HOW DO ELDERLY PEDESTRIANS PERCEIVE HAZARDS IN THE STREET?

-An initial investigation towards development of a pedestrian simulation that incorporates reaction of various pedestrians to environments-

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Summary

We investigated effects of lighting on the fixation behaviour of an elderly pedestrian. The participant was asked on a platform in the PAMELA facility, which simulated street environments and various hazards under four different lighting conditions. The hazards included obstacles, steps and combinations of vertical and horizontal gaps. In low lighting conditions, the participant fixated “hazard” objects more than “orientation” objects. For ascending steps, the duration of fixations corresponded to the step height, whereas for descending steps, the duration did not largely change according to the step height and it was less than that for ascending steps. These results suggest that pedestrians pay attention to hazards according not to actual danger but to the visual perception. Regardless of actual danger, visually obscure objects do not attract the attention of pedestrians. Further investigation should be made on pedestrians’ perception of hazard and orientation objects as well as the illuminance level below which pedestrians need more time/duration of fixation to perceive hazards (threshold).

Key words: fixation; street hazard; elderly pedestrian; lighting

1. Purpose of the study

In order to evaluate the accessibility of street and transport environments, such as railway stations, we are now developing a pedestrian simulation that incorporates elderly and disable pedestrians and their interaction with various environments including hazards on the street. For this development, it is necessary to understand how elderly and disabled pedestrians perceive hazards in the street and transport environments.

Many elderly people suffer from some visual impairment. A study in the UK suggested 12% of people aged 65 or over have binocular acuity of 6/18 or less (Van der Pols *et al*, 2000). It should be noted that a quarter of the UK population will be aged 65 or over by 2031 (The Government Actuary's Department, 2004). Because of age-related changes of visual perception organs, elderly people suffer not only visual acuity problems but also other forms of visual disabilities, such as visual field loss and less contrast sensitivity.

Lighting is considered to be an effective solution to let elderly and disable pedestrians perceive possible hazards in the street. Interestingly, British Standards for residential street lighting have not considered lighting needs of elderly pedestrians or pedestrians with visual disabilities (e.g. Fujiyama *et al*, 2005). In order to design street lighting that incorporates elderly and visually disabled pedestrians, it would be useful to understand how lighting improves the perception of hazards by elderly and disable pedestrians.

The aim of this paper is to understand how elderly pedestrians perceive different hazards and to address issues to be investigated in future research. This paper focuses on fixation patterns of elderly pedestrians on different hazards in the street under different lighting conditions. Analysing fixation patterns helps us understand how pedestrians perceive environments or hazards (Fujiyama, 2006). This paper presents the initial results of our analysis of the eye tracker data of an ordinary elderly participant.

2. Methods

2-1. Experiment overview

The empirical work took place in the Pedestrian Accessibility and Movement Environment Laboratory (PAMELA) at University College London. PAMELA is a laboratory used to test existing and proposed pedestrian environments under controlled conditions. There are several elements of the laboratory, perhaps the most obvious being a computer-controlled paved platform which can be varied in terms of layout, topography and surface type. The laboratory is also equipped with a lighting system. The lighting system is capable of representing lighting conditions from absolute darkness to near-daylight, including various levels and colours of artificial lighting.

The experiment was conducted as a part of our ongoing EMMA (Evaluating measures to enhance the mobility of older and disabled people) project. In this project, we recruit elderly people and people with various disabilities, and ask them to walk on the PAMELA platform with various street configurations, such as slopes, steps, crossfalls and obstacles. Their walking behaviour is then analysed and will be used as a reference dataset to assess the street environments.

As an initial investigation of the EMMA project, this paper presents the experiment results of an ordinary elderly participant. The participant was a male aged 74. His visual acuity was 0 in LogMAR scale (equivalent to 6/6), and his contrast sensitivity was 1.65 by the Pelli-Robson test. The participant walked on the PAMELA platform four times under different lighting conditions. The lighting conditions were 241; 27.0; 4.5; and 0.85 lux on average on the surface of the platform, and the lighting source used was high pressure sodium lamps, which are common for street lighting. The experiment order was 241; 27.0; 4.5; 0.85 lux. In order to analyse his fixation behaviour, we used an eye tracker. Details of the platform configuration and the eye tracker follow.

