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Comment on Empirical Evidence For The Design Of Public Lighting

Steve Fotios
University of Sheffield, UK.

Abstract

A recent article [Peña-García et al. 2015. Impact of public lighting on pedestrians' perception of safety and well-being. Safety Science, 78; 142-148] presented conclusions regarding the benefits of road lighting for pedestrians. Here it is demonstrated that those conclusions were drawn from incomplete evidence, in one case because the experimental designs leads only to a trivial solution and in a second case because of an incomplete search of the literature.

1. Introduction

Peña-García et al [2015] described an experiment investigating the impact of road lighting on pedestrians' visual needs. The conclusions of such work are important because they may influence the decisions made by the designers of outdoor lighting installations. This article raises questions regarding the method employed to measure perceived safety and their literature review for other pedestrian tasks. It is concluded that their conclusions deserve further consideration before being considered valid.

The focus of the article from Peña-García et al is a field survey of pedestrians' perceived safety in five roads of different lighting characteristics, specifically, variations in illuminance (the amount of light) and types of lamp (these having different colour characteristics). Evaluations were gained using category rating, a subjective assessment. Four conclusions were presented and the aim of the current article is to re-evaluate statements from two of those conclusions:

1. " … *the average scores for every question were found to increase with average illuminance* .."
3. "*This highlights the importance of the enhanced chromatic reproduction of white light for facial recognition*".

The first statement is suggested here to be trivial: all such studies show that higher illuminances lead to higher ratings of perceived safety, but that makes no contribution to finding desireable conditions for pedestrians. The second statement is suggested here to be incorrect: Peña-García et al relied on only one study to draw this conclusion, but there are many other studies and these do not support the proposal that chromatic effects for facial evaluations are significant.

2. Measuring Perceived Safety

Perceived safety (amongst other visual evaluations of the environment) was measured through an on-street survey of pedestrians, this being done in five streets each of which had a different combination of light source and light level. An independent samples approach was used with a different sample (n=55) used to evaluate each street. Questions raised here about the procedure suggest the findings are not credible; furthermore, given the trivial finding of this survey regarding the effect of a change in light level, it is suggested that an alternative procedure ought to have been used.

The survey sought opinions of the lighting using 11 questions, with a 5-point response scale for each question. Capturing responses using category rating is prone to bias associated with the stimulus range and the response range [Poulton 1989]. One tendency is for respondents to avoid the ends the response scale leading to a tendency toward the middle region, an effect exaggerated if the scale has an obvious middle category. Peña-García et al report the mean ratings (their Table 2) and these indicate a central tendency: of the 55 values reported, approximately 67% are within 0.5 units of 3.0, the centre of the response range. Two possible reasons for a central tendency are that the questions were not clear and that there was no anchoring.

Regarding question clarity, the comments that follow are made assuming that the questionnaire reported in English language is an accurate translation of the original which is likely to have been in Spanish. Consider three questions in particular:

- Q7. “Evaluate the level of stress you suffer when you walk along this street at night (when the public lighting is on)”
- Q9. “Does the lighting of this street have an influence on your frame of mind?”
- Q10. “Evaluate the lighting of this street in general terms”

Q7 and Q9 raise concepts for which naive respondents are unlikely to be familiar at evaluating, and furthermore unlikely to be familiar at providing a quantitative estimate of magnitude. This leads to uncertainty in response. Q10 is extremely broad and responses may have been based on a wide range of factors. What would a naïve test participant do if unsure of the meaning of a question? It is likely they would respond anyway [Milgram 1963], perhaps giving an arbitrary response just to complete the task. It is known that respondents will provide a rating response to questions about factors they do consider to be significant or relevant [Acuña-Rivera et al 2011]. In subsequent analyses, the data analyst is unaware of such doubts and assumes all responses to be meaningful opinion.

Peña-García et al do not describe any attempt to anchor the response range to a stimulus. Consider for example Q3, "*How intense do you find the lighting on this street?*": what is not known are the light intensities a respondent would have attributed to the response scale, such as whether the maximum level (5) represented their expectation of good street lighting, their expectation of office lighting, or their expectation of daylight. One approach to anchoring a scale is to provide written descriptions of the range, as was done by Vrabel et al [Vrabel et al, 1998]. Surveys need to clearly describe the meaning of questions and anchor the response scale to stimuli to promote consistency [Fotios and Atli, 2012]. The absence of such steps may again have promoted a central tendency in responses, this being the safe, non-controversial response, given when the respondent doesn't fully understand what is being asked.

