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UNIFORMITY PREDICTS PEDESTRIAN REASSURANCE BETTER THAN AVERAGE ILLUMINANCE

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Abstract

Reassurance describes the degree of confidence a pedestrian might have to walk, a critical concern where there are national plans to promote walking rather than driving for local journeys. This paper describes a field study carried out to measure the reassurance benefit of lighting using the day-dark method. The results suggest that reassurance is better predicted by uniformity or minimum illuminance than it is by average illuminance, which is the conventional metric.

Keywords: pedestrians, reassurance, illuminance, uniformity

1 Background

Reassurance describes the degree of confidence a pedestrian might have to walk; in the current context, this is the confidence to walk alone, after dark. Reassurance is used here as a synonym for perceived safety.

People who feel safer are likely to engage in more walking behaviour (Mason et al., 2013; Foster et al., 2016) a benefit for personal health and a benefit if more people walking means fewer people using motorised transport. The presence of road lighting enhances reassurance (Fotios et al., 2015) to a degree similar to that of access to help and greater than that provided by the physical features of an environment associated with prospect and refuge (see also Loewen et al., 1993).

Reassurance is associated with spatial brightness (Blöbaum and Hunecke 2005) and spatial brightness is modified by changes in the illuminance and spectrum of lighting (Fotios and Cheal 2011; Fotios et al., 2015a, 2015b). Several studies have used category rating to evaluate reassurance at different illuminances, tending to conclude that higher illuminances bring greater reassurance. One problem with measuring this effect is the influence of range bias (Poulton, 1977) – higher reassurance will correlate with higher brightness regardless of the absolute level of brightness (Fotios and Castleton, 2016; Fotios, 2016, 2018).

The day-dark method, proposed by Boyce et al (Boyce et al., 2000), may overcome the problem of range bias. In the day-dark method, the benefit of road lighting is determined by recording evaluations of reassurance in both daytime and after dark, with good lighting being that which minimises the difference between the daytime and after dark ratings. The range of locations evaluated is the same in both the daytime and after dark surveys, which should lead to similar range bias in both sets of evaluations.

Current guidance for pedestrian lighting recommends mean and minimum horizontal illuminances (CIE, 2010). The basis for the recommended values is unknown (Fotios and Gibbons, 2018). It would also be worthwhile to question the metrics by which road lighting is specified. Studies of lighting and reassurance have tended to consider only average horizontal illuminance, where this average should be determined from an array of measurements across a defined area (BSI, 2015). Mean illuminance says nothing about the spatial variation in spot measurements of illuminance: the same mean is possible from installations with low and high illuminance uniformity, and those with low uniformity can present dark, gloomy locations. If a low level of reassurance is associated with the presence of dark, gloomy locations within the field of view, it may be found that the spatial distribution of light provides a better measure of reassurance than does the quantity of light (Shepherd et al., 1992), and there is support for this from a field survey carried out within car parks (Narendran et al., 2016). Thus minimum illuminance or the uniformity of illuminance (minimum/mean) may exhibit better association with reassurance than does the mean.

This paper describes a field study carried out to measure reassurance in residential streets using the day-dark method.

2 Method

The day-dark method uses category rating to evaluate factors associated with reassurance with surveys at a particular location being conducted in both daytime and after dark.

Ten roads in a residential area of Sheffield (a city in the UK) were evaluated in November 2016. These were in fact eight residential roads, a pedestrian underpass and a pathway through a park, but for convenience, all ten locations are referred to hereafter as roads (R1 to R10). In six roads the road lighting was HPS, one used MH, one used fluorescent, and two used LEDs. Horizontal, hemispherical and semi-cylindrical illuminances were recorded at each location, following EN 13201-3:2015. The high degree of correlation between these for the 180 measurement locations (r^2>0,87) suggests similar trends would be established with either: we therefore used horizontal illuminances for analyses. For the eight roads and the footpath, the mean illuminances ranged from 4,2 lux to 10,6 lux; in the underpass the mean illuminance was 58 lux.