2-2. PAMELA platform configuration

The platform consisted of 4 lanes: Baseline, Pamelina, Obstacle, and Step lanes. On Baseline lane, there was no hazard. Pamelina lane had a combination of small vertical and horizontal gaps, which the participant had to step over. The size of the gaps was 55mm height and 300-600mm width. On Obstacle lane, we placed couples of 1.3m height posts on the lane like a slalom ski course, where the participant had to walk through the middle of each couple of posts. In Step lane, steps with various heights ranging from -125mm (to descend) to 125mm (to ascend) were situated. These lanes were adjacent to each other and the participant was told to walk on all the lanes at once under each lighting condition. The length of each lane was 10.8m. The participant took around 2.0 minutes to complete. (For the precise duration, please see "total" values in Fig 4.)

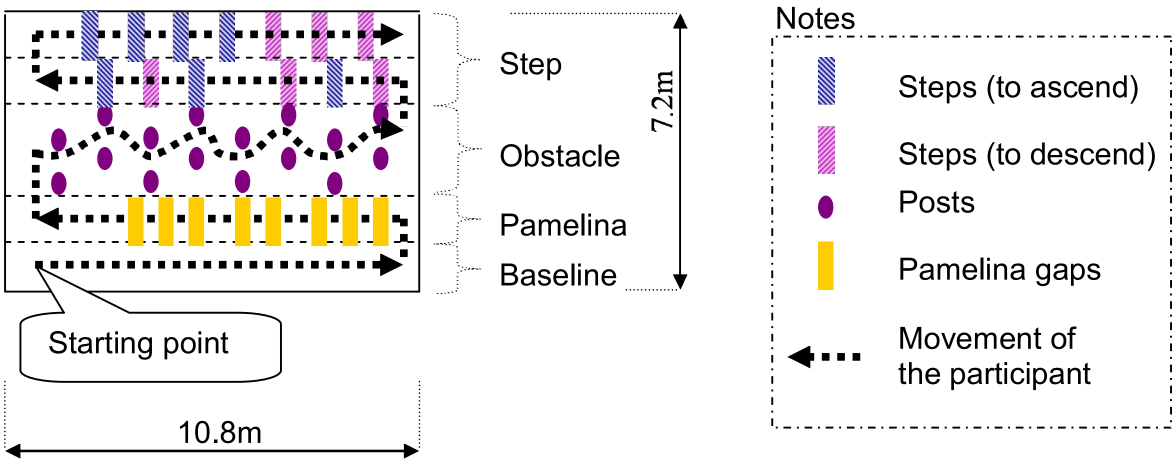

Fig 1. Platform configuration

2-3. Eye tracker

An iViewX Head Mounted Eye Tracking device (HED) for measuring eye movement (gaze position in this experiment) in response to visual stimulus, was used to analyse the fixation behaviour. The gaze position is the point in the person's field of view, where the eye is actually looking. The light weight helmet HED (manufactured by SMI) contains an Eye Camera (which records the eye movement), an angled Mirror (which directs the eye image to the eye camera) and a Scene Camera (which records the field of view of the person). HED also outputs the Scene Video with Gaze Position which is indicated by a Gaze Cursor in the field of view (see Fig 2). The video recording system in the computer can record the field of view every 0.04 second (25 frames per second) so that we know where the participant gazed each 0.04 second.

In order to determine when the participant was fixating, we defined that, when the participant gazed at the same point in two or more video frames in sequence (if the participant continued gazing at the same point more than 0.04 second), the participant was regarded as fixating on the object. It was often observed that the participant slightly moved the point he gazed at. If the next gaze point was on the same object and within the range of 3.0 degree (roughly 10cm) from the axis to the original gaze position, the participant was regarded as gazing at the same point (and thus fixating). These numbers have been used in past research (e.g. Suzuki and Okazaki, 2002). Please note that, fixation is a very slow eye movement corresponding to the person staring at a particular point, and contains small randomly drifting eye movements and quick adjustments to keep the target centred.

Fig 2. An example of the field of view

3. Results

3-1. Overall analysis

Recorded data were divided into 3 categories: *Fixation*, *NG* and *No Fixation*. *Fixation* indicates the data of fixation (seeing the same object in 2 or more frames) and the data can be analysed. *NG* shows the data in which the eye tracker cannot analyse where the participant gazed (e.g. the participant blinked). *No Fixation* means the data in which the participant did not continue gazing at the same point for more than 0.4 second and thus was regarded as "not fixating". In Fig 3 and 4, *Total* sums up all the three categories.

