Identifying Unusual Pedestrian Movement Behaviour in Public Transport Infrastructures

A. Millonig[1], G. Maierbrugger[1]

[1]Austrian Institute of Technology, Dynamic Transportation Systems; Giefinggasse 2, 1210 Vienna, Austria
Email: alexandra.millonig@ait.ac.at; gudrun.maierbrugger@ait.ac.at

1. Introduction

The investigation of pedestrian spatio-temporal behaviour and related influence factors plays an important role in the field of mobility research. In several of our research projects, we are particularly focusing on pedestrian activities and motion tracks in medium-scale investigation areas (e.g. large infrastructures or urban quarters). As part of one recently completed study we investigated motion behaviour and activities of passengers under time pressure in a public transport infrastructure. The overall aim of the project was to identify stress-inducing factors in transport infrastructures and their effects on navigation behaviour of passengers as well as the passengers' strategies of gathering information and coping with stress. We conducted experiments with participants of four different target groups (young and elderly people, both either experienced in using public transport or not) in a laboratory environment and during field tests, applying a combination of different complementary methods such as physiological measurements of heart rates, visual field analysis based on eye-tracking data, interviews, and semi-automated annotation of trajectories and activities for identifying potentially stress-influenced behaviour.

Observing and analysing the spatio-temporal movement patterns of the test subjects was a main part of the field tests. Several potential indicators for stress-induced behaviour can be identified through observation. For our study, we specifically focused on motion-related indicators such as

- unusual speed levels (high speed – hurrying, or very low speed – hesitating, indicating uncertainties),
- frequent stops (e.g. for gathering information), or
- uncertainties in route choice (e.g. changes in direction, turning back).

To collect the required spatio-temporal data, we used the method of "shadowing" (Millonig et al. 2009). "Shadowing" is a form of tracking where researchers follow the test subjects and annotate the test subjects' individual trajectories and related activities on a map. In the course of this study, this was done by applying specific software installed on a tablet PC, which allowed annotating the information in digital form. The use of technology in this phase (digital map on a tablet PC, tracking software) offers mainly two major advantages: firstly, a large investigation area can be covered without having to handle a large paper map, and secondly, all points drawn in the map are recorded with time-stamps and map coordinates, which allows calculating average speeds and detecting stops for each trajectory. Additionally, the system allows annotating specific activities carried out by the participants when they stop (e.g. gathering information from a public display).

The participants had to find a particular destination by using predetermined modes of public transport. The trajectories have been collected in the connecting stations the participants used on their way. In total, 25 test persons participated in Vienna, 10 test persons have been tracked in Graz.

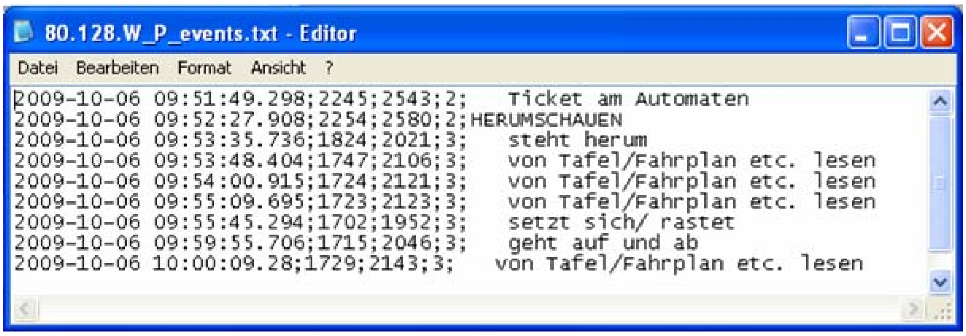
2. Description of Shadowing Datasets

Figure 1 shows an example for a trajectory collected in one of the connecting stations in Vienna. The coloured sections of the line represent different velocities which have been calculated in a first step of analysis.

Figure 1. Example of a typical trajectory.

For each participant, two datasets were produced: trajectories of the path a participant followed (with data collected in several layers for the different levels of the multi-storey infrastructures) and a list of annotated activities the person performed on the way through the station (e.g. gathering information, buying a ticket, waiting) including time and place of each activity.