In this study the light levels were clustered into three groups, with average illuminances of approximately 15 lux, 25 lux and 50 lux. Despite the lower of these three illuminances already being the upper category of light levels recommended for subsidiary roads (class P1 in CIE 115 [2010]) the conclusion indicates that this is still not enough light because lighting of higher illuminance leads to an increase in ratings (i.e. a more positive impression of the environment). This is a commonly drawn conclusion, that the higher of a small number of evaluated illuminances is the optimum as it leads to a higher rating of safety [Atkins et al, 1991; Blöbaum and Hunecke, 2005; Boomsma and Steg, 2014; Ishii et al, 2007; Loewen et al, 1993; Vrij and Winkel, 1991]. It is, however, a somewhat trivial conclusion for lighting design, because whatever illuminance is chosen such experiments suggest that an even higher illuminance would be better still. This can be demonstrated by review of Vrij and van Winkel [1991] who carried out a field survey and concluded that their fivefold increase in illuminance led to significantly higher ratings of safety, but in this case the increase was from 0.24 to 1.31 lux (horizontal illuminance on the footpath). Lighting design guidance needs evidence of an optimum illuminance and the experimental design of Peña-García et al does not lead toward this.

There is an alternative approach to investigating light levels and perceived safety. That is to record evaluations both in daytime and after dark and use the day-minus-dark difference as the measure of lighting effectiveness as was done by Boyce et al [2000]. In effect this approach uses the daytime rating as a control for the general level of perceived safety in a location and the day-dark difference then gives a more direct measure of the effect of lighting alone. Figure 1 shows the results of a survey of perceived safety in car parks in the US. With higher illuminances, there is a reduction in the difference between day and dark ratings: that this difference approaches zero suggests an optimum illuminance can be identified, above which the benefit of higher illuminance is negligible. For the data shown in Figure 1, Boyce et al [2000] note that in the range 0-10 lux, small increases in illuminance produce a large increase in perceived safety; for illuminances above 50 lux, increases make little difference; increases in illuminances in the range 10-50 lux follow a law of diminishing returns. The ability to draw these conclusions from the data is more useful than a conclusion that higher illuminance is better.

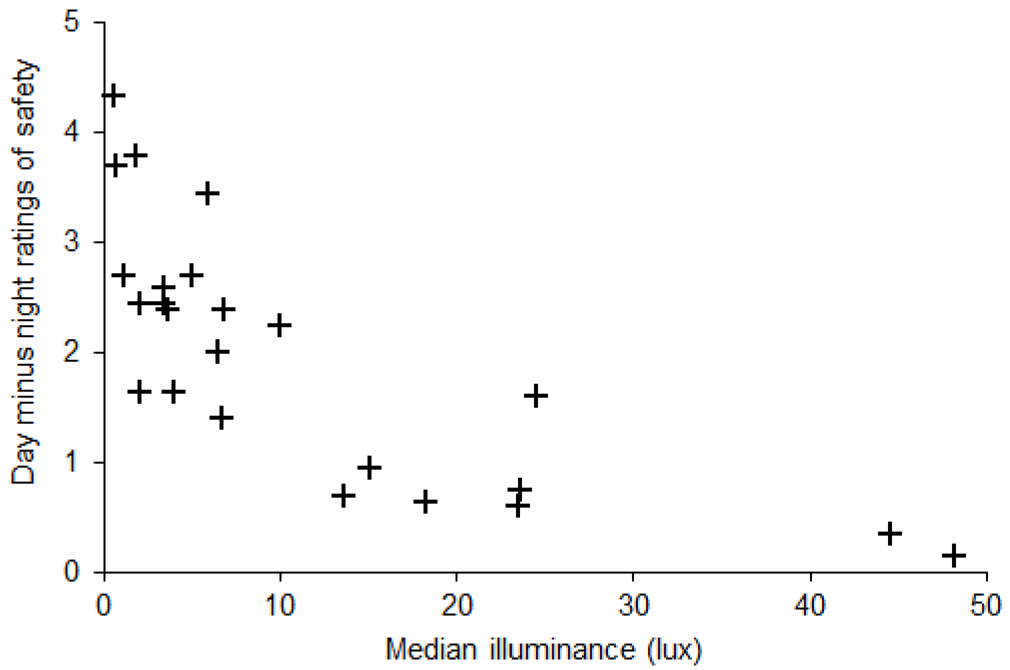

Figure 1. Difference between daytime and night-time ratings of perceived safety of car parks in New York plotted against median horizontal illuminance [Boyce et al, 2000].