The data is presented as number, duration, and duration divided by number (average duration). Together, these parameters help us to characterise the participant's visual activity during the experiment. For example, the duration spent gazing at two objects can be similar, but if one object has a larger number of fixations than the other this could indicate a more complex route where the participant had to cope with more than one perceived obstacle.

Fig 3 and 4 show the overall data summary. Percentage of the number of *Fixation* to *Total* is not so high in Fig 3, but the percentage of the duration is high in Fig 4. This implies that when walking the participant was always looking for gaze points, but actually gazed at a small number of points. Also, the figures show that there is not so much difference throughout the experiment in terms of the number and the duration of fixation.

3-2. Fixation patterns

In this section, we look into *Fixation* data. Objects in the platform are categorised into *Ground* (PAMELA pavement surface); *Obstacle* (posts arranged on the platform for the participant to navigate around); *Pamelina difference* (the edge of PAMELINA gaps); *Pamelina in-between* (spaces between edges of Pamelina gaps); *Step* (vertical differences in the step section); and *Target* (marks on the edge of the platform showing

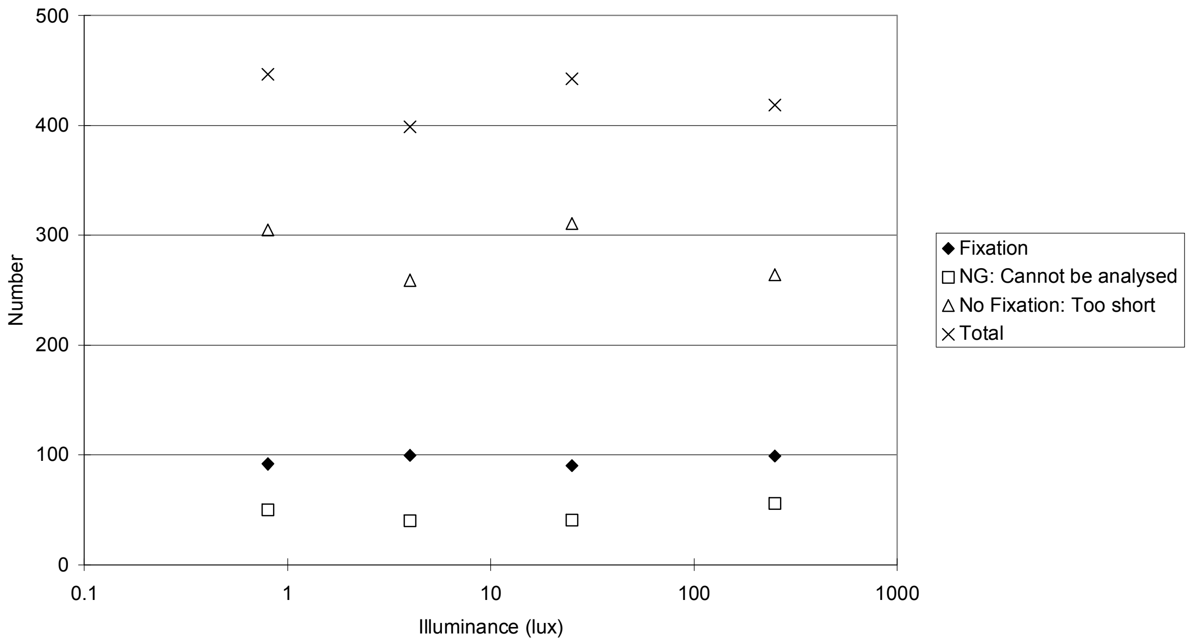

Fig 3. Data summary (Number)