The trajectory datasets comprise date, time, map coordinates, and layer for each point drawn in the map during observation. For each activity annotated during observation (selected from a predefined annotation list, e.g. waiting, gathering information from a monitor, buying ticket at vending machine) the annotation datasets comprise the same information (date, time, map coordinates, layer) and the corresponding activity (see Figure 2).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Datei Bearbeiten Format Ansicht ?

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2009-10-06 09:53:35.736;1824;2021;3;   steht herum
2009-10-06 09:53:48.404;1747;2106;3;   von Tafel/Fahrplan etc. lesen
2009-10-06 09:54:00.915;1724;2121;3;   von Tafel/Fahrplan etc. lesen
2009-10-06 09:55:09.695;1723;2123;3;   von Tafel/Fahrplan etc. lesen
2009-10-06 09:55:45.294;1702;1952;3;   setzt sich/ rastet
2009-10-06 09:59:55.706;1715;2046;3;   geht auf und ab
2009-10-06 10:00:09.28;1729;2143;3;   von Tafel/Fahrplan etc. lesen
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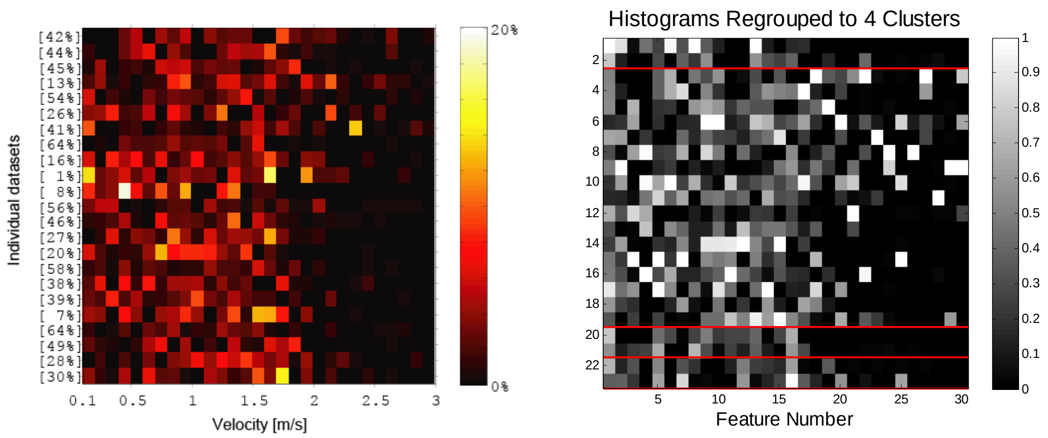
Figure 2. Example for annotation dataset.

3. Data Analysis

For identifying potentially stress-induced behaviour, we analysed the collected datasets with respect to three indicators: velocities (differences in individual speeds, velocity histograms), stops (frequency, duration, position of stops and activities carried out during stops) and unusual route choice or significant changes in direction. The aim was to select datasets with noticeable behaviour in one or more categories for a subsequent detailed interdisciplinary analysis.

3.1 Velocity histograms

To detect unusual speed patterns, we compiled speed histograms of each trajectory, showing the proportional amount of time (of the total time a test subject needed for completing the field scenario) an individual walked at a velocity within a specific speed interval. Figure 3(a) shows all histograms compiled from trajectory datasets collected in one connecting station. Each line shows the histogram of an observed participant at one of the connecting stations, with higher intensities (lighter colours) indicating higher percentages of time (velocity intervals in 0.1 m/s steps between 0.1 and 3 m/s); the values on the left represent the amount of time a person spent without moving. The histograms have been classified using a self-tuning clustering algorithm from the family of spectral clustering Zelnik-Manor and Perona 2004). The results are shown in Figure 3(b).



(a) (b)

Figure 3. Velocity histograms of 23 participants: (a) initial histograms, (b) normalised histograms regrouped to 4 clusters.

The clustering process resulted in 4 clusters with one cluster comprising the majority of initial histograms. Those are assumed to be the "normal" speed behaviour type. Cases belonging to the other 3 clusters are interpreted as "unusual" speed behaviour. Additionally, the average velocity of each participant has been used for identifying unusual behaviour: participants with comparatively high or low average speed, who were not yet included in the "unusual" clusters, were selected.