Evaluations were recorded using a series of category rating scales with 6-point response ranges (Figures 1 and 2). Ten questions were used in both the daytime and after dark surveys (Figure 1). This included eight questions related to reassurance and two control questions, a bogus question to check for attentiveness and a dark-specific question. Bogus questions are those which should have a clear and obvious answer and thus incorrect responses indicate a lack of attention (Meade and Craig, 2012). In Figure 1 this is "*I was born after 1979*" (other questions were used in different response sheets) to which any response other than "6" suggests inattention. 99% of responses to the bogus question were correct: The 1% of incorrect answers corresponded to unexpected personal characteristics, such as cultural diversity and eating habits.

Participants responded to the question "*How risky do you think it would be to walk alone here at night?*" in both their daytime and after-dark sessions. In the daytime session this therefore required a response based on an imagining of the environment after-dark. Responses were reverse coded so that a higher rating indicated less risky to walk alone at night, and mean ratings were calculated for each participant across all 10 roads combined. These data were normally distributed. A paired-sample t-test suggested ratings were significantly lower in the daytime session (mean = 3,53) than the after-dark session (mean = 3,78, p<0,01). Participants perceived the risk of walking alone at night to be higher when they were imagining this situation but viewing the street in daylight, compared with when they were physically present on the street at night. In turn, this suggests participants accurately read the questionnaire in the daytime session, responding appropriately by imagining the street when after-dark. Were this not the case, it was expected that ratings would be higher on the daytime session than on the after-dark session.

Five further questions about the lighting were evaluated in the after dark surveys only (Figure 2).

Twenty four participants were recruited for the experiment, these aged between 18 and 38 years, with a mean age of 24 years, and included an equal balance of males and females. A repeated measures design was used, in which subjects carried out evaluations of the same locations in daytime and after dark. Ethical approval was granted to conduct this experiment and all participants provided written consent before participating in trials.

The 24 participants were divided into four groups of six, with each group being taken to the ten locations together. The day-dark order (i.e. whether the daytime or after dark evaluation was carried out first) and the location order (i.e. forward or reverse route directions) were counterbalanced across these four groups. The typical starting time for the daytime sessions was 10.30 am and for the after-dark sessions approximately 4.45 pm, following a sunset time of approximately 4pm. A test session took approximately two hours. At each location the evaluation point was close to a lamp post. Before completing the questionnaire the test participants were asked to walk a short, predefined route, usually between the same two lamp posts as used for the lighting measurements. They were asked to face towards this same area when responding to the questions. The timing of each participant in the group was staggered by approximately 15 seconds so that they walked this route alone.

I can see clearly around me	Strongly disagree	1	2	3	4	5	6	Strongly agree
Apart from the researcher and any other participants, there are lots of other people on the street	Strongly disagree	1	2	3	4	5	6	Strongly agree
How safe do you think this street is?	Very dangerous	1	2	3	4	5	6	Very safe
This street is kept in good condition	Strongly disagree	1	2	3	4	5	6	Strongly agree
I was born after 1879	Strongly disagree	1	2	3	4	5	6	Strongly agree
How anxious do you feel when walking down this street?	Very anxious	1	2	3	4	5	6	Not at all anxious
I can see a lot of litter and rubbish on this street	Strongly disagree	1	2	3	4	5	6	Strongly agree
I would rather avoid this street if I could	Strongly disagree	1	2	3	4	5	6	Strongly agree
How risky do you think it would be to walk alone here at night?	Not at all risky	1	2	3	4	5	6	Very risky
How familiar are you with this particular street?	Not at all familiar	1	2	3	4	5	6	Very familiar

Figure 1 – the reassurance questions used in the daytime and after dark surveys.

The lighting on this street is:	Bad	1	2	3	4	5	6	Good
	Bright	1	2	3	4	5	6	Dark
	Not glaring	1	2	3	4	5	6	Glaring
	Unevenly spread (patchy)	1	2	3	4	5	6	Evenly spread (uniform)
Overall, how satisfied are you with the lighting on this street?	Very dissatisfied	1	2	3	4	5	6	Very satisfied

Figure 2 – the additional lighting-related questions used only in the after dark surveys.