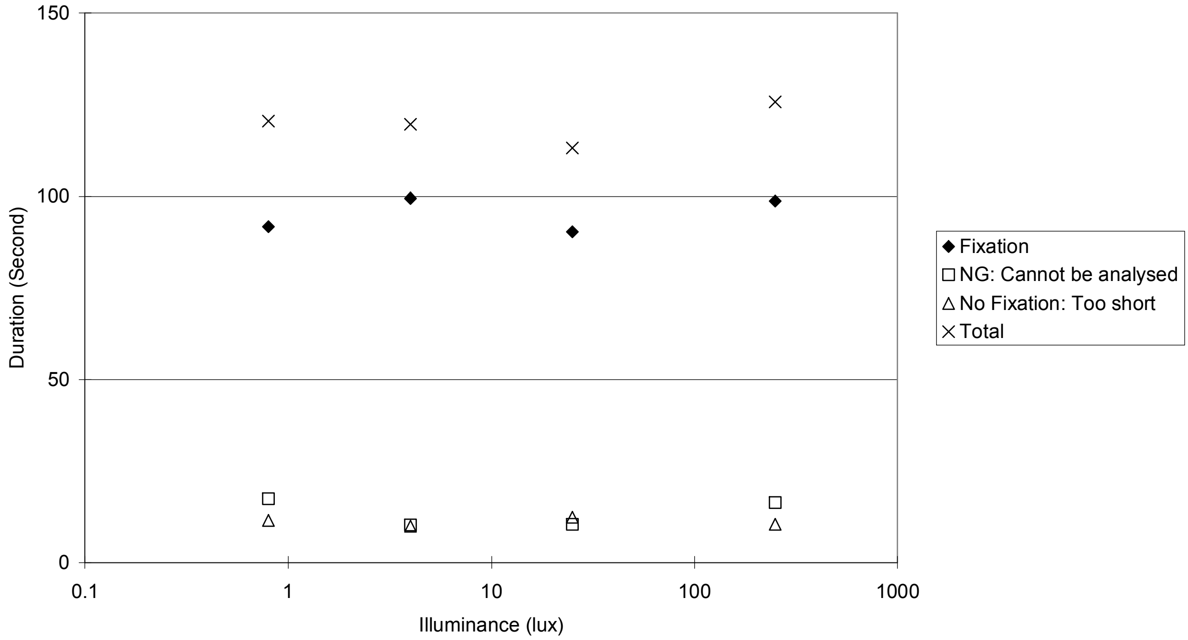

Fig 4. Data summary (Duration)

the walking direction). Please also see Fig 1.

Fig 5 shows the average fixation duration for all the categories. It was observed that *Target* shows higher values than other categories. The aim of the analysis here is to see

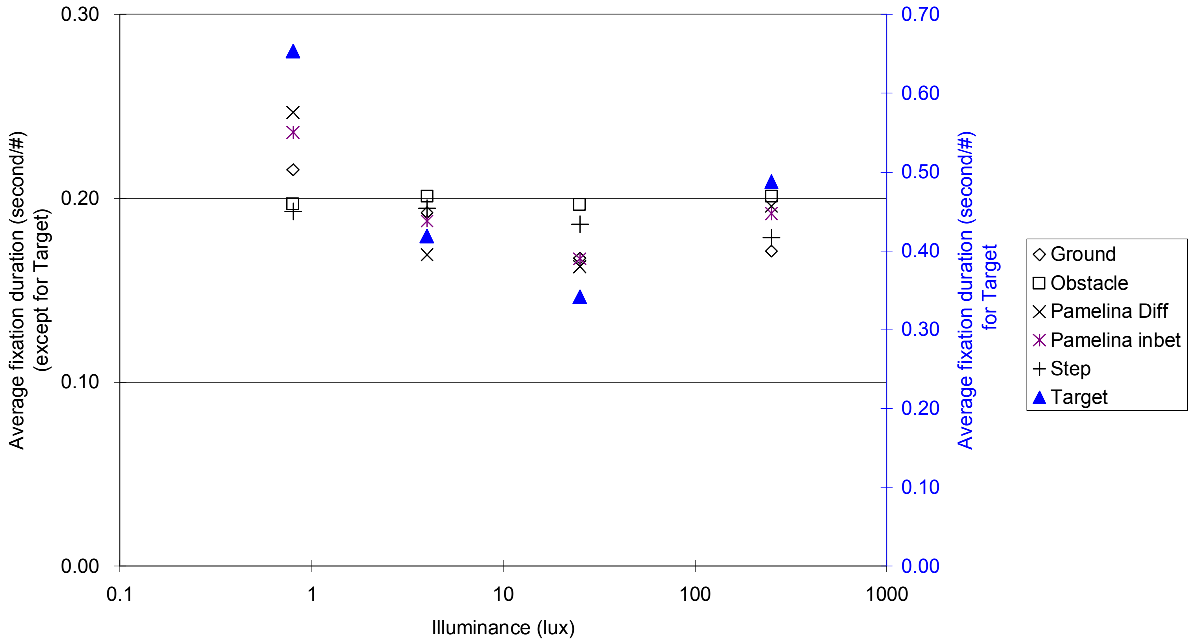

Fig 5. Average fixation duration for all categories

the effects of the illuminance on each category, and therefore in Fig 5 *Target* uses the right axis with the others the left.