The day-dark approach, however, still employs subjective evaluation rating to measure perceived safety. There are alternative approaches which provide a more objective approach. For example, if the level of reassurance is associated with the number of calls for police assistance, then the frequency of such calls would provide an alternative measure of the benefit of road lighting. This was examined in one survey in the US [Quinet and Nunn, 1998] which found that an increase in lighting did lead to a reduction in calls for police service, although here they measured the increase in lighting by the number of light fittings rather than as a photometric quantity.

3. Facial Recognition

One possible reason why Peña-García et al did not consider the above questions is that their literature survey was not sufficiently extensive. One indication of this is that their reference list does not include any articles from peer-reviewed journals which focus on lighting research, of which two examples are Lighting Research & Technology and Leukos. This limitation also extends to the conclusion drawn regarding the effect of lighting on facial recognition.

It is stated in their third conclusion that the higher safety scores associated with the whiter light sources is due to the "*enhanced chromatic reproduction of white light for facial recognition*." This statement regarding the effect of lamp spectrum on facial recognition was derived from just one source, the non-peer-reviewed facial recognition study of Raynham and Saksvikrønning [2003]. There are many other studies available and a robust conclusion would require consideration also of these other studies. When that broader set of published studies is examined it can be seen that while some further studies also suggest a significant effect of lamp spectrum [Knight 2010; Yao et al, 2009; Iwata et al 2015], at least three do not [Alferdinck et al., 2010; Boyce and Rea, 1990; Rea, Bullough and Akashi, 2009].

Given these mixed results, one approach to drawing a conclusion is to consider the experimental procedures used, and in particular, the degree to which test conditions resemble conditions pertinent to pedestrians experience. Investigations carried out to identify how facial recognition is affected by experimental design have demonstrated that recognition performance is affected by the duration of observation, the visual size of the stimulus (i.e. the distance between the observer and target), and the procedure used in the experiment [Dong et al, 2015; Lin and Fotios, 2015].

Regarding distance, past studies of facial recognition have tended to use a stop-distance procedure: the test participant walks towards a static target person and stops at the distance they are able to make the required recognition distance. A greater distance is assumed to imply lighting which offers enhanced recognition performance. One limitation of this approach is that it reveals the distance at which a recognition task could be done, not the distance as which a pedestrian might desire to make the judgement, and it is performance at that distance which should guide lighting design. Distance affects the visual size of a target, with the target subtending a smaller visual arc at the observers' eye when at a greater distance: it is well known that size affects visual acuity, the ability to discriminate detail [Boyce 2014]. Consideration of eye tracking data and perceived comfortable distances suggested that the desired distance would be in the region of 15 m [Fotios et al, 2015a, Townsend, 1997].

Regarding duration, past studies have tended to promote continuous observation on the target. This is not a realistic situation but generally there is a tendency to avoid looking at others for anything but a brief period. Measurements of gaze duration in a conversation between two people suggest the average length of gaze is 3.0 s, reducing to 1.2 s for mutual gaze when both parties look at one another [Cook, 1977]. Eye tracking was used to establish the typical duration for which a pedestrian visually fixates on other people and the results of two studies suggested this is approximately 500 ms [Fotios et al, 2015a; Jovancevic-Misic and Hayhoe, 2009].

Regarding experimental procedure, Fotios and Raynham [2011] suggested that recognition of the emotion conveyed by facial expression (facial emotion recognition) would better represent pedestrians' needs than does facial identity recognition. Facial expressions are associated with an approach-avoid response [Willis et al, 2011] and this may be a more useful evaluation than identity. A focus on facial evaluations is considered appropriate because of the (at least partially) automatic tendency to attend to the eyes of other people [Risko et al, 2012], because facial features are associated with trust behaviour and with perception of trust [Stirrat and Perrett, 2010]; if a scene includes a person the tendency to fixate that person is significantly greater than chance when weighted by area and viewing time on the face is greater than that on the body [Fletcher-Watson et al, 2008].