3 Results

Principal Components Analysis (PCA) was used to explore responses to the eight questions of Figure 1, i.e. excluding the two control questions. This analysis used the day-dark difference scores, the difference between the daytime and after dark responses, for each respondent, for each rating item, in each road. This resulted in 240 data values for each question (24 participants x 10 streets).

Two components were extracted from the data. The present work only considers the first of the extracted components as this is interpreted as relating to the concept of reassurance. In this perspective, the component loadings that were ≥0,4, and thus weightier for the reassurance construct, were street avoidance (0,796), to feel anxious (0,776), to feel safe (0,767), to see clearly (0,624) and good condition of the street (0,409) (Table 1).

Table 1 – Component matrix extracted using principal component analysis and component scores

Survey question	Component loading	Component score
I would rather avoid this street if I could	0,796	0,329
How anxious do you feel when walking down this street?	0,776	0,321
How safe do you think this street is?	0,767	0,318
I can see clearly around me	0,624	0,258
This street is kept in good condition	0,409	0,169
Apart from the researcher and any other participants, there are lots of other people on the street	0,164	0,068
How familiar are you with this particular street?	0,088	0,037
I can see a lot of litter and rubbish on this street	0,004	0,002

Component scores, calculated using the regression method (Field, 2014), were used to weight the survey response data to establish a composite reassurance score. We included here the responses to all eight questions, since those items not suggested to belong to the reassurance component (loading <0,4) have a relatively low component score and would therefore have negligible effect.

For each participant on each road a composite reassurance score was calculated by weighting (using the component scores of Table 1) the day-dark differences for each rating item and summating these weighted values. These scores were averaged per test location and normalised to a scale of -5 to +5 to match the theoretical range of differences available using the original response scale items.

Table 2 shows the mean composite score and its standard deviation (SD) thus determined for each road. A smaller composite score indicates a smaller day-dark difference in reassurance, and thus a better effect of lighting. A positive score indicates higher reassurance in daytime than after dark; a negative score indicates higher reassurance after dark than in daytime. A negative score was found here for R10, the underpass.

Figure 3 shows mean day-dark differences for the composite reassurance score plotted against mean illuminance, minimum illuminance and illuminance uniformity. The trends were well explained by a logarithmic function. Minimum illuminance (r^2=0.84) and uniformity (r^2=0.85) exhibit a stronger association than does mean illuminance (r^2=0.54).

Table 2 – Composite reassurance day-dark difference scores

Road	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Mean	0,62	1,41	0,37	0,17	0,10	0,07	0,82	0,75	1,23	-0,40
SD	0,70	0,78	0,64	0,62	0,57	0,57	0,68	0,73	0,92	0,81