In Fig 5, *Target*, *Ground*, *Pamelina in-between*, and *Pamelina Difference* show a U shape curve, whereas *Obstacle* indicates a steady decrease from the high illuminance toward the low illuminance.

Fig 6 shows the total fixation duration for all the categories. It was observed that *Ground* shows higher values than other categories. The aim of the analysis here is to see the effects of the illuminance on each category, and therefore in Fig 6 *Ground* uses the right axis with the others the left.

In Fig 6, *Target* and *Obstacle* show a positive proportionate relationship to the illuminance. On the other hand, *Pamelina difference* and *Pamelina in-between* show a negative proportionate relationship.

3-3. Fixation patterns to steps

In this section, we focus on *Fixation* on *Step*. It was observed that sometimes the participant gazed at an object situated not on the lane where he was walking but on another lane. In the analysis here, we extracted the data of *Fixation* on *Steps* made while the participant was on *Step* lane. Fig 7 shows the total fixation duration for the illuminance levels.

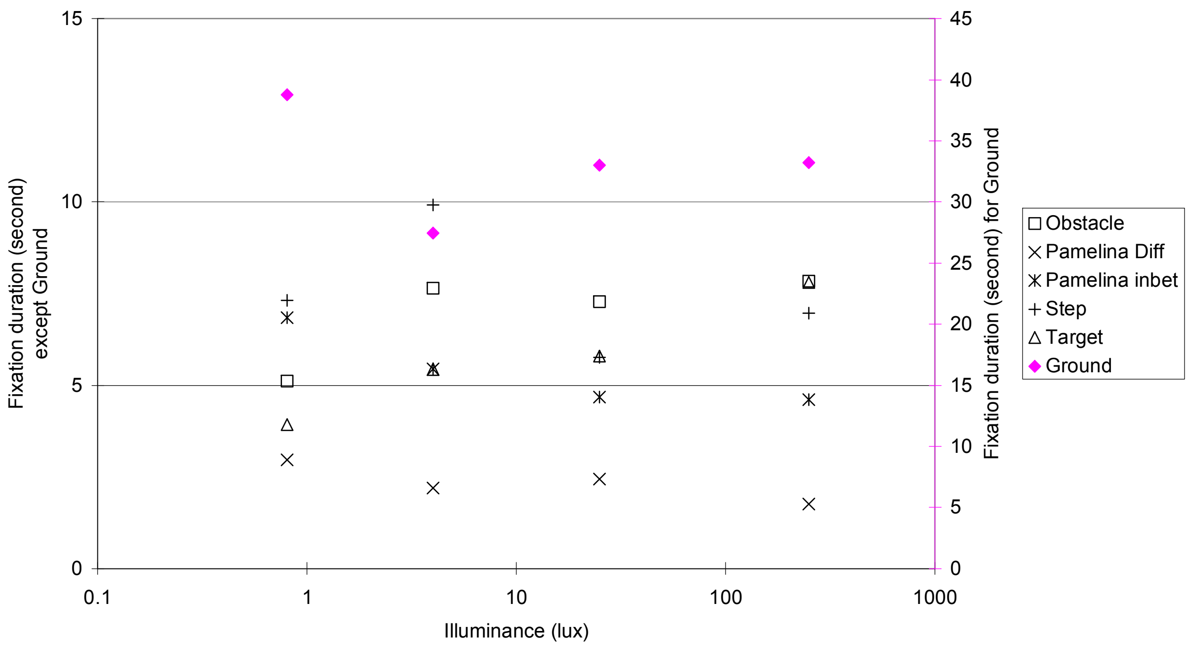

Fig 6. Fixation duration for all categories

In Fig 7, a negative number of the step difference indicates the step the pedestrian descended, whereas a positive number of the step difference indicates the step the pedestrian ascended. If there was more than one step on the platform with the same step difference height, the fixation duration for that step height has been averaged over the number of steps.

Fig 7 shows that, as the step height increases, the fixation duration increases. This increase is greater for positive step heights (ascending) than it is for negative step heights (descending).

4. Discussion

This paper presents an initial result of our series of experiments aimed at understanding how elderly pedestrians perceive different hazards. It focuses on fixation patterns of elderly pedestrians on a variety of hazards in the street under different lighting conditions. There are three points to be addressed here.