3.2 Stop detection

The analysis of stopping behaviour included the detection of stops (defined as staying within a radius of 3.25 m for at least 5 s) and the analysis of annotated activities performed during those stops. To identify unusual behaviour, we focused on activities indicating uncertainties (e.g. high amount of time for gathering information) and stress coping activities (e.g. pacing up and down). Figure 4 shows the amount of time each participant spent for different activities.

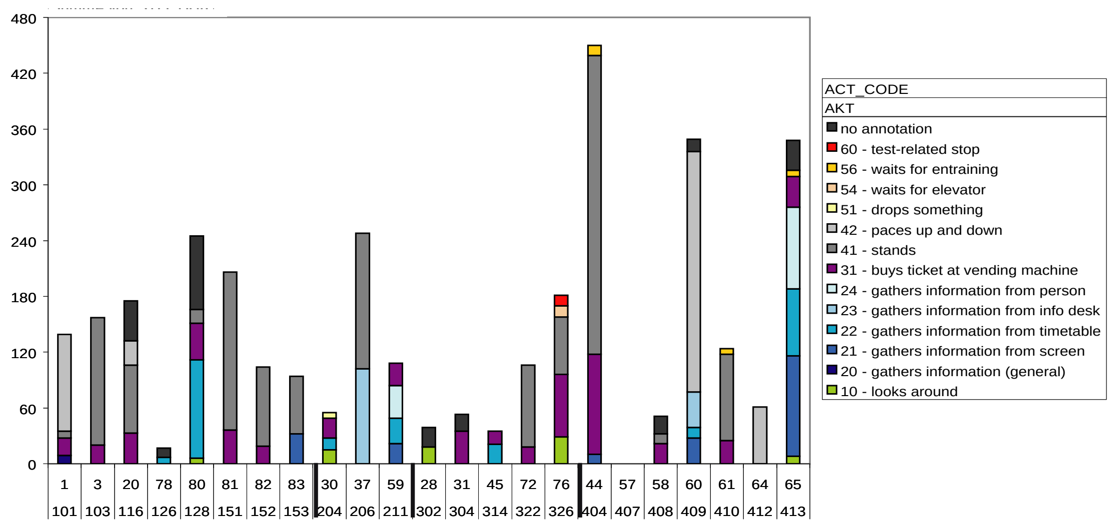


Figure 4. Amount of time spent for specific activities for each participant.

3.3 Route choice analysis

To identify unusual route choice, we qualitatively compared the routes of all participants and selected examples of differing paths or changes in direction that were obviously due to foregoing incorrect decisions.

4. Discussion of Methodology

The limited number of participants made it difficult to explicitly identify uncommon behaviour, as it was not easy to define “normal” behaviour based on the small amount of cases we observed due to narrow resources in the project. Therefore, the aim was to focus on distinctive effects which could potentially indicate specific stress-related behaviour patterns.

Although the clustering process produced one cluster containing the majority of cases which can be interpreted as representing unremarkable, “normal” behaviour, the result is not clear and the cluster still appears to be rather heterogeneous. Using the average speed of each participant provides a feature which can be easily used as an indicator, but the influence of external factors (e.g. people crowds) on individual speed levels and waiting times is difficult to assess, although video footage from eye-tracking was used for further interpretation.

The investigation of stopping times (especially the time spent for gathering information) as well as the identification of unusual routes indicated potential stress-induced uncertainties and provided a useful basis for comparison with results from the complementarily applied methods (interviews, heart rate measurements).

Generally, the analysis of observation-based data for this problem alone limits the conclusions which can be drawn from it, but the results provide an essential link between the different empirical methods used in this study.

5. Outlook

Currently shadowing datasets are collected for a new scientific project in the same infrastructure. We focus on the investigation of movement behaviour and information acquisition of mobility impaired people groups (wheelchair users, individuals with baby prams, or people with sensory impediments). The shadowing data is complemented with information collected from the participants during the test by using the “thinking aloud” method. The aim is to include orientation and navigation behaviour characteristics of specific passenger groups in agent-based simulation models to achieve realistic simulations. The proposed number of participants is significantly higher than in the previous project, but the examined groups show more differences in behaviour and requirements which aggravates direct comparison of the results. Hence, it might be necessary to investigate group-specific behaviour without incorporating any results from other groups.

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References

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