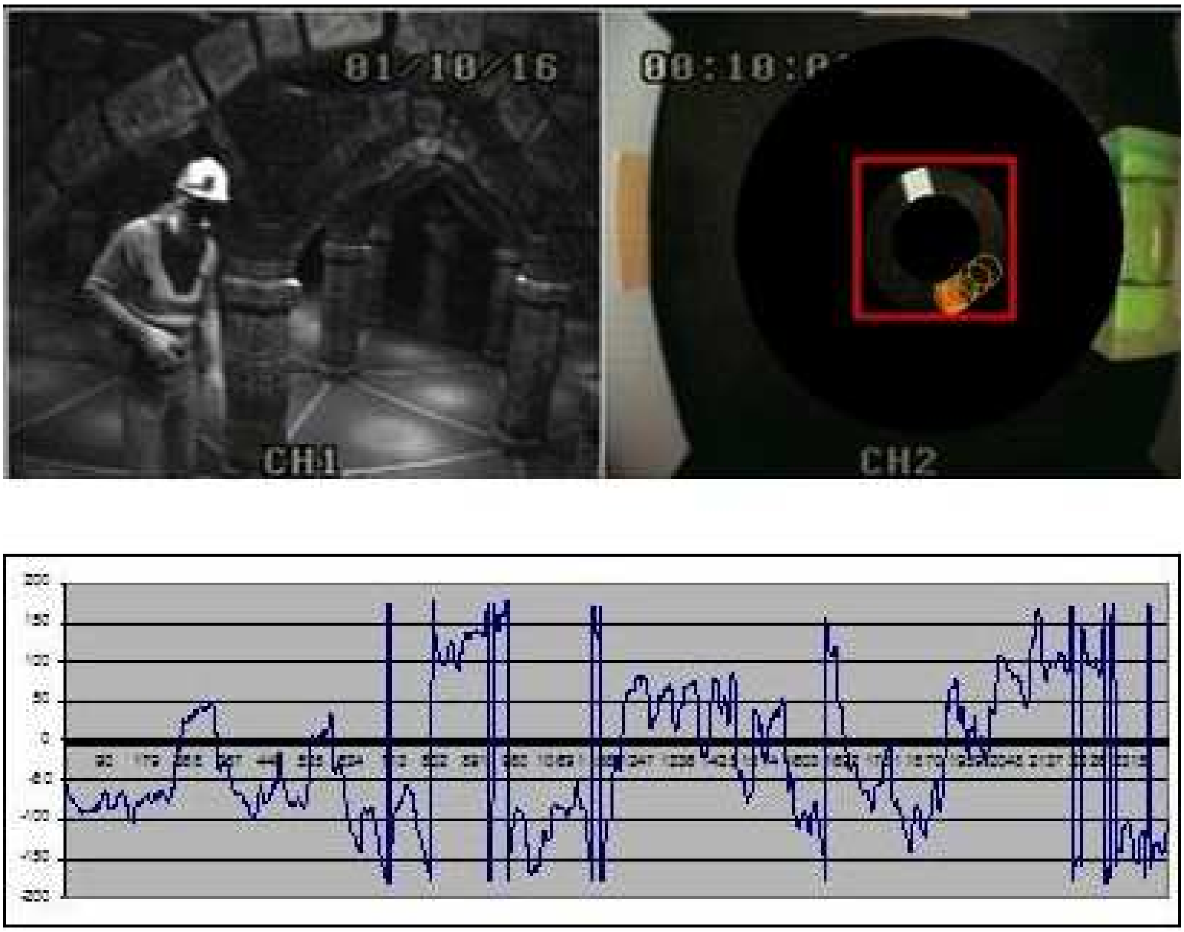

Figure 7: Automated recognition of orientation movements.