First, in Fig 5, some categories show a U-shape curve. Why a U-shape curve? In low lighting conditions, it can take time to get (visual) information about an object fixated because the object cannot be seen as clearly as in bright conditions. This can be one reason why average fixation durations are in a negative proportionate relation to the illuminance. On the other hand, given the experiment sequence (high illuminance to low),it is reasonable to assume that the participant did not need to fixate an object for a long time in the second run (27lux) and later (4.5 and 0.85 lux) because they already know it. This can be one reason why average fixation durations are in a positive

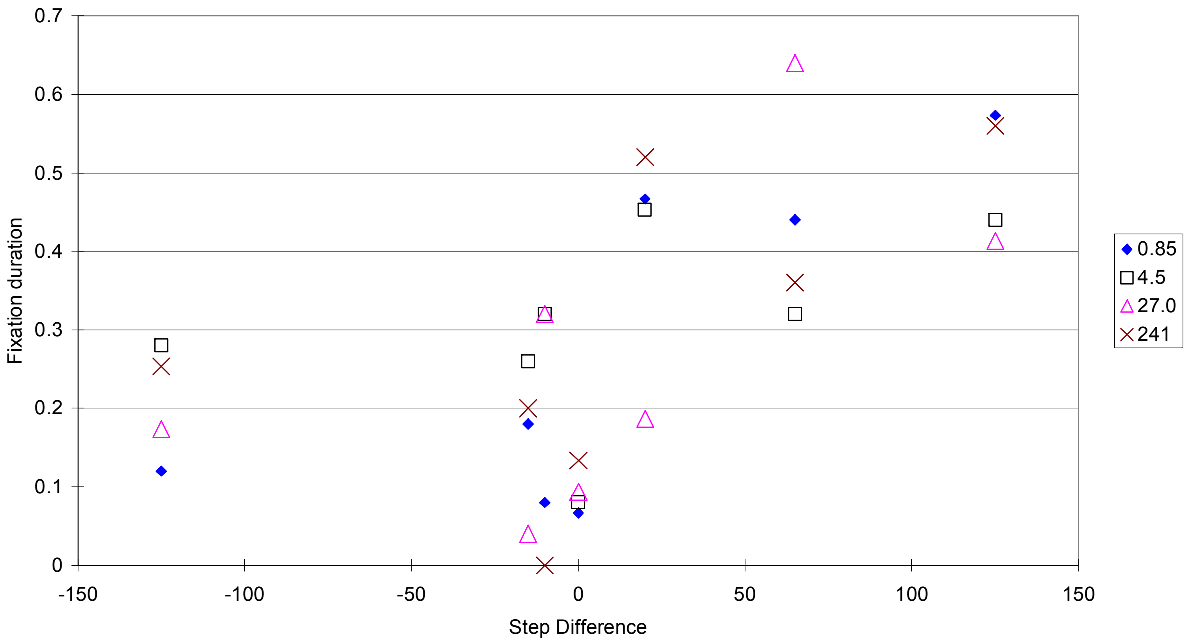

Fig 7. Fixation duration for steps

proportionate relation to the illuminance.

Because of these two reasons, the figure can show a U-shape curve in some categories. It can be interesting to find out the illuminance level below which pedestrians need more fixation duration to perceive hazards because this level can be a threshold to assess street environments. In the presented research, average fixation durations to a hazard object show a U-shape curve and the bottom of the curve is between 4.5 lux and 27 lux. More research is necessary to investigate this issue further.

Secondly, in Fig 6, *Target* and *Obstacle* show a positive proportionate relationship to the illuminance, whereas *Pamelina difference* and *Pamelina in-between* show a negative proportionate relationship. What does this mean? We could regard *Target* and *Obstacle* as “orientation” objects seen by the participant in order to decide the walking direction. Similarly, *Pamelina difference* and *Pamelina* can be regarded as “hazard” objects seen by the participant in order to detect possible hazards in front. *Ground* can also be interpreted as a hazard object because the participant fixated the ground in order to look for possible hazards. In low lighting conditions (or in later runs), the pedestrian fixated “hazard” objects more, whereas fixations on “orientation” objects decrease. This can be because in low lighting conditions, the participant may have been keen or tried to pay attention to hazard objects rather than to find out the correct walking direction. In addition, getting visual information of an object in low lighting conditions takes time. The decrease of the fixations on the orientation objects can also be due to the familiarity of the participant to the experiment site.