Three studies were carried out using a facial emotion recognition task, with targets sized to simulate interpersonal distances including 15 m and presented for limited durations (500 ms and 1000 ms) [Fotios et al, 2015b, 2015c, Yang and Fotios, 2015]. It is concluded in these studies that lamp spectrum does not affect facial emotion recognition, a conclusion which disagrees with that conveyed by Peña-García et al. Figure 2 shows the results from Yang and Fotios [2015] in which 20 test participants evaluated expressions in 24 target images under 72 combinations of lamp (three lamps of different colour characteristics), luminance (6), duration (2) and distance (2). It was found that distance and luminance have significant effect on emotion recognition probability (Friedman, $p<0.001$), but did not suggest lamp type to be significant. One limitation of these studies is that the target faces were photographs rather than live actors. While there is reason to suspect the results are ecologically valid for pedestrians' interpersonal judgements [Bond et al, 1994; Todorov et al, 2009; Valla et al, 2011] it would be desirable to repeat the work using live actors.

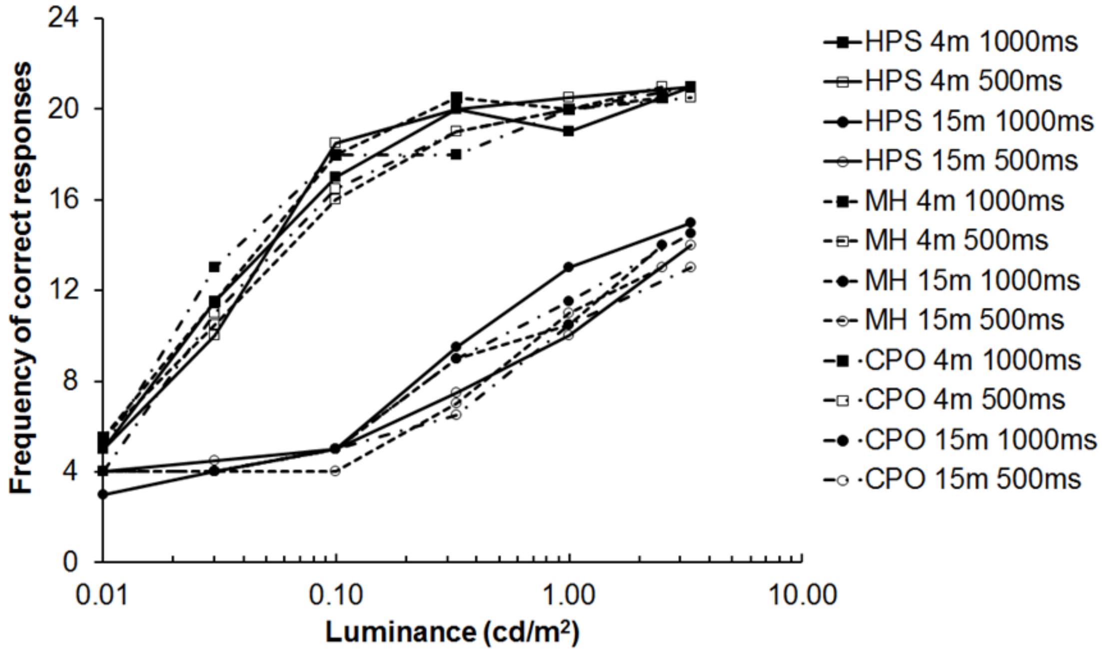

Figure 2. Median frequencies for correct identification of emotion from facial expression. The legends show lamp type (HPS, MH or CPO lamp), duration of presentation (500 or 1000 ms) and simulated target distance (4 or 15 m), after Yang and Fotios [2015].

4. Conclusion

This article has questioned two conclusions drawn by Peña-García et al [2015]. First, it is suggested that their conclusion regarding the increase in perceived safety following an increase in illuminance is trivial, as all studies tend to show that regardless of the illuminances examined. It is also suggested that an alternative procedure such as the day-dark ratings approach might be more informative. Second, it is suggested that their conclusion regarding the effect of lamp spectrum on face-based interpersonal evaluations demands further consideration with reference to the much broader (than one) range of peer-reviewed articles that are available. Evidence from studies which have attempted to better resemble pedestrian experience suggest that lamp spectrum does not affect face-based interpersonal evaluations.

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