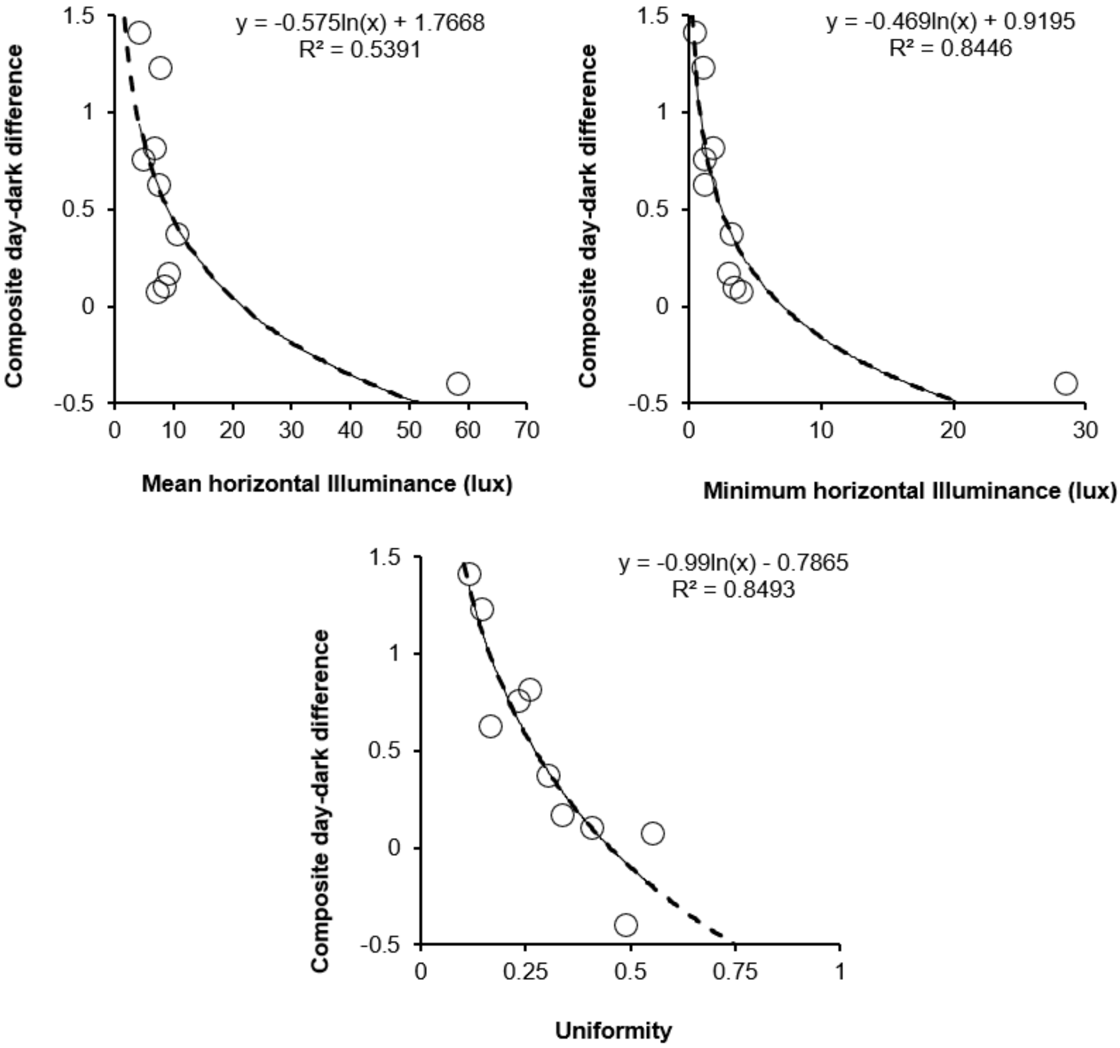

Figure 3 – Composite reassurance score plotted against mean, minimum and uniformity of horizontal illuminance.

Minimum illuminance and uniformity appear to provide a stronger correlation with the reassurance effect of road lighting than does mean horizontal illuminance. A series of multiple regression models were used to determine whether some combination of two or more of these metrics would provide a better prediction. While this suggested that either of the three possible two-term models (e.g. mean + minimum) would increase the r2 to 0,90, the improvement over consideration of either minimum illuminance (r^2=0,84) or uniformity (r^2=0,85) alone may not be practically significant (Fotios et al., 2018).

4 Conclusions

The results of a field survey in residential roads suggest uniformity or minimum illuminance to be a better predictor of pedestrian reassurance than mean illuminance. Further details of this study can be found (Fotios et al., 2018). A second field study was conducted in November 2018, using an expanded range of locations and a larger sample: results will be published when available.

With the awareness that category rating evaluations are prone to response bias (Fotios, 2018) validation from alternative methods is required. With the assumption that greater reassurance results in more walking we have counted pedestrian flows to determine the influence of ambient light, finding that for a given time of day (and thus similar purposes of walking) there are greater numbers of pedestrians at higher levels of ambient light (Uttley and Fotios, 2017; Fotios et al., 2019) but this itself requires validation in a wider range of contexts.

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