Indeed, how pedestrian gather and cope with both “hazard” information of and “orientation” information can be an important topic. When walking on a dark/misty road at night, we sometimes realise that we are in a wrong direction because we concentrated on finding possible hazards and missed the correct direction. On the other hand, when we walk in an unknown street, we tend to look at buildings along the street, which can be regarded as “orientation” objects (Chibana, 1999). Actually, in our experiments for different platform configurations, we observed that some participants did not recognise a step situated soon after the starting point and then tripped over it. This can be because the participants were concentrating on gathering “orientation” information. It would be worth investigating how pedestrians handle these two kinds of important information (orientation and hazard information) under sensory restricted spaces.

Thirdly, Fig 7 shows that fixation on the steps with a positive step difference shows a positive proportionate relationship to the step differences. On the other hand, fixation durations to the steps with a negative step difference are in a negative proportionate relationship to the step differences. This leads us to infer that regardless of actual danger, visually obscure hazards do not attract the attention of pedestrians. In fact, the participant fixated -125mm gaps for less time compared with 125mm gap although a -125mm gap is also a potentially big hazard. Also, the fixation durations to -125mm gaps were not so different from those to -15mm or -10mm gaps even though a -125mm gap can be more dangerous than -15mm or -10mm. On the other hand, for steps with a positive difference, fixation durations to the step corresponded to actual danger (the more difference the more dangerous). These results imply that defects of the street design are not always perceived according to actual danger.

As long as defects are inevitable, it can be not enough to make defects obvious. Making sure that pedestrians can recognise them is important. For example, it is impossible to demolish the gap between the train and the platform as long as a curve of tracks is situated in the station. The usual treatment for this hazard is to install a spot lighting or/and an audio alarm system. However, a question for this can be: Do all pedestrians, including the visually impaired, always notice it? If they do not perceive, they might trip. For these inevitable hazards, we should consider not only the presentation of the hazard and alerting systems (the design of facilities) but also perception of the hazard by pedestrians, including the visually impaired (the perception by pedestrians). It can be inappropriate to concentrate on design details without thinking about the perception by pedestrians. More research should be conducted on how pedestrians perceive hazards, and problems should be considered by a framework that incorporates not only the design of facilities but also the perception of hazards by pedestrians, including the visually impaired, and the interaction between design details and pedestrians’ perception.

5. Conclusion

As an initial investigation of our series of experiments, the aim of this paper was, to look at the fixation behaviour of an ordinary participant. Although the results presented were only one ordinary participant’s and thus the data size was too small to make an induction, the results suggested important and interesting points for the design of pedestrian environments.

The results suggested that the fixation behaviour on hazard objects and orientation objects are different, and that pedestrians pay attention to the hazards according not to actual danger but to the visual information obtained. Visually obscure hazards cannot attract attention regardless of actual danger. Further investigation should be made on the illuminance level below which pedestrians need more fixation duration to perceive hazards, on how pedestrians handle with both hazard and orientation objects and how attention to one kind affects the attention to the other, and on a framework that incorporates not only the design of facilities but also the perception of pedestrians and the interaction between design details and pedestrians' perception.

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7. Reference

(The web addresses cited were current on 31 Jan 2007)

Chibana K, 1999, A study on the spatial abilities by eye fixation behavior, *Journal of architecture, planning and environmental engineering*, **520**, pp159-164, in Japanese

Fujiyama T, 2006, Investigating density effects on the "awareness" area of pedestrians using an eye tracker, CTS Working Paper 2006/4, Centre for Transport Studies, University College London, London, ISSN 1747-6232

Fujiyama T, Childs CR, Boampong DK, Tyler N, 2005, Investigation of lighting levels for pedestrians, Paper presented to WALK21 conference, Zurich, Switzerland, September 2005

SMI (SemsoMotoric Instruments). For more information, see http://www.smi.de/

Suzuki T, Okazaki S, 2002, Visual search while climbing or descending the staircases at a subway station, *Journal of architecture, planning and environmental engineering*, **558**, pp151-158, in Japanese

The Government Actuary's Department, http://www.gad.gov.uk/Population/2004/uk/wuk04cc.xls

Van der Pols JC, bates JC, McGraw JR, Thompson JR, Reacher M, Prentice A, Finch S, 2000, Visual acuity measurements in a national sample of British Elderly people, *British Journal of Ophthalmology*, **84 (2)**, pp 165-170